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Western Journal of Emergency Medicine:

Integrating Emergency Care with Population Health

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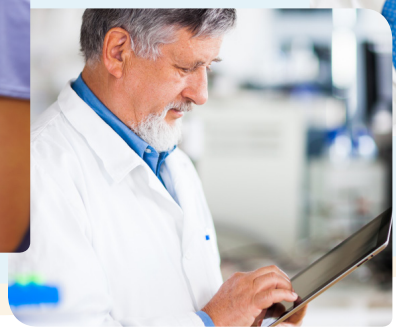

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As 2014 draws to a close, *West*JEM would like to honor the top reviewers and section editors of the past year. Without their generous contributions of time and expertise to the peer-review process, the *Journal* would not be able to advance its mission of emphasizing practical, efficient, and world-class emergency care. The top section editors and reviewers are chosen based on their quality of work, number of assignments, and timeliness of reviews.

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Integrating Emergency Care with Population Health

JOURNAL FOCUS

Emergency medicine is a specialty which closely reflects societal challenges and consequences of public policy decisions. The emergency department specifically deals with social injustice, health and economic disparities, violence, substance abuse, and disaster preparedness and response. This journal focuses on how emergency care affects the health of the community and population, and conversely, how these societal challenges affect the composition of the patient population who seek care in the emergency department. The development of better systems to provide emergency care, including technology solutions, is critical to enhancing population health.

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A BOLD IDEA: The "Population" Specialist

Judith E. Tintinalli, MD, MS University of North Carolina at Chapel Hill, Department of Emergency Medicine, Chapel Hill, North Carolina

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Emergency medicine today is very different from emergency medicine of the 1970s, when our practice was limited to the physical confines of the emergency department (ED) and the ambulance.

So—WHO ARE WE ANYWAY?
Family doctors take care of your family.
Surgeons cut you open.
Pediatricians take care of kids.
Anesthesiologists put you to sleep.
Cardiologists fix your heart.
Emergency physicians…….?

The definition of who we are is complicated by the fact that organ-specific specialties do not have discrete 'rights' to diagnostics or procedures that in the distant past might have characterized a specialty.[1] ST segment elevation myocardial infarction) STEMIs are diagnosed by emergency physicians, family practice physicians, internists, cardiologists, and emergency medical technicians. Lacerations are repaired by emergency physicians, plastic surgeons, mid-level emergency care providers, and family practice physicians. And the exponential growth and globalization of emergency care has changed the whole concept of emergency medicine.

A POPULATION-BASED SPECIALTY

Emergency medicine treats all disorders, all ages, any day and anytime. We provide care when prevention and community services fail. In general, the ED patient population reflects the age distribution and/or the prevalence of disorders in the community. For example, Nigeria has one of the highest road fatality rates in the world,[2] and motor vehicle accidents are responsible for a large burden of ED care.[3] In Taiwan from 2000-2009, 25% of ED visits were made by children, with about 22% of the population aged 0-17 for that same time period.[4] In the U.S., mood disorders are the third most common cause of hospitalizations for adults,[5] and in North Carolina from 2008-2010, of ED visits related to mental health disorders, about 60% of visits were by patients with mood disorders, and about 29% of those were admitted to the hospital.[6] As global population age proportions shift toward the elderly, so do ED visits, and worldwide, the elderly account for at least 12-24% of ED visits.[7]

A UNIQUE CLINICAL PRACTICE

There are several features of emergency medicine practice that are unique when compared to other specialties. We must care for any type of critical illness: for example, STEMI, stroke, sepsis, multisystem trauma, resuscitation, behavioral emergencies, abdominal catastrophe.

We provide care for multiple patients at a time—in the ED, at mass gatherings, and during disasters. This is done through a variety of functions: triage, standing orders, multitasking, rapid decision-making and patient prioritization. Compare our practice to your own visit to a primary care physician: one patient, one doctor in the examining room; one patient, one surgeon in the operating room; one patient, one cardiologist in the cardiac cath lab.

Emergency medicine is an integrative specialty. Core activities are coordination of care across specialty lines, and prioritizing care components between specialties.

Emergency medicine maintains a high sensitivity for illness and injury, whereas organ-specific specialties want high specificity for their own expertise: cardiologists want coronary artery disease, not atypical chest pain; surgeons want appendicitis, not undifferentiated abdominal pain; orthopedists want broken bones, not chronic back pain.

A MANAGEMENT SPECIALTY

Emergency physicians are decision makers above all. We are natural-born managers. We develop standardized and integrated policies and procedures and apply them to daily practice. We define roles and provide supervision for the emergency care system. We focus on operations. We categorize patient complaints into different levels of care (fast track, acute care, etc.) to improve efficiency. We use data analysis to monitor individual and group activity.

SYSTEMS-BASED PRACTICE

Systems-based practice is one of the six core competencies identified by the Accreditation Council for Graduate Medical Education, and applies to all specialties. However, systems-based practice is core to emergency medicine. Consultation, transfer and disposition must be tailored to local and regional healthcare resources. Every step of care must be fit to the patient's socioeconomics, compliance, and access to care. Many of us memorize the Wal-Mart $4 list so we can give the patient the best shot at affordable medications. We visualize the big picture: the patient's complaint is part of the body system, and the treatment plan is part of the healthcare system.

ANY AND EVERY ENVIRONMENT

No more 'locked-in syndrome.' Emergency medicine has stepped out of the ED and ambulance to manage poison control centers and hyperbaric chambers; incorporate critical care and palliative care into emergency care; practice alongside orthopedists in sports medicine; and develop leadership roles in information technology.

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Address for Correspondence: Judith E. Tintinalli, MD, MS. University of North Carolina at Chapel Hill, Department of Emergency Medicine, Chapel Hill, North Carolina. Email: judith_tintinalli@med.unc.edu.

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Emergency Medical Services Public Health Implications and Interim Guidance for the Ebola Virus in the United States

Christopher E. McCoy, MD, MPH
Shahram Lotfipour, MD, MPH
Bharath Chakravarthy, MD, MPH
Carl Schultz, MD
Erik Barton, MD, MBA

University of California, Irvine, Department of Emergency Medicine, Orange, California

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The 25th known outbreak of the Ebola Virus Disease (EVD) is now a global public health emergency and the World Health Organization (WHO) has declared the epidemic to be a Public Health Emergency of International Concern (PHEIC). Since the first cases of the West African epidemic were reported in March 2014, there has been an increase in infection rates of over 13,000% over a 6-month period. The Ebola virus has now arrived in the United States and public health professionals, doctors, hospitals, Emergency Medial Services Administrators, Medical Directors, and policy makers have been working with haste to develop strategies to prevent the disease from reaching epidemic proportions. Prehospital care providers (emergency medical technicians and paramedics) and medical first responders (including but not limited to firefighters and law enforcement) are the healthcare systems front lines when it comes to first medical contact with patients outside of the hospital setting. Risk of contracting Ebola can be particularly high in this population of first responders if the appropriate precautions are not implemented. This article provides a brief clinical overview of the Ebola Virus Disease and provides a comprehensive summary of the Center for Disease Control and Prevention's Interim Guidance for Emergency Medical Services (EMS) Systems and 9-1-1 Public Safety Answering Points (PSAPS) for Management of Patients with Known of Suspected Ebola Virus Disease in the United States. [West J Emerg Med. 2014;15(7):723-727.]

The Ebola virus has now arrived to the United States. The twenty-fifth known outbreak of Ebola virus disease (EVD) is unlike any of the previous epidemics and is now a global public health emergency. The first cases of the current West African epidemic of EVD were reported on March 22, 2014, with a report of 49 cases in Guinea.[1] By August 31, 2014, the World Health Organization (WHO) had reported 3,685 probable, confirmed, and suspected cases in West Africa, with 2,914 in Sierra Leone and Liberia and 771 in Guinea.[2] According to the most recent WHO update 6,574 cases have been reported as of September 23, 2014, from five West Africa countries (Guinea, Liberia, Nigeria, Senegal, and Sierra Leone).[3] This yields an increase in case rates of disease of over 13,000% during the six-month period. The current epidemic has already killed over 3,860 people – more than all previous Ebola epidemics combined.[4,5] The average EVD case fatality rate is approximately 50%, with rates as high as 90% in past outbreaks.[6] Despite the vast scale of the current outbreak, the clinical manifestations of the disease, duration of illness, case fatality rate, and degree of transmissibility are similar to those in earlier epidemics. It is therefore unlikely that the particularly devastating course of this epidemic can be attributed to biologic characteristics of the virus.[5] It is more likely the result of the combination of resource-poor health delivery systems, difficulties in surveillance, densely populated capitals, local customs, and high population mobility.

On September 30, 2014, the Centers for Disease Control and Prevention (CDC) confirmed, through laboratory tests, the first travel-associated case of Ebola to be diagnosed in the U.S.in a person who had traveled to Dallas, Texas, from West Africa.[7] Since this time, medical and public health

professionals, hospitals and emergency medical services (EMS) administrators, medial directors, and policy makers have been working with haste to develop strategies to prevent the disease from reaching epidemic proportions in the U.S. Owing to its rapid spread, high case fatality rate, and no current cure for the virus, recommendations for evaluation and management are time sensitive and may evolve as fast as our knowledge about the disease.

One area of public health services in particular that needs timely information is EMS. Prehospital care providers are the healthcare systems' first point of contact with patients in the prehospital setting. The objective of this article is to provide a brief clinical overview of EVD and to summarize the CDC's Interim Guidance for Emergency Medical Services (EMS) Systems and 9-1-1 Public Safety Answering Points (PSAPs) for management of patients with known or suspected EVD in the U.S.[8] The target audience includes but is not limited to paramedics, emergency medical technicians, emergency physicians and nurses, EMS agencies and system administrators, law enforcement, firefighters, and policymakers.

CLINICAL ASPECTS OF EBOLA

Signs and Symptoms of Ebola Virus Disease.[9]

- Fever (>38.6ºC or 101.5ºF)
- Severe headache
- Muscle pain
- Weakness
- Diarrhea
- Vomiting
- Abdominal pain
- Unexplained hemorrhage

Symptoms may appear from two to 21 days after exposure to Ebola with an average of eight to 10 days. During this latent period an individual may be infected with the virus yet not show any signs or symptoms.

Transmission[10]

Current research indicates that the first person becomes infected through contact with an infected animal. When the infection occurs in humans, the virus can be spread in several ways to others. Ebola is spread through direct contact (through broken skin or mucous membranes) with:

- Blood or body fluids (including but not limited to urine, saliva, sweat, feces, vomit, breast milk, and semen) of a person who is sick with Ebola
- Objects (like needles and syringes) that have been contaminated with the virus
- Infected animals

Ebola is not spread through air, water or, in general, by food. There is no evidence that mosquitos or other insects can transmit the virus. Healthcare providers caring for Ebola patients are at the highest risk of getting sick because they may come in contact with infected blood or body fluids. The disease can spread quickly within healthcare settings if appropriate protective precautions are not taken. However, with appropriate personal protective equipment (PPE) and exposure precautions, the risk of contagion can be greatly reduced.

Diagnosis

There are currently a variety of diagnostic tests available for Ebola; however, none of these are available in the prehospital care setting. Diagnosing Ebola in a person with the aforementioned signs and symptoms may be difficult in isolation as the signs and symptoms overlap with a multitude of other more commonly occurring medical and surgical conditions. However, knowledge that the patient has been in contact with someone with suspected or confirmed Ebola or has traveled to an area where Ebola is occurring can be obtained from the patient history and can greatly aid the healthcare provider in risk stratification.

Treatment

There are no FDA-approved vaccines or medications currently available for Ebola. Therefore, treatment is primarily supportive and may include intravenous fluids, maintaining oxygen status and blood pressure and treating any other underlying conditions or organ dysfunction. Recovery from Ebola is dependent on supportive care and the patient's immune response.

Several experimental drugs and vaccines are under development and may be given to individual patients on a case-by-case basis. No current algorithm is available to help determine an ethical method to allocate the limited supply of these agents. One drug, identified as ZMAPP, has been given to several patients, but it remains unclear if it was actually effective. ZMAPP is an experimental biopharmaceutical drug comprising three humanized monoclonal antibodies under development as a treatment for EVD. These monoclonal antibodies bind to the Ebola virus, rendering it less harmful. In addition, the National Institutes of Health's (NIH) National Institute of Allergy and Infectious Diseases (NIAID) is in the process of developing a vaccine against Ebola. The NIH announced that they will accelerate production and begin phase 1 clinical trials of this vaccine. At the end of August, the NIH announced that it would begin human testing of an investigational vaccine to prevent Ebola in the first week of September 2014. NIAID will supervise this testing.

SUMMARY OF INTERIM GUIDANCE FOR EMERGENCY MEDICAL SERVICES SYSTEMS AND 9-1-1 PUBLIC SAFETEY ANSWERING POINTS FOR MANAGEMENT OF PATIENTS WITH KNOWN OR SUSPECTED EBOLA VIRUS DISEASE IN THE UNITED STATES

EMS personnel have a vital role in responding to, triaging, and providing initial medical care for patients in the prehospital care setting. The prehospital care environment often requires EMS personnel to work in uncontrolled settings, often in small spaces, and with little medical information about the patient prior to initiating management. With the arrival of Ebola to the U.S., policies, protocols, and procedures may require modification to address this public health concern and to reduce the risk of transmission to healthcare providers as well as the public.

CASE DEFINITION FOR EBOLA VIRUS DISEASE (EVD)

Person under Investigation (PUI)

A person who has both consistent symptoms and risk factors as follows:

1. Clinical criteria, which includes fever > 38.6°C (101.5°F), and additional symptoms such as severe headache, muscle pain, vomiting, diarrhea, abdominal pain, or unexplained hemorrhage, AND
2. Epidemiologic risk factors within the past 21 days before the onset of symptoms, such as contact with blood or body fluids or human remains of a patient with the virus; residence in – or travel to – an area where EVD transmissions is active; or direct handling of bats or non-human primates from disease-endemic areas.

Probable Case

A PUI whose epidemiologic risks factors include high- or low-risk exposures(s).

Confirmed Case

A case with laboratory-confirmed diagnostic evidence of Ebola virus infection.

High Risk Exposures

- Percutaneous (e.g., needle stick) or mucous membrane exposure to blood or body fluids of EVD patient
- Direct skin contact with, or exposure to blood or body fluids of an EVD patient without appropriate PPE
- Processing blood or body fluids of an confirmed EVD patient without appropriate PPE or standard biosafety precautions
- Direct contact with a dead body without appropriate PPE in a country where an EVD outbreak is occurring

Low Risk Exposures

- Household contact with an EVD patient
- Other close contact (three feet) with EVD patients in healthcare facilities while not wearing recommended PPE

RECOMMENDATIONS FOR 9-1-1 PUBLIC SAFETY ANSWERING POINTS (PSAPs)

State and local EMS authorities may authorize PSAPs and other emergency call centers to use modified caller queries about Ebola when they consider the risk of Ebola to be elevated in their community.

Modified Caller Queries

- Important for PSAPs to question callers for possible Ebola infection and immediately notify EMS personnel prior to arrival if suspected
- Calls should be screened for symptoms and risks factors for Ebola:
  - Contact with blood or body fluids of a patient known to have or suspected to have Ebola;
  - Residence in – or travel to – a country where Ebola outbreak is occurring
  - Direct handling of bats or nonhuman primates from disease-endemic areas
  - If responding at an airport or other port of entry to the U.S., the PSAP should notify the CDC quarantine station for the port of entry http://www.cdc.gov/quarantine/quarantinestationcontactlistfull.html

RECOMMENDATIONS FOR EMS AND MEDICAL FIRST RESPONDERS (INCLUDING FIRE AND LAW ENFORCEMENT)

Patient Assessment

1. Scene safety:
- If PSAP call with suspicion of Ebola, EMS personnel to don PPE appropriate for suspected cases of Ebola before entering scene
- Keep patient separated from other persons
- Caution for unexpected movements (flailing) in Ebola patients with delirium, as may increase risk of infection

2. During patient assessment and management, EMS personnel should consider symptoms and risk factors of Ebola:
- Assess for symptoms of Ebola (fever > 38.6° or 101.5°F and additional symptoms: severe headache, muscle pain, vomiting, diarrhea, abdominal pain, or unexplained hemorrhage). If the patient has aforementioned symptoms, then ask about risk factors within the past three weeks, including:
  - Contact with blood or body fluids of patient known to have or suspected to have Ebola;
  - Residence in – or travel to – a country with an Ebola outbreak (a list of impacted countries can be accessed at the following link: http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/index.html), or
  - Direct handling of bats or nonhuman primates from disease-endemic areas.
- Put on PPE based on presence of symptoms and risk factors

EMS Transfer of Patient Care to a Healthcare Facility

It is vital that EMS personnel notify the receiving healthcare facility when transporting a suspected Ebola patient, so that appropriate infection control precautions may be prepared prior to patient arrival. Any U.S. hospital that is

following the CDC's infection control recommendations and can isolate a patient in a private room is capable of safely managing a patient with Ebola.[11] EMS personnel involved in the air or ground interfacility transport of patients with suspected or confirmed Ebola should wear recommended PPE.

Infection Control

EMS personnel can safely manage a patient with suspected or confirmed Ebola by following recommended isolation and infection control procedures, including standard, contact, and droplet precautions. Particular attention should be paid to protecting mucous membranes from splashes of infectious material, or self-inoculation from soiled gloves. It is recommended that an EMS agency managing a suspected Ebola patient should follow these CDC recommendations:

- Limit activities that can increase the risk of exposure to infectious material
- Limit use of needles and other sharps as much as possible

Use of PPE

Use of standard, contact, and droplet precautions is sufficient for most situations when treating a patient with a suspected case of Ebola. EMS personnel should wear:

- Gloves
- Gown (fluid resistant or impermeable)
- Eye protection (goggles or face shield that fully covers front and sides of face)
- Facemask
- Additional PPE may be required in certain situations, including but not limited to double gloving, disposable shoe covers, and leg coverings.

During prehospital resuscitation procedures (intubation, open suctioning of airways, cardiopulmonary resuscitation):

- In addition to recommended PPE, respiratory protection at least as protective as a NIOSH-certified fit-tested N95 filtering facepiece respirator or higher is recommended (instead of facemask).
- Additional PPE must be considered for these situations owing to potential increased risk of contact with blood and body fluids.

The CDC also provides recommendations on cleaning EMS transport vehicles after transporting a patient with suspected or confirmed Ebola. Their essential recommendation is to thoroughly clean all areas where patient care was provided, while wearing appropriate PPE.

Recommendations for EMS personnel who are exposed to body fluids from a patient with suspected or confirmed Ebola

The CDC recommends that EMS personnel with exposure to blood, body fluids, secretions, or excretions from a patient with suspected or confirmed Ebola should immediately:

- Stop working and wash the affected skin surfaces with soap and water. Mucous membranes should be irrigated with a large amount of water or eyewash solution
- Contact occupational health/supervisor for assessment and access to post-exposure management services; and
- Receive medical evaluation and follow-up care, including fever monitoring twice daily for 21 days, after the last known exposure. The CDC recommends they may continue to work while receiving twice-daily fever checks, based upon EMS agency policy

EMS personnel who develop signs and symptoms suggestive of and consistent with those seen with Ebola after an unprotected exposure to a patient with suspected or confirmed Ebola should:

- Not report to work or immediately stop working and isolate themselves;
- Notify their supervisor, who should notify local and state health departments;
- Contact occupational health/supervisor for assessment and access to post-exposure management services; and
- Comply with work exclusions until they are deemed no longer infectious to others.

Follow-up and/or reporting measures by EMS personnel after caring for a suspected or confirmed Ebola patient

EMS personnel should be aware of the follow-up and/or reporting measures they should take after caring for a suspected or confirmed Ebola patient. The CDC recommends that EMS agencies develop policies for monitoring and managing EMS personnel potentially exposed to Ebola.

The U.S. Department of Health and Human Services (DHHS), CDC, and Office of the Assistant Secretary for Preparedness and Response (ASPR), in addition to other federal, state, and local partners, encourage U.S.-based EMS agencies and systems to prepare for managing patients with Ebola and other infectious diseases. Their detailed EMS checklist for Ebola preparedness can be found on the CDC website.[12] The checklist provides practical and specific suggestions to ensure the agency is able to help its personnel detect possible Ebola cases, protect those personnel, and respond appropriately. The U.S. Department of Health and Human Services and the CDC have also put together a checklist for use when patients arrive to clinical settings such as emergency department triage.[13] (Appendix I) The CDC is available 24/7 for consultation by calling the CDC Emergency Operations Center (EOC) at 770-488-7100.

Address for Correspondence: Christopher Eric McCoy, MD, University of California Irvine Medical Center, Department of Emergency Medicine. 101 The City Drive South, Orange, CA 92868. Email: cmccoy@uci.edu.

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Ebola Virus Disease: Essential Public Health Principles for Clinicians

Kristi L. Koenig, MD*
Cassondra Majestic, MD*
Michael J. Burns, MD†

*University of California at Irvine, Center for Disaster Medical Sciences and Department of Emergency Medicine, Orange, California
†University of California at Irvine, Department of Emergency Medicine and Department of Medicine, Division of Infectious Diseases, Orange, California

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Ebola Virus Disease (EVD) has become a public health emergency of international concern. The World Health Organization and Centers for Disease Control and Prevention have developed guidance to educate and inform healthcare workers and travelers worldwide. Symptoms of EVD include abrupt onset of fever, myalgias, and headache in the early phase, followed by vomiting, diarrhea and possible progression to hemorrhagic rash, life-threatening bleeding, and multi-organ failure in the later phase. The disease is not transmitted via airborne spread like influenza, but rather from person-to-person, or animal to person, via direct contact with bodily fluids or blood. It is crucial that emergency physicians be educated on disease presentation and how to generate a timely and accurate differential diagnosis that includes exotic diseases in the appropriate patient population. A patient should be evaluated for EVD when both suggestive symptoms, including unexplained hemorrhage, AND risk factors within 3 weeks prior, such as travel to an endemic area, direct handling of animals from outbreak areas, or ingestion of fruit or other uncooked foods contaminated with bat feces containing the virus are present. There are experimental therapies for treatment of EVD virus; however the mainstay of therapy is supportive care. Emergency department personnel on the frontlines must be prepared to rapidly identify and isolate febrile travelers if indicated. All healthcare workers involved in care of EVD patients should wear personal protective equipment. Despite the intense media focus on EVD rather than other threats, emergency physicians must master and follow essential public health principles for management of all infectious diseases. This includes not only identification and treatment of individuals, but also protection of healthcare workers and prevention of spread, keeping in mind the possibility of other more common disease processes. [West J Emerg Med. 2014;15(7):728–731.]

On August 8, 2014, the World Health Organization (WHO) declared the Ebola outbreak in West Africa a public health emergency of international concern, noting that all nations "should be prepared to detect, investigate, and manage Ebola cases." Enormous media attention and public health resources have been expended, yet the average clinician will never see a case. To complicate matters, as was seen in the 2009 H1N1 pandemic, authoritative bodies such as WHO and the U.S. Centers for Disease Control and Prevention (CDC) may issue conflicting recommendations during these types of evolving public health emergencies, e.g., no travel restrictions versus limiting travel to West Africa. In addition, in a global environment, international policy makers have made seemingly contradictory statements to include that, "the threat from Ebola is vastly underestimated" while also suggesting that "the threat to the U.S. is extremely small." Nevertheless, the basic principles of management of a febrile traveler are essential competencies for physicians worldwide, in particular emergency physicians on the frontlines, who are often the first to encounter an acutely ill patient. These standards will remain important even as Ebola Virus Disease (EVD) fades and the next infectious disease emerges.

According to CDC, as of September 25, 2014, there have been at least 6,263 suspected and confirmed cases and 2,917 suspected case deaths across five countries in West Africa, and the numbers continue to grow.[1] This is the first recorded outbreak of Ebola in West Africa and the largest outbreak ever documented. EVD is an often-fatal disease (mortality rate 50%-70%) that is spread from person-to-person or animal to person via direct contact with bodily fluids or blood. The infectious dose is ≤10 viral particles. The incubation period ranges from 2-21 days (average 5-6 days). Early symptoms include abrupt onset of fever, myalgias, and headache. Vomiting, diarrhea and abdominal pain follow in 1 to 2 days, often progressing to hemorrhagic rash and life-threatening bleeding and multi-organ failure (acute respiratory, liver and renal) within a few days.[2] Laboratory findings include thrombocytopenia, leukopenia, and elevation in liver function enzymes. The disease is not transmissible until the patient is symptomatic, but continues to be contagious, even postmortem. A patient should be evaluated for EVD with both suggestive symptoms including unexplained hemorrhage, AND risk factors within 3 weeks prior, such as travel to an endemic area, direct handling of animals from outbreak areas, or ingestion of fruit or other uncooked foods contaminated with bat feces containing the virus are present.[2]

Current treatment of EVD is mainly supportive. This includes early implementation of intravenous fluids (or oral rehydration) and maintenance of adequate electrolyte balance, oxygen therapy, blood pressure control, and treatment of other infections if they occur.[2] The clinician should also consider ordering additional lab studies such as complete blood count, complete metabolic panel, coagulation factors, and type and cross or type and screen in cases with concern for hemorrhage.

Viremia develops after the fever. It may take up to 72 hours to confirm the diagnosis by laboratory testing.[3] Early diagnosis is confirmed by obtaining a blood sample that is tested for viral antigens by antigen-capture enzyme-linked immunosorbent assay or polymerase chain reaction in the lab. Later in the disease course, antibodies for the virus such as IgM and IgG, can also be detected.[4] If testing is indicated, local and state health departments should be notified immediately. CDC recommends that healthcare providers collect serum, plasma, or whole blood samples of at least 4 mL, to be shipped refrigerated or on ice to the appropriate health department for further testing.[2]

Physicians must be vigilant in the clinical workup of febrile travelers, especially important in the emergency department during the initial workup of disease. A timely and accurate differential diagnosis including exotic diseases, is essential. Knowledge of disease risk by geographic area is critical to evaluation of the traveler who returns ill. This will help guide the decision making of clinicians to order appropriate tests and treatment.[5] The likelihood of encountering a patient with EVD outside of the region of the outbreak is small. Returning travelers often do not have an exotic tropical infection as the cause of their illness. Instead they may have influenza, streptococcal pharyngitis, pneumococcal pneumonia, pyelonephritis, or other uncommon infectious diseases with hemorrhagic manifestations including meningococcemia, Staphylococcus aureus bacteremia, or rickettsial infections. Despite the low likelihood of encountering a patient with severe febrile illness, travelers may acquire unusual infections that are unfamiliar to most healthcare staff.[5] Clinicians should develop an appropriate list of differential diagnoses, taking travel history into consideration (Figure 1).

Many of these diseases present non-specifically, often with fever and malaise. In advanced cases, hemorrhage is common, but may be present in only about 50% of EVD cases. There have been at least 20 suspected cases of EVD in the U.S.; however, only about one-fifth of these cases met criteria for testing. Nevertheless, these suspected cases drain limited healthcare resources because of the heightened concern for EVD. Some of the patients ultimately had malaria and influenza.[1]

On September 30, 2014, CDC Director Dr. Tom Frieden announced at a national press conference that a visitor to the U.S. has been diagnosed with Ebola at a hospital in Dallas, Texas. This is the first person to be diagnosed in the U.S. after arrival here from an endemic area. He reportedly arrived 10

Differential diagnosis of an acute, severe, short-incubation (<21 days), febrile illness from sub-Saharan Africa includes:

- Malaria (especially falciparum malaria)
- Typhoid fever*
- Other bacterial enteritides*
- Leptospirosis
- Rickettsial infections
- Plague*
- Viral hepatitis*
- Dengue
- Chikungunya
- Yellow fever
- Rift Valley Fever
- Lassa fever*
- Marburg hemorrhagic fever*
- Severe influenza*
- African trypanosomiasis
- Bacterial pneumonia
- Meningococcemia*
- EVD*

Figure 1. Differential diagnosis of the febrile traveler.
EVD, Ebola virus disease
Infections found in sub-Saharan Africa having incubation periods >21 days should be considered if the patient has stayed in the endemic area for some time, including acute HIV infection*, African trypanosomiasis, brucellosis, filariasis (various types), malaria, secondary syphilis*, visceral leishmaniasis, acute schistosomiasis, amebic liver abscess, viral hepatitis*, rabies*, tuberculosis*, and melioidosis.
* Transmissible from person-to-person.

- Isolate patient on arrival
- Don appropriate personal protective equipment
- Notify health authorities
- Notify law enforcement if suspect terrorism
- Consider differential diagnosis - contact infectious and tropical disease experts (local and CDC)
- Manage media
- Patient education

Figure 2. Critical actions for emergency physicians caring for febrile travelers who might have Ebola or other infections transmitted from person-to-person.
CDC, Centers for Disease Control and Prevention

days earlier by air from Liberia and did not develop fever or other symptoms until 4-5 days later. He reportedly was initially seen at a healthcare facility when he first became symptomatic but was not isolated, not tested for Ebola, and was sent home. He was admitted to a Dallas hospital a few days later, placed in isolation, and viral testing confirmed Ebola.

If there is suspicion for a transmissible pathogen based on the patient's travel history and symptoms, the patient should be isolated immediately in a single-patient room with standard and droplet precautions. Only essential personnel should enter; medical equipment should be disposable. Despite what is shown with high-profile media cases, gloves, gowns, goggles, and a fluid resistant face mask to cover the nose and mouth are generally adequate for personal protective equipment (PPE). If copious amounts of blood, emesis or diarrhea are present, higher levels of PPE, e.g., double gloving, shoe and leg covers should be added. Aerosol-generating procedures should be avoided, but higher-level respiratory protection is required if these procedures must be performed.[6] This includes isolating the patient in a negative pressure room with the use of N95 respirators or possibly powered air purifying respirators (PAPR) utilized by staff caring for the patient. Ensure that all laboratory samples are transported in person rather than using tubing systems, and notify laboratory personnel regarding the possible infectious nature of the samples. Avoidance of the tube system is necessary in attempt to avoid damage of the tubes en route and risk of any viral sample aerosolizing. Blood draws in these high-risk patients should also be minimized to reduce the risk of needle sticks in hospital personnel.

Contacting the local health department and state, national, and international authorities if necessary is an essential step in care of these types of patients. The U.S. CDC classifies EVD as a category A bioterrorism agent; thus, these notifications should include law enforcement for suspicious circumstances.[7] In general, bioterrorism should be considered as a causative factor in an infectious disease case when: 1) there is a single suspected case of an uncommon disease, 2) similar disease is clustered in different locales but within the same time frame, 3) there is an unusual clinical, geographical, or seasonal presentation, or 4) there are increased deaths in an animal population.

There are therapeutic agents that may be available from CDC, such as the investigational new drug artesunate in a malaria patient. Emergency Use Authorization authority in the U.S. allows the Food and Drug Administration (FDA) commissioner to approve medical agents to be used for diagnosis, therapy, or prevention of disease when they are not the standard of care or supported by research that proves their safety.[8] This is exemplified in the recent cases of EVD, for which the two infected U.S. citizens received ZMapp, monoclonal antibodies produced in specially modified tobacco plants.[9] The FDA is reportedly permitting a second experimental drug, TKM-Ebola, to be used in infected patients. Although CDC, NIH and other federal agencies are working to produce a vaccine and continue production of these experimental therapies, supportive care remains the current standard treatment.[10]

With dozens of emerging infections identified each year,[11] it is essential for physicians to avoid undue influence from current media attention on a single disease and focus on implementation of systems and education and training on general principles that extend to all such situations. Additional issues to consider include: 1) planning for healthcare worker absenteeism (ill/dead, caring for loved ones, afraid or unable to come to work); and 2) being familiar with EVD in order to identify suspected cases, consider the differential diagnosis, and also to reassure patients seeking care who are *concerned* about the disease due to the media hype.

The current globalization of healthcare, including rapid international travel, climate change, economic development, and environmental and agricultural practices, means that microbial threats to the population have increased. Nevertheless, countries with modern healthcare facilities are well equipped to manage febrile travelers and limit disease spread if clinicians follow appropriate guidelines (Figure 2). These basic principles are valid for every infectious disease. A case could be made that the threat from seasonal influenza, with approximately 36,000 deaths per year in the U.S. alone and rapid airborne transmission potentially even before a patient is symptomatic, is as great or greater than that from EVD. Regardless of the perspective, the listed actions are critical competencies for all emergency physicians in order to manage both the threat from EVD and the next big thing, whatever emerging infectious disease that might be.

Address for Correspondence: Kristi L. Koenig, MD. Center for Disaster Medical Sciences, Department of Emergency Medicine, UC Irvine Medical Center, 101 The City Dr. South, Route 128, Orange, CA 92868. E-mail: kkoenig@uci.edu.

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Utility of Vital Signs in Mass Casualty-Disaster Triage

David E. Hogan, DO, MPH* *Oklahoma State University, Department of Emergency Medicine, Oklahoma City, Oklahoma
Travis Brown, DO† †Duncan Regional Hospital, Department of Emergency Medicine, Duncan, Oklahoma

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INTRODUCTION

The triage of patients during a mass casualty – disaster (MCD) event presents the emergency healthcare provider with a complex and difficult issue. The task of evaluating casualties rapidly, using primarily the skills of physical examination, while still accurately identifying casualties likely to have critical injury or illness, may be impossible to achieve in practice. Yet at the same time it is known that accurate triage under MCD conditions improves outcomes not only for the individual critically ill casualty, but also for the entire cohort of casualties presenting for care.[1,2]

To improve the accuracy of MCD triage, further scientific investigations must be conducted to determine what elements of the physical examination (determining specific anatomic and physiologic factors) correlate best with the probability of critical injury and illness. These investigations should be – when possible – carried out under conditions that closely approximate the MCD environment. In addition, studies must be carried out as to the utility of new technologies that may be applied to the MCD triage process to improve and extend the ability of the triage officer in rapidly determining the condition of the casualty. Some recent studies have reported on data collected under actual MCD conditions, as well as using computer simulation to approximate the conditions of the MCD environment.[3,4] These studies are encouraging and hopefully represent an emerging area of research into this area of emergency healthcare.

One question frequently posed is that of the utility of vital signs, or specific physiologic parameters reflective of formal vital signs, in the performance of MCD triage. Study of this question has been hampered by multiple factors, including the difficulty in collecting such detailed data under actual MCD conditions.[1] This paper provides an analysis of the potential impact of abnormal vital signs on clinical triage categorization in comparison to triage categorization derived from actual dispositions of casualties from two separate MCD events.

METHODS

This is a protocol-driven cohort study of data from two separate local institutional review board- (IRB) approved studies of casualties during mass casualty – disaster (MCD) conditions (a terrorist bombing and an F-5 tornado).[5,6] Additional approval of a protocol to study the two anonymous database collections was granted from the local facility IRB. We queried the database collections for cases with complete data points to include: initial clinical triage category, initial vital sign documentation, emergency department (ED) diagnosis, and final patient disposition.

Clinical triage categorization is defined as the initial triage category assigned to the casualty by the triage officer at the level of the ED and documented in the medical record. To assess the agreement of the clinical triage categorization with a standard, we applied a revised triage category to each case. This revised category is termed disposition triage category, and is based on ED disposition as an indicator of the severity of injury/illness for the case as utilized in previous studies.[5-7] This does not relate to the level of documentation found in the chart but rather to individual decisions of admission vs discharge. In addition, decisions as to where the casualty is admitted (taken to the operating room, intensive care unit, ward bed, etc.) are well preserved in most medical records after MCD event and are thought to relate directly with the level of casualty injury or illness. Under this protocol the ED disposition relates with disposition triage categorization as follows:

Category I (Immediate)-Operating Room or Critical Care Admission; Category II (Delayed)-Noncritical Care Admission; Category III (Minimal)-Discharge Home; Category IV (Expectant)-Excluded From Analysis.

The disposition triage category is used as a standard for calculation of overtriage (OT) and undertriage (UT) rates of the clinical triage category assignment.

Recorded vital signs are scored as normal or abnormal using the standard adult and age-adjusted vital signs for children as recommended in Steadman's Medical Dictionary.[8] The Glasgow Coma Score (GCS) is recorded in the database as a total score without scoring of the individual parameters.

Any score less than 15 is considered abnormal.

Because the triage data thus obtained are ordinal (ranked) in nature, agreement between clinical and disposition triage categories is assessed using the weighted kappa test and is reported as raw agreement, κ with the 95% confidence interval and probability. In addition, agreement using the Kendall tau statistic is performed and reported as τ and probability. Linear regression is also performed using first the clinical triage categories as the dependent variable then the disposition-adjusted triage categories against the independent variables of Glasgow Coma Score, pulse, respiration, and systolic blood pressure. The results of correlation are reported as r with 95% confidence interval and probability. We performed statistical analysis with Microsoft Office Excel® (version 11.5612.5606) and the statistical add-on package Analyze-it® (version 2.05).

RESULTS

Out of a total of 535 cases in the two database sets (388 bombing, 147 tornadodo) 103 (19.25%) cases met case criteria; 46 male, 57 female; mean age 35yr (range 86 – 1 years). The clinical triage categories and event sources of cases are demonstrated in Figure 1. There are no significant differences between the cases meeting inclusion criteria and those excluded in age or sex, p=0.765. Three category IV (expectant) cases were excluded from further analysis (all 3 expectant casualties had no signs of life on presentation to the ED) leaving 100 cases fit for analysis, Category I; 23, Category II; 11, Category III; 66. Rates for *Undertriage* (UT) and *Overtriage* (OT) comparing the clinical triage categories to disposition triage categories are UT=35% and OT=1%.

Evaluation of agreement between clinical and disposition triage categories provided a raw agreement of 0.540 and κ=0.33 (95% CI: 0.21 to 0.45) p<0.0001 indicating a "fair" level of agreement. Linear regression using the clinical triage categories as the dependent variable and GCS, heart rate, respiratory rate, and systolic blood pressure as the independent variables found a significant but small agreement with GCS: r=0.1425 (95% CI: 0.0937 to 0.1913) p<0.0001. Substitution of the disposition triage categories for y in the same regression demonstrated similar small agreement with both GCS [r=0.06994 (95% CI: 0.01829 to 0.12160) p=0.0085] and systolic blood pressure [r=0.00895 (95% CI: 0.00309 to 0.01481) p=0.0031]. The vital signs of abnormal pulse rate and abnormal respiratory rate are not noted to have significant levels of agreement with disposition triage categories.

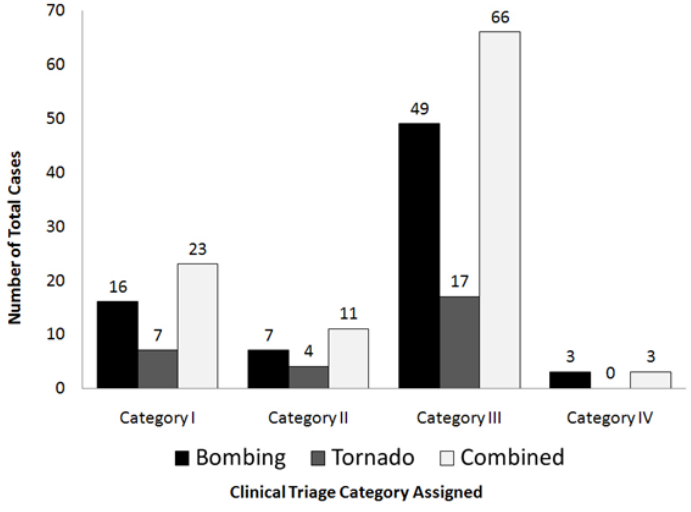

Figure. Distribution of mass casualty-disaster cases by clinical triage category and event type.

DISCUSSION

In general small numbers of cases were found with documentation of clinical triage categorizations and initial vital signs in the two study databases. This is consistent with the usual level of documentation that occurs during MCD events.[9] This is one of the issues making the study of the actual process of triage during MCD conditions so difficult. The low numbers can make the impact of any variable such as vital signs on triage categorization more difficult to resolve.

Undertriage, defined as the triage of a critical casualty as noncritical and overtriage, defined as the triage of a noncritical casualty as critical, are consistent problems encountered in MCD triage.[1] Overtriage has been reported to have an adverse impact on the outcomes of critical casualty cohort due to a misdirection and dilution of critical care resources away from truly critical casualties.[2,10] Undertriage primarily impacts the individual casualty by delaying his/her critical care interventions. Undertriage rates of 5% or less and overtriage rates of up to 50% have been generally agreed to be acceptable in prior publications.[10-13] The difficulties of studying activities of triage during MCD conditions are multiple and persistent.[1,14] The nature of these difficulties makes it even more challenging to evaluate the MCD triage process for the impacts of individual process elements (such as physiologic parameters). To our knowledge, this study includes some of the only data reported regarding a potential impact of vital signs on triage categorization collected under actual MCD conditions. As such, even with generally low numbers, there is value in their analysis, as long as that value is taken in the context of the study limitations.

Improvement of the MCD triage process is an important goal of emergency healthcare providers. The process of triage must obtain sufficient information regarding the anatomic and physiologic state of the casualty to avoid high levels of mistriage, which are known to adversely impact the entire cohort of injured/ill casualties.[2] At the same time the triage evaluation itself must remain nimble and abbreviated to prevent a bogging down of the process. As such, any elements of evaluation included in a "standardized" triage process should be validated as much as possible scientifically.

The data of this study demonstrate a small but significant level of agreement with increasing severity of triage categorization for mental status (based on the GCS) and systolic blood pressure. This suggests that a rapid mental status evaluation (such as the Mental status Alert, responsive

to Verbal or Painful Stimuli or Unresponsive method or GCS) as well as an evaluation for a radial pulse (as a surrogate for systolic blood pressure measurement) may be useful in improving the accuracy of MCD triage.

The presence of a radial pulse (as well as the strength and character of a radial pulse) has been associated with systolic blood pressure in previous studies.[15,16] In addition, both mental status and systolic blood pressure have been studied in the context of trauma systems triage and have been incorporated into various trauma scoring systems in that context.[17] An absent or weak radial pulse assessment by palpation may be considered an indicator of hypotension suggesting a level I (immediate) triage categorization. The data from this study suggest a link between these physiologic parameters and the patient dispositions under actual MCD triage conditions and should spur further prospective studies in this area.

LIMITATIONS

The reported overtriage and undertriage rates detected in this analysis are unusual, and thought to be a result of the process of case selection. The inclusion of only cases with complete sets of vital sign data points reduces the total case numbers considerably. Most of the cases removed from analysis for incomplete vital signs were also discharged home. As such, the large numbers of excluded cases represent "correct" triage decisions where clinical and disposition triage categories would agree. In addition, the cases most likely to have complete vital signs documented would logically be the more ill and injured casualties. For reasons discussed, such cases are more likely to have disagreement between clinical and disposition triage categories. This will skew the triage data towards the more critical cases in the numerator while eliminating less critical cases from the denominator. Therefore, as expected the undertriage rate will likely be falsely exaggerated and the overtriage rate falsely minimized. Estimation of triage sensitivity and specificity based on such potentially exaggerated rates has no real value. As such, sensitivity and specificity of triage categories correlated with vital signs are not calculated in this study. To do so would promote insensitive measure bias.[18]

In addition, the use of the disposition-adjusted triage category for a comparative standard makes OT and UT rates highly sensitive to the decision to admit casualties. In MCD events where medical resources are stressed but not completely overwhelmed (as was the case in both of the study events) physicians are more likely to admit casualties of lower acuity as a "safety measure" against missing injuries during the initial chaos of the event.[19] Such practice will further falsely elevate the UT rate in this study.

Measurement of the reliability of the triage process is a difficult proposition. The reliability of any particular process can often be estimated by evaluation of agreement between two observers (inter-rater reliability) or of the same observer on different observations of the same issue (intra-rater reliability).[20] The same statistic of agreement may be used to evaluate agreement between two measurements or outcomes on the same individual.[21] In this study the initial clinical triage categorization may be compared with the actual disposition of the casualty–and the implied triage category associated with that disposition.

Measurement of raw agreement alone is unsatisfactory in this case due to the potential for some level of agreement from random chance. Therefore, a statistical approach must be used to determine any agreement not associated with chance. The most commonly used is the kappa statistic that reports a value between 0=no agreement and 1=perfect agreement.[22] The kappa statistic, however, is based on the assumption that the data are nominal in nature. Triage data in the form of triage categories is ordinal (ranked). As such, either the weighted kappa statistic or the Kendell's tau-b statistic must be used to evaluate agreement.[22] Both of these values are provided in this study. Agreement in this case, when present to a sufficient degree, suggests a potential association, but it does not prove an association. The authors selected this method of analysis as sufficient for the robustness of the data and its level of bias.

CONCLUSION

Movement toward a standardization of MCD triage protocols intensifies the need for scientific analysis of the elements of that process. This study suggests a role of the physiologic parameters of mental status and systolic blood pressure in improving triage accuracy. These elements could be incorporated into a rapid triage evaluation formally or through a quick mental status examination and palpation for a radial pulse. The fact that any strong agreement between physiologic parameters and triage categorization was found suggests that further prospective data collection under MCD conditions should be performed to illuminate any potential association.

In a wider context however, researchers should consider what healthcare providers are being asked to do in MCD triage conditions. Given the temporal and physical limitations of the MCD triage examination and the limited type and nature of data those constraints allow one to collect, it may not be possible to achieve the levels of accuracy that emergency healthcare providers have set for themselves.

Address for Correspondence: David E. Hogan, DO, MPH, 5705 Parkhurst Road, Edmond, OK 73034. Email: shogan4@cox.net.

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Prehospital Use of IM Ketamine for Sedation of Violent and Agitated Patients

Kenneth A. Scheppke, MD*
Joao Braghiroli, MD†
Mostafa Shalaby, MD‡
Robert Chait, MD§

*University of Miami Miller School of Medicine Palm Beach Regional Campus, JFK Medical Center, Department of Emergency Medicine, Atlantis, Florida
†University of Miami, Miller School of Medicine, Miami, Florida
‡Metrohealth Medical Center Case-Western Reserve University, Department of Hospital Medicine, Cleveland, Ohio
§University of Miami Miller School of Medicine Palm Beach Regional Campus, JFK Medical Center, Department of Cardiology, Atlantis, Florida

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Introduction: Violent and agitated patients pose a serious challenge for emergency medical services (EMS) personnel. Rapid control of these patients is paramount to successful prehospital evaluation and also for the safety of both the patient and crew. Sedation is often required for these patients, but the ideal choice of medication is not clear. The objective is to demonstrate that ketamine, given as a single intramuscular injection for violent and agitated patients, including those with suspected excited delirium syndrome (ExDS), is both safe and effective during the prehospital phase of care, and allows for the rapid sedation and control of this difficult patient population.

Methods: We reviewed paramedic run sheets from five different catchment areas in suburban Florida communities. We identified 52 patients as having been given intramuscular ketamine 4mg/kg IM, following a specific protocol devised by the EMS medical director of these jurisdictions, to treat agitated and violent patients, including a subset of which would be expected to suffer from ExDS. Twenty-six of 52 patients were also given parenteral midazolam after medical control was obtained to prevent emergence reactions associated with ketamine.

Results: Review of records demonstrated that almost all patients (50/52) were rapidly sedated and in all but three patients no negative side effects were noted during the prehospital care. All patients were subsequently transported to the hospital before ketamine effects wore off.

Conclusion: Ketamine may be safely and effectively used by trained paramedics following a specific protocol. The drug provides excellent efficacy and few clinically significant side effects in the prehospital phase of care, making it an attractive choice in those situations requiring rapid and safe sedation especially without intravenous access. [West J Emerg Med. 2014;15(7):736–741.]

INTRODUCTION

It is not uncommon for paramedics and emergency medical technicians (EMTs) to be confronted with combative, violent and uncooperative patients. A subset of these patients will exhibit aggressive behavior, altered sensorium, and may demonstrate hyperthermia, "super human" strength, diaphoresis and a lack of willingness to yield to overwhelming force. Moreover, a certain percentage of these individuals will go on to expire from sudden cardiac arrest. Originally classified as "agitated delirium" or "excited delirium" by the forensic community, the term has now been adopted by the emergency medicine, psychiatric, law enforcement and prehospital literature. Recently, a task force convened by the American College of Emergency Physicians has coined the phrase excited delirium syndrome (ExDS) to cover

those patients with altered mental status who demonstrate severe agitation and combative or assaultive behavior.[1]

The management of ExDS is also difficult and the associated mortality warrants further study. The ability to gain "medical" control of these patients and allow resuscitative therapy to be administered is of the utmost importance. Many different medications can be given to effect sedation in the pre-hospital field including benzodiazepines, haloperidol and others. Many of the medications commonly used are far from ideal in that their onset of action is not immediate, the intravenous (IV) route is often preferred and, when given in the higher dosages required to adequately sedate violent patients, negative hemodynamic and respiratory side effects can make their use potentially harmful for the patient. Previous feedback obtained from local paramedic experience revealed a perceived lack of timely efficacy with haloperidol and benzodiazepine use in the field. The ideal medication, if one exists, would be given intramuscularly, have a near-immediate onset of action, a high efficacy rate even with the most violent and agitated patients, and have zero negative hemodynamic and respiratory side effects. With this as a background and due to the scant literature available, the medical director of five different municipal Fire/Rescue agencies (K.S.) developed a protocol for paramedics to administer intramuscular ketamine (Figure). Furthermore, it is well known that ketamine can cause an emergence reaction; therefore, midazolam was also to be administered to help avoid this potential reaction, but not for its sedative effects.

METHODS

We retrospectively screened paramedic run sheets from January 1, 2011 through May 1, 2014 for cases where the ketamine protocol was used for complaints of violent, aggressive behavior secondary to a psychiatric or substance-abuse issue. Reviewing the run sheets generated from these encounters we (R.C.) investigated the apparent benefits and risks of intramuscular ketamine given to sedate violent and agitated patients in the field. Approval from the university Institutional Research Board was obtained to review those records.

The medical director of several municipal fire/rescue agencies in Palm Beach County Florida (Boynton Beach Fire Rescue, Palm Beach Gardens Fire Rescue, Greenacres Fire Rescue, Town of Palm Beach Fire Rescue, and West Palm Beach Fire Rescue) has the authority and responsibility to develop medically correct standing orders for paramedics to use while treating patients in the prehospital setting.[2]

Under this authority, and in response to continuous feedback from paramedic crews about the difficulty and lack of success in dealing with and subsequently treating patients with violent or agitated behavior, a protocol was developed to allow rapid chemical restraint of these patients (including suspected ExDS) through the use of ketamine given as a single intramuscular injection at a dose of 4mg/kg of estimated body weight (Figure).

After initial sedation and control of the patient with ketamine, and per protocol, if possible, an intravenous line was established and a recommended dose of 2.0-2.5mgs of midazolam was given to prevent the well known but infrequent occurrence of a ketamine-induced emergence reaction.[3] Following appropriate chemical restraint, treatment of the underlying medical problem was to be initiated in the standard manner and the patient was transported to the closest appropriate hospital per protocol. We obtained cases where use of the ketamine sedation protocol occured from the above noted fire/rescue agencies from January 1, 2011 through May 1, 2014 and reviewed these reports. As a matter of routine paramedic practice, several sets of vital signs were obtained during transport, and any adverse hemodynamic or respiratory effect of the ketamine was noted on the paramedic run sheet.

The primary endpoint was to determine if ketamine provided adequate sedation of sufficient duration to effectively treat and transport these patients to a receiving hospital. Two additional endpoints were the amount of time it took to obtain "medical control" of these patients and whether there were any untoward hemodynamic or respiratory side effects noted from the use of the drug. We defined "medical control" as an adequate level of sedation to allow standard transport and treatment without further violence or agitation. Untoward hemodynamic effects was defined as any resuscitation needed for systolic blood pressure below 90. We defined untoward respiratory effects as any intervention requiring positive pressure ventilation.

RESULTS

A total of 52 patients with violent or agitated behavior were treated from the five service areas during the specified time period. The most common causes of the agitated and aggressive behavior (as noted by the paramedics) was either documented or suspected substance abuse and psychiatric emergencies (Table).

The average dose of ketamine used was 4 mg/kg and suitable sedation was obtained in every case but two (96%). Excluding the two ineffective uses, time to achieve effective sedation and medical control averaged just over two minutes. There were three cases (6%) of significant respiratory depression. One case required brief use of a bag valve mask, and two cases endotracheal tube intubation. Of note, in all three cases where respiratory depression was noted, the patients had also received midazolam. The average time to arrival to the emergency department from the time of injection was just under 19 minutes and, aside from the two ineffective uses, sedation was still present in every case. Nearly half of the patients did receive midazolam at a dose between 2-2.5mg either IV or intramuscular (IM) following or concurrently with the administration of the ketamine IM.

DISCUSSION

Psychomotor agitation occurs via several mechanisms. Cocaine causes an increase in the central nervous system excitatory amino acids glutamate and aspartate, and release

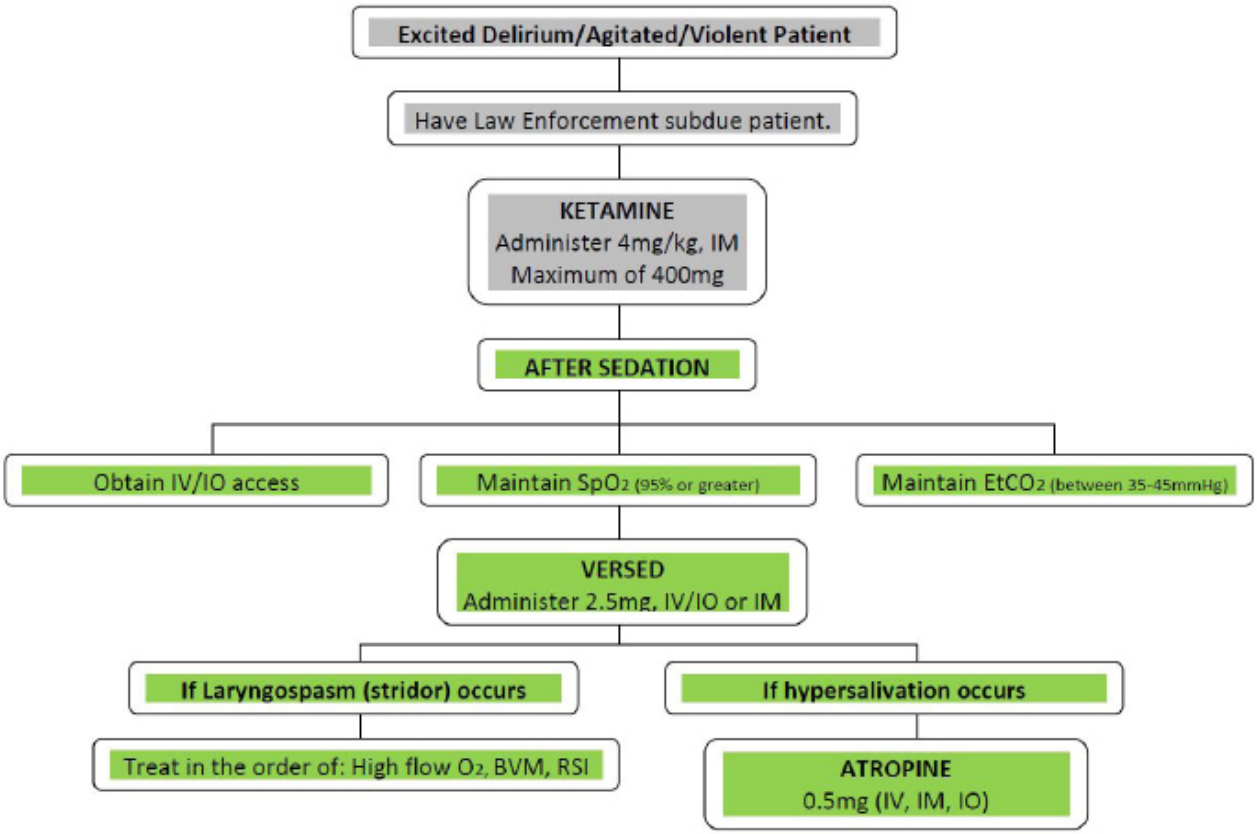

Figure. Prehospital ketamine protocol flowchart.
IM, intramuscular; *IV*, intravenous; *IO*, intraosseous infusion; *$EtCO_2$,* end tidal CO_2; *BVM*, bag-valve-mask; *RSI*, rapid sequence intubation

of the excitatory neurotransmitters norepinephrine, serotonin, and dopamine. The hyperthermia seen in cocaine-intoxicated patients is directly related to the extent of their psychomotor agitation and the ambient temperature.[4]

Cocaine-associated agitated delirium is a syndrome of hyperthermia with delirium and severe agitation that can progress to respiratory arrest and death. Restrained patients appear to be at particularly high risk with this syndrome.[5-10] The pathophysiology of cocaine-associated agitated delirium is a complex process involving down-regulation of dopamine receptors with subsequent dopamine excess during times of cocaine binges.[9,11-13] When patients with cocaine or other stimulant- associated agitated delirium are restrained, especially in the prone position, interference with normal respiratory mechanics increases the likelihood of hypoventilation, hypercarbia, acidemia and hypoxemia, ultimately leading to asphyxia and death. It has also been suggested that excessive muscle activity producing lactic acidosis is an additional exacerbating factor. Additionally, stress caused by the restraining process may increase the risk of fatal cardiac arrhythmias due to catecholamine surge in an already cocaine-sensitized myocardium.[9-11]

Ketamine is a phencyclidine derivative that causes dissociation between the cortical and limbic systems, which prevents the higher centers from perceiving visual, auditory or painful stimuli. It has a rapid onset and a short duration of action and produces significant sedation and analgesia.

There is no consensus about which of many available medications is the best to manage the prehospital agitated or violent patient. Route of administration along with potential for untoward side effects must be weighed when choosing which agent to use. Intramuscular agents are attractive due to their relative ease of administration in a violent patient; however rapidity of onset of sedation is equally important.

Prehospital determination of which patients require sedation also has a range of criteria. A study by the Israel Defense Force uses the inability to place a pulse oximeter on the patient to rule out hypoxemia as an indication for sedation.[14] In that study of 18 patients, several patients received ketamine intravenously. In our study only intramuscular ketamine was given, and suitable sedation was achieved in every case but two. There were no reported signs of emergence reaction noted during the prehospital portion of care; however, this case series was not designed to determine if any developed later in the course of hospital treatment.

Ketamine is a potentially ideal drug for prehospital sedation as it has an excellent safety profile, potent anesthetic effects and rapid onset of action with an absence of respiratory depression

Table. Characteristics and demographics of patients with violent or agitated behavior treated with ketamine by paramedics.

Pt	Gen	Age	DX	DOSE	Time	TA	MID	HR	BP	Temp	RR	SA
1	M	58	PSY	400	UNK	5	2.5	90	160/85	UNK	28	NO
2	M	37	TAS	400	3	16	2	126	145/80	UNK	16	NO
3	M	33	PSY	320	UNK	UNK	0	UNK	206/106	UNK	28	NO
4	F	23	PSY	200	2	22	2.5	125	110/80	UNK	30	NO
5	M	81	PSY	200	2	44	0	98	150/110	UNK	24	NO
6	F	35	E	320	2	14	2.5	116	160/110	101	18	NO
7	M	49	PSY	400	2	27	5	80	160/100	UNK	18	NO
8	M	29	D	400	2	28	0	74	140/100	UNK	24	NO
9	F	35	E	400	2	6	2.5	88	130/P	UNK	22	NO
10	M	49	PSY	200	2	29	0	122	120/80	UNK	26	NO
11	M	27	D/CO	200	2	9	2.5	110	150/102	UNK	18	NO
12	F	24	PSY	200	2	32	0	108	148/104	UNK	18	NO
13	M	54	UNK	400	2	23	5	130	UNK	98	24	NO
14	M	26	UNK	400	2	14	0	116	148/106	UNK	22	NO
15	F	57	PSY	400	2	UNK	2.5	122	228/130	UNK	28	NO
16	M	53	PSY	400	2	24	2.5	104	142/80	UNK	26	NO
17	F	37	D	400	2	30	2	88	128/P	UNK	22	NO
18	F	42	PSY	400	2	25	0	130	142/96	98	UNK	NO
19	M	54	D	400	1	30	0	100	140/90	98	26	NO
20	M	25	D	400	3	UNK	0	UNK	UNK	99	UNK	NO
21	M	27	D/E	400	3	UNK	0	162	140/90	UNK	22	NO
22	F	23	D	400	3	13	0	140	UNK	99	16	NO
23	M	21	D/CO	400	2	7	2	180	122/82	UNK	30	NO
24	M	45	PSY	400	3	39	2	120	158/114	UNK	20	ETT
25	M	36	D	400	2	6	0	176	180/100	104	22	NO
26	M	24	UNK	400	3	8	2	148	160/110	UNK	30	NO
27	M	45	PSY/TAS	400	1	5	2	130	UNK	UNK	26	NO
28	M	20	PSY	400	2	11	2	128	158/96	101.5	22	NO
29	F	29	D	200	2	17	2.5	152	134/84	99.4	28	NO
30	M	17	D	320	3	10	0	129	205/108	98	20	NO
31	F	17	D	320	2	26	0	78	118/90	UNK	30	NO
32	M	19	D	400	NOEF	20	0	124	UNK	UNK	UNK	NO
33	M	86	PSY	400	2	13	0	80	220/120	UNK	20	NO
34	M	22	D	300	2	20	0	134	166/82	UNK	20	NO
35	F	48	UNK	400	2	34	0	124	120/76	UNK	26	NO
36	M	29	D	500	5	20	0	112	170/80	UNK	18	NO
37	M	33	D/CO	400	1	20	0	136	160/70	99	24	NO
38	M	52	PSY	200	2	20	2	120	170/90	UNK	14	NO
39	M	19	PSY	400	1	18	0	108	138/64	101	24	NO

DX, diagnosis by paramedics; *DOSE*, ketamine dose in mg; *Time*, time to sedation; *TA*, time to arrival at hospital; *MID*, midazolam dose in mg; *HR*, heart rate; *BP*, blood pressure initially; *T*, temperature; *RR*, respiratory rate; *SA*, side effects from ketamine noted; *TAS*, Taser; *D*, Drug reaction; *E*, ETOH; *Psy*, psychiatric problem; *CO*, cocaine; *UNK*, no documentation; *NOEF*, no effect; *BVM*, bag valve mask required; *ETT*, required intubation.

Table (continued). Characteristics and demographics of patients with violent or agitated behavior treated with ketamine by paramedics.

40	M	49	PSY	200	1	10	2	120	164/72	UNK	24	NO
41	M	24	PSY	400	3	14	2	148	160/110	98.7	30	BVM
42	M	23	D	400	1	15	2	80	134/88	UNK	22	NO
43	M	43	D/CO	400	1	15	2	158	148/100	UNK	26	NO
44	M	41	PSY	400	5	17	0	90	110/80	UNK	18	NO
45	F	30	PSY	300	4	14	0	144	227/153	UNK	20	NO
46	M	47	D/PSY	400	NOEF	10	0	140	150/60	UNK	28	NO
47	M	23	PSY	400	3	16	0	110	160/102	UNK	16	NO
48	M	69	PSY	400	3	21	0	90	178/99	UNK	20	NO
49	M	34	D/CO	320	3	21	2.5	180	161/73	UNK	30	NO
51	M	23	PSY	400	2	24	0	108	178/104	UNK	18	NO
52	M	30	D/PSY	400	1	17	2	270	168/102	98.7	36	ETT

DX, diagnosis by paramedics; *DOSE*, ketamine dose in mg; *Time*, time to sedation; *TA*, time to arrival at hospital; *MID*, midazolam dose in mg; *HR*, heart rate; *BP*, blood pressure initially; *T*, temperature; *RR*, respiratory rate; *SA*, side effects from ketamine noted; *TAS*, Taser; *D*, Drug reaction; *E*, ETOH; *Psy*, psychiatric problem; *CO*, cocaine; *UNK*, no documentation; *NOEF*, no effect; *BVM*, bag valve mask required; *ETT*, required intubation.

and a short duration of action. In all but three cases it was felt that the drug was effective in three minutes or less, in two cases the time to effective sedation could not be extrapolated from the run report and in two cases it failed to achieve adequate sedation. There have been previous reports on the use of ketamine in the prehospital setting.[15] The drug provides effective analgesia and amnesia to pain and events. There are minimal cardiovascular effects. A previous study by Porter demonstrated the drug may be safely used by non-physician personnel.[16] Ketamine also has dissociative properties that can be induced with 1-2mg/kg intravenously (IV) or 4-5mg/kg intramuscularly. Duration of action is typically 10-15 minutes when administered IV and 20-30 minutes when given IM. The dissociative state has no progressive depth nor level and is either present or not, and additional doses do not enhance or deepen the sedation. Thus, adequate sedation can be reliably and safely achieved with one dose even without IV access. Ketamine has been used in burn patients, long bone fractures, other traumatic problems and multiple medical problems, as well as pre-procedural sedation, all of which suggests a wide range of potential beneficial uses for this agent.[17]

Our study demonstrated the use of ketamine by paramedics to be safe. This is consistent with ketamine's track record of safety, including reports where inadvertent overdoses of 5 to 100 times the intended dose demonstrated no adverse outcomes.[18] In the three cases where respiratory sedation required paramedic intervention, it was co-administered with midazolam, suggesting that extra caution with regard to airway management must be given when using both medications simultaneously.

While we find that ketamine worked well in our study, our evaluation also revealed some sedation protocol violations. Several patients, while noted to be very agitated, did not have their temperatures taken. It is recognized that in these violent patients, obtaining full vital signs is not always readily achievable. However, this also represents an educational opportunity for the paramedics regarding the ExDS and the importance of ruling out hyperthermia and its consequences after chemical restraint allows a more complete evaluation. In addition, approximately half of the patients did not receive a post-ketamine dose of midazolam to help prevent potential emergence reactions, yet they were adequately sedated for the entire transport. Paramedics interviewed by one of the authors (K.S.) regarding this apparent repeated protocol violation, revealed that midazolam was frequently omitted by some paramedics due to the excellent sedation routinely achieved by ketamine alone and therefore the feeling that further sedation with midazolam was unnecessary, while others adminstered it routinely despite excellent sedation because it was in the protocol. Given the three cases of respiratory depression that occurred with the co-administration of midazolam, the excellent sedation with ketamine alone, and the sole use of midazolam in the protocol as prophylaxis for possible emergence reactions, this suggests that further sedation with a benzodiazepine could potentially be delayed until hospital arrival.

LIMITATIONS

This was an uncontrolled observational study with a limited number of subjects. As such, care needs to be taken in generalizing from this study. While the literature is limited, there is evidence that the use of ketamine in the prehospital setting is an effective and safe practice with multiple benefits. We have shown that paramedics, given appropriate training and following a protocol, can administer the drug to violent and agitated patients with great success and minimal risk. An additional limitation of the study is in the selection process for patients to review. While the authors believe the vast majority of ketamine uses have been entered into the data set, it is possible some cases were not discovered owing to the retrospective

nature of the chart review. Another potential limitation of the study is reliance on documentation of side effects by paramedics. While it is recognized that the management of these patients is very difficult, it is interesting to note that there was a significant amount of missing data on the run sheets, which may have also played a role in our analysis. However, while the lack of some documentation by paramedics may be an issue, it probably does not alter the important aspects of this study, as any severe side effect would require an intervention such as intubation that would otherwise mandate documentation.

CONCLUSION

This study demonstrates that IM ketamine in the prehospital setting is a good choice to gain rapid medical control of patients with potential ExDs and those exhibiting violent and agitated behavior. A prospective head-to-head trial of ketamine versus other drugs should be carried out with clearly defined endpoints to fully delineate which therapeutic regimen is best for the rapid sedation and control of this difficult-to-manage patient population.

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Address for Correspondence: Kenneth A. Scheppke, MD, 5301 South Congress Avenue, Atlantis, Fl 33462. Email: kenneth.scheppke@shcr.com.

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Ketamine for Pre-hospital Control of Agitated Delirious Patients: Promising but Not yet Ready for Prime Time

Carl H. Schultz, MD University of California, Irvine School of Medicine, Center for Disaster Medical Sciences, Department of Emergency Medicine, Orange, California

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Providing acute medical care to severely agitated patients in the pre-hospital setting is a significant challenge. These patients often pose a serious safety threat to themselves and emergency medical services (EMS) providers. The dilemma confronting paramedics is they can't provide medical care until the can restrain the individual and they can't restrain the individual until they provide sedation. This is a bit reminiscent of the dilemma confronting individuals seeking their first job – you know how the phrase goes. Currently, no real solution to this problem exists. Most agents currently available act too slowly or require establishing an intravenous (IV) line. Of course, if you can establish an IV, you probably don't need to sedate the patient in the first place.

The use of ketamine in the field by paramedics for chemical restraint could be an important new development. This is a relatively new concept, but if it proves safe and effective, it would absolutely change medical practice. This alone makes the article by Scheppke et al. published in this issue of the journal worth reading.[1]

The authors of this manuscript describe a retrospective chart review of patients who received intramuscular (IM) ketamine for chemical restraint in the field by EMS providers. The study covered a 39-month period and included patients from five different catchment areas who received ketamine solely for chemical restraint in the field per a paramedic protocol (standing order). Researchers abstracted the patients' pre-hospital medical record looking for specific endpoints. The primary outcome was the adequacy and duration of field sedation. Secondary outcomes included the elapsed time to achieve medical control of patients, any airway or respiratory side effects, and the presence of hemodynamic compromise. The authors conclude that ketamine was both safe and effective in sedating 50 out of 52 patients. The average time to sedation and medical control was just over 2 minutes for the 50 patients successfully sedated. No hemodynamic complications occurred, and paramedics recorded only 3 cases of respiratory compromise requiring intervention. Tastes great, less filling. So what's not to like?

Before you go out and begin buying stock in pre-hospital ketamine use, however, a more detailed review of the company is warranted. I do understand the authors' exuberance over their findings, but stating ketamine is safe and effective based solely on a sample size of 52 patients is probably a bit premature. While potentially promising, significant reservations remain.

The major problem with this study is that the number of patients enrolled is too small to advance the authors' hypothesis. While providing a trend, the data lack the statistical power to provide real evidence of ketamine's safety and efficacy. In fact, the authors offer no real statistical analysis of their work. They state only 6% of patients required airway intervention but offer no confidence intervals around this number. If you do the math, the upper level of the 95% CI is 16%. Hmmm, this changes things a bit. If one out of seven patient receiving IM ketamine required airway intervention, it would probably be back to the drawing board. Even the 50/52 proportion for successful sedation has a lower confidence limit of 87%.

Another important issue is that significant other data are missing. Complications from ketamine administration that occurred after the patient arrived in the emergency department (ED) were not recorded. Even if pre-hospital ketamine use was 100% effective with no complications, it would be unusable if 40-50% of patients then required intubation in the ED or suffered cardiovascular compromise. It would only require a few ED deaths from this practice to make pre-hospital ketamine as popular as the military anti-shock trousers.

The authors offer no measurement of patient agitation and did not control for alcohol consumption or other drugs and conditions. So it makes it more difficult to interpret the data. How many patients may have used other substances that

could explain the complications? Even the inclusion criteria are somewhat vague. The medics had to state in the narrative that the patient was agitated. It is easy to see how medics could have easily missed these items during a difficult patient encounter since they would be unaware of the future study and would not necessarily know they had to make these entries in the record. While it appears the paramedics use of ketamine was reliably captured, identifying the indications for its use may have been less robust.

The basic methodology for data abstraction was retrospective chart review. Therefore, the authors should have made some comments regarding their adherence to the standard methods of chart review. I don't want to get too anal about this, but no reference was made to any of these criteria and the article by Gilbert and Lowenstein does not appear in the references. They do not address who abstracted the charts, if they used a standard tool, how discrepancies between abstractors were resolved, etc. The definition for an agitated patient that would initiate the ketamine protocol is absent and seems patient selection for treatment was totally by paramedic discretion.

The use of midazolam by the paramedics also seems somewhat confusing. In the methods section, the authors state midazolam was given after IM ketamine, if IV access was obtained after securing sedation. However, in the results section, they comment that nearly half of the patients received IV or IM midazolam. This seems to imply that paramedics could have administered midazolam either IV or IM. If midazolam could be given IM, it is unclear why only 50% of subjects received the drug. In addition, the conclusion that midazolam may have been responsible for the respiratory complications is in doubt. Assuming half of the subjects received midazolam (the authors suggest this in the article), the incidence of respiratory depression is approximately 3 out of 25 for those receiving the drug and 0 out of 25 for those that did not. The 95% CI for the difference in these proportions crosses zero (-3% to 30%), meaning there is no statistical significance between these groups. Recent evidence is fairly convincing that the use of midazolam in adults significantly reduces the incidence of recovery agitation (emergence reaction).[2] As such, the use of midazolam would be considered an important adjunct to pre-hospital ketamine use unless clearly contraindicated. Unfortunately, this pilot study does not provide a clear answer.

Lastly, the authors are a bit optimistic regarding the safety profile for ketamine. In several sections of the manuscript, they state ketamine is safe and effective in the pre-hospital setting. However, they simply don't have the data to support this. While I do actually believe this is true, the investigation by Scheppke et al. is preliminary and does not have the power to support this statement. In fact, ketamine is primarily a myocardial depressant. This effect is generally not seen due to the immediate release of catecholamines that accompany drug administration. In individuals who are catecholamine depleted, however, ketamine can cause cardiovascular compromise and rarely transient cardiac arrest. Given the results from this study are also consistent with the need for intubation or bag-valve-make ventilation in as many as 16% of individuals receiving pre-hospital IM ketamine, a blanket statement that ketamine is safe may be inconsistent with the data.

In summary, I think the authors should be congratulated for providing preliminary evidence for the use of ketamine in the pre-hospital setting. While not definitive, these data can provide support to justify larger, randomized trials which can establish the safety and efficacy of ketamine and further clarify the risks of midazolam, if any. If the data in this study are ultimately proven correct, the standard of care for pre-hospital management of agitation would change, and those who adopted this practice early will look as brilliant as the investors who purchased stock in a small company called Microsoft in 1985.

Address for Correspondence: Carl Schultz, MD, 101 The City Drive, Rt 128-01, Orange, CA 92868. Email: schultzc@uci.edu.

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National Trends in the Utilization of Emergency Medical Services for Acute Myocardial Infarction and Stroke

Katie Tataris, MD, MPH
Sean Kivlehan, MD, MPH
Prasanthi Govindarajan, MD, MS

University of California at San Francisco, Department of Emergency Medicine, San Francisco, California

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Introduction: The emergency medical services (EMS) system plays a crucial role in the chain of survival for acute myocardial infarction (AMI) and stroke. While regional studies have shown underutilization of the 911 system for these time-sensitive conditions, national trends have not been studied. Our objective was to describe the national prevalence of EMS use for AMI and stroke, examine trends over a six-year period, and identify patient factors that may contribute to utilization.

Methods: Using the National Hospital Ambulatory Medical Care Survey-ED (NHAMCS) dataset from 2003-2009, we looked at patients with a discharge diagnosis of AMI or stroke who arrived to the emergency department (ED) by ambulance. We used a survey-weighted $\chi 2$ test for trend and logistic regression analysis.

Results: In the study, there were 442 actual AMI patients and 220 (49.8%) presented via EMS. There were 1,324 actual stroke patients and 666 (50.3%) presented via EMS. There was no significant change in EMS usage for AMI or stroke over the six-year period. Factors independently associated with EMS use for AMI and stroke included age (OR 1.21; 95% CI 1.12-1.31), Non-Hispanic black race (OR 1.72; 95% CI 1.16-2.29), and nursing home residence (OR 11.50; 95% CI 6.19-21.36).

Conclusion: In a nationally representative sample of ED visits from 20003-2009, there were no trends of increasing EMS use for AMI and stroke. Efforts to improve access to care could focus on patient groups that underutilize the EMS system for such conditions. [West J Emerg Med. 2014;15(7):744–748.]

INTRODUCTION

Acute myocardial infarction (AMI) and stroke are both time-sensitive conditions with significant morbidity and mortality across the United States.[1] In 2013, an American Heart Association update found the burden of cardiovascular disease (CVD) remains high throughout the U.S.[1] Each year in this country an estimated 915,000 people experience a new or recurrent myocardial infarction or coronary heart disease death, and approximately 795,000 people experience a new or recurrent stroke.[1] The emergency medical services (EMS) system plays a crucial role in the chain of survival for both conditions by facilitating timely access to the emergency care system through early recognition in the field, advanced notification to the receiving facility, prompt emergency department (ED) evaluation and imaging and therapeutic intervention.[2-4] Therefore, national guidelines by the American Heart Association and the Centers for Disease Control and Prevention (CDC) recommend that the public activate the 911 system upon recognition of warning signs of an AMI or stroke.[1,2] While there have been several efforts to improve the use of 911 in time-sensitive conditions, regional data have not shown a significant increase in use of 911.[5,6] However, national trends in use of 911 comparing utilization for AMI and stroke have not been studied before. Improved public health awareness of AMI and stroke symptoms, combined with recent focus on prehospital systems of care could lead to a higher national utilization of EMS for these time-sensitive conditions. The primary objective of this study was to describe

the prevalence of EMS use by AMI and stroke patients across the U.S. Our secondary objectives were to ascertain EMS utilization trends over a six-year period and examine patient factors that may influence its use.

METHODS

We analyzed data collected between 2003 and 2009, by the National Hospital Ambulatory Medical Care Survey-ED (NHAMCS), which is a nationally representative, multicenter, stratified sample of ED visits.[7] This six-year period was chosen as there were changes in the data format after 2009. NHAMCS provides data on the utilization of emergency care in non-institutional general (excluding federal) and short-stay hospitals throughout the U.S. This survey is conducted by the National Center for Health Statistics, a branch of the CDC. Details of the survey methodology are available online. In brief, field investigators collect a random sample of standard patient record forms from all visits to EDs within the primary sampling units (PSUs) in a random four-week period. PSUs are randomly chosen from 1,900 county-sized population units first identified for the National Health Interview Study. These data are publicly available and therefore exempt from institutional review board approval.

We included patients with a primary diagnosis of AMI and ischemic stroke, defined by International Classification of Diseases, Ninth Revision (ICD-9) codes. The primary search parameter was ED arrival by ambulance. We used survey visit weights provided by the NHAMCS to estimate the national proportion of patients diagnosed with AMI and stroke in EMS transported patients. A survey-weighted χ^2 test for trend was used to examine the statistical significance of changes in ambulance use over time for each of these conditions. Logistic regression modeling was used to determine factors independently associated with EMS use. We performed data analysis in SAS version 9.2 (Cary, NC) and Sudaan, version 10.0 (Research Triangle, NC), using the threshold of statistical significance was a 2-sided α level of 0.05.

RESULTS

The total study patients and characteristics associated with EMS arrival in AMI and stroke patients can be found in Table 1. We analyzed the entire age group as shown in Table 1, but focused on the 65-80 subgroup as they contributed to the highest proportion of stroke patients. In the AMI group, there were 41.2% female and 39.5% of the total patients within the 65-80 years of age category. In the stroke group, there were 56.0% female and 36.5% of total patients within the 65-80 years of age category. In this study, the actual number of patients represents the weighted N or number as part of the total population. There were 442 AMI patients (estimated number in the population was 737,397) included in the study and 220 (49.8%) presented to the ED via EMS. During this same period, 1,324 stroke patients were analyzed (estimated number in the population was 2,316,655) and 666 (50.3%) presented via EMS. The majority of patients in both groups were non-Hispanic white and listed home as their primary residence. There is a similar distribution between insurance groups for both AMI and stroke. A higher percentage of AMI and stroke patients in this sample called EMS from the South region and were found in urban areas. In terms of ED care, the most common triage time grouping for both AMI (59.2%) and stroke (44.2%) was less than 15 minutes, and the majority of patients were admitted to the hospital, indicating a high acuity. For AMI patients, variables associated with EMS arrival were race/ethnicity, nursing home residence and insurance (Table 1). Older age, nursing home residence, insurance status and geographic regions were all associated with arrival via EMS for stroke patients.

EMS usage for AMI and stroke was evaluated annually from 2003-2009 (Figure). For both of these conditions there was no significant change in 911 activated transports over the six-year time period.

Logistic regression analysis revealed the factors independently associated with EMS use for both AMI and stroke patients combined (Table 2). Patient factors evaluated were age, race, geographic region, residence, and time. For the analysis, we used one patient factor as the reference or baseline for which the others were compared against and this is listed on the table as 'Reference.' The statistically significant factors were age (OR 1.21; 95% CI 1.12-1.31), non-Hispanic black race (OR 1.72; 95% CI 1.16-2.29), and nursing home residence (OR 11.50; 95% CI 6.19-21.36). These factors are bolded on Table 2.

DISCUSSION

Using data from a nationally representative sample of ED visits, we found that despite national efforts to improve EMS use for time-sensitive conditions, trends have remained stable over time. Our results indicate that across the U.S., only 50% of patients with AMI and stroke present to the ED by EMS. While this number appears low, it is consistent with prior regional published studies that also show about 50% EMS utilization for time-sensitive conditions.[5,8] These results indicate that warning symptoms may be going unrecognized in the community and delaying the time to diagnosis and treatment. While ongoing studies are exploring reasons for lack of 911 usage in time-sensitive conditions, future work should focus on identifying high-risk populations and targeting efforts towards non-users of EMS.[9,10]

While the majority of the sample using EMS for both conditions was comprised of white non-Hispanic patients, black non-Hispanics were more likely to use EMS for transport than white non-Hispanic patients. Prior studies have shown race to be a variable factor in EMS utilization for AMI

Table 1. Patient characteristics associated with emergency medical services arrival in acute myocardial infarction (AMI) and stroke patients.

		Actual number of patients with ICD - 9 of AMI, unweighted n=220 (%) Weighted N =737,397	Actual number of patients with ICD - 9 of Stroke, unweighted n=666 (%) Weighted N =2,316,655
Sex	Female	94 (41.2)	371 (56.0)
	Male	126 (58.8)	295 (44.0)
Age	18-44	20 (8.2)	42 (7.2)
	45-64	69 (33.1)	167 (23.3)
	65-80	82 (39.5)	224 (36.5)
	>80	49 (19.2)	233 (33.0)
Race/ethnicity	NH white	160 (71.4)	497 (76.8)
	NH black	27 (12.4)	98 (14.5)
	Hispanic	18 (9.0)	42 (5.7)
	Other	15 (7.2)	29 (3.0)
Patient residence	Nursing home/ institution	28 (13.4)	114 (15.6)
	Home/other	173 (77.7)	500 (76.5)
	Unknown	19 (8.9)	52 (7.9)
Triage	<15 minutes	132 (59.2)	302 (44.2)
	15-60 minutes	42 (19.5)	202 (31.3)
	>1 hr-2 hrs	11 (4.0)	82 (12.2)
	>2 hrs-24 hrs	7 (5.2)	14 (1.9)
	Unknown	28 (12.1)	66 (10.4)
Insurance	Private	93 (42.0)	232 (37.0)
	Medicare	76 (34.6)	273 (39.3)
	Medicaid	28 (13.2)	86 (12.3)
	Indigent	10 (3.4)	40 (6.7)
	Other	5 (2.3)	14 (2.0)
	Missing	8 (4.5)	21 (2.7)
Disposition	Transfer	34 (15.9)	56 (7.1)
	Admit CCU/ICU	70 (32.1)	129 (20.1)
	Admit to hospital	95 (42.2)	379 (58.7)
	Admit observation	2 (0.3)	14 (2.3)
	DOA/died in ED	13 (7.2)	3 (0.2)
	Other	6 (2.3)	85 (11.6)
Geographic region	Northeast	57 (22.5)	188 (25.1)
	Midwest	53 (25.4)	138 (22.5)
	South	71 (34.5)	215 (34.0)
	West	39 (17.6)	125 (18.4)
Metropolitan Statistical Area (MSA)	Urban	186 (82.2)	579 (84.0)
	Rural	34 (17.8)	87 (16.0)

ICD, International Classification of Diseases; *NH*, non-Hispanic; *CCU*, coronary care unit; *ICU*, intensive care unit; *DOA*, dead on arrival; *ED*, emergency department

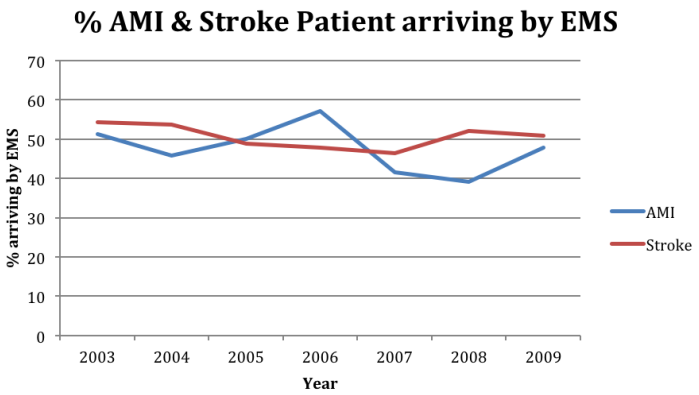

Figure. Emergency medical services (EMS) use for acute myocardial infarction (AMI) and stroke between 2003-2009.

and stroke.[11-13] Our results could be explained by increased severity of symptoms, lack of personal vehicle access, awareness of the EMS system, or success of recent targeted public heath campaigns. In our study, we found nursing home patients are overall high users of the EMS system, and have a much higher odds of EMS use with time-sensitive conditions. This could in part be explained by the fact that healthcare providers with prior knowledge of AMI and stroke are the ones accessing the emergency care system. The odds of EMS use were highest in the Northeast when compared to other regions in our analysis. A greater proportion of urban settings with established EMS systems and therefore an increased access to care or effective public health messaging could explain this finding.

While review of the NHAMCS dataset from 2003-2009 showed no increase in EMS utilization for AMI and stroke during those six years analyzed, recent national proposals have attempted to address this challenge. In September 2011, the CDC launched the Million Hearts Campaign to prevent heart disease and stroke using a multidisciplinary approach. This six-year project attempts to prevent one million heart attacks and strokes by 2017. The campaign identifies "improving access to effective care" as an important component to the initiative.[14] Future studies are needed to show if these efforts translate into increased use of the 911 system as a means of accessing care.

Our results indicate that ongoing efforts have not resulted in a national increase in EMS use for AMI and stroke. However, data have shown the importance of early detection and timely transport for these time-sensitive conditions. Therefore, understanding if efforts should be directed toward improving knowledge or facilitating translation of knowledge into calling 911 is critical. Also, whether efforts should be targeted or generalized to the community needs to be better studied. Further, similar efforts are underway for other disease processes, such as out of hospital cardiac arrest (OHCA), and it is important to learn from the successes of those targeted efforts aimed to improve cardiopulmonary resuscitation in the community.

LIMITATIONS

Some limitations to our findings are that the NHAMCS database uses survey weighting to estimate national probability and may not be representative of all regions in the U.S. We recognize this is a hypothesis-generating study and it does not provide answers to why

Table 2. Factors independently associated with ambulance transport in AMI and stroke patients.

	Unadjusted OR	95% (CI)	Adjusted OR	95% (CI)
Age (deciles)	1.25	(1.16, 1.35)	1.21	1.12, 1.31
Race				
NH white	Reference	-	Reference	-
NH black	1.3	(0.92, 1.84)	1.72	1.16, 2.29
Hispanic	0.9	(0.54, 1.49)	1.03	0.53, 1.62
Other	1.22	(0.69, 2.17)	1.48	0.80, 2.72
Geographic region				
Northeast	Reference	-	Reference	-
Midwest	0.64	(0.43, 0.96)	0.68	0.44, 1.03
South	0.55	(0.41, 0.74)	0.63	0.47, 0.85
West	0.56	(0.36, 0.85)	0.64	0.42, 0.99
Patient residence				
Nursing home	14.45	(7.85, 26.58)	11.5	6.19, 21.36
Other	Reference	-	Reference	-
Missing	1.97	(1.27, 3.07)	1.9	1.22, 2.95
Time (continuous)	0.98	(0.92, 1.03)	0.98	0.93, 1.03

NH, non-Hispanic

utilization of EMS continues to be low. In addition, our selection of the time period to be investigated was in part due to the change in data format of NHAMCS after 2009 and to avoid complexities in analyzing the two differently formatted datasets.

CONCLUSION

In addition to current efforts, there should be continued attempts to understand the reasons for the lack of EMS activation when time-sensitive conditions such as AMI and stroke present. Targeting efforts towards communities who underutilize EMS could be beneficial and should be considered.

Address for Correspondence: Katie Tataris, MD, MPH, University of California San Francisco, 505 Parnassus Ave., San Francisco, CA 94143. Email: katietataris@gmail.com.

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Does Pre-hospital Endotracheal Intubation Improve Survival in Adults with Non-traumatic Out-of-hospital Cardiac Arrest? A Systematic Review

Ling Tiah, MBBS, MPH[*]
Kentaro Kajino, MD, PhD[†]
Omer Alsakaf, MD[‡]
Dianne Carrol Tan Bautista, PhD[§]
Marcus Eng Hock Ong, MBBS, MPH[¶‖]
Desiree Lie, MD, MS.ED[#]
Ghulam Yasin Naroo, MBBS[**]
Nausheen Edwin Doctor, MBBS[‖]
Michael YC Chia, MBBS[††]
Han Nee Gan, MBBS[*]

[*]Changi General Hospital, Accident and Emergency Department, Singapore
[†]Ministry of Health, Labour and Welfare, Government of Japan, Department of Acute Medicine & Critical Care Medical Center, Osaka National Hospital, Osaka, Japan
[‡]Dubai Corporate for Ambulance Services, Dubai, United Arab Emirates
[§]Duke-NUS Graduate Medical School, Center for Quantitative Medicine, Singapore
[¶]Duke-NUS Graduate Medical School, Health Services and Systems Research, Singapore
[‖]Singapore General Hospital, Department of Emergency Medicine, Singapore
[#]Duke-NUS Graduate Medical School, Office of Clinical Sciences, Singapore
[**]Rashid Hospital, Department of Health & Medical Services, ED-Trauma centre, Dubai, United Arab Emirates
[††]Emergency Department,Tan Tock Seng Hospital, Singapore

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Introduction: Endotracheal intubation (ETI) is currently considered superior to supraglottic airway devices (SGA) for survival and other outcomes among adults with non-traumatic out-of-hospital cardiac arrest (OHCA). We aimed to determine if the research supports this conclusion by conducting a systematic review.

Methods: We searched the MEDLINE, Scopus and CINAHL databases for studies published between January 1, 1980, and 30 April 30, 2013, which compared pre-hospital use of ETI with SGA for outcomes of return of spontaneous circulation (ROSC); survival to hospital admission; survival to hospital discharge; and favorable neurological or functional status. We selected studies using pre-specified criteria. Included studies were independently screened for quality using the Newcastle-Ottawa scale. We did not pool results because of study variability. Study outcomes were extracted and results presented as summed odds ratios with 95% CI.

Results: We identified five eligible studies: one quasi-randomized controlled trial and four cohort studies, involving 303,348 patients in total. Only three of the five studies reported a higher proportion of ROSC with ETI versus SGA with no difference reported in the remaining two. None found significant differences between ETI and SGA for survival to hospital admission or discharge. One study reported better functional status at discharge for ETI versus SGA. Two studies reported no significant difference for favorable neurological status between ETI and SGA.

Conclusion: Current evidence does not conclusively support the superiority of ETI over SGA for multiple outcomes among adults with OHCA. [West J Emerg Med. 2014;15(7):749-757.]

INTRODUCTION

Timely establishment of a patent airway with adequate ventilation has long been regarded as a primary objective in the management of non-traumatic out-of-hospital cardiac arrest (OHCA). Advanced airway intervention by emergency medical services (EMS) personnel was first introduced in the

1970s as a superior alternative to basic airway control such as bag-mask-valve ventilation for pre-hospital resuscitation.[1-3]

Endotracheal intubation (ETI), the standard for securing a definitive airway in in-hospital resuscitation, has since gained widespread support as one of the advanced airway modalities for OHCA patients. Over the past four decades, EMS personnel in various parts of the world have been increasingly trained and certified to perform pre-hospital ETI as part of advanced cardiac life support care.[1,4,5] Advocates maintain that with comprehensive and continuous training, ETI by field EMS personnel is safe and may be associated with improved outcomes in selected patient groups.[6-9] Others remain concerned about the use of ETI in relatively unskilled hands in pre-hospital settings where infrequent exposure and limited experience may potentially lead to prolonged attempts, unrecognized complications and compromised patient care.[10-12]

Supraglottic airway devices (SGA) are inserted without laryngoscopy and provide ventilation by delivering oxygen above the level of glottic opening. As such, they are an attractive alternative to ETI due to their relative ease of insertion, better skill retention by users and comparable ventilation adequacy.[13-16] The different types and models of SGA have evolved considerably over the years. Earlier generations, such as the esophageal obturator airway, the esophageal gastric tube airway and the pharyngeal tracheal lumen airway, have largely been abandoned due to questionable efficacy and associated serious complications.[13,17-20] Nonetheless, there are still challenges associated with other SGA available for use by EMS personnel, such as esophageal perforations, tracheal injury and insufficient protection against pulmonary aspiration.[21-24]

Despite decades of advanced airway intervention by EMS in the field, there remains a lack of high-quality evidence supporting the use of ETI over SGA. The scarcity of true randomized controlled trials in this area reflects underlying ethical concerns and logistical challenges. Recent literature reviews suggest a need to re-evaluate the presumed benefits of pre-hospital ETI for selected study populations such as those with major trauma and pediatric patients.[3,25-27] The objective of this systematic review is to determine whether ETI compared to SGA is associated with improved survival and other outcomes among adults with non-traumatic OHCA. We hypothesized that among these patients, ETI is superior to SGA for survival and other outcomes.

METHODS

Search Strategy

Three authors (KK, OA, TL) conducted a search of the MEDLINE, Scopus and CINAHL databases for eligible studies published in English between January 1, 1980, and April 30, 2013. The search strategy used relevant keywords as Medical Subject Headings terms in MEDLINE; and free-text words in the other two databases in the following combinations: (intubation or endotracheal or intratracheal or supraglottic or laryngeal mask or combitube or esophageal tracheal or esophageal tracheal) and [(out-of-hospital or pre-hospital) and (cardiac arrest or heart arrest)] and (emergency medical services or paramedic). Filters were applied to include only human studies and to exclude studies involving only children.

For the purpose of this review, we defined ETI as the placement of a secured cuffed tube in the trachea. SGA in this review refer to devices currently in use by most EMS systems, such as the laryngeal mask airway, the laryngeal tube and the esophageal-tracheal Combitube.[13,28,29] We excluded use of now- obsolete, earlier generation devices.[26]

Study Eligibility Criteria and Data Extraction

We included randomized controlled trials and cohort studies with patient outcomes comparing the use of ETI and SGA in pre-hospital settings. We excluded studies that provided a comparison of either ETI with bag-valve-mask ventilation only or SGA with bag-valve-mask ventilation only. We also excluded reviews of studies, editorials and other papers without patient data.

We restricted our review to studies that involved adults 18 years or older with non-traumatic OHCA. We excluded studies with undifferentiated study populations of adults and pediatric patients (younger than 18 years) and those with undifferentiated causes of OHCA. EMS personnel involved in the advanced airway management could be physicians, nurses, paramedics, emergency medical technicians or basic-level emergency medical technicians. Studies that involved military medical and evacuation services were excluded.

Studies had to provide at least one of the following patient-based outcomes: (1) return of spontaneous circulation (ROSC), defined as the presence of a palpable pulse without cardiopulmonary resuscitation, which could be specified to be before or upon arrival in the emergency department or unspecified; (2) survival to hospital admission to an inpatient ward; (3) survival to hospital discharge, regardless of the length of hospital stay; and (4) favorable neurological or functional outcome with the use of validated measures, such as the Cerebral Performance Category Score, the Modified Rankin Scale or the Health Utilities Index.[30-32] We excluded studies that reported only non-patient-centered outcome measures relating to personnel ease of use, device complications or effectiveness of ventilation in terms of biochemical or physiological markers.

Three authors (KK, OA, TL) screened titles and abstracts of studies generated from the search (KK, OA, TL). Full text articles were next obtained for studies eligible for inclusion. Only studies meeting the inclusion and exclusion criteria were then selected for final quality review.

Two reviewers (GHN, TL) then independently reviewed the included studies for assessment of methodological quality. None of the included studies were randomized trials, so we chose the Newcastle-Ottawa Scale (NOS) for

rating study quality.[33,34] The NOS assigns a minimum of zero and a maximum of four stars for three criteria (patient selection, comparability and outcome) based on a total of eight questions. The stars were then tallied to provide four categories of study quality (poor = 0 to 3 stars; fair = 4 to 5 stars; good = 6 to 7 stars and excellent = 8 to 9 stars).

We extracted information about study design, participants, sample size, airway modalities investigated (ETI versus SGA), patient outcome measures, key findings and authors' conclusions or recommendations and collated it into a descriptive summary table. The results were not pooled into a meta-analysis because of variation across EMS systems among the included studies. Instead, two authors (DB, TL) extracted data pertaining to the effect size of respective outcome measures from each study (where provided or available). If the adjusted analysis was not available, we calculated the unadjusted odds ratios (OR) with 95% CI based on number of events in respective outcome measures for ETI versus SGA (if reported).

RESULTS

Search Results

The electronic search yielded 490 studies of which 147 were duplicates (Figure 1), leaving 343 studies for title and abstract review. After title and abstract review, seven were found to meet eligibility criteria. After reviewing their full texts, two of the studies were further excluded. One study included patients aged 15 years and above with no further differentiation of its study population into adults and pediatric patients (younger than 18 years).[35] The other study included patients of all ages receiving either ETI or laryngeal mask airway (LMA), similarly with no further subgroup analysis differentiated by adult and pediatric (younger than 18 years) population.[36] Five studies were eventually included in the final analysis.

Characteristics of Included Studies

The five included studies (Table 1) involved a total of 303,348 non-traumatic OHCA adult patients receiving pre-hospital advanced airway management in the form of either ETI or SGA. Mean patient age ranged from 55 years to 75 years; and two thirds of patients were male. Study size ranged from 172 to 281,522 patients and study duration from 12 months to eight years.

One study was quasi-randomized,[37] another was a secondary analysis of another study;[38] and the remaining were prospective[39,40] and retrospective[41] cohort studies. Two studies were conducted in North America, two in Japan and one in Austria. Only one study had experienced physicians as part of their EMS teams, while the rest had paramedics and emergency medical technicians. Among the five studies, two compared ETI with esophageal-tracheal Combitube only (an SGA device) while the other three compared ETI with SGA as a combined group without differentiating among the particular SGA devices.

The quality of the studies was good to excellent (Table 2). Agreement for quality score was 100% between the two reviewers (GHN, TL).

Comparison of Outcome Measures

The results of the respective included studies were summarized in Table 3. All five studies addressed ROSC as

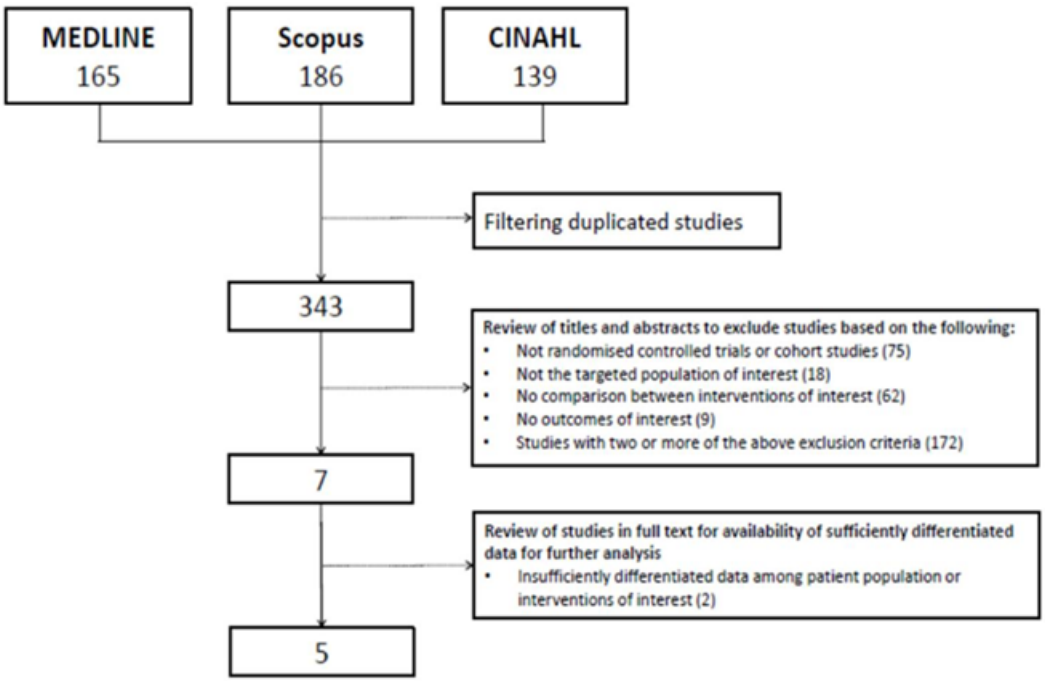

Figure 1. Search and selection process for comparison of endotracheal intubation (ETI) and supraglottic airways (SGA) patient outcomes, 2011 and 2013 updated search results.
CINAHL, Cumulative Index to Nursing and Allied Health Literature

Table 1. Included studies comparing endotracheal intubation (ETI) with supraglottic airways (SGA): Summary of study characteristics.

Study	Study design and study period	Patient group and emergency personnel	Interventions (ETI or SGA) and outcome measures
Cady et al. (2009)	Retrospective cohort study Study period: 1 January 1997 to 31 December 2005	Patient group: 5,822 adults (21 years or more) Emergency personnel: EMS teams (non-physician) of one county in the United States of America	Interventions: ETI versus SGA (esophageal-tracheal Combitube only) Outcome measures of interest: ROSC (unspecified); Survival to hospital admission; Survival to hospital discharge
Hasegawa et al. (2013)	Prospective cohort study Study period: 1 January 2005 to 31 December 2010	Patient group: 281,522 adults (18 years or more) Emergency personnel: EMS teams (non-physician) of all prefectures in Japan	Interventions: ETI versus SGA* Outcome measures of interest: ROSC (pre-hospital); Favorable neurological outcome at one month (Cerebral Performance Category = 1 or 2)
Kajino et al. (2011)	Prospective cohort study Study period: 1 January 2005 to 31 December 2008	Patient group: 5,377 adults (18 years or more) Emergency personnel: EMS teams (non-physician) of one prefecture in Japan	Interventions: ETI versus SGA Outcome measures of interest: ROSC (pre-hospital and in emergency department); Survival to hospital admission; Survival at one month; Favorable neurological outcome at one month (Cerebral Performance Category = 1 or 2)
Rabitsch et al. (2003)	Quasi-randomisation study Study period: 12 months	Patient group: 172 adults (18 years or more) Emergency personnel: EMS teams (physician-led) of one city in Austria	Interventions: ETI versus SGA (esophageal-tracheal Combitube only) Outcome measures of interest: ROSC (unspecified); Survival to emergency department; Survival to admission to intensive care unit; Survival to hospital discharge
Wang et al. (2012)	Secondary analysis of a randomized controlled trial Study period: June 2007 to November 2009	Patient group: 10,455 adults (18 years or more) Emergency personnel: EMS teams (non-physician) affiliated with 10 universities and medical institutes in the United States of America and Canada	Interventions: ETI versus SGA Outcome measures of interest: ROSC (unspecified); Satisfactory functional status at hospital discharge (Modified Rankin Scale ≤ 3)

EMS, emergency medical services; *ETI*, endotracheal intubation; *ROSC*, return of spontaneous circulation; *SGA*, supraglottic airways
*Although the original article compared bag-valve-mask ventilation with advanced airway management as a group, there were adequate differentiated information to allow comparison of outcomes between ETI and SGA.

one of the outcome measures, either as adjusted or unadjusted analysis, with varying results. Cady et al.[41] and Rabitsch et al.[37] compared the association of ROSC with ETI versus esophageal-tracheal Combitube (i.e. SGA) use and found no significant difference, with OR=1.03 (95% CI 0.90–1.18) and OR=0.76 (95% CI 0.29–2.00) respectively. The other three studies compared ETI with SGA and found a benefit in favor of ETI with higher proportion of ROSC associated with ETI use. The ORs were 1.61 (95% CI 1.56–1.69),[39] 1.75 (95% CI 1.49–2.08)[40] and 1.78 (95% CI 1.54–2.04)[38] (Figure 2a).

Table 2. Summary of criterion scores and overall methodological quality (reviewers A and B) for five included studies comparing endotracheal intubation (ETI) and supraglottic airways (SGA) outcomes based on the Newcastle-Ottawa Scale (NOS) scores.

	Criterion scores[1]							
	Cohort selection		Cohort comparability		Validity of outcome measure		Overall methodological quality[2]	
Study	Reviewer A	Reviewer B	Reviewer A	Reviewer B	Reviewer A	Reviewer B	Reviewer A	Reviewer B
Cady et al.	★★★★	★★★★	★★	★★	★★	★★	Excellent	Excellent
Hasegawa et al.	★★★★	★★★★	★	★★	★★★	★★★	Excellent	Excellent
Kajino et al.	★★★★	★★★★	★★	★★	★★★	★★★	Excellent	Excellent
Rabitsch et al.	★★★	★★★	★	★	★★	★★	Good	Good
Wang et al.	★★★★	★★★★	★★	★★	★★★	★★	Excellent	Excellent

1. Star (★) indicates the score given to study according to the NOS quality assessment scale, with more stars reflecting better quality.
2. Determined by the total number of stars assigned to study: 0-3 Stars = Poor; 4-5 Stars = Fair; 6-7 Stars = Good; 8-9 Stars = Excellent

Table 3. Adjusted and unadjusted odds ratio (OR) comparing endotracheal intubation (ETI) and supraglottic airways (SGA) for outcome measures.

Study	Key findings	Remarks
Cady et al.	ETI (n=4,335) versus SGA (n=1,487) Adjusted* OR: ROSC = 1.03 (0.90, 1.18) Survival to hospital admission = 0.99 (0.86, 1.15) Survival to hospital discharge = 1.01 (0.79, 1.34)	Suggested no difference between ETI and SGA
Hasegawa et al.	ETI (n=41,972) versus SGA (n=239,550) Unadjusted OR: ROSC = 1.61 (1.56, 1.69) Favorable neurological outcome = 0.90 (0.81, 1.00)	Suggested no difference between ETI and SGA for favorable neurological outcome at one month, although there was higher proportion of ROSC with ETI use
Kajino et al.	ETI (n=1,679) versus SGA (n=3,698) Adjusted† OR: Favorable neurological outcome = 0.71 (0.39, 1.30) Unadjusted OR: ROSC = 1.75 (1.49, 2.08) Survival to hospital admission = 1.12 (1.00, 1.27)	Suggested no difference between ETI and SGA for favorable neurological outcome at one month, although there was higher proportion of ROSC with ETI use
Rabitsch et al.	ETI (n=83) versus SGA (n=89) Unadjusted OR: ROSC = 0.76 (0.29, 2.00) Survival to hospital admission = 0.69 (0.24, 2.04) Survival to hospital discharge = 0.41 (0.08, 2.22)	Suggested no difference between ETI and SGA
Wang et al.	ETI (n=8,487) versus SGA (n=1,968) Adjusted‡ OR: ROSC = 1.78 (1.54, 2.04) Satisfactory functional status at discharge = 1.40 (1.04, 1.89)	Suggested better outcomes for those with ETI use

ETI, endotracheal intubation; *OR*, odds ratio; *ROSC*; return of spontaneous circulation; *SGA*, supraglottic airways
*Adjusted for: age, gender, bystander-witnessed arrest, bystander cardiopulmonary resuscitation (CPR), bystander use of automated external defibrillator and initial cardiac rhythm.
†Adjusted for: age, gender, bystander CPR, initial cardiac rhythm, duration of resuscitation, location of arrest, status of Emergency Life-Saving Technicians, epinephrine use and etiology.
‡Adjusted for: age, gender, bystander or emergency medical services witnessed arrest, bystander CPR, initial cardiac rhythm, trial site and trial arm of primary study.

Survival to hospital admission was analyzed in three studies and all three suggested no significant difference in this outcome between ETI and SGA use. The ORs were 0.99 (95% CI 0.86–1.15)[41], 1.12 (95% CI 1.00–1.27)[40] and 0.69 (95% CI 0.24–2.04)[37] (Figure 2b). Similarly, for the outcome of survival to hospital discharge, two studies comparing ETI with esophageal-tracheal Combitube (i.e. SGA) found no difference, with OR=1.01 (95% CI 0.79–1.34) by Cady et al.[41] and OR=0.41 (95% CI 0.08–2.22) by Rabitsch et al.[37] (Figure 2c).

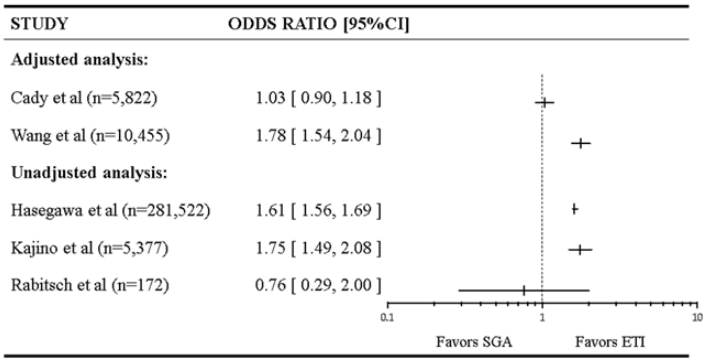

Figure 2a. Associations of pre-hospital advanced airways [endotracheal intubation (ETI) versus supraglottic airways (SGA)] with return of spontaneous circulation.

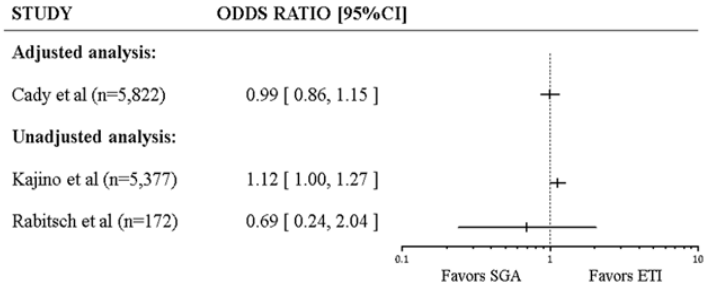

Figure 2b. Associations of pre-hospital advanced airways [endotracheal intubation (ETI) versus supraglottic airways (SGA)] with survival to hospital admission.

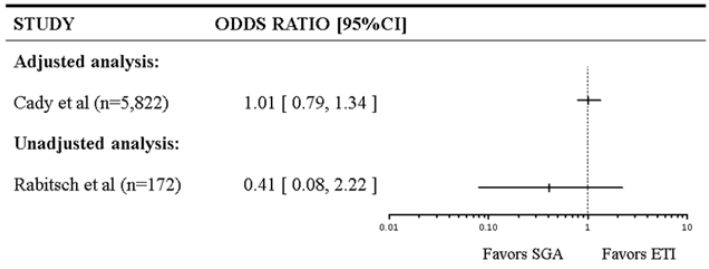

Figure 2c. Associations of pre-hospital advanced airways [endotracheal intubations (ETI) versus supraglottic airways (SGA)] with survival to hospital discharge.

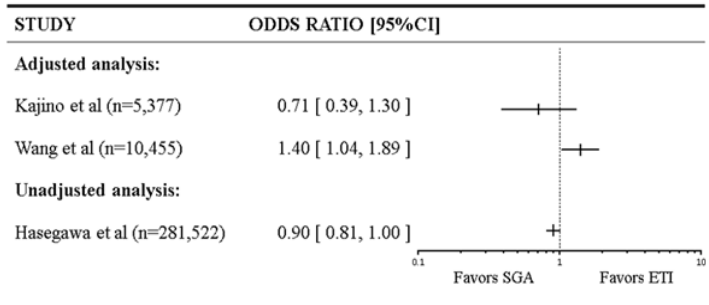

Figure 2d. Associations of pre-hospital advanced airways [endotracheal intubations (ETI) versus supraglottic airways (SGA)] with favorable neurological or functional outcome.

Three of the five studies evaluated neurological outcome or functional status as the primary outcome (Figure 2d). Kajino et al.[40] compared the neurological status based on the Cerebral Performance Category Score for those treated with ETI versus SGA and the adjusted OR was 0.71 (95% CI 0.39–1.30) suggesting no significant difference between the two.[40] In an unadjusted analysis of results from Hasegawa et al., there was also no significant difference in the neurological status based on the Cerebral Performance Category Score between patients who received ETI versus SGA, with OR=0.90 (95% CI 0.81–1.00).[39] In both studies, however, the direction of results seemed to favor SGA. In the secondary analysis of the Resuscitation Outcomes Consortium Prehospital Resuscitation using an Impedance valve and an early versus delayed study by Wang et al., patients who received ETI compared with SGA were more likely to have satisfactory functional status based on the Modified Rankin Scale at discharge, with OR=1.40 (95% CI 1.04–1.89).[38]

DISCUSSION

We conducted a systematic review to examine our initial hypothesis that ETI was superior to SGA for survival and other patient outcomes among adults with non-traumatic OHCA. The results of the review, however, do not conclusively support this hypothesis. There were no significant differences between ETI and SGA in terms of survival to hospital admission and survival to hospital discharge among the studies that analyzed these two outcomes.[37,40,41] In terms of ROSC, there were conflicting results. Wang et al.,[38] Hasegawa et al.[39] and Kajino et al.[40] suggested a benefit in favor of ETI with a higher proportion of ROSC associated with ETI use while Rabitsch et al.[37] and Cady et al.[41] suggested no difference between ETI and SGA.

For neurological or functional status, Hasegawa et al.[39] and Kajino et al.[40] found no significant difference between ETI and SGA for favorable neurological outcome at one month. Both the studies by Hasegawa et al. and Kajino et al. drew from the same country database with overlapping study periods and similar methodology. Hasegawa et al.[39] was comparing bag-valve-mask ventilation with advanced airway management at a national level while Kajino et al.[40] was specifically comparing ETI with SGA in one prefecture in Japan. Therefore, it was probable that the population enrolled by Kajino et al. was a subset of the population analyzed by Hasegawa et al. With the largest cohort comprising almost 90% of patients in this review and a sound methodology, the study by Hasegawa et al. could make for a compelling case against the superiority of ETI over SGA in terms of neurological outcome.[39] Although it was an unadjusted analysis, the finding was congruent with the adjusted comparison between ETI and SGA for neurological status by Kajino et al.[40] The study by Wang et al., involving EMS teams affiliated with universities and medical institutes across the United States of America and Canada, suggested otherwise.[38] There was a higher proportion of satisfactory functional status at discharge among patients with ETI use based on an adjusted analysis, possibly supporting the hypothesis for superiority

of ETI over SGA for this outcome in their study population. However, as the authors themselves had highlighted, this was a secondary analysis of another trial that had not been designed to compare advanced airway management.[38] As such, their findings would have to be interpreted within the appropriate context and limitations.

Overall, there was no consistent trend demonstrating superiority of ETI over SGA for the five outcomes examined. Our finding is similar to other related studies and reviews examining the perceived benefits of pre-hospital ETI compared with alternative airway modalities among various study populations.[27,42-44] Thus, the intended impact on relevant patient outcomes with ETI use in the field is still not convincingly demonstrated.[3]

The lack of a consistent positive association between ETI use and favorable patient outcomes when compared with SGA has been attributed to several factors. One is the relative complexity of the procedure itself. EMS personnel need to attain and maintain a certain level of competency to perform successful ETI.[26,39] In addition, potential complications and pitfalls associated with ETI could negatively impact patient outcomes, such as esophageal tube placement, main bronchial intubation or barotrauma.[45-47] Failure to gain mastery of the required skills and inability to address related complications or errors could offset the potential benefits of pre-hospital ETI use when compared with the lower skill requirements and lower complication rate of SGA.

The inconclusive evidence surrounding the role of pre-hospital ETI for OHCA has prompted calls for randomized controlled trials to optimally evaluate the hypothesized causal relationship between ETI use and survival outcomes.[38-40] The potential value of such studies notwithstanding, it should be emphasized that the utility of ETI would be most relevant to the context in which it is being studied. Given the inherent differences in organizational structure, resources and geographical coverage of EMS systems in different regions and countries, the impact of ETI use in one system may not be reproducible in another system that is run and staffed differently.[8,48-51] Even within the same EMS system, it may be prudent to identify certain selected groups of patients for whom ETI may be beneficial.[39] As Eich et al.[48] had responded to a comment about pre-hospital pediatric ETI use, perhaps the "question is not if but rather when, where and by whom."

LIMITATIONS

Firstly, there were no true randomized controlled trials that fulfilled our inclusion criteria for this review. Instead, our search resulted in a small selection of quasi-randomized and observational studies, deemed to be relatively weaker in the hierarchy of evidence. Secondly, we considered the decision to use the NOS for methodological assessment of the included studies, which was based on its relevance to cohort studies and its simplicity in application. A comprehensive review by Deeks et al.[33] evaluated the suitability of available tools for assessing non-randomized studies and found the NOS to be among those appropriate for use in terms of the domains covered but cautioned the lack of information about its reliability and validity. Therefore, although the overall methodological quality of included studies was deemed to be mostly "excellent" based on the NOS, results from these studies should be interpreted with appropriate caution. The concern about the inter-rater reliability between reviewers using the NOS has also been raised by others and highlighted the need for other alternatives.[52,53] To address this concern, we evaluated the inter-rater agreement between the two independent reviewers and it was found to be high. While ongoing work is being done to further refine and develop better instruments for the assessment of non-randomized trials, the NOS remains listed as one of the useful tools in the last updated version of the Cochrane Handbook.[54] Lastly, because we excluded studies with undifferentiated study population of adults and pediatric patients (younger than 18 years), our review is potentially missing the subgroup data from those studies. There were two such studies. One included patients aged 15 years or older and had about 138,000 cases.[35] However, this study population was extracted from the same nationwide database with similar eligibility criteria over a period captured by Hasegawa et al., which was included in our review.[39] The other study included patients of all ages with 641 of them receiving either ETI or LMA and our review might have missed some of them because of the exclusion criteria.[36]

CONCLUSION

The evidence presented in our review does not conclusively support the current practice assumption that pre-hospital ETI use, compared to SGA, improves survival among adult patients with non-traumatic OHCA. This concurs with other related work in the literature examining the benefits of ETI use in the field among various patient populations.

Address for Correspondence: Tiah Ling, Accident and Emergency Department, Changi General Hospital Singapore, 2 Simei Street 3. Singapore, 529889. Email: ling_tiah@cgh.com.sg.

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Availability and Utilization of Cardiac Resuscitation Centers

Bryn E. Mumma, MD, MAS
Deborah B. Diercks, MD, MSc
James F. Holmes, MD, MPH

University of California Davis, Department of Emergency Medicine, Sacramento, California

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Introduction: The American Heart Association (AHA) recommends regionalized care following out-of-hospital cardiac arrest (OHCA) at cardiac resuscitation centers (CRCs). Key level 1 CRC criteria include 24/7 percutaneous coronary intervention (PCI) capability, therapeutic hypothermia capability, and annual volume of ≥40 patients resuscitated from OHCA. Our objective was to characterize the availability and utilization of resources relevant to post-cardiac arrest care, including level 1 CRCs in California.

Methods: We combined data from the AHA, the California Office of Statewide Health Planning and Development (OSHPD), and surveys to identify CRCs. We surveyed emergency department directors and nurse managers at all 24/7 PCI centers identified by the AHA to determine their post-OHCA care capabilities. The survey included questions regarding therapeutic hypothermia use and specialist availability and was pilot-tested prior to distribution. Cases of OHCA were identified in the 2011 OSHPD Patient Discharge Database using a "present on admission" diagnosis of cardiac arrest (ICD-9-CM code 427.5). We defined key level 1 CRC criteria as 24/7 PCI capability, therapeutic hypothermia, and annual volume ≥40 patients admitted with a "present on admission" diagnosis of cardiac arrest. Our primary outcome was the proportion of hospitals meeting these criteria. Descriptive statistics and 95% CI are presented.

Results: Of the 333 acute care hospitals in California, 31 (9.3%, 95% CI 6.4-13%) met level 1 CRC criteria. These hospitals treated 25% (1937/7780; 95% CI 24-26%) of all admitted OHCA patients in California in 2011. Of the 125 hospitals identified as 24/7 PCI centers by the AHA, 54 (43%, 95% CI 34-52%) admitted ≥40 patients following OHCA in 2011. Seventy (56%, 95% CI 47-65%) responded to the survey; 69/70 (99%, 95% CI 92-100%) reported having a therapeutic hypothermia protocol in effect by 2011. Five percent of admitted OHCA patients (402/7780; 95% CI 4.7-5.7%) received therapeutic hypothermia and 18% (1372/7780; 95% CI 17-19%) underwent cardiac catheterization.

Conclusion: Approximately 10% of hospitals met key criteria for AHA level 1 CRCs. These hospitals treated one-quarter of patients resuscitated from OHCA in 2011. The feasibility of regionalized care for OHCA requires detailed evaluation prior to widespread implementation. [West J Emerg Med. 2014;15(7):758–763.]

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) occurs at a rate of 52.1 per 100,000 population and has a high mortality rate.[1] Early cardiac catheterization and therapeutic hypothermia improve outcomes among post-OHCA patients,[2-9] but both are currently underutilized.[7,9-14] To improve access to these therapies, the American Heart Association (AHA) recommends regionalized OHCA care, including level 1 and 2 cardiac resuscitation centers (CRCs).[15] Key criteria for level 1 CRCs include 24/7 percutaneous coronary intervention (PCI) capability, therapeutic hypothermia capability, and annual volume

of ≥40 patients with return of spontaneous circulation following OHCA. The extent to which CRCs are available in the care of OHCA patients remains unknown. Our objective was to describe the availability and utilization of resources relevant to post-OHCA care. We hypothesized that fewer than 10% of hospitals would meet key level 1 CRC criteria and that a minority of OHCA patients would be admitted to these hospitals.

METHODS

Availability of Resources

We obtained a list of acute care hospitals in California from the Office of Statewide Health Planning and Development (OSHPD) and a list of 24/7 PCI centers in California from the AHA. We surveyed emergency department (ED) directors and nurse managers at all 24/7 PCI centers to determine their post-OHCA care capabilities. The survey included questions on therapeutic hypothermia, OHCA patient volume, and intensivist coverage (Appendix A). It was pilot-tested locally prior to distribution.We mailed surveys to ED directors at all 24/7 PCI centers in late 2011. A website link for online survey completion was provided in the cover letter. If no response was received after two mailings, we attempted to contact the medical director or nurse manager via telephone to verbally administer the survey.

Utilization of Resources

We performed a retrospective cohort study including all patients in the OSHPD Patient Discharge Database admitted during 2011, from an ED with a "present on admission" diagnosis of cardiac arrest (ICD-9-CM 427.5) or sudden death (ICD-9-CM 798). Acute care hospitals in California (excluding Veterans Affairs and military facilities) are required by law (California Health and Safety Code Section 128736) to report data for every inpatient encounter to OSHPD. These data do not represent a sample, but rather surveillance with 100% coverage. We excluded patients for whom hospital data were missing. For patients transferred from one hospital to another, the initial hospital providing care was considered the treating hospital. If the patient's length of stay was one day or less, however, the hospital accepting the patient transfer was considered the treating hospital. Data obtained from OHSPD included patient age, gender, race, ethnicity, source of admission, source of payment, length of stay, disposition, diagnoses, "present on admission" codes, procedures, and treating hospital. Diagnoses include up to 25 conditions that existed at admission, developed during hospitalization, or affected treatment during hospitalization. Procedures include up to 21 procedures related to the patient's stay. Diagnoses and procedures were coded according to the ICD-9-CM.[16]

We used the number of patients admitted to each hospital following OHCA to determine whether the hospital treated ≥40 patients resuscitated from OHCA. These data were combined with AHA data regarding 24/7 PCI status and with survey data regarding therapeutic hypothermia protocols. We merged data using hospital name and confirmed by hospital address. Key level 1 CRC criteria were defined as having 24/7 PCI capability, having a therapeutic hypothermia protocol, and admitting ≥40 patients following OHCA in 2011.[15]

Outcomes

The primary outcome was the proportion of hospitals meeting key level 1 CRC criteria. The secondary outcomes were the proportion of patients treated at a CRC and the proportion of patients receiving cardiac catheterization and therapeutic hypothermia.

Analysis

Data are described with descriptive statistics and 95% confidence intervals (CI) where appropriate. We performed analyses using STATA 12.0 (StataCorp LP, College Station, TX) and Google Maps (Google, Inc., Mountain View, CA). This study was deemed exempt from review by our institutional review board.

RESULTS

Availability of Resources

Of the 333 acute care hospitals in California, 125 were identified as 24/7 PCI centers by the AHA and were surveyed regarding their post OHCA resources (Figure 1). Seventy (56%; 95% CI 47-65%) responded to the survey; responding and non-responding hospitals were similar with regards to OHCA volume, number of licensed beds, teaching status, and trauma center status (Table).

Nearly all (69/70; 99%, 95% CI 92-100%) reported having a therapeutic hypothermia protocol by 2011 (Figure 1). The remaining respondent noted that a protocol was being developed but was unsure whether it had been implemented. Per data from OSHPD, 54/125 (43%, 95% CI 34-52%) 24/7 PCI centers admitted ≥40 patients following OHCA in 2011. Overall, 31 hospitals (9.3%, 95% CI 6.4-13%) met key level 1 CRC criteria. An additional 23 (6.9%, 95% CI 4.4-10%) 24/7 PCI centers admitted ≥40 OHCA patients but did not respond to the survey regarding their therapeutic hypothermia protocol. The geographic distribution of cardiac resuscitation centers is shown in Figure 2.

Half (34/68; 95% CI 38-62%) of the responding hospitals indicated that their protocol applied to patients with all arrest rhythms, and 40% (27/68; 95% CI 28-52%) reported that their protocol applied only to patients with ventricular tachycardia or ventricular fibrillation. Thirty-three hospitals (47%, 95% CI 35-59%) reported having 24/7 in-hospital intensivist staffing in their intensive care unit, 27 (39%, 95% CI 27-51%) reported intensivist staffing with limited in-hospital hours, and 10 (14%, 95% CI 7.1-25%) reported no intensivist staffing. Consistent with data from the AHA, all but one of the survey respondents reported that

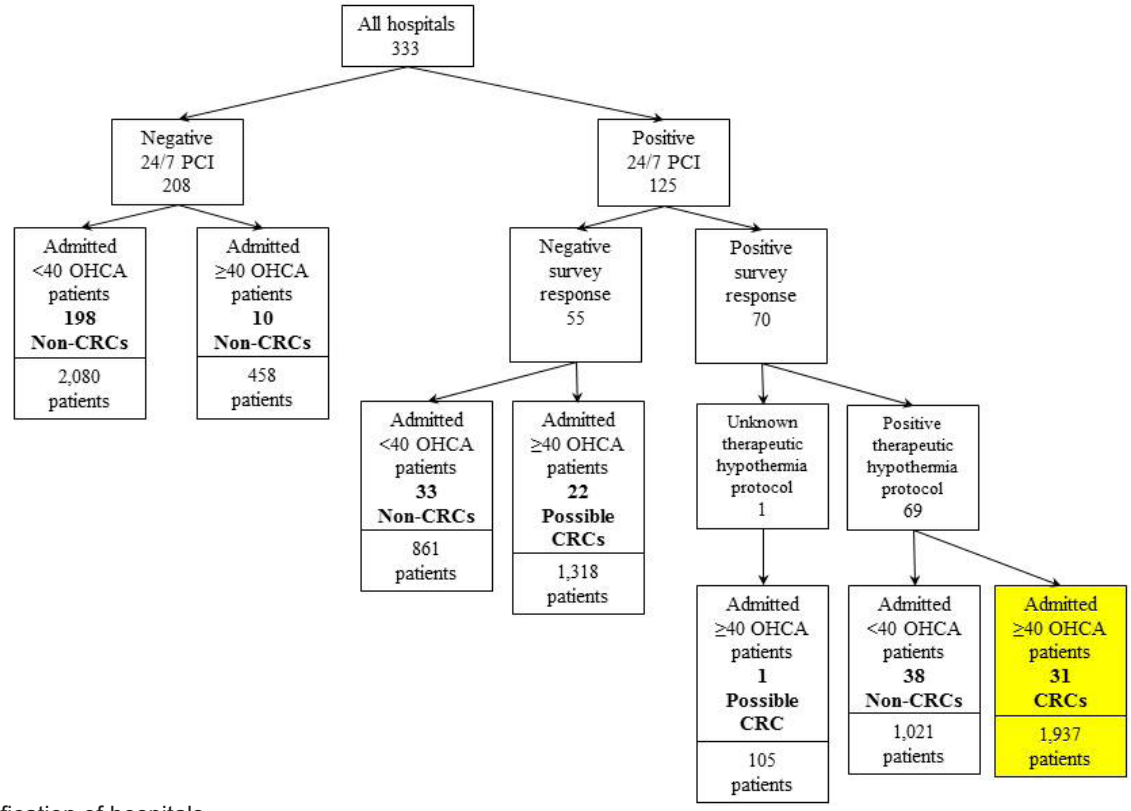

Figure 1. Classification of hospitals.
PCI, percutaneous coronary intervention; *OHCA*, out-of hospital cardiac arrest; *CRC*, cardiac resuscitation center

Table. Characteristics of responding vs. non-responding hospitals.

Hospital characteristics	Respondents (n=70)	Non-respondents (n=55)	p-value
Number of admitted OHCA patients*	39 (27-55)	38 (25-53)	0.33
Total licensed beds*	340 (246-422)	290 (223-401)	0.37
Teaching hospital	27 (39%)	21 (38%)	0.91
Trauma center status			0.22
Level 1	10 (14%)	3 (5%)	
Level 2	14 (20%)	11 (20%)	
Level 3	3 (4%)	2 (4%)	
Non-designated	43 (61%)	39 (71%)	

OHCA, out-of-hospital cardiac arrest
*Data presented as median (interquartile range).

their hospitals had 24/7 interventional cardiac catheterization lab facilities (99%, 95% CI 92-100%).

Utilization of Resources

We identified 7,948 patients admitted to an acute care hospital in California with a "present on admission" diagnosis of cardiac arrest or sudden death. After excluding 168 patients for whom admitting hospital data were unavailable, we analyzed 7,780 patients. Median age was 66 years (interquartile range 55-79 years), and 4,493 (58%) were male. Ventricular rhythms were reported in 2,140 (28%). One quarter (1,937; 95% CI 24-26%) were treated at level 1 CRCs, and an additional 18% (1,423; 95% CI 17-19%) were treated at 24/7 PCI centers that admitted ≥40 patients resuscitated from OHCA (Figure 1). Only 129 patients were transferred from one acute care hospital to another, and the majority (105; 81%, 95% CI 74-88%) of these were not transferred to a level 1 CRC. Three quarters (95/129; 74%, 95% CI 65-81%) of transferred patients had managed care insurance, compared to 39% (3003/7780; 95% CI 38-40%) of all admitted OHCA patients.

Overall, 18% (1,372; 95% CI 17-19%) underwent cardiac catheterization, with two-thirds (912; 95% CI 64-69%) of these patients undergoing the procedure on the day of

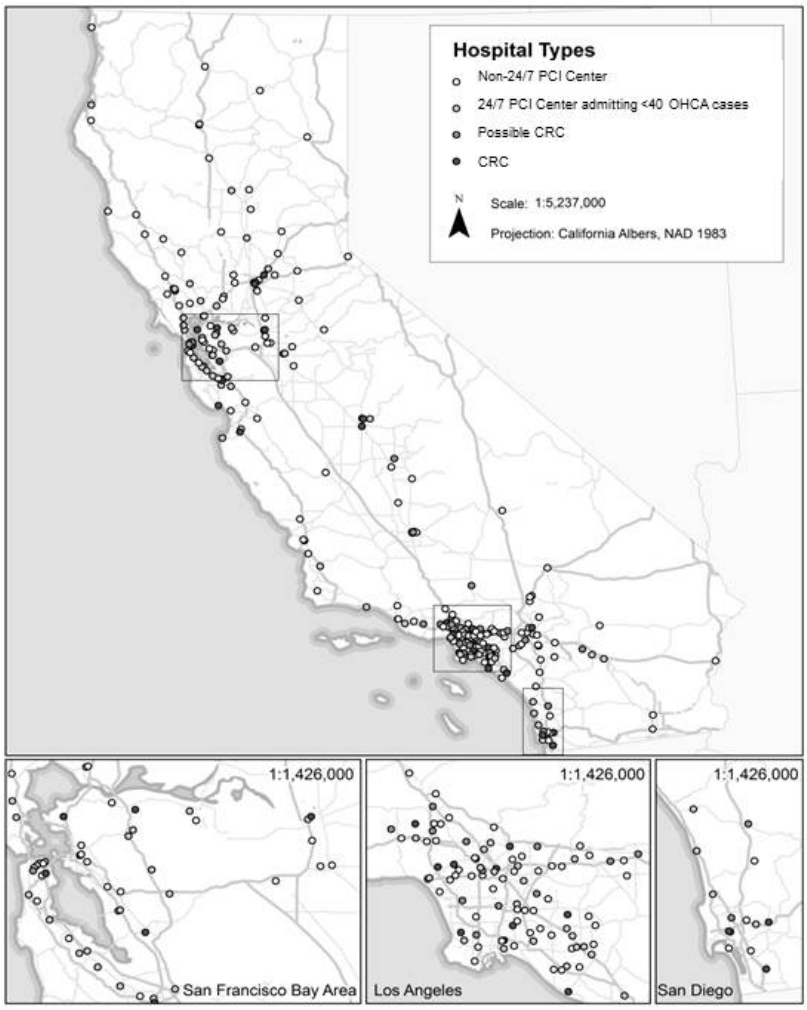

Figure 2. Geographic distribution of cardiac resuscitation centers.
PCI, percutaneous coronary intervention; *OHCA*; out of hospital cardiac arrest *CRC*, cardiac resuscitation centers; *NAD*, North American Datum

admission. Only 5% (402/7780; 95% CI 4.7-5.7%) of patients were reported to have received therapeutic hypothermia, and half of these had a ventricular rhythm (208/404; 51%, 95% CI 46-56%). Among the 47 hospitals with a therapeutic hypothermia protocol in 2010, only two (4.3%, 95% CI 0.5-15%) reported applying it to more than 20 patients in 2010. The majority indicated that it was used in five or fewer patients (15/47; 32%; 95% CI 19-47%) or were uncertain how often it was used (15/47; 32%, 95% CI 19-47%).

DISCUSSION

We identified 31 hospitals meeting key criteria for level 1 CRCs. Our survey data indicate that nearly all 24/7 PCI centers in California had a therapeutic hypothermia protocol established by 2011. This suggests that the 22 24/7 PCI centers admitting ≥40 resuscitated patients but not returning the survey also met key level 1 CRC criteria. Thus, approximately 15% of acute care hospitals in California meet key AHA criteria for level 1 CRCs and admit 43% of patients resuscitated from OHCA.

An important feature of systems of care in OHCA is early transfer of patients to level 1 CRCs.[15] In our data, very few resuscitated patients were transferred to a level 1 CRC or to a 24/7 PCI center admitting ≥40 resuscitated OHCA patients. Insurance plan appeared to influence transfer practices, with transferred patients having a substantially higher rate of managed care coverage. Our data suggest that regionalized care between level 2 and level 1 CRCs is poorly developed and an area for future improvement. The geographic distribution of these hospitals with respect to the population requires evaluation to determine the feasibility of regionalized care for patients resuscitated from OHCA, particularly in rural areas. In addition, policy makers and hospital administrators need to determine the need for these centers to maximize availability of limited resources.

Similar to previous studies, both cardiac catheterization and therapeutic hypothermia were widely available but infrequently used in the study patient population.[13,14,17] This finding is concerning as evidence suggests both these interventions improve patient outcomes. Prior studies

suggest that lack of an organized protocol is a significant barrier to using therapeutic hypothermia,[17] but this seems unlikely to be the reason for low utilization in our population given the widespread availability of therapeutic hypothermia protocols. Limited awareness of or agreement with the evidence supporting these recommendations and perception of poor patient prognosis may have contributed to low utilization.[17,18] Additionally, concerns regarding cardiac catheterization outcome reporting may dissuade physicians and hospitals from performing this procedure in post-OHCA patients.[19] Future research should investigate variables associated with the failure to perform cardiac catheterization and therapeutic hypothermia in this population. Once reasons these patients are not receiving these interventions are identified, interventions to maximize these procedures can be designed.

LIMITATIONS

The survey response rate was 56%, subjecting the data to response bias. Where possible, we used data from independent sources to minimize the effect of response bias. OSHPD includes up to 21 procedures for each patient; if a patient received more than 21 procedures during hospitalization, cardiac catheterization and/or therapeutic hypothermia may not have been reported. However, the OSHPD data regarding cardiac catheterization are similar to those recently reported in a Los Angeles cohort,[20] and the OSHPD data on therapeutic hypothermia utilization are consistent with our survey results. We were unable to evaluate all elements in the AHA's recommendations for regionalized systems of care in OHCA.[15] Last, our data reflect availability and utilization of resources in California and may not be generalizable to areas outside of California. Resource allocation and healthcare spending priorities may differ between California and other areas.

CONCLUSION

Approximately 10% of hospitals meeting key AHA level 1 CRC criteria treated 25% of patients resuscitated from OHCA in 2011. Cardiac catheterization and therapeutic hypothermia were used in 18% and 5% of patients, respectively. The reasons for low utilization of cardiac catheterization and therapeutic hypothermia among resuscitated OHCA patients and the feasibility of regionalized care for these patients require detailed evaluation prior to widespread implementation.

Address for Correspondence: Bryn E. Mumma, MD, MAS, University of California, Davis, Department of Emergency Medicine, 4150 V Street, PSSB #2100, Sacramento, CA 95817. Email: mummabe@gmail.com.

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What Do Patients Want? Survey of Patient Desires for Education in an Urban University Hospital

Thomas Seibert, MD, MS*
Kathryn Veazey, MD, BA*
Paul Leccese, BS*
Jeffrey Druck, MD†

*University of Colorado, School of Medicine, Aurora, Colorado
†University of Colorado, School of Medicine, Department of Emergency Medicine, Aurora, Colorado

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Introduction: This study examines the emergency department (ED) waiting room (WR) population's knowledge about the ED process and hospital function and explores the types of educational materials that might appeal to patients and their companions in an ED waiting room. Our goal was to identify potential high-impact opportunities for patient education.

Methods: A 32-question survey about demographics, usage of primary care physicians (PCP), understanding of the ED and triage process, desire to know about delays, health education and understanding of teaching hospitals was offered to all qualified individuals.

Results: Five hundred and forty-four surveys were returned. Fifty-five percent reported having a PCP, of which 53% (29% of all WR patients) called a PCP prior to coming to the ED. It was found that 51.2% can define triage; 51% as an acuity assessment and 17% as a vital signs check. Sixty-nine percent knew why patients were seen according to triage priority. Seventy-two percent wanted to know about delays, yet only 25% wanted to know others' wait times. People wanted updates every 41 minutes and only three percent wanted a physician to do this. Forty-one percent wanted information on how the ED functions, 60% via handouts and 43% via video. Information on updates and common medical emergencies is significantly more important than material on common illnesses, finding a PCP, or ED function ($p<0.05$). Median estimated time for medical workup ranged from 35 minutes for radiographs, to one hour for lab results, computed tomography, specialist consult, and admission. Sixty-nine percent knew the definition of a teaching hospital and of those, 87% knew they were at a teaching hospital. Subgroup analysis between racial groups showed significantly reduced knowledge of the definitions of triage and teaching hospitals and significantly increased desire for information on ED function in minority groups ($p<0.05$).

Conclusion: The major findings in this study were that many visitors would like handouts about ED function and medical emergencies over other topics. Additionally, the knowledge of functions such as triage and teaching hospitals were 70% and 69%, respectively. This was reduced in non-Caucasian ethnicities, while there was an increased desire for information on ED function relative to Caucasians. This research suggests increasing updates and educational materials in the waiting room could impact the waiting room and overall hospital experience. [West J Emerg Med. 2014;15(7):764-769.]

INTRODUCTION

There were 129.8 million emergency department (ED) visits annually in the United States in 2010.[1] Nationally, ED visits have been increasing every year, with the mean occupancy rate increasing at an even more rapid rate.[2] As a result, a substantial amount of time is spent in ED waiting

rooms. A 2006 study estimated that the average ED wait time was 45 minutes with a range of 27 to 83 minutes.[3] Time spent in the waiting room may bring frustration to patients and their family members as wait times extend, other patients receive care, and no updates are given. Educating patients while they wait to be seen could be a valuable tool that has been minimally studied. Studies on health education in the ED waiting room have shown that patients are interested in wellness topics and desire education in the form of brochures and books.[4] A study evaluating the effectiveness of showing patients a video explaining what to expect during an ED visit demonstrated increased patient satisfaction with the visit.[5] However, no study to date has specifically assessed patients' knowledge of the ED visit process including the length of or cause for delays, what information they would like to know while they wait, and their understanding of the triage process. The lack of information and understanding of patient's desires and knowledge of the ED process makes it very difficult for hospital administrators, physicians, and staff to address patients' needs. It also creates challenges when trying to deliver the desired information to the waiting room (WR) population in order to create a better ED experience with increased patient satisfaction.

The objective of this study was to determine baseline knowledge of ED and hospital processes, and to establish types of information WR patients want, including expected wait times, causes of delays, and the triage process. Furthermore, we sought to determine how they would like this information delivered. In addition, we asked patients and family members what were expected estimated times for labs, imaging studies, and admission. Secondarily we sought to determine if different desires correlate with racial groups, and to assess if patients wanted educational health materials.

METHODS

Study Design, Setting, Population, and Protocol

Study design and methods were approved by the local institutional review board. The study was conducted at an urban university teaching hospital in the WR of the ED. The 32-bed ED had 72,000 annual visits at the time of the study and is an American College of Surgeons Level II trauma center. A written survey was distributed to eligible participants during convenience-selected blocks of time between December 2011 and February 2013. These survey blocks ranged in length from two to eight hours and were chosen to include various times of day and days of the week. Inclusion criteria included patients registering for medical care and their accompanying family members, friends, or coworkers, age greater than 18, the ability to understand written English or Spanish, arrival by personal transportation to the ED, and not needing immediate medical attention. Any person meeting inclusion criteria was offered a survey by the research assistant (RA) after the registration process was completed. Only one member of each group of a patient plus his or her companions was offered a survey. Participants were asked to fill out the survey and place it in a collection box when finished, thereby maintaining confidentiality; they were informed that the survey was optional both verbally and by reading the first paragraph of the survey. The RA was available to answer questions and monitored the WR while participants filled out the survey.

The survey was developed through a consensus panel of emergency physicians (EP) that was subsequently evaluated through mock participants. The English survey was translated into Spanish by a native speaking, certified translator. Surveys were deployed in paper format. Final survey design resulted in 32 mixed response questions with a Flesch-Kincaid reading grade level of 6.5 (see appendix A). Answers to "free-text" questions were deemed correct or incorrect as compared a standard set by a consensus of EPs and researchers. For questions 7-9, asking why some patients are seen before others despite order of arrival, responses were judged to be correct if some mention was made of patients being seen in order of acuity. For question 11, asking the definition of triage, responses were sorted into three categories: Those making a mention of triage as an acuity check, those defining triage as a vital signs check, and all others (which were judged to be incorrect).

Measurements and Data Analysis

We did data analysis with R version 3.1.0 (Vienna, Austria) and Microsoft Excel 2010 (Redmond, Washington), with the assistance from the university's Research Consulting Laboratory. Responses for each question on the survey were first compared between the English and Spanish surveys. We analyzed differences between language groups as categorical variables using a Chi-squared test. When the assumptions of the Chi-squared test were not met, a Fisher's exact test was used. For this analysis, questions 1 and 20-24 were analyzed as continuous variables and compared between language groups using a two-sample t-test. Because 47 comparisons were made, we used a significance threshold of $p<0.0001$ for all comparisons.

No significant differences were noted between English and Spanish language survey responses except for race/ethnicity (See Results). As a result, in subsequent analysis, responses from English and Spanish surveys were combined and analyzed as a single group. We compared the responses to questions 20-24 using analysis of variance with the question as a categorical predictor and the response as a continuous outcome. Questions 14 and 28 were compared on the log-scale using two-sample t-tests and then the results were converted back to a normal scale due to highly skewed results. The results for these items are presented as the geometric mean and a 95% confidence interval. We omitted responses with a value of 0 from this portion of the analysis.

Finally, we made comparisons between racial/ethnic groups for questions 5, 10, 16, and 25. Native American and

Asian respondents were combined with "Other" respondents in statistical analysis, while Caucasians, African-Americans, and Hispanics were analyzed as their own groups. We made comparisons between groups using logistic regression. Differences between individual ethnic groups were compared when the overall test ratio reached significance. We used the Tukey honest significant difference method to adjust p-values for multiple pairwise corrections for multiple hypotheses testing. Adjusted p-values less than 0.05 were considered significant.

On two separate surveys, participants responded "No" to question 10 ("Do you know what triage means?") and then also attempted to define triage, which they were not instructed to do unless answering "Yes" to question 10. These two results were included in the subsequent analysis despite this discrepancy.

RESULTS

A total of 544 surveys were returned to the collection box (93.7% of those that were distributed to consenting participants), supporting acceptable research protocol. Of these surveys, 7.1% were in Spanish. Only ethnicity/race was significantly different between English and Spanish surveys ($p<0.0001$). For all subsequent analyses, results from English and Spanish surveys were therefore combined and analyzed as a group. On average, 25 out of the 32 of the questions were completed. Demographic data regarding respondents is displayed in Table 1.

Of respondents, 54.9% reported having an established relationship with a primary care physician (PCP). Of those respondents with a PCP, 53.0% called their PCP. The PCP informed 45.1% of those who called they were ill enough to require a visit to the ED, 33.4% were told there were no appointments available, 14.4% were told they needed further testing, and 6.9% were told they were no longer the PCP's patient.

Of all respondents, 68.8% claimed to know why some patients were seen sooner than others despite arriving later. Of that group, 87.0% were able to give a valid reason, determined by a consensus of professional opinion of EPs and the research group (see Methods), for this practice while 13.0% were not. Of all respondents 31.2% reported they did not know why some patients were seen sooner than others despite arriving later. We observed a statistically significant difference in the percentage of respondents reporting it is fair to see some patients before others between the group who did not claim to know why this happens and the group who both claimed they did know why this happens and provided a valid explanation as to why (Table 2).

Of respondents, 48.7% claimed to know what triage meant. Of respondents who attempted to define triage, 51.9% defined it as an evaluation of the patient's acuity, 17.5% defined in as a vital signs check, and 30.6% of respondents gave an incorrect answer as judged by the authors using a consensus definition of triage (See Methods).

When asked what information they would like to be provided with, 72.2% of respondents indicated they would like to know about foreseeable delays, while only 24.6% of respondents wanted to know about other patients' wait times. Respondents wanted to receive updates every 41 minutes on average (SD ± 32 minutes). Seventy-four

Table 1. Demographics of respondents surveyed.

Age	n (%)	Race	n (%)	Role	n (%)
18-19	22 (5)	Caucasian	221 (41)	Patient	377 (69)
20-29	154 (28)	African American	123 (23)	Family member	132 (25)
30-39	111 (20)	Hispanic	125 (23)	Friend	30 (6)
40-49	99 (18)	Asian	19 (4)	Coworker	2 (0.4)
50-59	89 (16)	Native American	7 (1)	Has a PCP	297 (55)
60-69	41 (8)	Other	43 (8)		
70-79	19 (3)				
>80	3 (1)				

PCP, primary care physician

Table 2. Proportion of respondents reporting it is fair to see some patients before others despite later arrival, stratified by self-reported knowledge of why this occurs and ability to provide a valid reason why it does.

Claim to know why some patients are seen before others	Able to provide a valid reason for this practice	Percentage of group who thought this practice was fair
Yes	Yes	96.2%*
Yes	No	86.0%
No	-	55.0%*

* Indicates statistically significant difference between groups ($p<0.0001$).

percent of respondents had no preference who gave these updates, while 13.7% of respondents felt a clerk should provide the updates, 9.0% of respondents preferred a nurse, and 3.3% of respondents preferred the updates coming directly from physicians.

Forty-one percent of respondents would like to be provided with more information on how the ED functions. When asked in which medium they would like this information, 59.9% of respondents indicated they would like handouts, 42.9% indicated they would like videos, and 9.5% indicated they would like updates through a computer in the waiting room (note: percentages do not add to 100% because respondents were able to choose multiple answers). When asked what information they found important on a scale of 1 (not important) to 4 (very important), information on updates (mean 2.93; 95% CI 2.85-3.02) and serious medical conditions such as cerebral vascular accidents and myocardial infarctions (mean 2.90; 95% CI 2.81-2.99) were significantly more important to respondents ($p<0.05$) than information regarding common illnesses (mean 2.68; 95% CI 2.59-2.77), finding a PCP (mean 2.71; 95% CI 2.62-2.80), and ED function (mean 2.66; 95% CI 2.57-2.75) (Figure 1).

In regards to knowledge about teaching hospitals, 69.2% of respondents claimed to know what a teaching hospital was, and 87.4% of this group knew they were currently in a teaching hospital. When asked to identify aspects that differentiate a teaching hospital from other hospitals, respondents selected attributes shown in Figure 2.

Respondents were asked to estimate the time it would take to complete lab work, x-rays, computed tomography (CT), specialist consultations, and hospital admission. The ranges of responses were large with the mean considerably skewed from outliers so interquartile ranges (IQR) were reported along with medians instead of means and standard deviations. Lab work had an IQR of 0.5 to 1 h with a median of 1 h. X-rays also had an IQR of 0.5 to 1 h and a median of 0.58 h. CTs had an IQR of 0.5 to 1.34 h with a median of 1 h. Consultations with specialists had an IQR of 0.5 to 1.5 h and a median of 1 h, and admissions had an IQR of 0.62 to 2 h with a median of 1 h. None of these were found to be significantly different from another.

Compared to Caucasians, there was reduced likelihood of answering "yes" when asked what triage meant among African-Americans (OR 0.46, 95% CI 0.29-0.72, $p=0.003$), Hispanics (OR 0.23, 95% CI 0.14-0.37, $p<0.001$), and "Others" (OR 0.36, 95% CI 0.20-0.63, $p=0.002$). Conversely, compared to Caucasians there was an increased likelihood of answering "yes" when asked about a desire for information on ED function by African-Americans (OR 3.01, 95% CI 1.89-4.84, $p<0.001$), Hispanics (OR 1.99, 95% CI 1.24-3.20, $p=0.016$), and "Others" (OR 3.12, 95% CI 1.76-5.58, $p<0.001$). Furthermore, compared to Caucasians, there was a decreased likelihood of answering "yes" when asked whether the university hospital was a teaching hospital among African-Americans (OR 0.40, 95% CI 0.24-0.68, $p=0.002$), Hispanics (OR 0.17, 95% CI 0.10-0.28, $p<0.001$), and "Others" (OR 0.40, 95% CI 0.21-0.75, $p=0.015$).

DISCUSSION

Multiple factors, such as increased length of stay, lack of hospital beds leading to ED boarding and an aging population, have led to increased ED WR times.[6] While many strategies have been attempted to expedite and improve the WR experience, hospitals continue to struggle with how to manage their ED waiting rooms to improve patient satisfaction of the visit. Extended length of stay in the WR is a serious concern, and it is the number one reason patients with possible critical medical issues leave without being seen by a provider.[7] Many strategies have been used to reduce the time or improve the experience of the WR, including physician/physician assistant

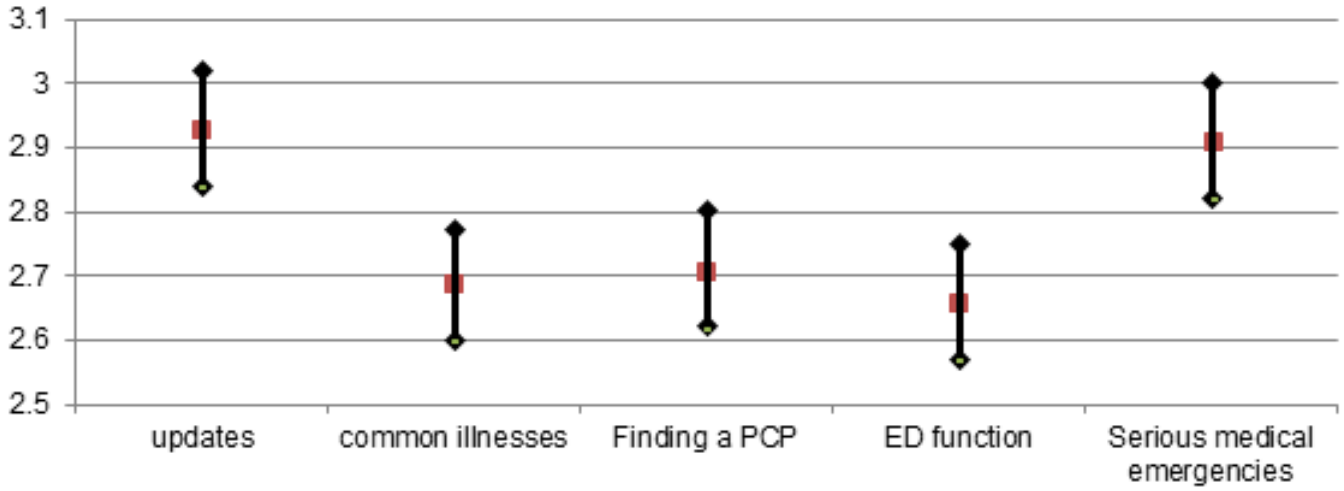

Figure 1. Rated level of importance of information available in the emergency department waiting room on a scale from 1 (not important) to 4 (very important); mean value with 95% CI displayed.
PCP, primary care physician; *ED*, emergency department

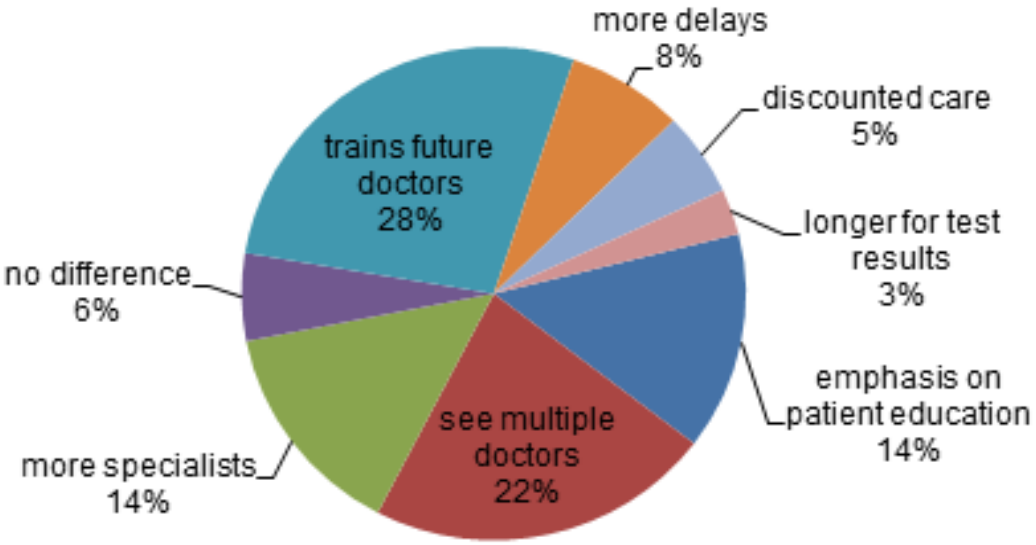

Figure 2. Aspects of teaching hospitals compared to other hospitals by waiting room respondents.

triage, wait-time timers, and remodeling waiting rooms.[4,8]

Patients who left without being seen also cited lack of communication as a major reason for leaving.[9] To reduce the communication barrier between patients and medical providers and to interact effectively with the WR population, the medical community must understand what patients wish to know as they wait and how to best describe ED workflow to patients.

This study allows us to approach ED communication improvement projects with a better understanding of what needs to be conveyed to improve the experience in the WR. Defining how the ED functions appears to be an area of improvement as only 70% of respondents were able to give a valid definition of triage – a mainstay of ED function. Explaining how the ED functions via handouts or video, combined with information on serious medical conditions, may be helpful in a number of ways. Past studies have shown that patients are interested in wellness topics and desire education in the form of brochures and books in the ED, and providing health and wellness information in that context could have public health impact. Videos explaining what to expect during an ED visit have been shown to increase patient satisfaction with the visit,[4] and keeping patients in the waiting room occupied with educational material could theoretically reduce perceived wait time and alleviate some of the stress of the wait.[10] Though participants in another survey thought a time tracker would improve their experience, our study shows that only around one-quarter of people actually want to know the wait times of others.[11] Our study showed what seemed more important to the WR population as a whole was frequent updates about foreseeable delays coming from any person on the ED team; it did not need to be a physician giving updates.

Only 69% of our survey respondents knew the functions of a teaching hospital. This means that facts about the hospital being visited and about the meaning of a teaching hospital could be communicated to those in the ED waiting room to great effect. Providing this information could help remove some of the stress-inducing confusion patients may experience when they do not understand certain aspects of their visit, such as why they are seen by trainees at various levels of education. Information about average times for procedures, radiology, laboratory tests, consults, and admission seem to be greatly needed; respondents' estimates of these times had massive standard deviations, indicating limited knowledge of ED time courses. This would increase transparency as patients gain understanding of what is happening during their visit and how much time they can reasonably expect it to take. In theory, this could also reduce the stress and frustration of waiting.[10]

Non-Caucasian ethnicities seem especially primed for increased education and communication as compared to Caucasians; their understanding of ED function and teaching hospitals was significantly lower while their requests for information on ED function was significantly higher. These differences do not appear to be related to language, since the proportions of respondents who correctly answered these questions were not significantly different between the Spanish and English surveys. Among other things, these findings could represent variations in cultural beliefs regarding the value and objective of a healthcare visit or disparities in healthcare literacy between different ethnic groups.

LIMITATIONS

There are limitations to this study. First, the survey was only distributed in one ED with its given demographics. This limits the ability to generalize our findings to other EDs. In particular, suburban or rural ED demographics might differ substantially from ours and thus might limit generalizability

of our findings to those settings.

Second, there were respondents who did not, or were not able to, return our survey after agreeing to participate. Among other reasons, this occurred because patients were called into the ED to be seen, patients left without being seen, and patients reconsidered their decision to participate in the survey before completing it. Our decision to concentrate primarily on the WR as a focus for patient education guided our methodology of administering a survey in the WR before a patient visit in the ED proper. This limited our ability to assess patient satisfaction with the visit itself or patient understanding of discharge instructions. We are thus not able to draw any conclusions about patients' comprehension of those aspects of their visit.

We did not explore whether a higher proportion of respondents would have reported a preference for receiving updates from higher-level providers (e.g., physicians or nurses) if they knew those updates would not influence their wait time. While our survey text did not suggest any link between receiving updates from physicians or nurses and increased wait times, we cannot rule out the possibility that many respondents held this belief. This presents an additional opportunity to educate patients about the workflow within the ED.

Finally, our survey was only in two languages. This restricted responses from a minority of people approached because of fluency in only an additional language. Financial, time, and availability constraints limited the availability of interpreters for use in this study. Future avenues of research could include repeating this study in additional locations; adding more languages; expanding the survey to examine patient understanding of actual visits with a physician and subsequent discharge instructions; and implementing and evaluating the findings of this research, such as by providing more information on ED function and major medical emergencies.

CONCLUSION

The ED waiting room is the first stop for the majority of patients to be seen at the hospital. Here, we have identified multiple areas where limited knowledge, 70% knowledge of triage and 69% knowledge of teaching hospitals, and a desire for more information overlap in the ED waiting room population. The significant differences in knowledge and desire for education material in non-Caucasian ethnicities are an important finding and should direct future projects to take each ED's ethnicities into account. These findings suggest possible high-impact targets for intervention in patient education and ED throughput with the goal of improving patient satisfaction. These could include providing educational materials about hospital and ED function and severe health conditions (both reported as highly desired), as well as giving regular updates regarding foreseeable delays. Further study, potentially including targeted trials of the above interventions, would be needed to address whether these changes would have any measurable impact on patient satisfaction or would improve the patient experience in the ED.

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Address for Correspondence: Thomas Seibert, MD MS, 1542 Tulane Avenue Room 452 Box T4M2, New Orleans, LA 70112. Email: Thomas.Seibert@ucdenver.edu.

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Using Lean-Based Systems Engineering to Increase Capacity in the Emergency Department

Benjamin A. White, MD
Yuchiao Chang, PhD
Beth G. Grabowski, MBA
David F.M. Brown, MD

Massachusetts General Hospital, Department of Emergency Medicine, Boston, Massachusetts

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Introduction: While emergency department (ED) crowding has myriad causes and negative downstream effects, applying systems engineering science and targeting throughput remains a potential solution to increase functional capacity. However, the most effective techniques for broad application in the ED remain unclear. We examined the hypothesis that Lean-based reorganization of Fast Track process flow would improve length of stay (LOS), percent of patients discharged within one hour, and room use, without added expense.

Methods: This study was a prospective, controlled, before-and-after analysis of Fast Track process improvements in a Level 1 tertiary care academic medical center with >95,000 annual patient visits. We included all adult patients seen during the study periods of 6/2010-10/2010 and 6/2011-10/2011, and data were collected from an electronic tracking system. We used concurrent patients seen in another care area used as a control group. The intervention consisted of a simple reorganization of patient flow through existing rooms, based in systems engineering science and modeling, including queuing theory, demand-capacity matching, and Lean methodologies. No modifications to staffing or physical space were made. Primary outcomes included LOS of discharged patients, percent of patients discharged within one hour, and time in exam room. We compared LOS and exam room time using Wilcoxon rank sum tests, and chi-square tests for percent of patients discharged within one hour.

Results: Following the intervention, median LOS among discharged patients was reduced by 15 minutes (158 to 143 min, 95%CI 12 to 19 min, p<0.0001). The number of patients discharged in <1 hr increased by 2.8% (from 6.9% to 9.7%, 95%CI 2.1% to 3.5%, p<0.0001), and median exam room time decreased by 34 minutes (90 to 56 min, 95%CI 31 to 38 min, p<0.0001). In comparison, the control group had no change in LOS (265 to 267 min) or proportion of patients discharged in <1 hr (2.9% to 2.9%), and an increase in exam room time (28 to 36 min, p<0.0001).

Conclusion: In this single center trial, a focused Lean-based reorganization of patient flow improved Fast Track ED performance measures and capacity, without added expense. Broad multi-centered application of systems engineering science might further improve ED throughput and capacity. [West J Emerg Med. 2014;15(7):770–776.]

INTRODUCTION

Emergency department (ED) crowding remains a national crisis, and a multitude of studies have demonstrated myriad negative effects on patient care efficiency, quality, and safety.[1-20] Moreover, the burden of capacity constraints on United States EDs is predicted to worsen in the future.[20]

In addition, while multiple studies and governing bodies, including the Institute of Medicine (IOM),[20] have suggested

increased use of systems engineering and improvement science to combat this growing problem, only recently has the emergency medicine literature started to demonstrate the successes that many similarly complex industries discovered long ago.[21-24] Still, there remains significant opportunity to refine the use and application of these tools across EDs in an effort to continue to optimize care, especially with respect to streamlining processes and improving throughput, and thus creating much needed capacity.[25-30] For example, Lean methodologies, originally designed for use in process improvement in the manufacturing industry, represent one potential tool for use in improving systems of care and throughput in the ED.[31-33] While much interest has been generated recently in other settings, these tools have been only minimally studied in health care as a whole, and less so in the ED specifically.[34-37]

Finally, in terms of systems improvement opportunities, emergency medicine is somewhat unique in that, in most instances, increased patient care efficiency not only decreases waste and costs, but also improves, rather than just maintains, quality. This occurs through effects on the IOM domains of timeliness, efficiency, effectiveness, and safety.[20] In addition, the Centers for Medicare & Medicaid Services (CMS) have recently added publically-reported ED performance metrics to their clinical quality measures, including ED length-of-stay (LOS) for admitted and discharged patients (NQF 0495 & 0496), and the door to diagnostic evaluation by medical personnel (NQF 0498).[38,39]

In this study, our ED used Lean-based systems engineering tools to reorganize patient flow through the Fast Track area, with the goal of improving capacity without added expense or resources. Drawing on multiple systems engineering theories, including queuing theory, the theory of constraints, and demand-capacity matching, we sought to optimize patient care given available resources, and begin to quantify the value of such an intervention.

METHODS

Study Design

This prospective controlled before-and-after analysis of Fast Track (FT) process improvements compared performance measures over two six-month periods (June-October, 2010 and June-October, 2011). We chose the period of six months to provide adequate sample size, and we chose the identical months to avoid any seasonal effect. The ED staff and all participants were unaware of the data collection or analysis, but could not be blinded to the intervention. The intervention occurred over the winter of 2010-2011, and was completed by May 2011. This was a quality assurance project examining internal operations, specifically our new triage system. We reviewed administrative data, but not individual patient medical records. As such the study was exempted from full Istitutional Review Board review.

Study Setting and Population

The study was performed in a large, urban, academic ED with an annual census of approximately 95,000. The ED serves as a Level I trauma center for adult and pediatric patients, as well as a regional burn center. The admission rate is approximately 26%, and approximately 31% of all visits arrive by ambulance. Patient flow in the ED follows a relatively standard course with triage, registration, evaluation in a care area, and disposition. Our ED has six separate care units, differentiated largely by the acuity or age of the patients in each unit. Patients triaged to Fast Track are of the lowest acuity, and consist of chief complaints similar to other EDs (e.g. lacerations, minor injuries, isolated extremity fractures, simple cellulitis, etc). The patient population seen in the control area, Supplemental Triage and Rapid Treatment (START), are of medium acuity (e.g. abdominal pain, flank pain, dizziness, etc). These patients are initially examined by an MD/PA team in dedicated "screening" (exam) rooms, and then cared for in a large internal waiting and treatment area. This process has been described previously.[40,41] We used the screening exam room time of START patients as a comparison, as there were no changes made to this process flow during the study period.

Selection of Participants

We included all adult patients triaged to the FT (i.e. non-emergent), and START areas during the study periods in the analysis.

Data collection and processing

We obtained data from an electronic patient tracking system (EDIS) regarding individual throughput data in both the pre-intervention period and the post-intervention period. EDIS is a software program developed specifically for our ED by our institution. Data points included age, sex, hospital visit level (E/M code), disposition, and time stamped data, including ED LOS and time spent in an exam room. Our ED does not use Emergency Severity Index.

Intervention

The intervention was a focused Lean-based reorganization of patient flow through existing FT rooms, based in systems engineering science and modeling, including queuing theory, demand-capacity matching, and Lean methodologies.

As is common with Lean interventions, we began by modeling the current state of patient flow through the FT area of our ED. Patients are directed to the Fast Track area after triage (by an experienced RN) and registration; this process was not altered. Upon arrival to Fast Track, patients were directed to a waiting room, where they were then escorted to an exam room or stretcher space for evaluation. Evaluation was performed by an RN, PA, resident MD, attending MD, or some combination thereof, and often in serial. (All patients are seen by the attending MD in our ED.) There was no change to

the staffing model or caregiver types during the study period. Following evaluation, patients received further diagnostic testing and treatment, including procedures, and often spent the time waiting for these serial process steps in an exam room. If the patient was discharged, this process was also frequently completed by staff in the exam room.

After modeling the system, we collected and analyzed baseline data regarding our patient flow, including input-throughput-output, and standard ED performance metrics including ED LOS. We also stratified the patient population by needs to determine how best to ration our most limited "bottleneck" resources of rooms, MD time, and RN time. Using medians, we determined that we see approximately 68 patients per day in the Fast Track area, five (7%) of whom are admitted to an inpatient care unit, and three (4%) of whom are admitted to an ED-based observation unit. While FT is open 24 hours per day, peak arrivals occur between 11am-8pm, with approximately 4-7 patients per hour, and resulting in a steadily increasing peak census of 12-20 patients present from noon-10pm. Of those patients, all receive an exam, and approximately 53% receive some form of nursing intervention or treatment, and 32% have a procedure performed (e.g., laceration repair, abscess incision and drainage). We created a rudimentary model based on estimated cycle times of exams and various procedures, and predicted resources needed, and determined the best use of our limited treatment room space. We also investigated the most common diagnoses seen in the FT area, and collected baseline data on LOS and disposition.

Next, we reviewed the relevant systems engineering theory that might apply to our planned future state. These included Lean methodologies, Six Sigma, Queuing theory, demand/capacity management, the Theory of Constraints, managing variation, forecasting and scenario analysis. With that background in mind, we developed clear goals for the future state, including:

1) Simplify whenever possible
2) Reduce waste, especially of limited resources (e.g., staff, exam rooms)
3) Maintain forward progress at all times
4) Support and plan for inherent behaviors of both staff and patients
5) Plan capacity to meet demand, and exceed it if possible
6) Draw on successes & test new ideas, with an aim to the future state
7) Develop a culture of continuous quality improvement ("Kaizen")

As such, our specific intervention focused on decreasing time to MD exam, and thus order entry; decreasing non-value added room time; maintaining throughput at all process steps; eliminating bottlenecks when identified; and planning capacity to meet demand.

The crux of the intervention was a re-organization of room use and patient flow, in which three of the seven treatment rooms were re-allocated as "exam-only" rooms, and four rooms optimized as "procedure rooms." In the new patient flow (Figure), patients are met by a greeter RN,

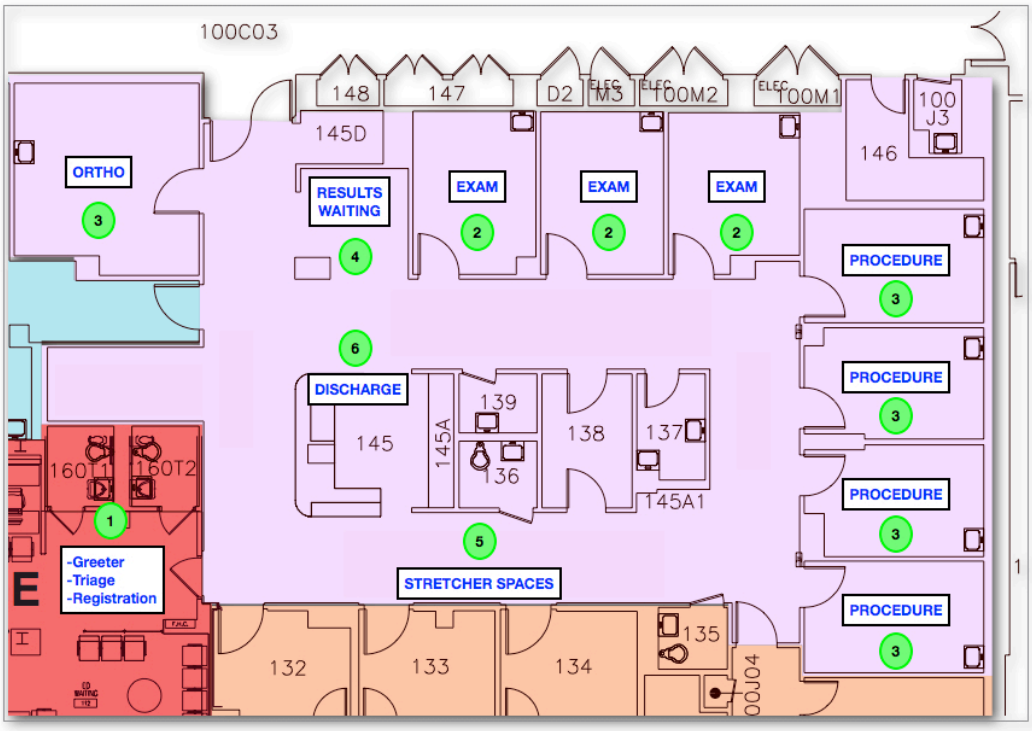

Figure. Lean patient flow intervention with associated change in text.

triaged, and registered in an identical fashion as prior to the intervention (1). They are then directed to an exam room (2) on arrival to FT and seen by the MD/PA team, unless there is a queue, in which case they are directed to the waiting room (4). If patients have an obvious diagnosis requiring a procedure, such as an actively bleeding wound or fracture, they are directed to a procedure room or a previously existing optimized orthopaedics room (3). Following the exam, the patient is either directed to a procedure room if intravenous therapy or a procedure is indicated (3), directed to the results waiting area (4), directed to a stretcher space if needed (5), or discharged (6). If the patient requires admission, they are admitted from any of the above locations.

Regarding optimizing room turnaround time, "procedure carts" were created in each of the procedure rooms, such that providers would not have to leave the room each time to gather supplies, and based on Lean "5S" methodology a workplace organization system (i.e., sorting, setting in order, systematic cleaning, standardizing, and sustaining) was set up. Paper roll dispensers were also installed in each of the exam rooms to decrease room turnover time. Finally, the patient chart/paperwork system was re-designed in order to simplify its organization, and such that a patient's information was no longer tied to the room they were occupying (given the rapidity with which it was predicted that the room would change).

There were no changes to staffing or resources added during this intervention. In addition, there were no other significant and identifiable operations changes affecting FT patient flow between the two study periods.

Methods of measurement

The primary outcomes measured were FT LOS, defined as the time interval between patient registration in the ED and leaving the ED, percentage of patients discharged in less than one hour, and exam room time, defined as the time interval during which a patient was physically in a room, as measured by our computerized tracking system (EDIS). Patient characteristics, LOS, and percentage of patients discharged in less that one hour were also measured in a control patient care area in which the intervention was not applied. This medium acuity patient care area, called START, did not undergo any significant operational changes during the study periods.

Primary Data Analysis

We summarized patient characteristics between the two time periods using mean and standard deviation for continuous variables and percentage for categorical variables. ED LOS and exam room time were summarized with medians and inter-quartile ranges, and compared between groups using Wilcoxon rank sum test since the distribution for LOS was usually skewed. We used bootstrap sampling methods to calculate the 95% CI for the difference in medians. The percentage of patients discharged within one hour was presented with 95% confidence intervals and compared between groups using Chi-squared test. Two-sided p-values ≤ 0.05 were considered statistically significant. We did all analyses using SAS version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

The total FT patient volume was 11,185 during the pre-intervention period, and 11,168 during the post-intervention period. Patient volumes in the control area (START) were 19,065 pre-intervention and 18,269 post-intervention. We included all of these patient visits in the analysis, and patient characteristics, including age, sex, hospital visit level, and disposition, were similar across the two groups (Table 1), despite the statistical significance due to the large sample size.

Following the intervention, median LOS among discharged patients in the FT area was reduced by 15 minutes (158 to 143 min, 95%CI 12 to 19 min, p<0.0001) (Table 2). The number of patients discharged in <1 hr increased by 2.8% (from 6.9% to 9.7%, 95%CI 2.1% to 3.5%, p<0.0001), and median exam room time decreased by 34 minutes (90 to 56 min, 95%CI 31 to 38 min, p<0.0001). In comparison, patients

Table 1. Patient characteristics.

	Fast Track			START		
	6/10-10/10	6/11-10/11	p-value	6/10-10/10	6/11-10/11	p-value
Patient volume	11,185	11,168		19,065	18,269	
Mean age (SD)	42 (17)	41 (17)	0.058	44 (24)	45 (24)	<0.0001
Sex (male) %	56.7	56.0	0.33	49.1	48.0	0.04
Hospital visit level %			<0.0001			<0.0001
1	1.2	1.4		0.8	1.1	
2	31.6	38.3		7.2	8.6	
3	44.8	39.4		26.7	26.3	
Disposition %			0.0005			<0.0001
Discharged	85.5	86.6		62.2	61.6	
Admitted (inpatient)	6.1	5.5		22.7	21.7	

START, Supplemental Triage and Rapid Treatment

Table 2. Before and after intervention results.

	Fast Track			START		
	6/10-10/10	6/11-10/11	p-value	6/10-10/10	6/11-10/11	p-value
Discharged LOS (min)	158 (103, 234)	143 (93, 213)	<0.0001	265 (166, 408)	267 (169, 408)	0.69
Discharged <1 hour	6.9	9.7	<0.0001	2.9	2.9	0.98
Exam room time (min)	89.9 (46.9, 160.2)	56.1 (28.2, 99.3)	<0.0001	28.0 (16.2, 43.3)	35.6 (20.3, 55.6)	<0.0001

START, Supplemental Triage and Rapid Treatment; *LOS*, length of stay

seen in START had no change in median LOS (265 to 267 min) or in proportion of patients discharged in <1 hr (2.9% to 2.9%), and a significant increase in median exam room time (28 to 36 min, p<0.0001).

DISCUSSION

In this single center trial, a focused Lean-based reorganization of patient flow decreased discharged patient LOS by 15 minutes, and exam room time by 34 minutes, without added expense and with very little resource use. If confirmed in other studies and settings, our results have important implications. First and foremost, these results exemplify the potential value of applying systems engineering and improvement science to create capacity in the ED. Consider that for a capacity-constrained ED, creating 34 minutes of room capacity over 11,168 patients is the equivalent of creating 6,328 hours of room capacity, or approximately 35 hours per day. This is equivalent to building 1.5 new rooms in the ED, but without any added expense.

In addition, while the intervention required moderate effort in the modeling and data collection phase, the operational benefits gained far outweighed the resources spent on this project. This is a common experience with systems engineering solutions, and Lean methodologies specifically, and often leads to cultural change towards continuous quality improvement and improved staff satisfaction, resulting in a self-propagating positive feedback loop of process improvement and synergistic effects with upstream and downstream processes.[31-37] Another benefit of this approach is the team-oriented and multidisciplinary fashion with which these systems are modeled and improved. This not only encourages solution sharing and broad "buy-in," but also decreases the likelihood of the intervention(s), creating unintended bottlenecks or workflow imbalances.

In an era of increasing ED crowding nationwide, solutions that have the potential to increase throughput and reduce LOS, and thus increase efficiency and capacity, with minimal associated costs, may represent the most readily achievable gains for emergency medicine administrators.

LIMITATIONS

There are limitations with this study as performed. Most importantly, as with any before-after study, while the outcomes measured may have proved association, they do not confirm causality.

In addition, this study was performed at a single institution, and thus the findings might not be generalizable to EDs with markedly different demographics, or without a FT area. However, given that improvement science is by definition broadly applicable, our findings should be of value to most ED administrators on some level.

Thirdly, participants were not able to be blinded to the intervention, raising the possibility of contribution of the Hawthorne effect to study outcomes. However, the fact that the post-intervention study period occurred months after the intervention was initiated should serve to mitigate this effect, in that study participants had ample time to become familiar with the new system, and were less likely to alter their actions as if they were being observed.

Other known contributors to prolonging ED LOS, such as patient volume, did not change significantly in the intervention group during the period studied. A small change in percentage of level 2 and level 3 patients was noted following the intervention, as was a very small decrease in the percentage of admitted patients, and the degree to which this contributed to the results is unknown. It is also possible that the new, Lean-focused system slightly altered the overall treatment, documentation, and coding of patient visits, which may have altered the visit level as noted, especially given the visit levels in START did not change during the study period. In addition, while boarding inpatients is an issue in our ED, there was no significant change in boarding burden during the study period.

While there was a small decrease in patient volume in the control group during the post intervention phase, based on prior experience and extant literature, we would expect this to decrease LOS. However, LOS and exam room time actually increased slightly in the control group during the post-intervention phase, further emphasizing the significance of our results.

Finally, the intervention studied actually consisted of a number of smaller systems improvements grouped into a single process change. While this is more practically feasible and frequently the case with systems engineering and redesign, our study design does not permit interpretation of each component's individual contribution to the results.

We were otherwise unable to identify any other major systems or operations changes in the ED process flow during this time period, but other contributing factors cannot be fully excluded, such as differences in individual productivity, or subtle differences across the patient population studied.

CONCLUSION

In this single center trial, a focused, Lean-based reorganization of patient flow improved ED performance measures and capacity, without added expense. Broad, multi-centered application of systems engineering science might further improve ED throughput and capacity.

Address for Correspondence: Benjamin A. White, MD, Department of Emergency Medicine, Massachusetts General Hospital, Zero Emerson Place-3b, Boston, MA 02114. Email: bwhite3@partners.org.

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Impact of a Health Information Exchange on Resource Use and Medicare-Allowable Reimbursements at 11 Emergency Departments in a Midsized City

Steven H. Saef, MD, MSCR*
Cathy L. Melvin, PhD, MPH†
Christine M. Carr, MD*

*Medical University of South Carolina, Department of Medicine, Division of Emergency Medicine, Charleston, South Carolina
†Medical University of South Carolina, Department of Public Health Sciences, Charleston, South Carolina

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Introduction: Use clinician perceptions to estimate the impact of a health information exchange (HIE) on emergency department (ED) care at four major hospital systems (HS) within a region. Use survey data provided by ED clinicians to estimate reduction in Medicare-allowable reimbursements (MARs) resulting from use of an HIE.

Methods: We conducted the study during a one-year period beginning in February 2012. Study sites included eleven EDs operated by four major HS in the region of a mid-sized Southeastern city, including one academic ED, five community hospital EDs, four free-standing EDs and 1 ED/ Chest Pain Center (CPC) all of which participated in an HIE. The study design was observational, prospective using a voluntary, anonymous, online survey. Eligible participants included attending emergency physicians, residents, and mid-level providers (PA & NP). Survey items asked clinicians whether information obtained from the HIE changed resource use while caring for patients at the study sites and used branching logic to ascertain specific types of services avoided including laboratory/ microbiology, radiology, consultations, and hospital admissions. Additional items asked how use of the HIE affected quality of care and length of stay. The survey was automated using a survey construction tool (REDCap Survey Software © 2010 Vanderbilt University). We calculated avoided MARs by multiplying the numbers and types of services reported to have been avoided. Average cost of an admission from the ED was based on direct cost trends for ED admissions within the region.

Results: During the 12-month study period we had 325,740 patient encounters and 7,525 logons to the HIE (utilization rate of 2.3%) by 231 ED clinicians practicing at the study sites. We collected 621 surveys representing 8.25% of logons of which 532 (85.7% of surveys) reported on patients who had information available in the HIE. Within this group the following services and MARs were reported to have been avoided [type of service: number of services; MARs]: Laboratory/Microbiology:187; $2,073, Radiology: 298; $475,840, Consultations: 61; $6,461, Hospital Admissions: 56; $551,282. Grand total of MARs avoided: $1,035,654; average $1,947 per patient who had information available in the HIE (Range: $1,491 - $2,395 between HS). Changes in management other than avoidance of a service were reported by 32.2% of participants. Participants stated that quality of care was improved for 89% of patients with information in the HIE. Eighty-two percent of participants reported that valuable time was saved with a mean time saved of 105 minutes.

Conclusion: Observational data provided by ED clinicians practicing at eleven EDs in a mid-sized Southeastern city showed an average reduction in MARs of $1,947 per patient who had information available in an HIE. The majority of reduced MARs were due to avoided radiology studies and hospital admissions. Over 80% of participants reported that quality of care was improved and valuable time was saved. [West J Emerg Med. 2014;15(7):777–785.]

INTRODUCTION

One might assume that the transparent sharing of patient information through a health information exchange (HIE) between non-affiliated hospital emergency departments (ED) within a region would reduce cost per patient by avoiding duplication of laboratory tests and imaging studies and by reducing hospital admissions. Initial studies have demonstrated that this is indeed true.[1-4] Improved efficiency, measured as reduced lengths of stay in the ED, has been another benefit resulting from immediate access to health information from non-affiliated hospitals. We previously published data demonstrating reduced cost and improved efficiency at our academic medical center;[1] in this paper we show that reduction of cost and improved efficiency can be realized across all hospitals in our community.

ED visits in all communities are expected to rise in the next few years as access to health insurance outpaces the access to primary care (PC).[5] According to the National Hospital Ambulatory Medical Care Survey, there were an estimated 129.8 million visits to United States (U.S.) EDs in 2010 for an annual visit rate of 42.8 ED visits per 100 persons.[6] Many patients used multiple unaffiliated EDs, thereby receiving fragmented care due to limited information sharing between regional hospitals that resulted in inefficient, poor-quality and costly care.[20] Between 2003 and 2009, U.S. hospital admissions increased by 17%, largely due to admissions from the ED.[5] Office-based physicians have been directing to EDs some of the patients they previously admitted to the hospital from their offices. EDs have provided increasing support to primary care practices by performing complex diagnostic workups, handling patient overflow, and by seeing their patients after hours and on weekends.[5] Complicated outpatient work-ups that traditionally have been performed in the hospital have been re-located to the ED in this time of extended waits for inpatient beds, difficulty in arranging outpatient testing, stiffer requirements for reimbursement for inpatient care, and increased penalties for readmissions. This change in practice pattern has, until recently, been without immediate access to patients' health records at the point of care, resulting in expensive duplicative testing in the ED and extended lengths of stay.

The American Reinvestment and Recovery Act passed by Congress in 2009 has spurred the development of HIEs, causing their numbers to grow substantially in the last few years. Unfortunately, clinician adoption and use of HIE in EDs has not been as substantial as initially anticipated.[7-13] Factors contributing to low clinician adoption of HIE include disruptions in workflow, lack of user-friendly systems, requirements for multiple logons, and clinicians not understanding the benefits of HIE.[8,12] Some evidence suggests that ED clinicians are more likely to access HIEs when they anticipate information will be present.[9,14] The low physician adoption rate combined with immature sustainability models for HIE have contributed to the failure of many startup HIEs.[21] We believe that once ED clinicians understand the actual impact that consulting an HIE has on the cost and efficiency of care for their patients and have a system that provides appropriate visual queuing, use of HIE will improve. At present, a substantial body of literature does not exist connecting the use of HIE to reduced costs and improved quality and efficiency. Frisse et al.[15] illustrated the financial impact of an HIE at an 1-hospital system in Memphis, Tennessee, calculating that an annual savings of $1.07 million would be realized if all regional hospitals participated in and used the HIE. Frisse et al.[15] also reported that if an HIE were fully operational in the Memphis region, taking into account the potential savings from avoiding unnecessary use of the ED and using the HIE to steer patients toward appropriate primary care, estimated savings in excess of $8 million per year would be possible. Though two recent studies by Bailey et al.[3,4] showed that use of an HIE in the EDs of the Memphis area did not lower costs for the evaluation of back pain or headache, their studies were able to show that HIE use resulted in 64% lower odds of repeat diagnostic imaging for patients with back pain and 38% lower odds of repeat diagnostic neuro imaging. Bailey et al.[4] showed that for back pain, 24% of patients were reimaged when an HIE was not used, while only 10% of patients received additional imaging when an HIE was used. Studies like these will ultimately shift and improve the adoption of HIE in the ED, as they clearly show patient benefit and improved efficiency. In this article we present data that demonstrates a community-wide reduction in Medicare-allowable reimbursements (MARs) and ED throughput time (reduced length of stay) when the HIE was accessed and information was present in the HIE.

In the study region, an HIE was established in 2009 with funding by a grant from a philanthropic organization. Through the HIE, all ED clinicians working at each of eleven EDs belonging to four separate hospital systems (HS) in the region had access to a common electronic medical records (EMR). The HIE allowed ED clinicians to view actual lab results, transcriptions and imaging reports from all participating HS. We performed a pilot study in 2012 examining the impact of our HIE on resource use at an academic medical center. Based on data from the pilot study, we estimated cost savings of $283,477.69 ($2699.77 per patient) and a time savings of 121 minutes per patient who had information in the HIE over the four-month study period.[1,16] We hypothesized that the benefits seen in our pilot study would be reproducible in all of the eleven EDs operated by the four major hospital systems in our region through similar avoidance of duplicate testing and treatment and prevention of unnecessary admissions.

METHODS

The study was conducted during a one-year period beginning in February 2012 in a medium-sized metropolitan area in the Southeastern U.S. and its surrounding region (census of approximately 700,000 people in 2012). Study

sites included all eleven EDs within the region operated by four major hospital systems, including one academic ED, five community hospital EDs, four free-standing EDs and one ED/Chest Pain Center (CPC), all of which participated in the HIE.

The study design was an observational, prospective design using a voluntary, anonymous, online survey (see Appendix I, pdf copy and Appendix 2, Data Collection Instrument survey link). Eligible participants included attending emergency physicians, residents, and mid-level providers (PA & NP) collectively referred to as ED clinicians. Survey items asked ED clinicians whether information obtained from the HIE avoided resource use at the study sites and used branching logic to ascertain specific types of services avoided, including laboratory/microbiology, radiology, consultations, and hospital admissions. A separate item queried whether additions or changes were made to patient management other than avoidance of an event because of information obtained from the HIE. Additional items asked how use of the HIE affected quality of care and length of stay. We automated the survey using a survey construction tool (REDCap Survey Software © 2010 Vanderbilt University). ED medical directors at each hospital system agreed to serve as "site champions" to supervise operation of the study.

We invited ED clinicians to participate in the study via a "pop-up" window that activated when the HIE was queried. Clinicians could anonymously select whether or not they wished to participate using buttons labeled "Yes" and "Skip." The "Yes" button activated a link to the online survey. To optimize recruitment while allowing for the programming limitations of our HIE, the pop-up box was displayed each time the HIE was queried, thereby creating multiple opportunities for participants to complete the survey. To allow for this, the pop-up box contained instructions directing participants to complete no more than one survey for each patient encounter. We believe that most participants completed the survey when they first gathered information from the HIE; however, our design did not allow for a specific determination of when during the patient's ED course the survey was completed. The option to leave the survey open in a browser window was available to those who chose to do so; however, based on the frequent timing out of computers in the clinical areas, we do not believe that occurred at a significant rate. There were no incentives for ED clinicians to use the HIE or to complete the survey.

No identifiers for participants or their patients were collected. No protected health information was recorded. Approval was obtained from the Institutional Review Boards (or human subjects committees) of all four participating hospital systems.

Our HIE used a federated model. It took about 18 months to set up, and start-up costs including hardware, legal fees and administrative fees were approximately $2.8 million over three years. This secure network allowed ED providers to have immediate access to medical records from each of the four participating hospital systems (HS) for all patients in their EDs. Records included the following types of events: laboratory results, radiology studies, consultations, pathology reports, transcriptions and ED notes. The preceding 180 events of each type were available in the HIE regardless of when they occurred during the life of the HIE. The event-based format was based on clinician feedback and experience gained from use of our HIE and represented a change from our pilot study, which provided 180 days of availability. Our decision to change the programming of our system to one which retrieved a "set number of events" rather than "180 days of events" was intended to maximize the information available to the ED clinician while minimizing the time the edge servers would take to obtain data from other hospitals; larger numbers of events created increased retrieval times, which limited the utility of the system. During discussions with our vendor we determined 180 events as the number that would yield a practical balance between robustness of the system and expeditious retrieval of information. The ED clinicians were able to view records for four hours. The four-hour access time was pre-determined during negotiations between the participating hospital systems at the time the HIE was established and was based on average length of stay for ED patients at the participating hospitals. This restriction acknowledged proprietary concerns of the participating hospital systems and was intended to prevent other hospitals from retrieving data after a patient left the ED. Patients presenting to the EDs of participating hospitals were provided the opportunity to "opt out" of our HIE at the time of registration; however, no patients did so during the study period. We were fortunate to obtain an HIE with an "opt-out" design and, based on our experience, we highly recommend it as we believe it results in a more inclusive database.

We must acknowledge that, based on this design, our findings will provide an estimate of decreased MARs in terms of what the Institute for Healthcare Improvement (IHI) chooses to call "Light Green Dollars," those that are hypothetical and based on data other than actual figures. Savings to be obtained in terms of "Dark Green Dollars" will require further research.[27]

STATISTICAL METHODS

We uploaded data from REDCap into SAS, Cary, NC, for analysis. Inventory was made of the events that clinicians reported they were able to avoid by consulting the HIE (radiology studies, laboratory studies, consultations, and hospital admissions). We calculated total avoided MARs by multiplying the avoided numbers and types of services by the MARs specified for each item. Average cost of an admission from the ED was based on 2009 data from the Healthcare Cost and Utilization Project (HCUP), which validated the figure of $9844.32 (obtained from direct cost trends at the study site,) which we used for the cost of an admission in our pilot study.[1,22,23] Consultation fees were based on MARs. Estimated

time saved was gauged by the clinician participating in the study using a slider bar on a visual analogue scale displaying a range of zero to six hours. We took a straight average of the results from this field for all participants.

RESULTS

During the 12-month study period we had 325,740 patient encounters and 7,525 logons to the HIE (ED clinician utilization rate of 2.3%) by 231 ED clinicians practicing at the study sites. We collected 621 surveys representing 8.25% of logons of which 532 (85.7% of surveys) reported on patients who had information available in the HIE. Participating ED clinicians were distributed among the four HS participating in our HIE as shown in Figure 1: (HS1: 150; HS2: 231; HS3 94; HS4: 57).

This comprised the sample upon which our analysis was performed. For 397 of these 532 patients, the clinicians completing the survey reported a decrease in health-services use. Within this group the following services and Medicare-allowable reimbursements (MARs)were reported to have been avoided [type of service: number of services; total MARs]: Laboratory/Microbiology tests: 187 events, $2,073; Radiology studies: 298 events, $475,840; Consultations: 61 events, $6,461; Hospital Admissions: 56 events, $551,282; Grand Total = $1,035,654. By far the most important contributors to avoided MARs were radiologic studies and admissions (Figure 2).

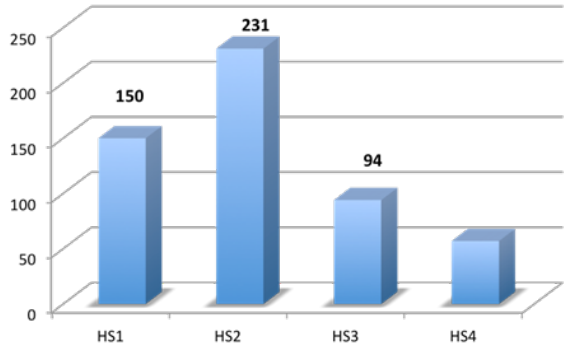

Figure 1. Number of emergency department clinicians reporting on patients with information in the health information exchange by hospital system (HS). HS1 is academic hospital. Others are community hospitals.

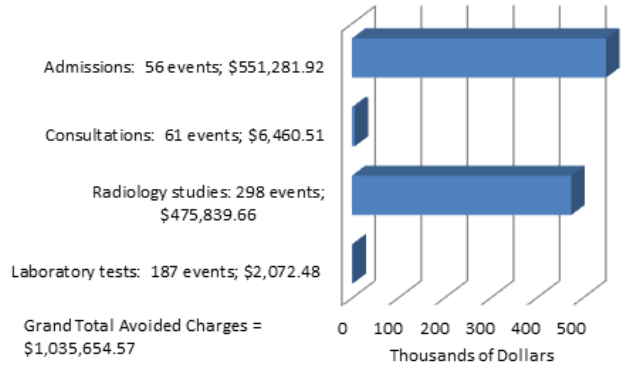

Figure 2. Interventions and Medicaid allowable charges avoided.

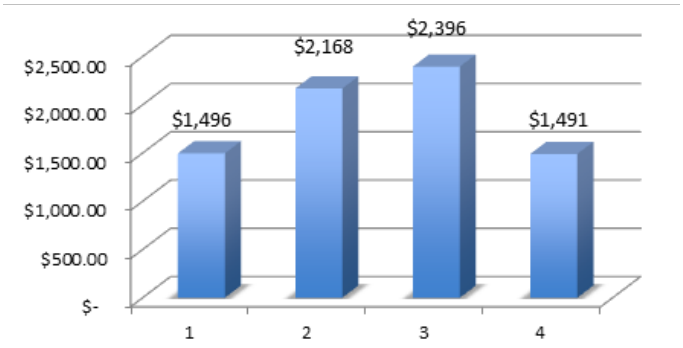

Figure 3. Reduction in Medicare-Allowable Reimbursements per emergency department patient with information in the Health Information Exchange by hospital system (HS). HS1 is academic hospital. Others are community hospitals.

The average reduction in MARs was $1,947 per patient who had information available in the HIE, Range: $1,491 - $2,396, SD = 455.23, between hospital systems (Figure 3).

There were 510 participants (81%) who responded to the survey item, which addressed "additions or changes made to patient management other than avoidance of an event because of information obtained from the HIE." Of these 32.2% (164 participants) reported changes made. Participants responding in the affirmative were offered a menu requesting the category of event added or changed. In order to limit the length of the survey, menus were not offered requesting specific types of events as they were for avoided events. This limited our ability to detail this information beyond category level of information. The following types and frequencies of events were reported to have been added or changed when studies were not avoided [event type (number of responses, % of total)]: Add/Change Laboratory/Microbiology testing (28, 17.5%), Add/Change Radiology studies (66, 41.3%), Add/Change Consultation (19, 11.9%), Add/Change Admission (11, 6.9%), Other (30, 18.8%). In order to provide a rough comparison between total MARs for studies avoided vs. studies added or changed, we imputed the value of studies added by using ratios calculated from MARs avoided. A summary of MARs avoided and MARs added is provided in the Table. Of note is that, in our data, the ratio of total MARs avoided to total MARs added was nearly 5:1. This suggests that consultation of an HIE is much more likely to reduce MARs than to increase them (see Discussion).

ED clinicians stated that the quality of care was improved for 89% of patients with information in the HIE. Eighty-two percent of the clinicians reported that valuable time was saved when information was available in the HIE: mean: 105.2 minutes; SD = 54.1 minutes; 95% CI: 100.1 – 110.5 minutes; median: 97.2 minutes, range: 0 -360 minutes.

DISCUSSION

HIE's are anticipated to reduce cost and improve quality, efficiency and safety.[2,20] Initial studies outline specific

Table. Medicare-allowable reimbersements (MARs) avoided and added.

	Avoided events	MARs avoided	Added events	MARs added*	Difference
# Respondents	532		510		
# Reporting an effect	392		164		
Laboratory/microbiology	187	$2,073	28	$310	$1,763
Radiology	298	$475,840	66	$105,387	$370,453
Consultations	61	$6,461	19	$2,012	$4,449
Admissions	56	$551,282	11	$108,288	$442,994
Total		$1,035,654		$215,997	$819,657
Average		$1,947		$424	

*MARs for events added were imputed based on calculated MARs for events avoided.

diagnoses where access to an HIE has reduced duplicative testing for a specific diagnosis[3,4,13] and/or has contributed to avoiding hospital re-admission.[2] Few have reported the overall impact of a regional HIE on cost reduction per patient and improved throughput other than Frisse, etal, who provided evidence that relatively limited use measured only in ED settings can confer a net societal financial benefit across an entire region.[15] We sought to do this using the perceptions of ED clinicians, accepting the limitations of observer bias in exchange for the utility of this method.

We previously demonstrated that access to a robust, community-wide HIE avoided redundant labs, imaging studies, consultations, and hospital admissions and improved the throughput for ED patients when information was available in the HIE.[1,16] In that study, the HIE was accessed for only 5.4% of encounters and information was present for 77% of patients for whom clinicians completed a survey. Those data reflected only a glimpse of the potential impact of an HIE at one academic institution. In the current study we sought to determine if those findings would be reproducible in a sample collected from eleven EDs belonging to four hospital systems; large and small, private and public.

The utilization rate in the current study was low at 2.3%, characteristic of this early era of HIE use. Furthermore, during our study period, two of the participating hospital systems changed EMRs, causing a 2-3 month delay in getting information successfully pushed to the HIE. We saw physician logons during the time of transition significantly decline in response to the limited availability of information. Once all systems were fully back online, adoption rates improved and we collected 621 surveys representing 8.25% of logons during the study period, 86% of which reported on patients for whom information was available in the HIE. The frequency with which ED clinicians who queried the HIE found information present regarding their patients was approximately 18%.

We believe our study was advantageous in that our HIE was constructed with an "opt-out" design, i.e., at the time of registration, patients were given the opportunity to decline access to their EMRs from other institutions. Registration personnel explained to patients the benefits of making information from other hospitals available and the commitment to privacy regarding their protected health information. We believe this design, as opposed to an "opt-in" design, enabled us to obtain a more robust enrollment, and we recommend its use whenever possible in all future HIE design.

The only way a clinician could know if information was present in our HIE was to look. At the time of the study no other mechanism existed to inform the clinician that information would be available. Eligible participants who reported having looked in the HIE and not finding information clicked a button indicating such and were excluded from the survey. Hence, our results are representative of a sample that was obtained when the HIE was accessed, data were present in the HIE, and the clinician chose to complete a survey. Within these data we showed that resource utilization was decreased. Using MARs as the yardstick by which to report the magnitude of the impact of our HIE, an average reduction of nearly $2000 per patient was demonstrated in this sample. Values ranged from approximately $1500 to $2400 between hospital systems with a standard deviation of $455, reflecting a moderate amount of variability between institutions. These figures are similar to the $2700 reduction/patient reported in our pilot study.[1] The variation between institutions can be attributed to a host of differences in the characteristics of the hospital systems under study including ED culture, type of community in which the ED is located, practice styles, patient characteristics, physician adoption of HIE, expectations of leadership, and others, none of which were controlled for in this study. Furthermore, each institution had independent access to its own EMR and the availability of internal information was another important variable for which we did not control. Nevertheless, we believe that the similarity of savings demonstrated between hospital systems in this study and the consistency of the findings between the current study and our pilot study provide some internal validation of our study design, and define a ballpark estimate for the potential reduction in MARs one might expect when ED patients have information in the HIE and the ED clinician seeks that information. In the current medical economy, our

findings should be well received in their demonstration of the potential to accomplish more with less when an HIE is available. Our data also inform stakeholders that investment in HIE infrastructure is worthwhile.

Our study was conceived as one that would gauge the extent to which HIE use avoided redundancy and reduced MARs. However, one can imagine that reviewing an HIE on a complex patient could easily lead to additional testing or consultation or even cause an admission to the hospital. We therefore included in our survey an item addressing whether an event was added or changed as a consequence of consulting the HIE. That item was not as robustly constructed in order to minimize the length of the survey; however, its branching logic provided an accounting of the types of studies added or changed. The Table reports these data and provides a comparison between estimates of the total MARs resulting from ED clinicians who used the HIE, found information, believed they *avoided* an event, and completed a survey to ED clinicians who used the HIE, found information, believed they *added* an event, and completed a survey. Costs added were imputed based on costs avoided (see Limitations). This comparison showed that, within our data, MARs avoided were approximately five-fold greater than MARs added. Hence, while allowing for the inevitable added events, our data still showed a marked overall advantage to use of an HIE.

This study was planned as one that would use minimal resources and yield preliminary, subjective data based on ED clinician perceptions regarding the ability of an HIE to impact care.

An argument can be made that use of the survey approach weakened our ability to quantify potential savings, being based as it was on clinician perceptions rather than objective data; however, there were some important advantages to this design. First, the ability to prospectively quantify what "might have been" is virtually impossible other than by asking the principal actors, in our case the ED clinicians, for their opinions. We entered upon this project with the premise that the perceptions of ED clinicians would carry some weight in convincing stakeholders to fund future study of our HIE and ultimately to sustain its existence. Furthermore, actual data was not required for this method and, at the time the study was conducted, very limited actual data was available owing to the newness of our HIE. When this project was completed, survey findings provided sufficient preliminary data in favor of a grant to support creation of a database for more effective analyses of the impact of our HIE. Using that database we have since been able to characterize patients who visit EDs belonging to more than one hospital system and compare the frequencies of computed tomographies (CT) for patients who do vs. those who do not visit EDs belonging to different hospital systems.[24,25] Further database analyses that compare the differences in cost of care for patients who had information in the HIE and for whom the ED clinicians caring for them did and did not consult the HIE are underway.

We believe a striking feature of our HIE was the cooperation demonstrated between the leaders of the four major hospital systems in our area. All showed altruism in their support of HIE and an appreciation for its potential to improve the care of our patients. Patient care clearly superseded the potential loss of revenue. However, there were aspects to HIE use that make good business sense as well: the increased efficiency resulting from use of an HIE makes it possible to see more patients in the same square footage. Furthermore, the clinician perceptions recorded in our data should amply demonstrate to hospital administration that, at the bedside, many of those caring for the patients see HIE as beneficial. Hopefully, the example we set in our community and findings of the sort we report here will lead hospitals that operate on fee-for-service business models to welcome utilization reduction despite the potential lost income from duplicative testing.

As reported above, our survey included a field for entry of studies added because of information obtained from the HIE. Within those data we noted slightly less than $1/5^{th}$ as many events were added as were avoided. Allowing for its limitations, the data appear to indicate that HIE is more likely to prevent an event than to create one. More research should be directed at clarifying this finding.

The implications of avoiding unnecessary tests can be measured in terms other than cost estimates. For instance, in this study, 271 radiologic studies were reported to have been avoided including 165 CTs. Analysis of our data in terms of the health benefit to be obtained from avoided radiographic studies showed a net reduction in Lifetime Attributable Risk (LAR) of cancer of 0.09% for women and 0.06% for men.[26]

The overwhelming majority of clinicians participating in our survey reported that valuable time was saved through use of the HIE. Improved throughput is highly predictable when one considers the time it takes to complete a CT, draw and wait for blood tests, and address the inevitable false positives and negatives. These time savings should, in turn, lead to improved patient and staff satisfaction and a reduction in the number of patients who leave without treatment. Both of these quantities imply potential for indirect secondary gains. Finally, in addition to the cost and time savings, nearly 90% of clinicians completing surveys for our study reported an improvement in quality of care for their patients.

The actual number of patients who visit multiple unaffiliated EDs in our community has been difficult to ascertain; that number did not exist at the time of our study; however, the data dictionary (DD) we have developed for future research using funding obtained with the results of this study should provide reliable estimates of that in the future. An early estimate of the number of patients in our community who visited unrelated EDs is at least 15% (unpublished data). Bailey reported that 50% of patients returned to the same ED, rendering an HIE potentially unnecessary.[4] Third-party payer organizations collect ED usage patterns about their own

beneficiaries, but analogous data have not been collected for the population as a whole. A Massachusetts study in 2010 revealed that 3.7 million patients accounted for 12.8 million ED visits and that 31.6% (1.13 million) of these patients visited the EDs of two or more hospitals during a five year period.[17] Future analysis of the DD from our HIE regarding the patient behavior of visiting multiple EDs will allow us to better predict the impact of a fully adopted HIE in our community. Such knowledge is only now becoming available using the accumulated data from recently created HIEs.

Several authors have shown that when ED clinicians have access to imaging, labs or transcriptions for patients who have been seen at other institutions, the time to disposition and ED length of stay (LOS) is reduced and redundant diagnostic testing and admissions are avoided.[1-4,18] The current study supports these findings by showing perceived decreases in need for diagnostic studies, admissions, and reduced LOS while increasing quality of care.

Additional benefits of HIE are expected as algorithms are developed to highlight which patients are most likely to have useful information in the system. It is not realistic or efficient for an ED clinician to access an HIE for every ED encounter; we need to study the scenarios that will yield the "biggest bang for the log-on." We are currently examining the clinical profiles, diagnoses, demographic information, and payer classifications of patients in our community who visit multiple unaffiliated EDs. With this information in hand, we hope to specify patients for whom the impact on cost, quality, and efficiency will be the greatest when an HIE is consulted. We anticipate visual queuing to indicate the availability of information about a particular patient and when the HIE should be used. This will become increasingly important as payment models shift away from fee for service to episodes of care, emphasizing the need for HIEs with sustainable business models.

Sustainability is a key challenge for most HIEs, 74% of which report struggling to recruit financial support from their stakeholders.[19] Fully communicating the benefit of HIE to hospitals, payers, patients and physicians will help formulate workable business models. Benefactors of HIE, other than the patients themselves, are those whose resources will be conserved through more appropriate use of healthcare property and procedures. Principal among these are third-party payers who have business plans based on capitated care and who stand to reap extraordinary savings from loss prevention. Hospitals will be large benefactors through prevention of unnecessary testing and treatment of unfunded patients; however, hospitals also are at risk for loss of revenue when testing and admissions prove unnecessary for insured patients. Despite these conflicts of interest, if the guiding principal is one of ethical and moral decision-making, with the interests of the patient kept central, the issue of seeking to profit through duplication should be rejected out of hand. Hence, the accumulating data supporting the benefit of HIE should trump the profit motive. Furthermore, HIE can conceivably "level the playing field" and empower patients to select the facilities where they feel they are treated best by making their records available at all points. Such a plan should lead to increased excellence at all sites in a given region.

LIMITATIONS

The design of our study suffered from significant limitations. Selection bias resulted from inclusion of only those ED clinicians who volunteered to complete a survey and from their subjectivity in deciding to use the HIE. Observer bias was inherent to our design through its dependence on ED clinicians' opinions regarding whether and what types of events were avoided or added from use of the HIE. One can legitimately question the utility of a survey-based study over a database analysis. As discussed above, our design made use of the resources at hand and succeeded in developing preliminary data in support of a larger the creation of a larger analytic database. Analyses of the larger database are underway and address important questions regarding the sustainability and physician adoption and use of HIE.

Our study most definitely falls into the category of one that proposes savings in terms of "Light Green Dollars," as defined by the Institute for Healthcare Improvement. The reduction in MARs we describe is one which is, at this stage, highly theoretical. Further study using actual cost and charge data will be necessary to determine if and how much of the reductions in MARs will translate into "Dark Green Dollars."[27]

Because of our design, we were unable to determine when during a patient's ED course, the ED clinician completed a survey. Responses to the survey may have been different based on whether the survey was completed early in the patient's ED course, as opposed to being completed after disposition. We chose to recruit participants using a pop-up box to optimize enrollment based on experience gained from testing our instrument prior to the study. Unfortunately, this almost certainly resulted in most ED clinicians completing the survey at the time they consulted the HIE, recording their opinions prior to disposition based on presumptions they made at the time of HIE consultation rather than after patient care was completed. Hence, changes in clinical reasoning that took place subsequent to survey completion may have been excluded from our data.

Our survey did not gather as detailed an inventory of the specific events that were added or changed as a result of HIE use. For the survey item addressing added events, we created menus for types of events but without the branching logic to identify specific events as was done for the portion of the survey addressing avoided events. This required us to impute the financial impact of added studies and weakened our ability to accurately describe the impact on cost of care from use of the HIE.

In this study, we did not allow for the fact that some services, such as consultations, have several gradations in

payment and some lab tests and diagnostic imaging studies have variations in allowable reimbursements depending on different versions of the test performed, ie, portable vs. non-portable radiographs, CBCs with or without manual differentials, scans with or without contrast, etc. These variations in tests were not alluded to in the clinician surveys and thus were not considered in the analysis. The list of tests about which the clinicians were surveyed was also limited for practical reasons.

Our study did not allow for the effect of internal EMR systems on decision making by ED clinicians. Throughout the study each institution had independent access to its own EMR and the availability of internal information was an important variable for which we did not control.

Our HIE used an "opt-out" mechanism by which patients were included unless they declined participation at the time of registration. As no patients declined participation, one must consider the possibility of a flaw in our registration practices. However, the HIE encompassed eleven EDs across four hospital systems and we therefore doubt significant failure in this area.

No information was collected on the reasons an admission was avoided. In retrospect, this would have been valuable to future HIE design.

Though participation in the study was anonymous, surveys were completed online during clinical shifts and the Hawthorne effect may have had influence. Using the HIE may have resulted in ordering of additional studies, the cost of which was not included in our calculations. Finally, the size of our sample was extremely small relative to the total population under study and, in truth, represented only a rarefied view of the population under study. Despite these limitations, we believe our study, which used ED clinician perceptions to gauge the impact of an HIE, has value and at least provides preliminary data in support of future research.

The ED is a high yield setting for an HIE to impact cost, quality and efficiency. Information sharing between hospitals at the point of care in the ED traditionally has been time consuming and difficult, contributing to errors of omission. The creation of HIEs overcomes this difficulty, in essence creating a single EMR for ED patients. The benefits demonstrated by our calculations in terms of avoided MARs, reduction in throughput times, and improved quality of care may only scratch the surface of the potential benefits to be had from this powerful innovation.

CONCLUSION

Observational data provided by ED clinicians practicing at eleven EDs in the region surrounding a mid-sized Southeastern city showed a reduction in resource use for patients who had information in an HIE. Cost analysis of our sample based on ED clinician perceptions of avoided services showed an average reduction in MARs of $1,947 per patient when ED clinicians queried the HIE, found information present, and completed a survey.

The majority of reduced MARs were due to avoided radiology studies and hospital admissions. Mean time savings of 105 minutes per patient was reported for patients with information in the HIE. This would be expected to provide secondary benefits by improving patient flow and increasing patient and provider satisfaction. Furthermore, a reduction in risk of disease from avoiding high energy radiographic imaging can be anticipated. We believe that our data supports further study of the impact of an HIE on emergency patient care.

Address for Correspondence: Steve Saef, MD, MSCR. 169 Ashley Avenue MSC 300, Charleston, SC 29425. Email: saefs@musc.edu

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Noninvasive Hemodynamic Monitoring in Emergency Patients with Suspected Heart Failure, Sepsis and Stroke: The Premium Registry

Richard M. Nowak, MD*
Prabath Nanayakkara, MD†
Salvatore DiSomma, MD‡
Phillip Levy, MD§
Edmée Schrijver, MD†
Rebecca Huyghe, RN*
Alessandro Autunno, MD‡
Robert L. Sherwin MD§
George Divine, PhD‖
Michele Moyer, BSN*

*Henry Ford Health System, Department of Emergency Medicine, Detroit, Michigan
†VU University Medical Center, Department of Emergency Medicine, Amsterdam, Netherlands
‡Sant' Andrea Hospital, Department of Emergency Medicine, Rome, Italy
§Wayne State University, Department of Emergency Medicine and Cardiovascular Research Institute, Detroit, Michigan
‖Henry Ford Health System, Department of Biostatistics, Detroit, Michigan

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Introduction: Noninvasive hemodynamic (HD) assessments in the emergency department (ED) might assist in the diagnosis, therapeutic plan development and risk stratification of acutely ill patients. This multinational observational study was designed to initiate noninvasive HD measurements prior to any ED patient therapeutic interventions and broadly evaluate them for potential diagnostic, therapeutic and predictive value.

Methods: We enrolled patients with suspected acute heart failure (AHF), sepsis or stroke. Continuous noninvasive HD monitoring was begun using the Nexfin finger cuff device (Edwards LifeSciences, BMEYE, Amsterdam, Netherlands). Beat-to-beat HD measurements were averaged for the initial 15 minutes, prior to therapeutic intervention. We performed suspected disease group comparisons and evaluated HD predictors of 30-day mortality.

Results: Of 510 patients enrolled: 185 (36%) AHF, 194 (38%) sepsis and 131 (26%) stroke. HD variables were significantly different ($p<0.05$) amongst the groups. Cardiac output and index and stroke volume index (SVI) were highest in sepsis (6.5, 3.5, 36), followed by stroke (5.5, 2.7, 35.8), and lowest in AHF (5.4, 2.7, 33.6). The in-group HD standard deviations and ranges measurements were large, indicating heterogeneous underlying HD profiles. Presenting SVI predicted 30-day mortality for all groups.

Conclusion: Presenting ED noninvasive HD data has not been previously reported in any large patient population. Our data suggest a potential role for early noninvasive HD assessments aiding in diagnosing of patients, individualizing therapy based on each person's unique HD values and predicting 30-day mortality. Further studies and analyses are needed to determine how HD assessments should be best used in the ED. [West J Emerg Med. 2014;15(7):786-794.]

INTRODUCTION

Acutely ill patients present daily to the emergency department (ED) requiring evaluation and treatment. To help distinguish amongst patients with similar symptoms, emergency physicians (EPs) use historical information, initial/repeat vital signs and physical examinations and results of laboratory, electrocardiographic, radiologic and ultrasonographic testing to estimate underlying hemodynamic (HD) status. Such estimates are important for making time-critical diagnoses, formulating therapeutic resuscitation plans and risk stratifying patients for disposition.

However, multiple studies report that physician estimations of HD values are inconsistent and inaccurate when compared to objective measurements. This has been reported for cardiologists,[1] intensivists,[2] trauma surgeons,[3,4] and Eps.[5,6] Thus, it is likely that acutely ill ED patients have suboptimal HD assessments. This increases the potential for inadequate/inappropriate management, unsuitable dispositions, and potentially avoidable adverse events.

Established technologies used to objectively measure HD variables have not been integrated into ED care as they require invasive methods; are time consuming to apply and calibrate; considered unreliable; can only be used intermittently; or a combination of these factors. Noninvasive measures of the HD status of ED patients are being increasingly used, adding new dimensions to monitoring variables.[7] However much of these applications are still being researched, and there have been no large studies reporting objectively measured pretreatment HD values of acutely ill patients.

We designed the Prognostic Hemodynamic Profiling in the Acutely Ill Emergency Department Patient (PREMIUM) multinational registry, a large prospective observational study using a novel monitoring device (Nexfin, Edwards LifeSciences, BMEYE, Amsterdam, Netherlands) to noninvasively and continuously measure the initial two to four hours of beat-to-beat HD measurements in a large number of ED patients with clinically suspected acute heart failure (AHF), sepsis or stroke. The presenting ED 15-minute averaged HD assessments are reported for the first time in these patient groupings and are broadly evaluated for potential diagnostic, therapeutic or predictive value.

METHODS

This was a prospective, observational, study of acutely ill patients presenting to the ED with EP suspicion of AHF, sepsis or stroke. Suspected disease states were studied as the investigators wished to capture presenting patient hemodynamics, unaltered by any ED therapy, before recording any further HD changes throughout the monitoring period. When available a trained clinical research associate obtained informed consent and then applied the Nexfin device using a standardized, previously reported methodology.[8] Continuous noninvasive finger cuff derived HD measurements were recorded for 2 – 4 hours. If a patient was required to leave the ED for diagnostic testing the Nexfin recording was paused until the patient returned, when it was restarted.

Treating EPS and nurses were blinded to all HD monitoring (Nexfin screen covered). Patient baseline characteristics, including reported race and medical history/medications were recorded. Also ED initial vital signs, testing and therapies, final diagnosis, length of stay (LOS), and disposition along with all in-hospital testing and therapies, total hospital LOS, final discharge diagnosis and discharge location were documented on standardized case report forms (CRFs). Patient-reported discomfort with finger cuff monitoring was also noted. Mortality and unscheduled medical visits were tracked (by phone and/or medical record review) through 30 days post-discharge.

Patients were enrolled in the PREMIUM registry from September 2010 – September 2012 in four large urban academic medical centers: Henry Ford Health System, Detroit, Michigan, USA (coordinating center); Detroit Receiving Hospital, Wayne State University School of Medicine, Detroit, Michigan, USA; VU University Medical Center, Amsterdam, Netherlands; and Sant'Andrea Hospital, University La Sapienza, Rome, Italy. The two U.S. medical centers were university affiliated (annual ED visits of 94,000 for each) while the two European sites were university hospitals (annual ED volumes of 32,000 and 55,000 respectively). The study was registered prior to being initiated. (ClinicalTrials: gov number; NCT01208077)

Individuals 18 years old who after initial evaluation by EPs were thought to have AHF, sepsis or stroke and had received no prior HD-altering therapy (supplemental oxygen and IV fluids at <50 ml/hour were allowed) were eligible for inclusion. If an ED patient required any additional therapy on presentation and before possible enrollment they were not eligible. The study investigators chose these three clinical conditions as a reasonable mix of common, acute medical problems that would yield a heterogeneous collection of HD measurements.

Suspected AHF patients were required to have as their primary complaint recurrent or worsening shortness of breath (< 3 days) thought by the EP to be caused by heart failure, a natriuretic peptide (BNP, NT pro BNP, MR-pro ANP) measurement ordered and a prior established heart failure diagnosis. Suspected sepsis individuals needed to have acute symptoms and signs (< 3 days), as clinically assessed by the EP, thought to be due to sepsis and blood cultures and/or blood lactate measurement planned. Suspected stroke patients had abnormal neurologic symptoms/signs (< 24 hours) believed by the EP to be caused by stroke and a non-contrast head computed tomography ordered.

Patients were excluded if they were unable to provide informed consent, could not be enrolled within four hours of ED arrival, had end stage renal disease (ESRD) (requiring hemo or peritoneal dialysis), were suspected or confirmed to be pregnant, had acute ST-segment elevation myocardial infarction (STEMI), unavailable for 30-day follow up, had any Do Not Resuscitate status, known to have aortic valvular

disease, transferred from another facility, excessively agitated, were receiving any ongoing intravenous home infusions, had a left ventricular assist device (LVAD), were previously enrolled in the PREMIUM registry or were currently in a therapeutic investigational study. ESRD patients were excluded as their HD profiles could have been dialysis dependent; those with aortic valvular disease as the Nexfin HD measurements are not accurate in the presence of aortic insufficiency, agitated patients, as excessive hand motion makes it difficult to keep the finger cuff in proper position, and those with an LVAD as they have non pulsatile blood flow.

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the International Conference on Harmonization Guidance for Good Clinical Practice. The protocol was approved by each participating center's institutional review board or ethics committee and written or oral informed consent was obtained from each subject before enrollment.

Nexfin is a FDA-approved and CE-marked (European Union cleared) device that uses pulse contour analysis to derive digital artery blood pressure (BP) noninvasively and continuously through proprietary finger cuff technology, based on the volume clamp method developed by Penaz and Wesseling.[9,10] Cardiac output (CO) and other HD variables are calculated from a reconstructed brachial artery BP waveform using the Nexfin CO-Trel pulse contour method.[11,12] The systemic vascular resistance (SVR) is calculated (mean BP – central venous pressure [CVP]) x 80/CO) with CVP fixed at 5 mm Hg. While the CO, SVR and other HD variables are beat-to-beat screen displayed in real time, measurements are also recorded enabling trending over time. When the peripheral finger arteries are severely constricted (significant circulatory shock, patients receiving vasopressors or who are hypothermic etc.) HD measuring may become very difficult or even impossible, and in this case the Nexfin issues a warning that no plethysmogram is detected.

All patient Nexfin recordings were inspected by BMEYE (blinded to any patient clinical data) to insure that they were analyzable. If the tracings in any individual patient were not thought to be generally analyzable, the principle author (RMN) reviewed the tracings, and if in agreement the subject was removed from the registry. The beat-to-beat measurements showed some variations/artifacts (Figure 1) as subjects were not intubated or sedated, could move freely and interact with relatives and ED personnel. To smooth out the Nexfin recordings we averaged all beat-to-beat measurements for each recorded minute. With any break in the monitoring, five complete minute averages prior to and post stoppage were averaged together and this value imputed for each minute average during the stoppage. This was done so that future trend analyses could compare patient values at the same real-time point after initiation of monitoring. For this report the presenting HD measurements are the averages of the first 15 complete minute averages recorded.

We performed statistical analysis using SAS 9.2 (SAS Institute Inc., Cary, NC, SAS/STAT 9.2 Users Guide, 2008) with level of significance set at $p \leq 0.05$. We used Chi-square tests to compare proportions and ANOVA to compare the mean continuous variables between the suspected disease specific groups. Logistic regression modeling was used to determine 30-day mortality predictors. To assess the predictive ability of each model we computed the c-statistic or area under the receiver-operator characteristic curve (AUC). All statistical analyses were completed by Henry Ford Health System statisticians.

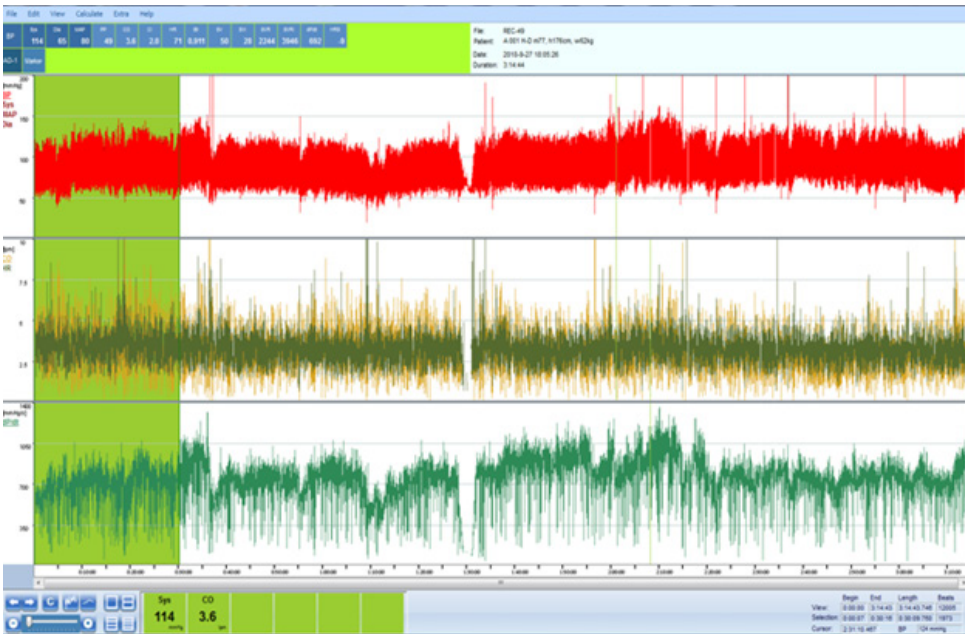

Figure 1. Nexfin continuous hemodynamic recording. Nexfin continuous HD recording in a non-sedated, non-intubated patient showing beat to beat variability. Averaging the first 15 minutes (shaded area) smooths out these variations.

Table 1. Baseline characteristics of patients studied.

Suspected disease	AHF	Sepsis	Stroke	p-value
Number (%)	185 (36)	194 (38)	131 (26)	0.0011
Age (Years)				
Mean (SD)	69.3 ±15.8	64.5 ± 16.9	67.5 ± 15.4	0.0132
Range	23 - 96	21 - 95	31- 100	0.0132
Gender (%)				
Male	86 (47)	105 (54)	67 (51)	0.3277
Female	99 (53)	89 (46)	64 (49)	0.3277
Race (%)				
African/Caribbean	94 (51)	44 (23)	67 (51)	<0.0001
Caucasian	89 (48)	135 (70)	60 (46)	<0.0001
Other	2 (1)	15 (7)	4 (3)	<0.0001
Medical history (%)				
Anemia	36 (20)	28 (14)	14 (11)	0.0937
Coronary artery disease	53 (29)	22 (11)	17 (13)	<0.0001
Cancer	18 (10)	56.(29)	17 (13)	<0.0001
Cerebral vascular disease	41 (22)	36 (19)	50 (38)	0.0002
Congestive heart failure	184 (100)	33 (17)	19 (15)	<0.0001
Cocaine use	10 (5)	6 (3)	5 (4)	0.5160
COPD	74 (40)	41 (21)	19 (15)	<0.0001
Diabetes	96 (52)	61 (31)	37 (28)	<0.0001
Alcohol abuse	14 (8)	19 (10)	10 (8)	0.6862
Myocardial infarction	62 (34)	23 (12)	22 (17)	<0.0001
Gallbladder disease	95 (51)	37 (19)	52 (40)	<0.0001
Hypertension	149 (81)	85 (44)	96 (73)	<0.0001
Infections	14 (8)	54 (28)	4 (3)	<0.0001
Liver disease	9 (5)	10 (5)	4 (3)	0.6419
Cardiac pacemaker	33 (18)	2 (1)	4 (3)	<0.0001
Peripheral vascular disease	16 (9)	6 (3)	0 (0)	<0.0005
Renal disease	74 (40)	41 (21)	8 (6)	<0.0001
Smoking history	42 (23)	28 (14)	35 (27)	0.0182
Thyroid disease	21 (11)	11 (6)	9 (7)	0.1075

AHF, acute heart failure; *COPD*; chronic obstructive pulmonary disease

As the PREMIUM Registry was strictly an observational trial recording the presenting underlying HD profiles of acutely ill ED patients (never studied before) no power calculations were completed for enrollment numbers needed to determine a difference in the HD measurements between the three disease states studied.

RESULTS

We enrolled 514 subjects in the study. Four (0.8%) were excluded (2 AHF, 2 sepsis) as their Nexfin recordings were not analyzable, thought to be secondary to finger cuff failure. There were no PREMIUM enrolled patients for whom the Nexfin device was unable to provide continuous noninvasive HD monitoring even though some had prior documented peripheral vascular disease. Less than 5% of patients expressed some discomfort in the monitored finger and this was resolved by moving the finger cuff to an alternate digit. Thus, the final registry consisted of 510 patients: 185 (36%) AHF, 194 (38%) sepsis and 131 (26%) stroke. Suspected group baseline demographic and clinical characteristics are shown in Table 1.

Overall preexisting comorbidities were common but within each suspected disease grouping the relative proportions differed significantly. Coronary artery disease (29%), congestive heart failure (100%), chronic obstructive lung disease (40%), diabetes (52%), myocardial infarction (34%), hypertension (81%), renal disease (40%), cardiac pacemaker (18%) and peripheral vascular disease (9%)

Table 2. Patient disposition, length of stay (LOS) and outcomes.

Suspected disease	AHF	Sepsis	Stroke	p-value
ED discharge (%)	19 (10)	23 (12)	32 (24)	0.0008
ED LOS (Hours)				
Mean (SD)	7.5 ± 10.0	4.2 ± 4.1	3.9 ± 3.0	<0.0001
Range	0.5 - 80.5	0.5 - 50.0	0.6 - 28.3	<0.0001
Dispositions (%)				
Transferred	9 (5)	14 (7)	4 (3)	0.2454
Observation unit	32 (17)	11 (6)	7 (5)	<0.0001
Admit hospital	123 (67)	142 (73)	87 (66)	0.2789
Admit to general ward	71 (38)	114 (59)	44 (34)	<0.0001
Admit to ICU	11 (6)	21 (11)	33 (25)	<0.0001
Admit to telemetry	41 (22)	7 (4)	10 (8)	<0.0001
Hospital LOS (Days)				
Mean (SD)	7.3 ± 11.5	9.5 ± 10.2	5.7 ± 5.7	0.0111
Range	1.0 - 126	1.0 - 72	1.0 - 37	
Death in hospital (%)	7 (4)	13 (7)	4 (3)	0.2381
Death in 30 days (%)	17 (9)	18 (9)	6 (5)	0.2400
Unscheduled 30 day visit (%)	43 (23)	39 (20)	22 (17)	0.3714

AHF, acute heart failure; *ED*, emergency department; *LOS,* length of stay; *ICU*, intensive care unit

were more frequently encountered in the AHF patients, while cancer (29%) and infections (28%) were more reported in those with sepsis. Cerebrovascular disease (18%) and smoking history (27%) were most often found in stroke patients.

Patient group LOS, disposition and outcome significantly differed in the suspected disease groupings (p-values, Table 2). Stroke patients had the highest ED discharge rate (24%), followed by sepsis (11%) with AHF subjects the lowest (10%). The mean ED LOS (hours) was longest in the AHF group (7.5), followed by sepsis (4.2) and shortest in stroke (3.9). Sepsis subjects were admitted to a general ward most often (59%), followed by AHF (38%) and stroke the least (34%). Stroke patients were most admitted to an intensive care unit (ICU), usually a stroke unit, (25%) with sepsis next (11%) and AHF the least (6%). AHF patients were most often transferred to an observation unit (17%) and admitted to telemetry (22%).

Admitted mean LOS (days) was for sepsis 9.5, 7.3 for AHF and 5.7 for stoke with large ranges. Group rates of in hospital mortality, 30-day death and unscheduled medical visits post discharge were not significantly different: AFH, 4%, 9%, 23%; sepsis, 7%, 9%, 20%; and stroke 3%, 5% , 17% respectively.

The 15-minute averaged mean HD variables were significantly different in the suspected disease groupings (p-values, Table 3). Blood pressures (systolic, diastolic, and mean in mm Hg) were highest in stroke and lowest in sepsis with AHF in between Heart rates (beats per minute) were highest in sepsis (96.6), followed by AHF (83.0) and lowest in stroke (77.6). Measurements of cardiac function (cardiac output, cardiac index [CI] and stroke volume index [SVI]) were highest in sepsis (6.5, 3.5, 36), followed by stroke (5.5, 2.7, 35.8), and lowest in AHF (5.4, 2.7, 33.6). The SVR was highest in stroke, followed by AHF and lowest in sepsis (1787.6, 1483.7, 1172.1 respectively). The within suspected group standard deviations and ranges for HD values were large, indicating very diverse HD measurements in patient populations with the same suspected disease.

Univariate HD parameters associated with 30-day mortality on logistic regression are reported in Table 4. AHF and sepsis had six individual predictors each and stroke had one. The single common 30-day mortality predictor for all groups was SVI (Figure 2) with different optimal cohort cut points (AHF 24.2, sepsis 35.3, stroke 22.16). Of note systolic blood pressure (SBP) and HR were only predictive of 30-day mortality for AHF.

DISCUSSION

Overall the multinational patient population studied was quite ill, having numerous medical comorbidities with relatively high rates of hospitalization, long LOS and high rates of 30-day unscheduled medical visits and mortality. No clinical scales or scoring systems were used to further define the severity of disease in the three studied groups. This patient population would benefit from enhanced ED assessments and resulting therapies to improve clinical outcomes.

Table 3. Presenting 15-minute averaged hemodynamic parameters.

Suspected disease	AHF	Sepsis	Stroke	p-value
Systolic BP (mmHg)				
Mean (SD)	125.7 ± 29.1	115.6 ± 28.4	142.8 ± 30.6	<0.0001
Range	55.9 - 233.2	39.1 - 233.2	76.2 - 240.8	<0.0001
Diastolic BP (mmHg)				
Mean (SD)	69.5 ± 16.0	65.0 ± 13.4	78.0 ± 16.5	<0.0001
Range	32.5 - 114.3	31.8 - 106.6	44.6 - 142.1	<0.0001
Mean BP (mmHg)				
Mean (SD)	89.4 ± 19.5	84.3 ± 18.4	102.4 ± 20.6	<0.0001
Range	43.9 - 154.9	39.8 - 152.1	57.1 - 178.4	<0.0001
Heart rate (beats/min)				
Mean (SD)	83.0 ± 17.6	96.6 ± 18.5	77.6 ± 15.6	<0.0001
Range	47.4 - 144.6	41.7 - 159.0	44.4 - 117.8	<0.0001
Cardiac output (L/min)				
Mean (SD)	5.4 ± 1.9	6.5 ± 2.0	5.5 ± 2.1	<0.0001
Range	1.1 - 12.3	0.9 - 11.7	2.0 - 12.6	<0.0001
Cardiac index (L/min/m^2)				
Mean (SD)	2.7 ± 0.8	3.5 ± 1.0	2.7 ± 0.9	<0.0001
Range	0.8 - 5.9	0.5 - 5.6	1.0 – 6.0	<0.0001
Stroke volume (mL)				
Mean (SD)	67.0 ± 23.9	68.5 ± 22.5	70.7 ± 22.8	0.3737
Range	13.1 - 155.1	11.5 -141.4	22.4 - 132.1	
Stroke volume index (mL/m^2)				
Mean (SD)	33.6 ± 10.5	36.2 ± 10.0	35.8 ± 10.1	0.0361
Range	9.3 - 68.4	6.0 - 67.2	11.6 - 58.1	
SVR (dynes sec/cm^5)				
Mean (SD)	1483.7 ± 613.7	1172.1 ± 618.4	1787.6 ± 927.4	<0.0001
Range	660.6 - 5216.68	525.6 - 6173.9	630.7 - 7235.5	
SVRI (dynes sec/cm^5/m^2)				
Mean (SD)	2868.6 ± 1053.4	2137.0 ± 932.2	3404.8 ± 1675.3	<0.0001
Range	1291.8 - 7271.8	1041.9 – 8429.2	1318.4 – 15102.9	

AHF, acute heart failure; *BP*, blood pressure; *SVR*, systemic vascular resistance; *SVRI*, systemic vascular resistance index

The presenting HD variables differed significantly amongst patients with suspected AHF, sepsis and stroke. These differences potentially could be useful to help distinguish one disease state from another, especially when overlapping features, such as dyspnea, are present. For example, without HD knowledge patients might be misdiagnosed with volume overload AHF and treated with diuretics when in fact they have infection with cardiac dysfunction due to high output failure. Disease differentiation using HD studies may be less important in those with suspected stroke syndromes.

However, most importantly, within each of the three patient groupings widely diverse HD profiles were seen indicating that individuals with suspected similar diseases have broadly different HD characteristics that are clinically unrecognized by treating physicians. Knowing an individual patient's presenting HD measurements enables increased understanding of their cardiovascular function and also may provide potential targets for optimal treatment. Early predictors of in-hospital mortality for AHF individuals are reported to be a BUN of > 43 mg/dl, serum creatinine of > 2.75 mg/dl and a systolic BP < 115 mmHg.[13] Others recommend scoring systems combining multiple clinical variables to risk stratify AHF patients.[14] However, these recommendations provide no specific guidance for therapeutic actions whereas the HD measurements might direct interventions. Additionally, modalities like the echocardiographic-determined ejection fraction (EF) do not help in patient management as they correlate poorly to CO

Table 4. Significant hemodynamic predictors for 30-day mortality.

	Optimal cut point	AUC	p-value
Acute heart failure			
Systolic BP	116.9	0.677	0.03
Heart rate	76.6	0.703	0.02
Cardiac output	5.81	0.686	0.01
Stroke volume	39.91	0.783	<0.01
SVI	24.2	0.730	0.01
SVR	1177.6	0.637	0.03
Sepsis			
Cardiac output	5.80	0.702	0.01
Cardiac index	3.17	0.685	0.01
Stroke volume	64.2	0.694	0.01
SVI	35.3	0.687	0.01
SVR	1310.1	0.605	0.02
SVRI	2334.5	0.583	0.04
Stroke			
SVI	22.16	0.741	0.05

ROC, receiver operator characteristic curve; *AUC*, area under curve; *BP*, blood pressure; *SVI*, stroke volume index; *SVR*, systemic vascular resistance; *SVRI*, systemic vascular resistance index

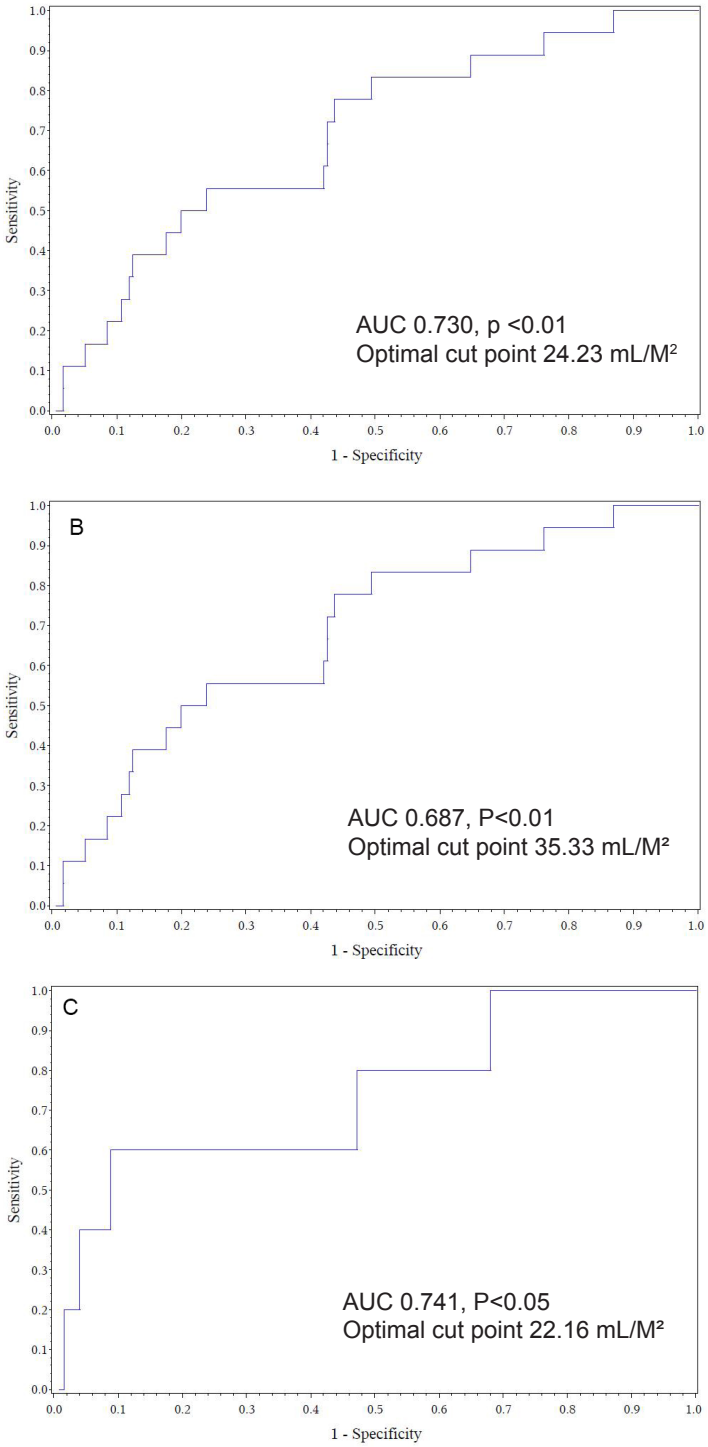

Figure 2. Stroke volume index receiver operating curves for 30-day mortality.
A, acute heart failure; *B*, sepsis; *C*, stroke; *AUC*, area under curve

(providing only crude measure of left ventricular contraction) without insight into SVR.[15]

If given optimal therapy guided by HD monitoring it might be possible to drive down hospital LOS and 30-day readmission rates (25%) in this patient population.[16] However, additional analyses of our data and further studies are needed to determine how to best manipulate these HD variables. It is known that patients with worsening heart failure in the first week of admission have low cardiac power and higher SVR.[17] These individuals could benefit by very early vasodilator therapy that is titrated by SVR monitoring as this results in significantly improved symptoms and renal function in those patients with inadequate response to standard therapies.[18] Patients with poor forward flow as evidenced by persistently low CO/CI/SVI might benefit from admission to an ICU where HD-guided therapy and management by heart failure specialists could occur. AHF patients with high CI/SVI would have additional therapy directed to the cause of the high output failure (sepsis, anemia etc.) rather simply aiming for volume reduction.

In septic patients the Mortality in Emergency Department Sepsis (MEDS) score, the Confusion, Urea nitrogen, Respiratory rate, Blood pressure, 65 years of age and older (CURB-65) score and a modified Rapid Emergency Medicine Score (mREMS) predict 28-day hospital mortality.[19] However, as with AHF, this information does not give direction for therapy. Nearly one in four admitted patients with sepsis, who lack evidence of shock or end-organ dysfunction on presentation, progress within 72 hours to severe sepsis or shock and those who develop septic shock have higher 30-day mortality than those who do not (8% v 2%).[20] These individuals are typically thought initially to be hemodynamically stable in the ED, based mostly on BP and pulse values, and are thus are admitted to a non-monitored/ICU setting. ED sepsis patients at risk for disease progression might be identified by noninvasive HD monitoring (low CI) and treated

more aggressively. The ability to identify cardiac dysfunction (low CI) may be particularly valuable as this perturbation is common in patients admitted with sepsis and septic shock and serves as a major predictor of in hospital mortality.[21]

Furthermore, patients with community-acquired pneumonia who experience disease progression and have late (1-9 days post admission) transfer to the ICU have higher 30-day mortality than those transferred within 24 hours of admission (47% v 23%).[22] Septic patients meeting criteria for early goal-directed therapy with low ED CI have higher in-hospital mortality.[23] This is secondary to reduced cardiac contractility requiring larger fluid boluses or early adjunctive inotropes to achieve resuscitation goals.[24] Thus, early HD monitoring of ED sepsis patients and prompt identification and further treatment of specific patients with low CI could potentially alter their outcomes.

Current early prognostic HD assessment of acute ischemic stroke involves BP. Elevated SBP on arrival is common (>184 mm Hg in 15%) but tends to decrease spontaneously within 90 minutes of stroke onset.[25] Some report a U-shaped relationship between admission BP and better outcomes (optimal SBP 121-200, diastolic blood pressure [DBP] 81-110mmHg)[26] while others do not, making best BP management unclear. Existing guidelines recommend that stroke patients not be given thrombolytic medications when the SBP >220 or DBP >120 mmHg.[27] As we have shown, there is heterogeneity in the presenting BP and other HD parameters in those suspected of stroke, and SVI, not BP, was associated with 30-day mortality. Thus knowledge of HD values may supersede the value of BP alone. This is not surprising as BP correlates poorly with CI.[28] Stroke patients admitted to an ICU overall have high SVRI and decreased CI and SVI, while non-surviving ischemic stroke patients have significantly even higher mean SVRI compared to survivors.[29] Additionally, rehabilitating stroke patients with a low EF (<35%) and presumed lower CI are less likely to return home.[30] Maintaining cerebral blood flow to the ischemic penumbra of the brain is important. However, in the 2013 AHA/ASA Stroke guidelines[27] there is no mention of HD assessment of these patients beyond BP. Further studies are needed to more completely characterize the meaning of HD variables in acute stroke and how they might be manipulated to improve outcomes.

LIMITATIONS

There are limitations to this report. This observational study was of convenience design and thus possibly not a representative sample of patients with the suspected diseases studied. Most but not all patients had their suspected disease verified upon further ED testing or during hospitalization. Additional analyses will be needed and are planned comparing the HD variables amongst those with confirmed to those with suspected disease. While we report individual HD variables as predictors of 30-day mortality, significant overlap exists for these variables and it will be necessary to distill out the ones that are most relevant. We have not yet analyzed the trending of HD variables over time, their response to treatments or what specific values were seen at monitoring end. These additional results could alter the predictive values of the variables reported. The study was carried out in urban academic medical centers and so measurements in other settings might be different.

CONCLUSION

In summary, technological advances now allow for routine noninvasive continuous monitoring of HD variables in acutely ill ED patients. We have reported for the first time the presenting ED HD values of large patient cohorts with suspected AHF, sepsis and stroke as measured by the Nexfin device. These initial HD measurements may be important for improving diagnosis, developing individualized therapeutic management plans/disposition decisions and predicting 30-day mortality. Further clinical studies are needed to determine how to best use these now obtainable HD measurements in the ED.

Address for Correspondence: Richard M. Nowak, MD, Henry Ford Health System, Emergency Department, 2799 West Grand Boulevard, Detroit, Michigan, 48202. Email: rnowak1@hfhs.org.

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Shock Index and Prediction of Traumatic Hemorrhagic Shock 28-Day Mortality: Data from the DCLHb Resuscitation Clinical Trials

Edward P. Sloan, MD, MPH*
Max Koenigsberg, MD†
James M. Clark‡
William B. Weir, MD§
Nora Philbin, DO‖

* University of Illinois at Chicago, Department of Emergency Medicine, Chicago, Illinois
† Advocate Illinois Masonic Medical Center, Department of Emergency Medicine, Chicago, Illinois
‡ Rush Medical College, Rush University Medical Center, Chicago, Illinois
§ University of Illinois College of Medicine at Urbana-Champaign, Carle Physician Group, Department of Emergency Medicine, Illinois
‖ Unity Point Methodist, Department of Pediatrics, Peoria, Illinois

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Introduction: To assess the ability of the shock index (SI) to predict 28-day mortality in traumatic hemorrhagic shock patients treated in the diaspirin cross-linked hemoglobin (DCLHb) resuscitation clinical trials.

Methods: We used data from two parallel DCLHb traumatic hemorrhagic shock efficacy trials, one in U.S. emergency departments, and one in the European Union prehospital setting to assess the relationship between SI values and 28-day mortality.

Results: In the 219 patients, the mean age was 37 years, 64% sustained a blunt injury, 48% received DCLHb, 36% died, and 88% had an SI≥1.0 at study entry. The percentage of patients with an SI≥1.0 dropped by 57% (88 to 38%) from the time of study entry to 120 minutes after study resuscitation (p<0.001). Patients with a SI≥1.0, 1.4, and 1.8 at any time point were 2.3, 2.7, and 3.1 times, respectively, more likely to die by 28 days than were patients with SI values below these cutoffs (p<0.001). Similarly, after 120 minutes of resuscitation, patients with a SI≥1.0 were 3.9x times more likely to die by 28 days (40 vs. 15%, p<0.001). Although the distribution of SI values differed based on treatment group, the receiver operator characeristics data showed no difference in SI predictive ability for 28-day mortality in patients treated with DCLHb.

Conclusion: In these traumatic hemorrhagic shock patients, the shock index correlates with 28-day mortality, with higher SI values indicating greater mortality risk. Although DCLHb treatment did alter the distribution of SI values, it did not influence the ability of the SI to predict 28-day mortality. [West J Emerg Med. 2014;15(7):795–802.]

INTRODUCTION

Despite efforts to optimize the resuscitation of traumatic hemorrhagic shock patients, significant mortality is still associated with this clinical condition.[1-3] The ability to accurately assess the degree of hemorrhage and the volume of resuscitation required to achieve a state of compensated shock is essential to maximizing patient outcomes.[4,5] The exact fluid resuscitation volume that achieves a compensated shock state is still not clearly defined, nor are the vital signs that define adequate compensation.[6] Even when vital signs are normalized, uncompensated traumatic hemorrhagic shock may persist and remain unnoticed by clinicians unless detected by

other means, such as serial serum lactate measurements.[7-9]

The use of a standardized tool for detecting shock compensation in traumatic hemorrhagic shock patients may optimize their resuscitation and assure adequate perfusion without accelerating hemorrhage.[10,11] The shock index (SI) has been proposed as an easy and clinically effective method of detecting uncompensated shock through determining the ratio of heart rate (HR) to systolic blood pressure (SBP) [SI = HR/SBP].[12] Published studies to date suggest that a SI > 1 (HR>SBP) generally indicates an uncompensated shock state that may require further resuscitation.[13-23]

Diaspirin cross-linked hemoglobin (DCLHb), a hemoglobin-based oxygen carrier (HBOC), was studied as a traumatic hemorrhagic shock resuscitation agent in part because of a proposed beneficial pressor effect related to its tetrameric structure[23-25] Two parallel efficacy trials in U.S. emergency departments (ED) and in the European Union (EU) pre-hospital setting studied DCLHb not only as an oxygen carrier, but also as a therapeutic agent that could increase critical organ tissue perfusion during hemorrhagic shock.[23, 26-29] Although a previous analysis of these studies failed to demonstrate consistent blood pressure changes with DCLHb use, there is still a theoretical concern that any DCLHb pressor effect could alter HR and SBP, causing the resuscitation of traumatic hemorrhagic shock patients to be inadequate, leading to an uncompensated shock state.[30] Prior study of these DCLHb data found that a SI $\geq$ 1 at the time of ED disposition better predicted trauma mortality than did HR or SBP alone, suggesting that an ED resuscitation that achieves HR that is lower than the SBP (SI < 1) may predict an improved survival

Table 1. Patient demographics and clinical variables in the United States (U.S.) and European Union (EU) DCLHb.

	Total	DCLHb	NS	p-value
N (%)	219 (100%)	106 (48.4%)	113 (51.6%)	--
Age (years)	37.3 ± 17.2	36.4 ± 17.6	38.1 ± 16.8	ns
Gender				
Male	159 (72.6%)	81 (76.4%)	78 (69.0%)	ns
Female	60 (27.4%)	25 (23.6%)	35 (31.0%)	
Study setting				
US	98 (44.7%)	52 (49.1%)	46 (40.7%)	
EU	121 (55.3%)	54 (50.9%)	67 (59.3%)	
Mechanism of injury				
Blunt	139 (63.5%)	64 (60.4%)	75 (66.4%)	ns
Penetrating	80 (36.5%)	42 (39.6%)	38 (33.6%)	
Blunt injury type				
MVC	94 (67.6%)	43 (67.2%)	51 (68.0%)	
Fall	31 (22.3%)	14 (21.9%)	17 (22.7%)	
Other	14 (10.1%)	7 (10.9%)	7 (9.3%)	
Penetrating injury type				
GSW	35 (43.8%)	18 (42.8%)	17 (44.7%)	0.20
Stab wound	27 (33.7%)	13 (31.0%)	14 (36.8%)	
Other	11 (13.7%)	9 (21.4%)	2 (5.3%)	
MVC	6 (7.5%)	2 (4.8%)	4 (10.6%)	
Fall	1 (1.3%)	0 (0.0%)	1 (2.6%)	
Baseline SI				
SI≥1	169 (87.6%)	83 (87.4%)	86 (87.8%)	ns
SI<1	24 (12.4%)	12 (12.6%)	12 (12.2%)	
ISS	30.4 ± 18.1%	31.3 ± 18.8%	69.6 ± 32.6%	0.13
TRISS-predicted survival rate				
Mortality				
Predicted	33.8%	38.0%	30.4%	
Actual	36.5% (80/219)	44.3%(47/106)	29.2%(33/113)	0.02

DCLHb, diaspirin cross-linked hemoglobin; *NS,* normal saline; *MVC*, motor vehicle crash; *GSW,* gun shot wound; TRISS, trauma and injury severity score; *ISS*, injury severity score; *SI,* shock index

likelihood for traumatic hemorrhagic shock patients.[31]

This study analyzed the ability of the SI to predict 28-day mortality in patients resuscitated in the DCLHb clinical trials. The findings from this study may elucidate the use of the SI as a guide to emergent trauma patient resuscitation both in clinical practice and in future HBOC clinical trials.

METHODS

We obtained data from two parallel, multi-center, randomized, single-blinded, normal saline (NS) controlled, efficacy studies of DCLHb in the treatment of severe traumatic hemorrhagic shock patients, which enrolled 98 patients from 17 U.S. trauma centers between February 1997 and January 1998, and 121 patients from 32 EU trauma centers from July 1997 to May 1998.[28,,29] We pooled the data because of the similarity of the traumatic hemorrhagic shock patients in these studies.

Inclusion criteria required that patients have hemorrhage and proven hypoperfusion as demonstrated by SBP < 90 mm Hg and HR > 120 beats/min, SBP < 90 mm Hg and HR < 60 beats/min, or a base deficit > 15 mEq/L. We excluded from the studies the following patients: those with demonstrated traumatic brain injury; patients with suggested imminent death, patients whose injury occurred more than four hours prior to infusion, patients less than 18 years of age, and pregnant women.

HR and SBP data were obtained for each patient in the U.S. trial at enrollment (Entry, 0 minutes), 30, 60, 90, and 120 minutes as well as after 2, 3, and 4 units of resuscitation fluid infusion, which corresponded to mean times of 46, 62, and 66 minutes, respectively. In the EU trial, values were obtained at enrollment, 15, 30, 45, 60, 90, and 120 minutes. The combined dataset contains data from 219 patients at these 10 collection time points. We used all SI values in the prediction of 28-day mortality, based on the supposition that any abnormal SI value from any time point may suggest uncompensated shock. All heart rates are expressed in beats per minute (beats/min), and all systolic blood pressures are expressed in mmHg.

We determined the SI using the definition of SI = HR/SBP.[12] The statistical analysis included the following: 1. mean and standard deviation comparison by two sample t-tests; 2. chi-square testing of demographics; 3. comparisons of the distribution of patients who had elevated SI values of ≥ 1.8, ≥ 1.4, and ≥ 1 in the different treatment, outcome, and mechanism of injury (MOI) groups via 2xN and chi-square testing; and 4. area under the curve (AUC) analysis of SI predictive power using receiver operator characteristic (ROC) curves. We used a logistic regression to model 28-day mortality based on SI on study entry, SI at 120 minutes, maximum SI during resuscitation, MOI, age, and study site (U.S. vs. EU). (IBM SPSS Statistics v20.0, Epi Info StatCalc v3.5.1, Microsoft Excel 2003) The SI cutoff values in this study were chosen based on their potential clinical impact as noted in the discussion. Final patient survival status (lived vs. died) was based on all-cause 28-day mortality.

The database for the current analysis came from the original datasets that were collected by Baxter Healthcare for the U.S. and EU studies. The protocols used in the U.S. and EU clinical trials were approved by the institutional review board (IRB) of each participating institution prior to the enrollment of any subjects. The U.S. study was conducted under federal regulations governing emergency research with an exception to informed consent (21CFR 50.24). We conducted the current analysis of the data with IRB approval from the local institutional review committee.

RESULTS

There were a total of 219 patients studied in the combined dataset, with 55% coming from the EU study (Table 1). The mean age was 37 $\pm$ 17 years, 64% of the patients sustained a blunt injury, 48% received DCLHb resuscitation, 73% were male, and the mean injury severity score (ISS) was 30 $\pm$ 18. In the 193 patients for whom a study entry SI was available, 88% had an SI $\geq$ 1. There were no differences in the baseline demographic and clinical variables, as well as predicted mortality, based on treatment group or study site. Actual mortality was 1.5x higher in patients treated with DCLHb as compared to those treated with NS (44 vs. 29%, 95% CI=1.1-3.6, p<0.02).

The distribution of the 1297 SI values from all of the time points differed based on treatment group (Figure 1). The incidence of SI < 0.6 values was 75% higher in DCLHb treated patients as compared to NS treated patients (15.2 vs. 8.7%, OR=1.9, 95% CI=1.3-2.8, p<0.001). The incidence of SI values between 1.00 and 1.39 was 46% higher in NS treated patients as compared to DCLHb treated patients (31.2 vs. 21.4%, OR=1.7, 95% CI=1.3-2.2, p<0.001) The incidence of SI $\geq$ 1.0 values was 19% higher in NS treated patients as compared to DCLHb patients (54 vs. 45%, OR=1.4, 95%CI=1.1-1.8, p<0.003) (Table

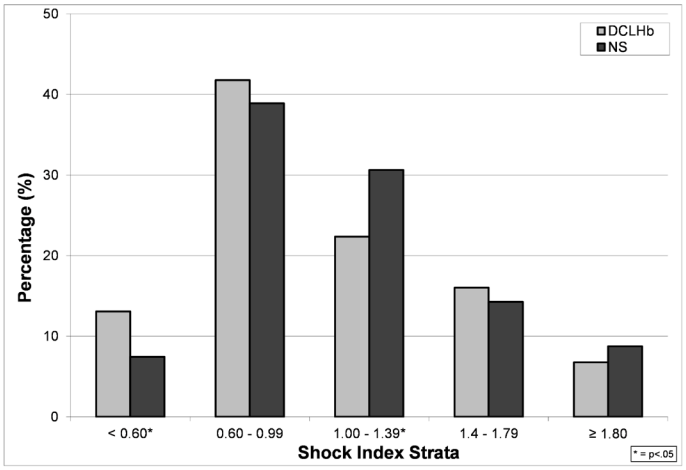

Figure 1. Distribution of shock index values in the United States and European Union DCLHb clinical trials at all time points by treatment.
DCLHb, diasprin crosslinked hemoglobin; *NS*, normal saline

Table 2. Elevated shock index frequencies based on clinical trial group and treatment group from the DCLHb traumatic hemorrhagic shock clinical trials.

Study	SI ≥ 1.8	p-value	SI ≥ 1.4	p-value	SI ≥ 1.0	p-value
Combined						
DCLHb	46/680 (6.8%)	ns	155/680 (22.7%)	ns	307/680 (45.1%)	0.003
NS	54/617 (8.8%)		142/617 (23.0%)		331/617 (53.6%)	
US trial						
DCLHb	18/313 (5.8%)	ns	69/313 (22.0%)	ns	136/313 (43.5%)	0.005
NS	23/274 (8.4%)		69/274 (25.2%)		142/274 (51.8%)	
EU trial						
DCLHb	28/367 (7.6%)	ns	86/367 (23.4%)	ns	171/367 (46.6%)	0.028
NS	31/343 (9.0%)		73/343 (21.3%)		189/343 (55.1%)	
All patients who lived						
DCLHb	12/392 (3.1%)	ns	60/392 (15.3%)	ns	139/392 (35.5%)	0.001
NS	29/462 (6.3%)		81/462 (17.5%)		220/462 (47.6%)	
All patients who died						
DCLHb	34/288(11.8%)	ns	95/288 (33.0%)	ns	168/288 (58.3%)	0.008
NS	25/155(16.1%)		61/155 (39.4%)		111/155 (71.6%)	

DCLHb, diaspirin cross-linked hemoglobin; *SI, shock index; NS,* normal saline; *US*, United States; *EU*, European Union

2). There were no differences based on treatment group in the incidences of SI values ≥ 1.4 and ≥ 1.8. Higher SI ≥ 1.0 values in NS treated patients (but not at the SI ≥ 1.4 and 1.8 cutoffs) were also observed within each study site subgroup and 28-day outcome subgroup.

There was no difference in the distribution of SI values based on treatment group at the time of study entry or after 120 minutes of resuscitation. However, the overall distribution of SI values at these two time points did differ as a result of the emergent resuscitation, with a 57% decrease in the number of trauma patients with a SI ≥ 1.0 after 120 minutes of resuscitation (38 vs. 88%, OR=11.5, 95% CI=6.5-20.6, p<0.001) (Figure 2).

At each study site and in both treatment groups, patients who had an elevated SI value above all three cutoff values were more likely to expire by 28 days (Table 3). Overall, patients with an SI ≥ 1.0, ≥ 1.4, and ≥ 1.8 at any time point had a 2.3x (95% CI=1.85-3.03), 2.7x (95% CI=2.1-3.6), and 3.1x (95% CI=2.0-4.7), respectively, greater odds of dying from the traumatic hemorrhagic shock than patients with all SI values below these cutoffs (p<0.001). At the 120 minutes resuscitation time point, patients with an SI≥1.0 had a 3.9x (95% CI=1.7-8.7) greater odds of dying from the traumatic hemorrhagic shock than patients with an SI value below this cutoff (28-day mortality 40 vs. 15%, p<0.001). At this same 120-minute time point, patients with an SI≥1.4 also had a greater odds of 28-day mortality (61 vs. 20%, OR= 6.4, 95% CI=2.3-18.3, p<.001) and those with an SI≥1.8 trended to have a greater odds of 28-day mortality (60 vs. 23%, OR=5.1, p < .09).

Patients who suffered a blunt trauma injury had a 1.5x (95% CI=1.2-1.9) and 1.4x (95% CI=1.1-2.0) greater odds of having an SI ≥ 1.0 and an SI ≥ 1.4, respectively, at any time point as compared to patients with a penetrating injury (p<0.001).

Mean SI values in DCLHb treated patients were comparable during the 120-minute resuscitation period except for the 90-minute time point, which had a higher mean SI value in NS treated patients (p<0.05) (Figure 3). Patients who expired as compared to those who survived had a higher mean SI at all but the "After 4 Units Infused" time point during the 120-minute resuscitation (p<0.05).

Because of the higher observed mortality in DCLHb treated patients only in the U.S. study, we analyzed mean

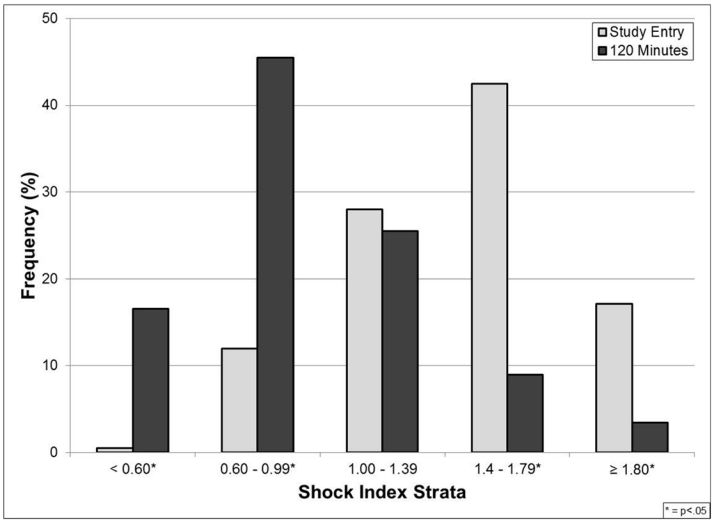

Figure 2. Shock index distribution at study entry and after 120 minutes of resuscitation.

Table 3. Relationship between elevated shock index values and 28-day mortality from the DCLHb traumatic hemorrhagic shock clinical trials.

Study	SI ≥ 1.8	p-value	SI ≥ 1.4	p-value	SI ≥ 1.0	p-value
Combined						
Lived	41/854 (4.8%)	0.001	141/854 (16.5%)	0.001	359/854 (42.0%)	0.001
Died	59/443(13.3%)		156/443 (35.2%)		279/443 (63.0%)	
US trial						
Lived	17/396 (4.3%)	0.001	73/396 (18.4%)	0.001	166/396 (41.9%)	0.001
Died	24/191(12.6%)		65/191 (34.0%)		112/191 (58.6%)	
EU trial						
Lived	24/458 (5.2%)	0.001	68/458 (14.8%)	0.001	193/458 (42.1%)	0.001
Died	35/252(13.9%)		91/252 (36.1%)		167/252 (66.3%)	
All DCLHb patients						
Lived	12/392 (3.1%)	0.001	60/392 (15.3%)	0.001	139/392 (35.5%)	0.001
Died	34/288(11.8%)		95/288 (33.0%)		168/288 (58.3%)	
All normal saline patients						
Lived	29/462 (6.3%)	0.001	81/462 (17.5%)	0.001	220/462 (47.6%)	0.001
Died	25/155(16.1%)		61/155 (39.4%)		111/155 (71.6%)	

DCLHb, diaspirin cross-linked hemoglobin; *SI, shock index; NS,* normal saline; *US*, United States; *EU*, European Union

SI values based on 28-day mortality and treatment group separately in the U.S. and EU studies. Similar to the aggregate analysis, higher mean SI values were more often seen in patients who expired as compared to those who survived in both the U.S. and EU studies. There was no difference in mean SI values over time based on treatment in the EU study.

To determine if the ability of the SI to predict 28-day mortality differed with DCLHb use, we generated ROC curves by treatment group. Although SI was not predictive of outcome at study entry, SI was equally predictive at all of the subsequent time points with an AUC value of 0.71 for patients in both treatment groups. (See supplemental digital content.)

We used logistic regression to analyze the predictive value of relevant clinical variables and SI in determining 28-day mortality. The SI at 120 min (t=12.1 p=0.001) and the trauma MOI (t=9.1, p=0.003) were both significant predictors of 28-day mortality. Logistic regression was also used to analyze the risk of the trauma patients sustaining an elevated SI. Blunt trauma injury was a significant predictor of a patient experiencing an SI ≥ 1.4 (t=10.5, p<0.001), and an SI ≥ 1.8 (t=13.1, p<0.001). Treatment group (DCLHb vs. NS) was not predictive in either logistic regression model.

DISCUSSION

Clinicians are required to assess whether or not traumatic hemorrhagic shock patients are adequately resuscitated in order to assure that tissue perfusion is supported and that critical organ failure does not occur.[2,4,5] Although strategies such as "permissive hypotension" are proposed in order to balance the need for adequate tissue oxygenation with the risk of accelerated hemorrhage, there are no published clinical guidelines that state either what is an adequate fluid resuscitation volume or what clinical variables (besides lactate levels and clearance) are best used as endpoints that reliably suggest that adequate resuscitation has occurred.[32] As such, it is often difficult to clinically assess the effectiveness of the emergent resuscitation of trauma patients with suspected uncompensated hemorrhagic shock.

The shock index is important clinically as it pairs two readily obtainable vital signs in creating an easily interpretable measure of shock compensation. Both HR and SBP are repeatedly measured during hemorrhagic shock resuscitation in the pre-hospital and in-hospital settings. Multiple SI readings give a clinical assessment of a patient's shock state both at any given moment and over time. Most importantly, these two values can be assessed by any emergency care provider, including the initial field EMS responder, paramedic, field medic, nurse, mid-level provider, or physician.

Prior analyses of the SI have found that critically ill patients who have relatively normal vital signs can be identified by a SI elevated beyond the normal range of 0.5-0.7. Rady found that a SI > 0.9 was a strong predictor of illness requiring ED resuscitation and admission to an intensive care unit.[33] In a pulmonary embolism patient study by Toosi, it was found that a SI ≥ 1 in conjunction with a pulmonary arterial pressure of > 50 mm Hg correlated strongly with increased in-hospital mortality.[16] Otero demonstrated that the SI provides high sensitivity in predicting 30-day mortality, and that the independent reading of a SBP < 90 mm Hg provides greater specificity in mortality prediction.[17] Zarzaur determined that a SI > 0.83 as a strong predictor of serious shock in patients age ≤ 55.[22] In

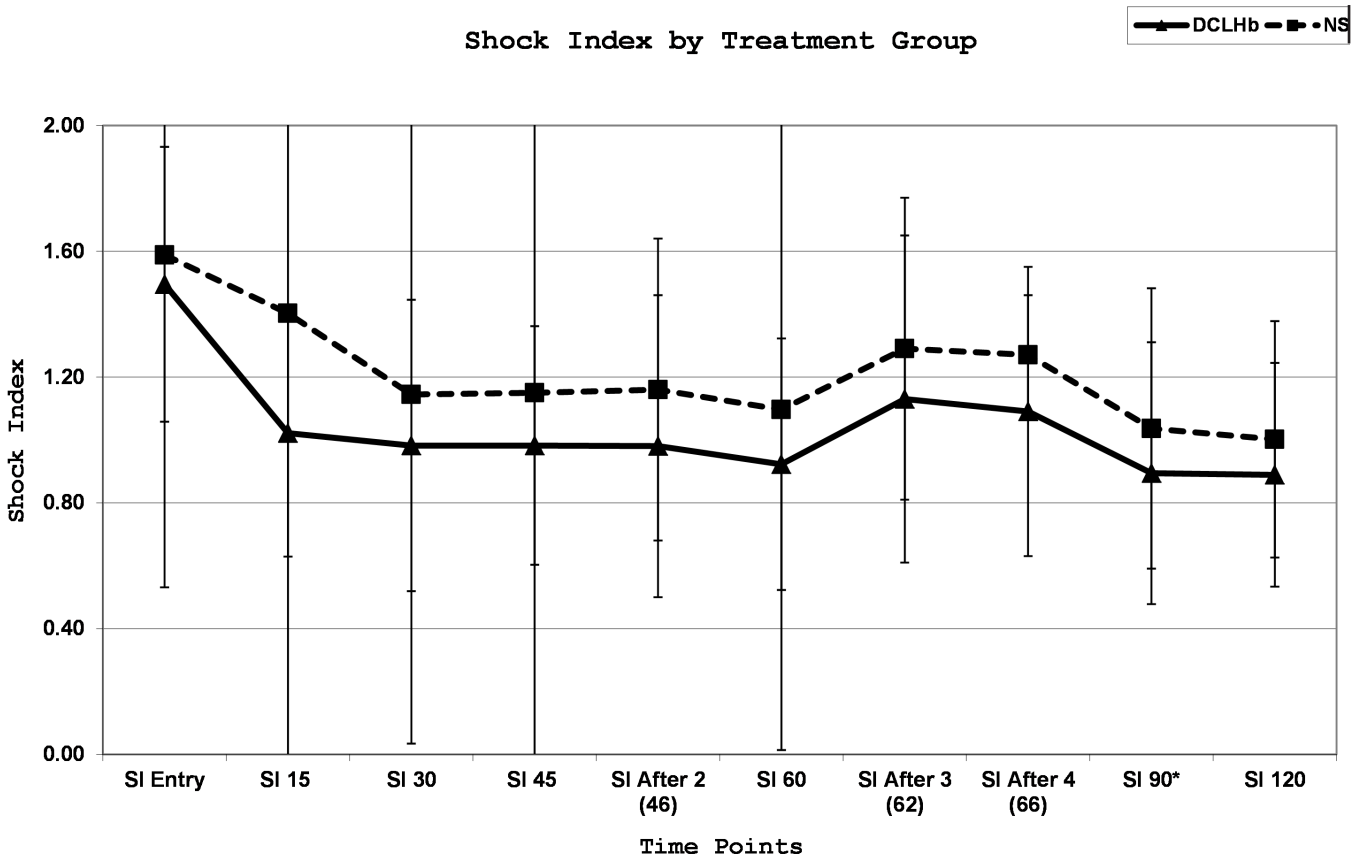

Figure 3. Mean shock index over time by treatment group in the United States and European Union diaspirin cross-linked hemoglobin-clinical trials.
SI, shock index; *DCLHb,* diasprin crosslinked hemoglobin; *NS*, normal saline

analyzing ectopic pregnancy patients, Birkhahn found that a SI > 0.85 gave a 15x greater chance for adverse events.[19]

No studies have specifically examined the utility of the shock index in treating traumatic hemorrhagic shock patients, nor was the SI used as a clinical adjunct in the DCLHb or PolyHeme blood substitute clinical trials.[28,29,34] In a traumatic hemorrhagic shock patient with a SBP of 90 mm Hg, the SI equals 1.0 when the HR is 90. With this same SBP of 90 mm Hg, the SI equals 1.4 when the HR is 126, and the SI equal 1.8 when the HR is 162, suggesting a significant lack of shock compensation. These cutoffs were empirically chosen for their potential clinical significance in severely traumatized patients with hemorrhagic shock.

Hemoglobin-based oxygen carriers (HBOCs) have been suggested to have a pressor effect that could alter both HR and SBP values in traumatic hemorrhagic shock patients.[23] Despite the belief that DCLHb could be associated with the greatest pressor effect because of its tetrameric structure, analysis of the two DCLHb clinical trials did not demonstrate a consistent blood pressure effect with DCLHb infusion.[30] Regardless of the absence of a measured pressor effect in the clinical setting with use of DCLHb, concern still exists that the changes in HR and SBP that could be seen with the infusion of HBOCs may lead clinicians to underutilize resuscitation fluids because patients could appear to be adequately resuscitated.[25] In the development of the HBOC-201 pre-hospital traumatic hemorrhagic shock clinical trial, this specific concern was made known to the trial developers by the Food and Drug Administration scientists.

The patient population of these paired clinical trials was typical of class III-IV hemorrhage patients, with most patients exhibiting a SI $\geq$ 1 at study entry and a majority sustaining a blunt mechanism of injury. Patients in the EU study received pre-hospital resuscitation with DCLHb, while U.S. study patients received in-hospital resuscitation. These two clinical trials (U.S. and EU) were similar with respect to all demographics, mechanism of injury, all baseline vital signs, and TRISS-predicted survival. These similarities allowed for a single aggregate analysis of the clinical trials data from these two separate studies, even though the SI values in the two clinical trials were not recorded at exactly the same times after the onset of the shock resuscitation.

The distribution of elevated SI values differed based on resuscitation treatment group (NS vs. DCLHb). NS treated patients more often had SI values in the 1.00 to 1.39 range, indicative of mild uncompensated shock. DCLHb treated patients more often had SI values < 0.6, which was consistent with adequate shock resuscitation. This

association could have occurred because of the purported pressor effect which may have raised the SBP in these DCLHb-treated patients. Despite these differences, the relationship between SI and 28-day mortality was not influenced by treatment with DCLHb. Additionally, the finding that there was no difference in the distribution of SI values at the higher cutoffs (SI ≥ 1.4 and SI ≥ 1.8) based on treatment group also suggests that any DCLHb or other HBOC pressor effects may only minimally influence SI values for the most critically ill trauma patients, in whom SI values and 28-day mortality are expected to be the highest.

The ROC prediction curves for DCLHb- and NS-treated patients were the same, suggesting no quantifiable DCLHb treatment effect on the ability of the SI to predict uncompensated shock that caused higher 28-day mortality in these clinical trials.

There was a significant reduction in the number of patients with elevated SI values at the 120- minute time point, suggesting a positive resuscitation effect. The preliminary analysis of the data from these two DCLHb clinical trials found that the SI at the time of ED disposition (after the resuscitation period) was the most predictive of short- and long-term patient outcome.[31] Elevated SI values in this present analysis were found to be predictive of higher 28-day mortality at all of the cutoff values during the two hours of resuscitation regardless of MOI or treatment subgroup. Also, patients with SI value ≥ 1 and ≥ 1.4 at 120 minutes had a higher 28-day mortality than those with SI values < 1, regardless of the study or treatment group. These observations suggest that the SI could be used in predicting a persistent uncompensated shock state during or at the end of the acute resuscitation phase.

The higher mortality in the U.S. study with DCLHb infusion was not associated with a significantly different SI value distribution, nor did it influence the relationship between SI values and 28-day mortality. The distribution of SI values differed based on MOI, a finding that could be related to the higher mortality seen with DCLHb use in penetrating trauma patients from the U.S. study, or due to the different quality and severity of injury seen with blunt trauma patients. Overall, mechanism of injury should continue to be examined as a covariate in any future study of SI in the resuscitation of traumatic hemorrhagic shock patients.

LIMITATIONS

This study establishes the potential ability of the SI to predict mortality and the need for further resuscitation in hypovolemic traumatic hemorrhagic shock patients, regardless of treatment with an HBOC product or other resuscitation drugs or devices. These observations are limited by a relatively small patient population, such that further examination of SI effects with HBOC use in traumatic hemorrhagic shock clinical trials be conducted, perhaps using the larger data set available from the PolyHeme study.[34] Additionally, there is the possibility for introduction of confounding variables when aggregating data from two study sites, even though study site did not appear to influence the mortality predictive ability of the SI. Lastly, the age of this data is of concern, as resuscitation methods may have changed in a manner significant enough to cause a difference in the relationship between SI and 28-day mortality in current traumatic hemorrhagic shock patients.

Future traumatic hemorrhagic shock clinical trials might assess the value of the SI and other clinically useful tools, such as serial serum lactate levels, in assessing adequate shock compensation and resuscitation. A more current data set from trauma patients treated using current shock resuscitation protocols will address the potential confounding effect of changing treatment methods on the predictive value of the shock index. Also, a data set that does not involve a study intervention may allow the SI to be evaluated without the potential confounding effect of a resuscitation therapy such as DCLHb. Future studies might also determine what minimal fluid requirements are necessary to provide adequate resuscitation, as the SI is of potential utility because it may detect patients who require further fluid resuscitation.[35]

CONCLUSION

In conclusion, we found a modest effect of DCLHb on the distribution of SI values from these two clinical trials. Regardless of this effect, elevated SI values still correlated strongly with the 28-day mortality of the traumatic hemorrhagic shock patients from these two DCLHb trauma clinical trials, especially at the time point 120 minutes following resuscitation.

Address for Correspondence: Edward P. Sloan, MD, MPH. University of Illinois at Chicago, Room 471H CME, Mail Code 724, 808 South Wood Street, Chicago, IL 60612-7354. Email: edsloan uic.edu.

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Optimizing Neurologically Intact Survival from Sudden Cardiac Arrest: A Call to Action

Jeffrey M. Goodloe, MD*
Marvin Wayne, MD†
Jean Proehl, RN, MN‡
Michael K. Levy, MD§
Demetris Yannopoulos, MD¶
Ken Thigpen, MD‖
Robert E. O'Connor, MD, MPH#

*The University of Oklahoma School of Community Medicine, Department of Emergency Medicine, Tulsa, Oklahoma
†University of Washington School of Medicine, Emergency Department, PeaceHealth St. Joseph Medical Center, Bellingham, Washington
‡Proehl PRN, LLC, Cornish, New Hampshire
§University of Alaska, Anchorage, Alaska
¶University of Minnesota Medical School, Department of Medicine, Duluth, Minnesota
‖St. Dominic Hospital – Jackson Memorial Hospital, Department of Pulmonary Services Jackson, Mississippi
#University of Virginia School of Medicine, Department of Emergency Medicine Charlottesville, Virginia

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The U.S. national out-of-hospital and in-hospital cardiac arrest survival rates, although improving recently, have remained suboptimal despite the collective efforts of individuals, communities, and professional societies. Only until very recently, and still with inconsistency, has focus been placed specifically on survival with pre-arrest neurologic function. The reality of current approaches to sudden cardiac arrest is that they are often lacking an integrative, multi-disciplinary approach, and without deserved funding and outcome analysis. In this manuscript, a multidisciplinary group of authors propose practice, process, technology, and policy initiatives to improve cardiac arrest survival with a focus on neurologic function. [West J Emerg Med. 2014;15(7):803-807.]

INTRODUCTION

For many years it has been documented that sudden cardiac arrest is among the leading causes of death, with victims numbering in the hundreds of thousands annually.[1] While the main focus of this manuscript is on out-of-hospital cardiac arrest, despite an upward trend in survival,[2] we believe the outcomes of these patients - as well as those treated for in-hospital arrests - could further improve.

A new paradigm in the management of sudden cardiac arrest is urgently needed. Why? In North America, the survival statistics remain markedly unfavorable in the vast majority of locales. The average reported survival-to-discharge-from-hospital rate is approximately 8%.[3] This rate has remained static for more than thirty years, even given detailed and frequently updated practice guidelines issued by prestigious international organizations, such as the American Heart Association and the International Liaison Committee on Resuscitation (ILCOR). Although there is evidence that individual communities and hospitals are reporting increased survival rates, the national picture is still one that begs for substantial improvement.

As a consequence of these persistent statistics, many healthcare professionals harbor expectation that patients will not survive their arrest, let alone be discharged from the hospital with their pre-arrest neurological function intact. This combination of negative expectations and the comparative difficulty of assessing the likelihood of intact neurological status without expert on-site neurologist consultation too often results in the premature cessation of post-arrest resuscitation efforts. The expectation of bad outcomes only reinforces their repeated occurrence.

Encouragingly, reports from some geographical areas do show dramatic improvements in survival, particularly over the past decade. Patients who experience sudden cardiac arrest in these regions most typically receive high-quality cardiopulmonary resuscitation (CPR) within a systems-based, community-wide approach that includes a combination of bystander CPR, improved and coordinated clinical procedures, and appropriately aggressive use of resuscitative technology, and thus have outcomes far exceeding the national average.[4,5] Amazingly, there can be as much as a 500% difference

in measured outcomes depending upon location; this is a staggering and unacceptable difference. What other medical condition would be allowed such disparate geographical outcomes? Cancer? If such highly varying statistics were reported for patients with neoplasms, it is likely that every institution involved in the treatment of these patients would be mobilized for change.

We believe that such mobilization by resuscitation scientists should be accelerated so that neurologically intact survival from cardiac arrest - whether out-of-hospital or in-hospital - will be a norm rather than an unexpected outcome. To this end, we offer the following, which constitutes a call to action.

Sudden cardiac arrest should be a reportable event. A national database of cardiac arrest events and outcomes should be established.

First, we can't improve what we don't consistently and reliably measure. Because sudden cardiac arrest is a leading cause of death in the U.S., classifying it as a reportable public health event holds the promise of improving both processes and outcomes across emergency medical services (EMS) and hospital organizations nationally. It would advance recognition of its impact on society and enhance accountability of communities, regions, and states that occurs only when outcomes data are shared across systems.

Mandated national reporting has been the norm in the field of communicable infectious diseases for many years, and while recognizing that some of the diseases included on the public health risk list have the potential to spread rapidly through populations if not urgently recognized and tracked, their modern day incidence and death rates are significantly lower than those for cardiac arrest. While mainstream media help to inform the public of the sporadic appearance of dangerous communicable diseases, the ongoing crisis of sudden cardiac arrest and its preventable lethality goes relatively unnoticed. The American Heart Association and other international organizations have frequently called for sudden cardiac arrests to be reported as public health events.[6] In 2006, the Institute of Medicine noted that the majority of EMS organizations cannot document the impact of cardiac arrest on the communities they serve.[1]As a result, there has been a longstanding call - remaining largely unanswered - for integrated methods of data collection from EMS agencies, hospitals, and communities.

The Cardiac Arrest Registry to Enhance Survival, or CARES system, initiated in 2004, uses a standardized data collection system, and where it is implemented, it has provided EMS leaders with better understanding of the efficacy of resuscitation efforts in their communities.[1] The usefulness of this system, even in a limited way, is a good indicator of how valuable a national reporting base would be. Recently, the National Institutes of Health and the Center for Communicable Diseases announced their collaboration in the creation of the Sudden Death in the Young Registry for arrest victims up to the age of 24. Data from as many as 15 states or major metropolitan areas will be entered into a centralized database from participating state public health agencies.[7] Expansion of this concept to include all sudden cardiac arrests would increase the value of this registry.

For advancing and implementing a national reporting system, the Centers for Medicare and Medicaid Services (CMS) could be helpful in requiring outcomes reporting as a quality measure linked to reimbursement. CMS has the technical capability of comparing survival rates in different regions of the country in much the same way that it compares costs of treatment of medical conditions in different regions of the country. The data could be used to improve critical interventions, minimize future risk, and document strategies that prove most useful when deployed as a standardized, coordinated bundle of care. The analysis of the whole could provide targeted education and training for both layperson rescuers and resuscitation providers and increase general understanding of the overall problem across the country.

To complement the role of CMS, the Joint Commission and equivalent agencies could do the same for in-hospital arrests. Reporting in-hospital cardiac arrests is now voluntary. Mandating the reporting of in-hospital cardiac arrest incidence and outcomes would offer a key advantage as an out-of-hospital arrest reporting system: encouraging the adoption of protocols validated as associated with better neurological outcomes. Post-arrest outcomes of patients should also be a quality metric of hospital performance linked to reimbursement, an exact complement to what CMS could accomplish for out-of-hospital cardiac arrest.

High-Quality CPR, practiced in a system-wide, community-supported setting, should be a national norm.

The 2013 consensus paper from the American Heart Association addresses the key areas of high-quality CPR: providing compressions of adequate rate and depth, not leaning on the chest between compressions so that the chest can fully recoil, minimizing interruptions in chest compressions, and avoiding excessive ventilation. It emphasizes team logistics, monitoring, feedback, and continuous quality improvement on all levels.[8]

The guidance provided in the paper is an important step towards achieving the goal of high-quality CPR as a national norm. It is especially relevant in light of several publications from 2005, that described inconsistent and substandard CPR quality among those who resuscitate patients in sudden cardiac arrest in the field as well as those who treat in-hospital cardiac arrest.[9,10] Those publications were intended as a wake-up call to resuscitation providers that the principles of high-quality CPR were not being widely practiced.[11] For example, the authors showed that when rescuers compressed at a suboptimal rate, survival-to-discharge rates after out-of-hospital arrests were reduced by as much as 30%.[12] When rescuers compressed too slowly, return of spontaneous

circulation for in-hospital cardiac arrests declined from 72% to 42%.[11]

In addition to the basics in CPR,[8] there are management steps that were described, including the rigorous and ongoing training of resuscitation team members, the choreography of their interrelationship during resuscitation, the appropriate use of technologies that enhance good neurological outcomes, rotation of members to decrease fatigue, good communication within the team so that each member clearly knows his/her role, and continual monitoring and feedback both in real time and post event. All of these are features of high-quality CPR.

Technologies and procedures that support the administration of high-quality CPR should be included in treatment protocols when there is substantial laboratory evidence and clinical experiential observation to support their use.

Randomized clinical studies are the gold standard of evidence-based care, but these are often difficult to design and execute meaningfully, particularly given the dynamics of the resuscitation environment in the out-of-hospital setting. Many accepted medical procedures and treatments have not been put to the test of randomized clinical trials, such as closed-chest massage, pre-hospital defibrillation, and artificial rescue breathing.[13] The multidimensional aspects of cardiac arrest interventions, applied in situations that are sometimes chaotic, often lead to problems with adherence to intended protocols which in turn affect both the accuracy and applicability of results. This dynamic has been described as "fundamental tensions between the principles of randomized trial design and the practice of resuscitation that make the conduct of any clinical trial of out-of-hospital cardiac arrest challenging."[13] This is not to say that high-quality research attempts should not continue but rather that treatments that appear beneficial to a consensus of resuscitation leaders should not be withheld until benefit is fully demonstrated in primary and confirmatory randomized controlled trials.

Increasingly, the treatment of cardiac arrest is leaning towards a bundled approach, where studying each intervention in isolation is not simple, and may not be necessary when it is clear that the whole leads to a positive treatment effect. A "bundle" is a group of interventions applied from the outset of a 911 call through post-arrest care in hospital, in a standardized, coordinated way, inclusive of resuscitation technology. As examples of technology, automated external defibrillators (AED) have for some time been used for early defibrillation when a shockable rhythm is present. Methods employed to increase circulation and lower intracranial pressure improve mean arterial pressure and cerebral perfusion.[14,15] While presently published studies do not confirm statistically significant benefit to outcomes using at least one commercially available device, many emergency clinicians still utilize an impedance threshold device for its touted physiological effects on coronary and cerebral perfusion. Mechanical chest compression devices are also being usefully deployed, particularly in settings with limited numbers of available professional rescuers on scene, so that compressions can be continued uninterrupted at optimal rate and depth. The combination of these and other technologies should be considered important tools in the hands of well-trained rescue teams implementing bundled, high-quality CPR.

Regional resuscitation centers of excellence should be established that optimize both out-of-hospital and in-hospital treatment.

As already noted, survival rates from out-of-hospital cardiac arrest vary widely not only in the pre-hospital setting but also after patients are transported to the hospital for post-arrest treatment. Most regions do not have a well-coordinated approach to post-arrest care[18] despite the many efforts of professional organizations to develop and disseminate treatment guidelines.

There are long-standing precedents for implementation of regional centers of care. Trauma, stroke, burn, and acute myocardial infarction treated in regional centers have experienced significant improvement in outcomes.[19] Emerging interventions for cardiac arrest including early goal-directed therapy, glucose control, seizure control, hemodynamic support, therapeutic hypothermia, cardiac catheterization, and automatic implantable cardioverter defibrillator screening, can be carried out best in a regional specialty center. If high-quality CPR becomes a national standard, hospitals can expect to receive more patients who require treatments that can lead to improved neurological outcomes. There are issues to be resolved that include the need for a strong research infrastructure to validate new therapies, and the commitment of financial resources required to care for critically ill patients.[20]A thorough discussion of the concept and implementation of regional systems for cardiac arrest resuscitation has been published by the American Heart Association.[18] We recommend that community stakeholders convene to discuss their pros and cons in light of the recognized benefits in other serious medical conditions that have taken this approach.

"Neurologically intact survival" should be the criterion by which treatment success is ultimately judged. Post-arrest psychological distress should be regarded as an element of neurological status.

Research into the neurological status of patients after cardiac arrest has been lacking. There is a general perception among neurologists called to assess patients that those who are unresponsive following return of spontaneous circulation have poor prognoses, although they have tools to mitigate poor prognoses. Neurologists can give guidance on whether continuous electroencephalographic monitoring in the intensive care unit should be the standard of care, whether an escalation of anti-seizure medications for refractory seizures should be given, on the duration of induced hypothermia and

other neuro-protective techniques, and on how to prevent reperfusion injury. Detailed neurological investigation of patients is needed before a decision is made to end post-arrest, intensive care treatment. Without such specialty consultation, termination of treatment may well occur prematurely.

EMS personnel are very aware that perfusing the brain is as important as perfusing the heart and is an essential part of high-quality CPR. It has been well accepted that achieving return of spontaneous circulation counts as a successful outcome, and now there is a rapidly emerging consensus that returning the patient to pre-arrest neurological functional status is far more important than simple return of circulation to define treatment success. Studies have verified that this is an achievable goal. Early defibrillation, active compression and decompression and the use of an impedance threshold device have been shown to be important to neurological outcome. Therapeutic hypothermia has been much discussed as another advance favoring neurological outcome, but recent studies have concluded that pre-hospital initiation may not impact survival or neurologic status.[21] Cooling in the hospital setting does make a difference, although the exact depth of targeted temperature is still a matter of debate.[22]

Another aspect of neurological injury includes post-arrest psychological distress in the form of anxiety, depression, and post-traumatic stress syndrome. Incidence rates of depression have ranged from 14% to 45%; anxiety rates have ranged from 13% to 61%; posttraumatic stress disorder rates reportedly range from 19% to 27%.[23] These high percentages call for better psychological screening, earlier intervention, and more frequent post-arrest evaluation for much longer periods, from six months to perhaps two years.

Public policy changes that would increase bystander CPR - a well-recognized factor in patient survival - should be addressed.

Successful CPR depends upon citizens and rescuers working together in a web of community-based strategies designed to smooth out the vast differences in survival rates now seen from region to region. It is well known that bystander CPR is a major factor in survival from out-of-hospital cardiac arrest, and yet fewer than half of sufferers receive it. Public education is a major factor. One of the ways this could be remedied is to institute a national training program in schools. As of this date, 36 states require CPR training for high school graduation, but training could begin earlier. There is evidence that students as early as the eighth grade can become and remain proficient at CPR and the use of an AED.[24] We recommend that all states require CPR training in schools beginning at the middle school level and continuing through high school. Most people are aware that giving blood is a lifesaving gift. The public is not as aware that bystander CPR is also a lifesaving gift. Community outreach programs and public service announcements could make learning CPR as valued as giving blood.

Establishing a tradition of multi-specialty communication and care co-ordination throughout the treatment pathway is a vital initiative for improved outcomes.

Sudden cardiac arrest is a complex disease process requiring co-ordination of care among many specialties - emergency care, neurology, respiratory therapy, cardiology, critical care, psychiatry, anesthesiology, rehabilitation medicine, among others - and many disciplines - EMS providers, medicine, nursing, respiratory care, etc. Routine collaboration across the continuum of care is not customary. A model can be taken from Tumor Boards consisting of the many specialties that guide the therapeutic pathway of patients with cancer. Committed leaders in resuscitation science could help organize such teams and publicize successful models.

Some specialties have developed sub-branches that have accomplished these goals, for example, stroke neurologists, medical and interventional cardiologists, and medical and radiation oncologists. We recommend that corresponding subspecialties of resuscitation be developed, such as resuscitation cardiology and neuro-resuscitation, a concept that would likely fit best in regional resuscitation centers of excellence. Barring the ability to implement these centers in the near term, we recommend that the disciplines named above participate in each other's meetings and publish papers in each other's journals. Such steady collaboration could transform the field of resuscitation, leading to formal interdisciplinary scientific investigations, clinical protocol development, outcomes analysis, and clinical education.

Collaboration would also highlight the fact that patients should be the focus of clinical care, whether they are located in the pre-hospital setting, the emergency department, the critical care unit, inpatient unit, the rehabilitation unit, or back in their homes and communities after discharge. A coordinated approach to the care of the patient will ultimately result in an improved rate of neurologically intact survival, the goal of resuscitation.

SUMMARY

We are well aware that, on average, survival statistics from cardiac arrest have been less than optimal despite many years of the efforts of individuals, communities, and professional societies focused on improving them. Reasons are partly the lack of financial resources and infrastructure available to local, state, and national entities, and partly due to the lack of effective and persistent commitment and leadership within communities.

We believe that measures can and should be taken on a local, regional, and national scale that can make a difference in outcomes. The lack of financial resources cannot be underestimated, but even in their absence, there are helpful decisions that can be made within the respective specialties

that treat sudden cardiac arrest.

The unwillingness to adopt new ideas and therapies until they are proven beyond any doubt via randomized clinical trials also holds back progress. Overwhelming evidence is often years in coming, and while we wait, patients die. The context in which we work as resuscitation scientists is dynamic, complex, and even sometimes chaotic, yet we have made great strides in discovering new processes and technologies that have resulted in better outcomes. We are learning that a bundled, system-wide approach to resuscitation in the field, and multi-specialty and multi-disciplinary collaboration for post-arrest treatment in the hospital and beyond, can lead to better results. We are beginning to understand that systematic continuous quality improvement may be more useful as a treatment model, with less dependence on specific study results and more on strategies that make a verifiable difference in positive neurological outcome. We urge action on the ideas we have offered, and invite all who review them to join us in our pledge to move neurologically intact survival from sudden cardiac arrest forward.

Address for Correspondence: Jeffrey M. Goodloe, MD, NRP, The University of Oklahoma School of Community Medicine, 1145 South Utica Avenue, 6th Floor, Tulsa, Oklahoma 74104. Email: jeffrey-goodloe@ouhsc.edu.

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Bedside Ultrasonography as an Adjunct to Routine Evaluation of Acute Appendicitis in the Emergency Department

Samuel H.F. Lam, MD
Anthony Grippo, MD
Chistopher Kerwin, MD
P. John Konicki, DO
Diana Goodwine, MD
Michael J. Lambert, MD

Advocate Christ Medical Center, Department of Emergency Medicine, Oak Lawn, Illinois

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Introduction: Appendicitis is a common condition presenting to the emergency department (ED). Increasingly emergency physicians (EP) are using bedside ultrasound (BUS) as an adjunct diagnostic tool. Our objective is to investigate the test characteristics of BUS for the diagnosis of appendicitis and identify components of routine ED workup and BUS associated with the presence of appendicitis.

Methods: Patients four years of age and older presenting to the ED with suspected appendicitis were eligible for enrollment. After informed consent was obtained, BUS was performed on the subjects by trained EPs who had undergone a minimum of one-hour didactic training on the use of BUS to diagnose appendicitis.They then recorded elements of clinical history, physical examination, white blood cell count (WBC) with polymophonuclear percentage (PMN), and BUS findings on a data form. We ascertained subject outcomes by a combination of medical record review and telephone follow-up.

Results: A total of 125 subjects consented for the study, and 116 had adequate image data for final analysis. Prevalence of appendicitis was 40%. Mean age of the subjects was 20.2 years, and 51% were male. BUS was 100% sensitive (95% CI 87-100%) and 32% specific (95% CI 14-57%) for detection of appendicitis, with a positive predictive value of 72% (95% CI 56-84%), and a negative predictive value of 100% (95% CI 52-100%). Assuming all non-diagnostic studies were negative would yield a sensitivity of 72% and specificity of 81%. Subjects with appendicitis had a significantly higher occurrence of anorexia, nausea, vomiting, and a higher WBC and PMN count when compared to those without appendicitis. Their BUS studies were significantly more likely to result in visualization of the appendix, appendix diameter >6mm, appendix wall thickness >2mm, periappendiceal fluid, visualization of the appendix tip, and sonographic Mcburney's sign ($p<0.05$). In subjects with diagnostic BUS studies, WBC, PMN, visualization of appendix, appendix diameter >6mm, appendix wall thickness >2mm, periappendiceal fluid were found to be predictors of appendicitis on logistic regression.

Conclusion: BUS is moderately useful for appendicitis diagnosis. We also identified several components in routine ED workup and BUS that are associated with appendicitis generating hypothesis for future studies. [West J Emerg Med. 2014;15(7):808-815.]

INTRODUCTION

Appendicitis is the most common acute abdominal disorder that requires surgery.[1-2] The diagnosis is commonly made on the grounds of a combination of history, physical examination, laboratory tests, and diagnostic imaging findings. As these diagnostic steps often take place in a serial fashion in the emergency department (ED), patients suspected of appendicitis tend to stay for prolonged periods of time, requiring considerable staff and physical resources.[3-5]

To avoid excessive testing while minimizing missed diagnosis, investigators have derived various appendicitis scores based on components of history, physical examination, and laboratory test results.[6-13] Typically these scores are used to rule out appendicitis, yielding a post-test population with moderate to high probability for the condition. While most of these scoring systems have high sensitivities, they cannot be used solely to select patients for surgical intervention because of inadequate specificities. Often further imaging is required to clarify the diagnosis, corresponding to a considerable time and resource burden as patients wait for its completion and interpretation. In addition, the accuracies of these scores tend to worsen when tested by unaffiliated investigators at different sites.[13,14]

In recent years, studies have been published on the use of beside ultrasound (BUS) to diagnose appendicitis in the ED.[15-17] This is based on the radiology literature, which has shown that ultrasound is moderately to highly sensitive and specific in the diagnosis of appendicitis.[18] Furthermore, BUS emits no ionizing radiation, and can be performed and interpreted rapidly at the bedside, providing obvious advantages to clinicians and patients alike.

The purpose of the study was to determine if emergency physicians (EP) can accurately diagnose appendicitis using BUS, after a brief training in graded-compression abdominal ultrasonography. We also aimed to identify components of ED history, physical examination, laboratory workup, and BUS associated with the diagnosis of appendicitis.

METHODS

This was a single-site, prospective study on patients treated at the Advocate Christ Medical Center Emergency Department for suspected appendicitis. It was approved by the Advocate Health Care Institutional Review Board. The hospital is a community tertiary referral center with approximately 100,000 ED visits per year. The ED is staffed entirely by board-certified EPs and sponsors a three-year emergency medicine residency training program. On-site staff radiologists provide interpretation of radiologic studies at all hours.

Patients four years of age and older presenting to the ED with abdominal pain concerning for appendicitis (as determined by the ED attending physician after history and physical examination) were eligible for enrollment. Exclusion criteria included previous appendectomy, pregnancy, unstable vital signs, frank peritonitis, neurological deficits interfering with the ability to localize abdominal pain, wards of the state, and subject/guardian refusal of consent. Potentially eligible subjects were identified by treating EPs, study investigators or the research nurse, by screening of the ED patient tracking board. Enrollment was by convenience sampling, depending on whether a study investigator was available. Investigators were EPs who had undergone a minimum of one-hour didactic training given by the senior investigator (ML) on the use of ultrasound to diagnose appendicitis. Topics discussed during the didactic session included the use of graded compression technique and anatomical landmarks to identify the appendix, appearance of the normal and inflamed appendix, and examples of sonographic findings associated with acute appendicitis as delineated in the data collection sheet. Study investigators were allowed to simultaneously function as treating EPs, and were not blinded to the presentation and clinical history of the subjects.

After informed consent was signed, a focused clinical history and physical examination was obtained from each study subject, followed by a focused BUS of the abdomen performed using a Zonare Z. One (Mountain View, CA) or Sonsite M-Turbo (Bothell, WA) machine. Each subject was asked to direct the investigator to the point of maximal pain. The area was then scanned with a high frequency (5-10 Mhz) transducer using graded compression technique. Investigators concluded their BUS when, in their judgment, the best possible images in the subjects were obtained. All BUS studies were completed prior to any radiology department studies or surgical consultations. Study images were recorded and archived at the ED ultrasound office, and were reviewed weekly for quality assurance. Investigators' overall impressions of the BUS, based on real-time sonographic findings as recorded on the data collection sheet, were documented in the patients' medical records. All patients were treated according to the judgment of the ED attending physicians or consultants.

Subject data collected included age, sex, height, weight, body mass index (BMI), time of onset of symptoms, menarche if applicable, ED treatment (pain medication, intravenous fluid, antiemetic) prior to BUS; the presence or absence of anorexia, pyrexia, nausea, vomiting, diarrhea, right lower quadrant (RLQ) pain, migration of pain to right lower quadrant from elsewhere in the abdomen, tenderness to percussion/cough/hopping, leukocyte (WBC) count, and polymorphonuclear neutrophil (PMN) percentage.

Sonographic data collected included visualization and compressibility of the appendix; diameter and wall thickness of the appendix; presence of free fluid, fecalith, or any complex mass in right lower quadrant; and sonographic McBurney's sign (elicitation of pain when concerning structure is compressed with the ultrasound transducer).

Diagnostic test and imaging results, pathological reports, intra-operative findings, and subject hospital course, if

available, were obtained by review of the medical record. A research nurse made follow-up telephone calls at 24 hours and 30 days to subjects who were discharged from the ED or who did not receive operative intervention. Three separate attempts to establish contact were made before subjects were deemed lost to follow-up. One of the investigators (SL) adjudicated final patient outcome based on the information obtained by the above-mentioned means. Diagnosis of appendicitis was based on intraoperative or pathological findings. Diagnosis of "no appendicitis" was based on intraoperative findings, presence of alternate diagnosis, resolved symptoms during inpatient observation or at follow-up telephone calls, lack of appendectomy at subsequent ED visits, or negative abdominal computed tomography results in patients who were otherwise unable to be followed up.

We recorded all study information on patient data sheets,and then entered it onto an Excel (2007, Microsoft Corp., Redmond, WA) spreadsheet for analysis. All data entries were double-checked by one of the investigators for accuracy. We analyzed data by SPSS (version 20.0, IBM Corp., Armonk, NY). Student's t test was used for continuous variables and chi square for categorical variables. We calculated the sensitivity, specificity, positive predictive value, negative predictive value of ED BUS studies using the defined outcomes above as the gold standard. We performed univariate analysis on the recorded demographic, history, laboratory, and BUS findings to identify factors associated with appendicitis. Multivariate logistic regression was then performed incorporating significant findings in univariate analysis to determine predictive factors of appendicitis and calculate the degree of association in diagnostic BUS studies.

Table 1. Subject demographic characteristics.

Subject	Number (percentages)
Sex	
Female	57 (49)
Male	59 (51)
Age	
4-8	17 (14.7)
8-12	16 (13.8)
12-18	37 (31.9)
≥19	46 (39.7)
Body mass index	
<18.5	25 (21.6)
18.5-24.9	46 (39.7)
25-29.9	23 (19.8)
30-34.9	12 (10.3)
≥35	10 (8.6)

Table 2. Calculated test characteristics assuming all non-diagnostic bedside ultrasound studies were deemed negatives at the bedside.

Test characteristics	Values (95% CI)
Sensitivity	72% (56-84%)
Specificity	81% (70-89%)
Positive predictive value	72% (56-84%)
Negative predictive value	81% (72-89%)
Positive likelihood ratio	3.86 (2.29-6.51)
Negative likelihood ratio	0.35 (0.22-0.55)

RESULTS

A total of 125 subjects consented for the study, and 116 had adequate image data for final analysis. Subject demographics are listed in Table 1. Mean age of the subjects was 20.2 years, and 51% were male. Sixty percent were 18 years of age or younger. Prevalence of appendicitis was 40%.

Fifty-two (45%) of the 116 BUS studies were diagnostic. There were 33 true positive, 13 false positive, 6 true negative, and no false negative BUS studies. This corresponds to a sensitivity of 100% (95% CI 87-100%), specificity of 32% (95% CI 14-57%), positive predictive value of 72% (95% CI 56-84%), and negative predictive value of 100% (95% CI 52-100%) of BUS. Alternatively calculated test characteristics assuming all non-diagnostic BUS studies were deemed negative at the bedside are listed in Table 2. Inclusion of subjects with inadequate image data did not worsen these test characteristics. Table 3 lists the BUS findings, final diagnoses, image review comments, and clinical course of subjects with false positive BUS. The majority of these 13 cases had intra-abdominal or pelvic pathology leading to the presence of peritoneal free fluid. Nine of the cases did not have the appendix clearly depicted, or depicted an appendix with a diameter <6mm as determined at the time of image review.

Table 4 compares the demographic, history, laboratory and BUS characteristics of subjects with and without appendicitis. There was a male predominance in subjects with appendicitis. On univariate analysis, subjects with appendicitis had a significantly higher occurrence of anorexia, nausea, vomiting, and a higher WBC count and PMN percentage. BUS of these subjects were also significantly more likely to result in visualization of the appendix, appendix diameter >6mm, appendix wall thickness >2mm, periappendiceal fluid, visualization of the appendix tip, and sonographic Mcburney's sign ($p<0.05$).

In subjects with diagnostic BUS studies, WBC, PMN, visualization of appendix, appendix diameter >6mm, appendix wall thickness >2mm, periappendiceal fluid were found to be predictors of appendicitis on multivariate logistic regression (Table 5).

BUS success and accuracy were independent of operator, parenteral narcotic or antiemetic administration, or scanning time.

DISCUSSION

Apart from individual case reports, currently there have

Table 3. Bedside ultrasound (BUS) findings, final diagnoses, image review comments, and clinical course of false positive BUS.

Patient	Age, Sex	BUS Findings	Additional comments on image review	Final diagnosis	Clinical course
1	15, male	D, NC, F, TV, MB	N/A	Abdominal pain	CT no appendicitis. Returned one week later for same complaint, and was discharged with symptomatic care. On 30-day followup no surgery was performed
2	56, male	NC, MB	Appendix not visualized	Sigmoid diverticulitis with phlegmon	Taken to surgery based on BUS and clinical findings. Underwent sigmoid colectomy/ colon anastomosis, and was eventually discharged home.
3	8, female	D, T, NC, FF, TV, MB	Appendix diameter <6mm	Abdominal pain	CT no appendicitis. Patient discharged home. Lost to phone followup. No further emergency department visit.
4	21, female	D, T, F, FF, TV, MB	N/A	Pelvic inflammatory disease	CT no appendicitis. Hospitalized for observation. Cervical swab tested positive for gonorrhea. Patient treated and discharged.
5	20, female	D,T, NC, MB	Appendix wall thickness <2mm	Abdominal pain	CT and US non-diagnositic. Admitted for observation. Pain improved while hospitalized and patient discharged home. Did well on 30-day followup.
6	6, female	D, NC, FF, TV, MB	N/A	Ovarian torsion	Taken to surgery based on BUS findings. Found to have ovarian torsion secondary to dermoid cyst. Resection performed.
7	47, female	D, NC, F, CM, FF, MB	Appendix not visualized	Colonic diverticulitis	CT showed inflammation around distal cecum/ proximal ascending colon but no appendicitis. Admitted for observation and discharged on oral antibiotics.
8	37, female	D, NC, TV, MB	Appendix not visualized	Abdominal pain	US non-diagnostic. CT no appendicitis. Patient discharged home and had no further intervention on 30-day followup.
9	29, female	D, NC, CM, TV, MB	Appendix not visualized	Diverticulitis	CT showed ascending colon inflammation/ diverticulitis. Admitted for observation and and discharged home on oral antibiotics.
10	24, female	NC, F, CM, FF, TV, MB	Appendix 4.7mm	Ruptured ovarian cyst	CT no appendicitis. Final diagnosis made on pelvic US. Patient discharged home. On followup still had intermittent pain but no appendectomy.
11	31, female	D, NC, FF, TV, MB	Appendix not visualized	Mesenteric adenitis	Discharged and returned 1 day later. Admitted for observation. No surgery performed. Asymptomatic on followup.
12	11, male	D, NC, F, CM, FF, TV, MB	Appendix not visualized	Terminal ileitis	US non-diagnostic. Diagnosis made by CT. Unremarkable colonoscopy. Discharged home with symptomatic care.
13	18, male	NC, FF, MB	Appendix not visualized	Abdominal pain/ pancreatitis	Lipase elevated. US non-diagnostic. CT no appendicitis. Admitted for observation. No further symptoms on followup.

CT, computed tomogrpahy; *US*, ultrasound study performed by the radiology department; *D*, appendix diameter > 6mm; *T*, appendix wall thickness > 2mm; *NC*, appendix non-compressible on BUS; *F*, Fecalith within appendix; *CT*, computed tomography of abdomen and pelvis; *CM*, complex mass in right lower quadrant; *FF*, Periappendiceal free fluid collection; *TV*, appendiceal tip visualized; *MB*, sonographic McBurney's sign

been three published clinical trials on EP-performed BUS for the diagnosis of appendicitis. Chen et al. found that BUS had a sensitivity of 96.4% and a specificity of 67.6% for diagnosis of appendicitis, compared to 86.2% sensitivity and 37% specificity based on surgeons' clinical judgment.[15] However, prevalence of appendicitis was 75% in their study, and all physician sonographers had extensive BUS experience, reflecting a setting atypical for most EDs in the United States Fox et al. published two studies on the topic. Their first study was a retrospective registry review, which revealed that EPs without focused training on the use of BUS to diagnose appendicitis had a sensitivity of 39% and specificity of 90%.[16] This was followed by a prospective study (in which all physician investigators received standardized training), which concluded that BUS was 65% sensitive and 90% specific in diagnosing appendicitis.[17] This latter study was conducted

Table 4. Univariate analysis of demographic, history, laboratory and bedside ultrasound (BUS) characteristics of subjects with and without appendicitis.

Variable (Mean/percentage)	Subjects with appendicitis	Subjects without appendicitis	p-value
Demographics			
Age (years)	20.4	20.1	0.749
Sex (percentage male)	71.1	38.0	0.001
BMI	24.0	24.3	0.523
Duration of symptoms (hours)	30.6	39.9	0.289
Presenting symptoms			
Anorexia	86.7	62.9	0.005
Fever > 100.4°F	21.4	14.3	0.330
Nausea	81.8	61.8	0.024
Vomiting	60.0	41.4	0.052
Diarrhea	13.3	18.6	0.460
Pain in RLQ	97.8	91.4	0.243
Migration of pain to RLQ	62.2	48.5	0.154
Laboratory results			
WBC count ($10^3/mm^3$)	15.6	9.7	<0.001
PMN percentage	82.6	67.3	<0.001
BUS findings			
Visualization of appendix	80.0	37.7	<0.001
Appendix diameter > 6mm	91.9	48.5	<0.001
Appendix wall thickness > 2mm	50.0	20.0	0.018
Appendix non-compressible	94.1	75.9	0.068
Fecalith within appendix	24.3	17.6	0.491
Complex mass in RLQ	30.6	12.8	0.061
Periappendiceal free fluid collection	77.8	33.3	<0.001
Appendiceal tip visualized	55.6	91.9	<0.001
Sonographic McBurney's sign	54.7	45.3	0.016

BMI, body mass index; *RLQ,* right lower quadrant; *WBC*, white blood cell*; PMN*, polymorphonuclear percentage

Table 5. Appendicitis predictor variables and their odds ratios on logistic regression of diagnostic bedside ultrasound (BUS) studies.

Variable	Odds ratio (95% CI)
WBC	1.42 (1.18-1.72)
PMN	1.10 (1.04-1.17)
Visualization of appendix on BUS	6.62 (2.75-15.92)
Appendix diameter > 6mm on BUS	13.95 (2.57-75.59)
Appendix wall thickness > 2mm on BUS	4.73 (1.06-21.15)
Periappendiceal free fluid collection on BUS	6.19 (1.74-22.02)

WBC, white blood cell*; PMN*, polymorphonuclear percentage

in a similar setting to ours (teaching hospital, moderate appendicitis prevalence, brief training of sonographers). The major difference between our study and theirs was the diagnosis criteria for appendicitis. In the Fox study, diagnosis was based on three chosen criteria after visualization of the appendix on BUS (internal diameter > 6mm, lack of peristalsis, noncompressibility in the transverse plane), and absence of any of these findings or inability to visualize the appendix was considered a negative BUS study. In our study, diagnosis of appendicitis was based on overall beside impression of the BUS, and investigators were allowed to deem their BUS as non-diagnostic. As a result, there were only a few negatives, but many non-diagnostic BUS studies. This likely accounted for the unusually low calculated specificity in our results. Indeed, when the test characteristics were calculated assuming all non-diagnostic BUS were negative studies, the results fell within the same range as the Fox study. Additionally, as far as the authors are aware, our study was also the first to examine the association of appendicitis with specific BUS findings.

On multivariate logistic regression BUS findings, we found that appendix diameter of > 6mm was the strongest predictor of appendicitis, followed by visualization of appendix, periappendiceal free fluid collection, and

appendix wall thickness > 2mm. In addition, visualization of the appendix tip on BUS and sonographic McBurney's sign were found to be significant on univariate analysis. This is largely in concordance with the current radiology literature. Goldin et al. found that classifying studies based on findings of appendix diameter ≥7mm or appendix wall thickness >1.7mm would have accomplished 97% diagnostic accuracy in a retrospective review of pediatric ultrasound studies performed at their institution.[19] This is similar to the study by Kessler et al., which found that appendix diameter ≥6mm on ultrasound had both sensitivity and specificity of 98%.[20] Likewise, Je et al. determined that the optimal appendix diameter and wall thickness cutoff for diagnosis of pediatric appendicitis were 5.7mm and 2.2mm respectively.[21] In another study, Van Randen et al found that thickened appendix (>6mm), transducer tenderness, and periappendiceal fat infiltration to be significant variables predicting ultrasound diagnostic accuracy.[22] Pinpoint tenderness under ultrasonography was also found by Soda et al. to be 87% sensitive and 90% specific for appendicitis diagnosis.[23] Both Goldin and Franke found periappendiceal fluid collection to be highly specific (99%) but insensitive (20%, 14% respectively) for appendicitis diagnosis, yielding a moderate accuracy (77%).[19,24] Due to the design of most bedside ultrasound machines and abbreviated scanning time of most BUS studies, findings such as periappendiceal fat infiltration might be difficult to discern, and it is possible that some of the significant findings in BUS might be different from those derived from radiology department ultrasound studies. Hence, further studies with a larger sample size might be required to confirm our study findings.

Our BUS had a lower sensitivity and specificity than that generally reported in the radiology literature.[25-27] We also had a significant number of false positive BUS studies. We speculate this might be related to the limited application-specific training and experience of our sonographers. Appendiceal sonography can be hard to master given the difficulty in visualizing the uninflamed appendix, frequent anatomical variation, common interference from the surrounding structures, and mimics from other intra-abdominal pathologies. Though all of our investigators were relatively experienced sonographers (fellow or attending credentialed in emergency ultrasound in our ED), many were new to the application at the time of the study, with limited hands-on experience beyond the one-hour didactic training. On image review by expert sonographers, many of the false positives were deemed not to have the appendix clearly depicted. If all such cases were excluded, specificity would have improved to 91%, making BUS quite useful for ruling in appendicitis. It might also be helpful to acquire dedicated pelvic BUS views in females, given the prevalence of gynecological pathology. In addition to more in-depth education and hand-on experience prior to implementation of appendix BUS protocol, we would recommend low threshold for confirmatory studies on inconclusive or difficult bedside studies based on our anecdotal experience.

Based on a combination of presenting symptoms, signs, laboratory findings, as well as radiologist-performed sonography, Tzanakis et al. developed an acute appendicitis scoring system and found it to be highly sensitive and specific in diagnosing appendicitis, with an overall accuracy of 96.5%.[28] Ultrasound result carried a much heavier weight than the other components (RLQ tenderness, rebound tenderness, WBC >12,000/μL), though specific sonographic findings were not mentioned. Similarly, we also found significant associations between appendicitis and certain components of history, laboratory workup, and BUS. However, due to limited appendicitis cases and the large number of variables examined, we were unable to derive a predictive model. Future potential trials based on our results may include derivation of a "BUS appendicitis score" comprised of the above-mentioned components, possibly leading to better accuracy than BUS alone. If found to highly accurate as in Tzanakis' case, BUS may be used as an adjunct to streamline appendicitis workup, and lead to more effective resource allocation in the ED.

Limitations

A major limitation of the study was convenience sampling of the subjects, leading to selection bias. Nevertheless, our prevalence of appendicitis and demographic characteristics were similar to other published studies on the topic, and BMI of our subjects appeared to follow a normal distribution. Investigators were also unblinded to the history and clinical examination findings of the subjects. Awareness of these findings, however, is exactly what distinguishes BUS from ultrasound performed by non-clinicians, and thuswe do not consider this a weakness of our study. Our sample size was relatively small, leading to large confidence intervals in some of our calculated test characteristics. Future large-scale studies would be necessary to confirm our findings. All investigators who performed BUS in our study were ED ultrasound fellows or faculty, with ultrasound experience exceeding that recommended by the American College of Emergency Physicians.[29] Hence, our study findings may not be applicable to operators with different BUS skill levels.

CONCLUSION

Bedside ultrasound performed by emergency physicians with limited training is moderately useful for the diagnosis of appendicitis. We have identified several history, laboratory and BUS components predictive of appendicitis in our study, which might be helpful in generating hypotheses for future studies.

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Address for Correspondence: Samuel H.F. Lam, MD. Advocate Christ Medical Center, Department of Emergency Medicine, 4440 W. 95th Street, Oak Lawn, IL 60453. Email: HiuFungSamuel.Lam@AdvocateHealth.com

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Gastrointestinal Manifestations of Hereditary Angioedema Diagnosed by Ultrasound in the Emergency Department

Christine Riguzzi, MD*
Lia Losonczy, MD MPH*
Nathan Teismann, MD†
Andrew A. Herring, MD*
Arun Nagdev, MD*

*Highland Hospital-Alameda Health System, Department of Emergency Medicine, Oakland, California
†UCSF School of Medicine, Department of Emergency Medicine, San Francisco, California

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Abdominal angioedema is a less recognized type of angioedema, which can occur in patients with hereditary angioedema (HAE). The clinical signs may range from subtle, diffuse abdominal pain and nausea, to overt peritonitis. We describe two cases of abdominal angioedema in patients with known HAE that were diagnosed in the emergency department by point-of-care (POC) ultrasound. In each case, the patient presented with isolated abdominal complaints and no signs of oropharyngeal edema. Findings on POC ultrasound included intraperitoneal free fluid and bowel wall edema. Both patients recovered uneventfully after receiving treatment. Because it can be performed rapidly, requires no ionizing radiation,and can rule out alternative diagnoses, POC ultrasound holds promise as a valuable tool in the evaluation and management of patients with HAE. [West J Emerg Med. 2014;15(7):816-818.]

INTRODUCTION

In the emergency department (ED), angioedema may be due to an environmental allergy, adverse reaction to an angiotensin-converting-enzyme inhibitor (ACE-I), or more rarely, to hereditary angioedema (HAE). Although most clinicians associate acute attacks of HAE with oropharyngeal edema, acute abdominal pain may be the only presenting symptom. More than 90% of patients with diagnosis of HAE will have recurrent abdominal attacks.[1] Acute episodes of abdominal HAE can present with nausea, vomiting, and abdominal tenderness, and can be an under-recognized presentation. Computed tomography (CT), the most common imaging modality used to diagnose abdominal HAE, typically demonstrates thickened bowel wall and ascites in such patients.[2] Point-of-care (POC) ultrasound can also be used to identify these findings and has the potential advantages of being rapidly performed at the bedside and not associated with ionizing radiation. Here, we describe the first two cases of acute attacks of abdominal HAE identified with POC ultrasound.

CASE REPORT

Case 1: A 14-year-old girl with a history of HAE presented to the ED with nausea and abdominal pain for four hours. Two months prior, she had had a similar episode of abdominal pain and was treated as an outpatient with fresh frozen plasma (FFP). Significant clinical findings in the ED included tachycardia, epigastric tenderness, leukocytosis, and elevated hemoglobin. A POC ultrasound was performed, demonstrating free intra-abdominal fluid in Morison's pouch and in the pelvis (Figure 1). Segments of small bowel appeared edematous with focal areas of increased echogenicity. She was treated with intravenous fluids, pain medications and two units of FFP. The patient was observed on the pediatric service with improvement of clinical symptoms and resolution of the above findings on a repeat consultative ultrasound examination the following day.

Case 2: A 47-year-old female with known history of HAE presented to the ED with abdominal pain and nausea for 12 hours. She had been hospitalized several times for abdominal angioedema and also required intubation twice for oropharyngeal

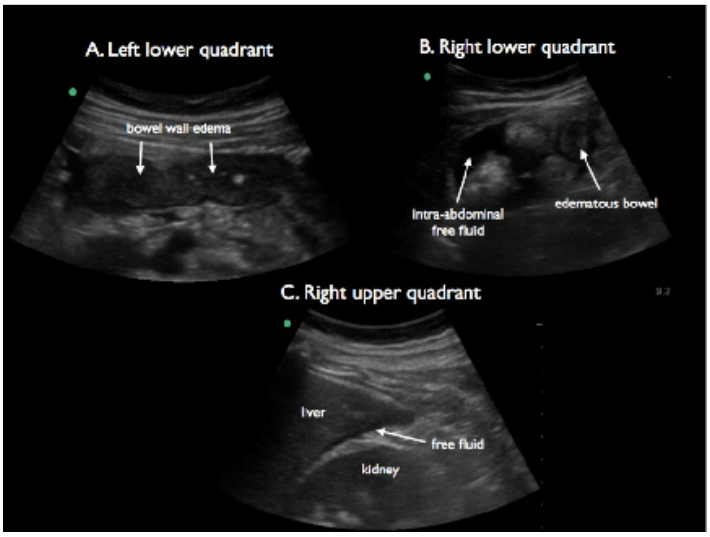

Figure 1. Arrows showing free fluid in the pelvis adjacent to the uterus in longitudinal (A) and transverse planes (B) and in Morison's pouch (C).

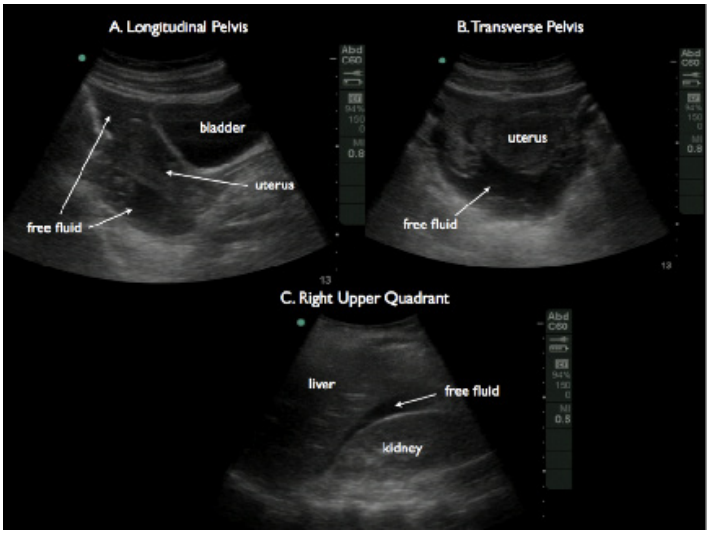

Figure 2. Thickened and hypoechoic bowel wall demonstrating edema (A), free fluid surrounding abnormal bowel (B) and free fluid in Morison's pouch (C).

edema. In the ED, she was found to have moderate tenderness in the lower quadrants with a mild leukocytosis and increased hemoglobin. A POC ultrasound revealed free fluid in Morison's pouch and her right lower quadrant (Figure 2). In the left lower quadrant, the bowel wall appeared diffusely thickened and echogenic with a narrowed, hypoechoic lumen and surrounding free fluid. During a previous episode of abdominal HAE, she underwent a CT that demonstrated similar findings. She was admitted to the hospital, and by the following day her abdominal pain had significantly improved following treatment with icatibant, and a consultative ultrasound confirmed resolution of the above findings. She was discharged and continued taking her home danazol and folic acid.

DISCUSSION

In the above cases, emergency physician-performed POC ultrasound was used to identify intraperitoneal free fluid and bowel wall edema, findings consistent with acute attack of abdominal HAE. HAE is a rare autosomal-dominant disease caused by serum C1 inhibitor deficiency. This deficiency leads to an up-regulation of complement, activating the bradykinin pathway and causing vascular permeability and subsequent mucosal edema. In abdominal HAE, edema in the bowel wall causes fluid to accumulate in the peritoneum, leading to abdominal pain and nausea, and making the diagnosis of HAE possible with POC ultrasound.

Several small studies of ultrasound in abdominal HAE have demonstrated the presence of bowel wall edema with ascites, which appears to correlate with clinical symptoms and response to treatment.[3-5] While the use of CT has been reported previously,[2] ultrasound has not been described in the emergency medicine literature. In these cases, the emergency physician was able to visualize intraperitoneal free fluid and bowel wall edema with thickening, leading to an expedited diagnosis of abdominal HAE in the ED.

In the cases presented, free fluid was noted in the abdomen, specifically in the right upper quadrant and pelvis. In contrast to intra-abdominal blood, which often contains subtle, granular, internal echoes, the free fluid seen in abdominal HAE should appear completely echolucent, similar to what is seen in patients with ascites. In young women, this feature may allow for differentiation between abdominal HAE and a ruptured ovarian cyst, which may have a similar clinical presentation. In acute abdominal HAE, thickened and edematous bowel wall can also be readily visualized as slightly echolucent and should measure 5mm or greater, from the outer wall to the lumen of the bowel.[6]

In summary, POC ultrasound allows for a rapid assessment of patients with HAE who present with abdominal complaints and can also be useful in excluding other diagnoses such as biliary disease, ectopic pregnancy, and appendicitis. Risk stratifying these patients early in their clinical course allows for early treatment of what can be a life-threatening presentation. Because of the recurrent nature of abdominal HAE, the use of POC abdominal ultrasound may be able to reduce cumulative ionizing radiation exposure from repeated CT. If further study supports the observations in the above cases, POC abdominal ultrasound may emerge as an ideal initial imaging modality for the evaluation of patient's with HAE and abdominal pain.

Address for Correspondence: Christine Riguzzi, MD, Department of Emergency Medicine, Highland Hospital-Alameda Health System, 1411 East 31st Street, Oakland, CA 94602-1018. Email: christineriguzzi@gmail.com.

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Ultrasound-Guided Diagnosis and Aspiration of Subdeltoid Abscess from Heroin Injection

Amanda Clauson, MD
Tom Mailhot, MD
Mikaela Lynn Chilstrom, MD

Los Angeles County + University of Southern California Medical Center, Department of Emergency Medicine, Los Angeles, California

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A 49-year-old man presented to the emergency department (ED) with shoulder pain after intramuscular injection of heroin into his right deltoid muscle. Point-of-care (POC) ultrasound identified a subdeltoid abscess, and ultrasound-guided aspiration of the fluid collection was performed. The patient was admitted and improved on antibiotics and made a complete recovery. POC ultrasound and ultrasound-guided aspiration can assist in the diagnosis and treatment of deep musculoskeletal abscesses. [West J Emerg Med. 2014;15(7):819–821.]

INTRODUCTION

Point-of-care (POC) ultrasound is commonly used in the emergency department (ED) to evaluate for subcutaneous abscesses. Studies have shown that ultrasound is superior to clinical exam in detecting drainable superficial fluid collections in soft tissue infections.[1-5] In one study, ultrasound was found to change the management in nearly half of ED patients with cellulitis and a low clinical suspicion for abscess.[1] Superficial abscesses are located in the skin or subcutaneous tissue, while deep musculoskeletal abscesses are located deep to, or within the muscle. Although the role of ultrasound in superficial soft tissue infections is well established, the evidence supporting the use of POC ultrasound to detect deep musculoskeletal abscesses is limited to case reports.[6,7]

CASE REPORT

A 49-year-old right-handed man with a history of injection drug use presented to the emergency department (ED) with two days of right shoulder pain. Approximately four days prior to his visit, he injected heroin into his right deltoid muscle, inserting the needle completely to its hub. He reported mild pain at rest, but severe pain with minimal movement of his right shoulder; he denied weakness or numbness of the right upper extremity. He had no previous shoulder injuries or surgeries, no allergies, and was not taking any medications. On review of systems, he denied fever, but reported subjective chills.

The patient's vital signs were: oral temperature 99.4°F, pulse 76 beats/minute, blood pressure 128/78mm Hg, respiratory rate 20 breaths/minute, and oxygen saturation of 100% on room air. Observation of the right upper extremity revealed subtle swelling over the anterior aspect of his right shoulder (Figure). His anterior and lateral deltoid were tender to palpation, but there was no warmth, induration, erythema, or fluctuance. Both active and passive range of motion of his right shoulder were limited by pain, most significantly with abduction. A neurovascular examination of his arm was normal and his arm compartments were soft. The remainder of his physical examination was normal.

Anterior-posterior, oblique, and lateral radiographs of the right shoulder revealed no dislocation, fracture, gas or other evidence of abscess. Laboratory studies were notable for a

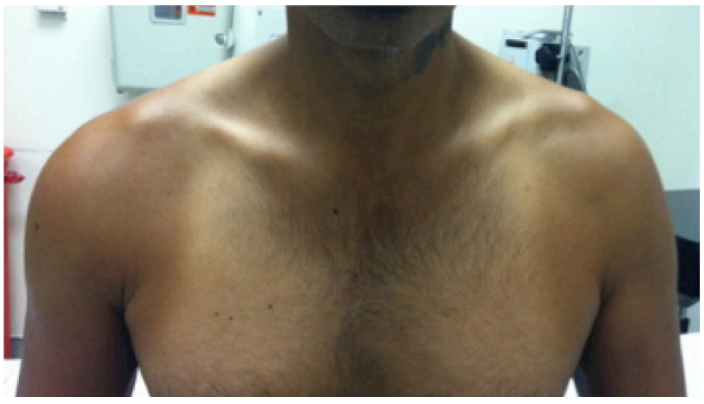

Figure. Subtle swelling over the anterior aspect of the patient's right shoulder.

white blood cell count of $12.6x10^3/\mu L$ and a C-reactive protein level of 108mg/L.

POC ultrasound of the patient's right shoulder revealed a 2x3cm fluid collection deep to the right deltoid with surrounding inflammatory changes, but no evidence of a joint effusion or fluid- filled bursa. Using real-time ultrasound guidance, the provider inserted an 18-gauge needle into the fluid collection and aspirated approximately 3mL of purulent material (Video).

Given the evidence of an abscess deep to the deltoid muscle, orthopedic surgery was consulted. In the ED, the orthopedic surgeon made a small incision and drainage at the site of the previous aspiration (without ultrasound guidance), which did not produce further purulent material. The wound was irrigated with normal saline and betadine. The patient was admitted to the hospital and received intravenous vancomycin, with a plan for a more extensive incision and surgical washout in the operating room.

The following day, as the patient was being prepared for surgery, he left against medical advice. He was prescribed oral trimethoprim/sulfamethoxazole and was told to return to the ED for a wound check in 1-2 days.

The following day, the patient returned to the ED and stated he had been taking the oral trimethoprim/sulfamethoxazole as directed. He denied fevers, chills, or purulent drainage from the wound, but noted improvement in his right shoulder pain with increased range of motion of the right shoulder. The wound culture sent from the initial aspiration grew oxacillin-sensitive Staphylococcus aureus. An orthopedic surgeon was again consulted, and the radiology department performed a shoulder ultrasound, revealing inflammatory changes but no discrete fluid collection.

Given the patient's clinical improvement and the absence of fluid on the ultrasound, orthopedic surgery felt that the initial ultrasound-guided aspiration of the deep-space abscess had likely decompressed the abscess sufficiently to allow non-operative treatment. The patient was discharged with instructions to continue the complete course of oral trimethoprim/sulfamethoxazole. He was later seen in primary care clinic and was reported to have made a full recovery.

DISCUSSION

There is a growing body of evidence to support the use of POC ultrasound to aid in the diagnosis of superficial soft-tissue infections in the ED.[1-5] The role of POC ultrasound to evaluate for abscesses deep to or within the muscle has only been described in case reports, and has not been studied more formally.[6-8] Typically deep musculoskeletal abscesses are more occult in presentation, include a much broader differential diagnosis (including septic joint and pyomyositis), and often require more extensive imaging with computed tomography (CT) or magnetic resonance imaging. POC ultrasound may be helpful in identifying the presence of deep musculoskeletal abscesses, as illustrated in this case of a subdeltoid abscess.

Once diagnosed, deep musculoskeletal abscesses are treated more aggressively with an incision and drainage and debridement of the infection in the operating room or percutaneous CT-guided drainage with catheter placement.[9-11] Our patient was managed initially with ultrasound-guided aspiration and antibiotics, and ultimately made a complete recovery. Although there is evidence to support ultrasound-guided needle aspiration of subcutaneous breast and trunk abscesses in the radiology literature, a randomized study in the ED showed significantly worse outcomes with ultrasound-guided aspiration compared to incision and drainage of superficial abscesses.[12-14] Ultrasound-guided aspiration is less invasive than incision and drainage and requires only minimal local anesthetic, but it may not eliminate the full extent of the infection. Further studies are needed to evaluate conservative management of deep musculoskeletal abscesses with ultrasound-guided aspiration and antibiotics, thus potentially reducing the need for general anesthesia and more invasive procedures.

Address for Correspondence: Mikaela Lynn Chilstrom, MD, Los Angeles County + University of Southern California Medical Center, Department of Emergency Medicine, Los Angeles, California. Email: mchilstrom@gmail.com.

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Video. Sagittal ultrasound of the right shoulder performed with a linear probe demonstrates a heterogenous fluid collection deep to the deltoid. Ultrasound-guided aspiration revealed pus.

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Ultrasound Evaluation of an Inguinal Mass

Jeffrey L. Wiswell, MD* *University of California Davis, Sacramento, California
Benjamin J. Sandefur, MD† †Mayo Clinic, Rochester, Minnesota

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A 33 year-old female presented to the emergency department (ED) with of two weeks of diffuse abdominal pain, right flank pain, and a slowly enlarging right inguinal mass. She had no associated fever, chills, nausea, vomiting, or diarrhea. She was evaluated by her primary care physician, and an inguinal ultrasound was obtained prior to referral to the ED. On arrival in the ED, her vital signs were unremarkable, and she was afebrile. On exam, there was no abdominal tenderness, and a 2cm x 2cm non-reducible, mildly tender right inguinal mass was noted. A bedside ultrasound (Figures 1 and 2) was performed in the ED. [West J Emerg Med. 2014;15(7):822–823.]

DIAGNOSIS

Amyand's Hernia: Named for Claudius Amyand, sergeant-surgeon to King George II of England, Amyand's Hernia is an appendix within an inguinal hernia.[1] In the index case, he is credited with performing the first successful appendectomy in 1735, on an eleven year-old boy with this condition.[2] Although relatively rare, (0.13% of cases of acute appendicitis occur in external hernias),[3] it is important to consider this diagnosis in the setting of abdominal pain with an associated inguinal mass. In addition, Amyand's Hernia may mimic an acute scrotum in cases of appendiceal rupture after a period of incarceration.[2] In this particular case, bedside ultrasound demonstrated a non-compressible 7.4 mm tubular structure within a hernia sack (Figures 1 and 2), representing the appendix. The patient was taken to the operating room for open appendectomy and femoral hernia repair. She was discharged without any complications the following day.

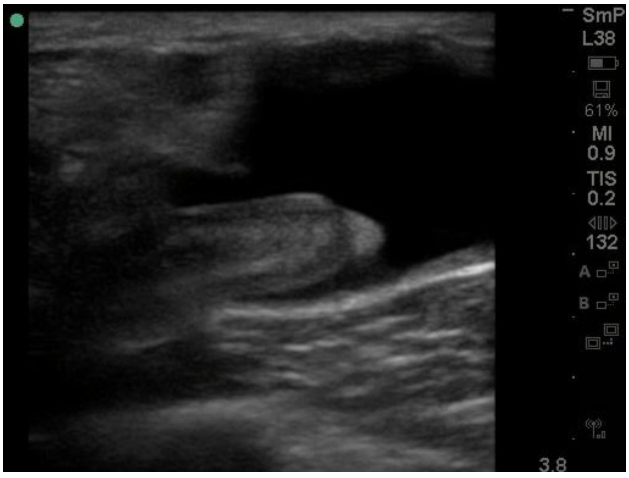

Figure 1. Long axis view ultrasound of an inguinal mass.

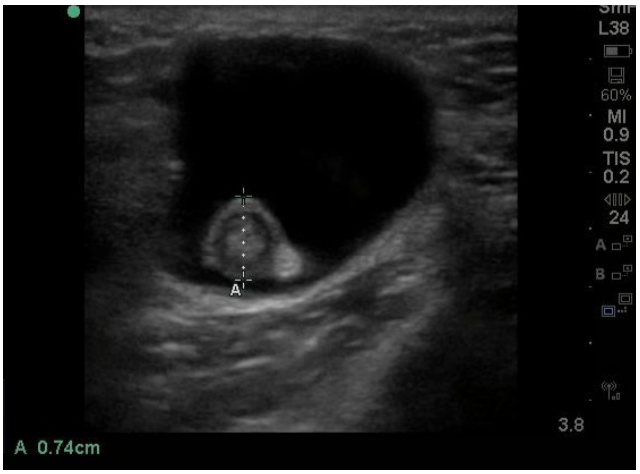

Figure 2. Short axis view ultrasound of an inguinal mass.

Address for Correspondence: Jeffrey L. Wiswell, MD, Department of Emergency Medicne, 200 First Street SW, Rochester, MN 55905. Email: wiswell.jeffrey@mayo.edu.

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Ultrasound-Guided Small Vessel Cannulation: Long-Axis Approach Is Equivalent to Short-Axis in Novice Sonographers Experienced with Landmark-Based Cannulation

Catherine S. Erickson, MD*
Michael M. Liao, MD, MSc[†‡]
Jason S. Haukoos, MD, MSc[†‡§]
Erica Douglass, MD[†‡]
Margaret DiGeronimo, MD[†‡]
Eric Christensen, RN[†]
Emily Hopkins, MSPH[†]
Brooke Bender, MPH[†]
John L. Kendall, MD[†‡]

* Oregon Health and Science University, Department of Emergency Medicine, Portland, Oregon
† Denver Health Medical Center, Department of Emergency Medicine, Denver, Colorado
‡ University of Colorado School of Medicine, Department of Emergency Medicine, Aurora, Colorado
§ Colorado School of Public Health, Department of Epidemiology, Aurora, Colorado

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Introduction: Our primary objective was to describe the time to vessel penetration and difficulty of long-axis and short-axis approaches for ultrasound-guided small vessel penetration in novice sonographers experienced with landmark-based small vessel penetration.

Methods: This was a prospective, observational study of experienced certified emergency nurses attempting ultrasound-guided small vessel cannulation on a vascular access phantom. We conducted a standardized training, practice, and experiment session for each participant. Five long-axis and five short-axis approaches were attempted in alternating sequence. The primary outcome was time to vessel penetration. Secondary outcomes were number of skin penetrations and number of catheter redirections. We compared long-axis and short-axis approaches using multivariable regression adjusting for repeated measures, vessel depth, and vessel caliber.

Results: Each of 10 novice sonographers made 10 attempts for a total of 100 attempts. Median time to vessel penetration in the long-axis and short-axis was 11 (95% confidence interval [CI] 7-12) and 10 (95% CI 6-13) seconds, respectively. Skin penetrations and catheter redirections were equivalent and near optimal between approaches. The median caliber of cannulated vessels in the long-axis and short-axis was 4.6 (95% CI 4.1-5.5) and 5.6 (95% CI 5.1-6.2) millimeters, respectively. Both axes had equal success rates of 100% for all 50 attempts. In multivariable regression analysis, long-axis attempts were 32% (95% CI 11%-48%; p=0.009) faster than short-axis attempts.

Conclusion: Novice sonographers, highly proficient with peripheral IV cannulation, can perform after instruction ultrasound-guided small vessel penetration successfully with similar time to vessel penetration in either the long-axis or short-axis approach on phantom models .
[West J Emerg Med. 2014;15(7):824–830.]

INTRODUCTION

Many emergency department (ED) patients are characterized as having difficult peripheral intravenous (IV) access due to underlying medical conditions, such as obesity, dehydration, and a history of intravenous drug abuse. Historically, failed attempts at peripheral IV access lead to

physician-attempted central venous access. However, placing central venous catheters is costly and puts patients at increased risk for complications.[1]

An alternative for those with difficult IV access is the placement of IV peripheral catheters under ultrasound guidance. Prior studies have shown that physicians, nurses, and technologists can use ultrasound guidance to obtain successful peripheral venous access when landmark approaches have failed.[2-4] However, suboptimal technique leads to unnecessary early complications and morbidity; including posterior wall penetration, arterial punctures, hematoma formation, excessive needle punctures and redirections within the skin, and delays in obtaining access.[5] Long-axis and short-axis approaches remain the primary methods for ultrasound guidance. Each has distinct advantages and disadvantages that may either increase or decrease complications.[6]

To our knowledge, there are only a few prior studies comparing long-axis and short-axis approaches. These studies found short-axis to be faster, but each reported different times to vessel penetration and complications.[7-9] Ultrasound-guided vessel cannulation requires combining skills in cannulation and ultrasound usage. Prior studies were potentially confounded by the inclusion of sonographers with varying proficiency with standard landmark IV placement. Studying ultrasound-guided approaches may be improved by removing inexperience in placing peripheral lines as a confounding factor.

The primary aim of this study was to describe the time to vessel penetration and difficulty of long-axis and short-axis approaches for ultrasound-guided small vessel penetration in novice sonographers experienced with landmark-based small vessel cannulation.

METHOD

This was a prospective observational study of novice sonographers performing vessel penetration on block phantom models designed to simulate peripheral vessels to assess the performance of long-axis and short-axis approaches. The novice sonographers were proficient in placing landmark-guided peripheral intravenous lines. The Colorado Multiple Institutional Review Board approved this study.

The inclusion criteria were full-time nurses at our institution who were both registered nurses and certified emergency nurses who had no prior hands-on ultrasound experience. Denver Health Medical Center is a Level I trauma center with an annual census of approximately 55,000 annual ED patient visits. All certified emergency nurses at our institution have extensive experience with the technical skill of obtaining landmark-based IV access.

The primary outcome was time to vessel penetration. Secondary outcomes were number of skin penetrations and number of catheter redirections. Time to vessel penetration was defined as the time from placing the ultrasound probe on the phantom surface to successful penetration. We defined successful vessel penetration as the point at which artificial blood became visibly present in the catheter chamber and the needle tip was confirmed by real-time ultrasound as being within the vessel lumen. Both artificial blood and needle tip were required before time was stopped. A skin penetration was defined as the number of times the catheter penetrated the phantom surface and was completely withdrawn prior to vessel penetration. We defined a catheter redirection as any insertion of the catheter after the first insertion that was visibly different from the preceding axis of insertion without fully withdrawing the catheter.

All data were collected over two consecutive days. Each subject received one hour of didactics followed by hands-on instruction by the principal study investigator. The didactic session included a description of ultrasound physics, transducer orientation, vessel identification, and techniques for performing ultrasound guidance of vessel penetration. Each subject practiced vessel identification without attempting cannulation on a volunteer human model to demonstrate proficiency with both approaches. Following didactics and the hands-on training, each subject was given two practice attempts on a single phantom model.

Ultrasound guidance was performed in real-time using a General Electric (Fairfield, CT) LOGIQ e with a 4-12 MHz linear transducer. All subjects used a single operator technique. Five different phantom block models (Blue Phantom, Kirkland, WA) were used for the study. Each block was of similar size, but contained two or more vessels with slight differences in vessel position, depth, and caliber.

Immediately following the two practice attempts, subjects performed 10 vessel penetrations using ultrasound guidance, alternating between using long-axis and short-axis approaches. Subjects, blinded to the study question, could initially decide which axis approach to begin with, but subsequent attempts followed an alternating sequence. Only one short-axis and one long-axis approach were attempted on each block phantom before moving on to the next block phantom. Subjects were not allowed to access the same vessel twice. Additionally, once a vessel was identified, and the first skin puncture attempted, subjects could not change the axis approach or the target vessel.

Two first-year emergency medicine residents blinded to the study purpose and trained by the principal investigator performed data collection. Residents were trained by the principal investigator in data collection on the same model until no errors were made in data collection. They recorded time to vessel penetration, number of skin penetrations, and number of catheter redirections. They also confirmed that when the flash was visualized, ultrasound images confirmed that the needle tip was in the vessel lumen. After successful vessel penetration, the observer measured the target vessel's depth and caliber using the ultrasound machine. The reference point under which measurements were obtained was the point

of catheter entry into the target vessel. We defined vessel depth as the distance from the phantom's surface to the anterior wall of the target vessel. Vessel caliber was defined as the distance from the anterior to posterior wall of the target vessel.

Descriptive statistics included median and 95% confidence intervals (CI). We estimated CI for medians using percentile bootstrap with 2,500 repetitions.[10] The difference between long-axis and short-axis was calculated as long-axis minus short-axis for each outcome. Given nonparametric paired data, we used the Wilcoxon signed rank sum test with associated binomial exact 95% CI for bivariate comparison. We stratified data into attempts 1 through 5 prior to analysis, each attempt representing one single pair of long-axis and short-axis consecutive attempts; attempt 1 corresponding to the first long-axis and short-axis attempts, and attempt 5 corresponding to the last long-axis and short-axis attempts.

We also performed multivariable analyses to evaluate the relationship between long-axis and short-axis approaches and the outcomes, while adjusting for repeated measures and potential confounders. The comparison of long-axis versus short-axis for the primary outcome of time to vessel penetration was performed using a multivariable linear mixed model accounting for two within subject repeated measures, namely axis and attempts.[11] We adjusted the model for vessel depth and vessel caliber to control for potential confounding. Additionally, the outcome of time to vessel penetration was log transformed to address non-normal residuals. Interaction terms were not evaluated in the model. For the secondary outcomes of skin penetration and catheter redirection, we performed a multivariable generalized linear model with a Poisson distribution accounting for the two within subject repeated measures of axis and attempts. The model was again adjusted for vessel depth and vessel caliber, and no interaction terms were evaluated in this secondary model. Significance was defined as $p < 0.05$ for all analyses. No adjustment for multiple comparisons was performed, nor did we performa priori power calculation. All statistical analyses were performed using SAS Version 9.2 (SAS Institute, Inc., Cary, NC) or Stata Version 10.1 (Stata Corporation, College Station, TX).

RESULTS

We studied 10 subjects, each completing 10 attempts at vessel penetration on a phantom mode, for a total of 100 attempts (50 in short-axis and 50 in long-axis). There were no missing data. Subjects had a median of seven (IQR 5 to 10) years of experience as registered nurses and a median of two (IQR 1 to 4) years of experience as certified emergency nurses.

Median time to vessel penetration in the long-axis was 11 seconds (95% CI 7-12) and for the short-axis was 10 seconds (95% CI 6-13). For long-axis, skin penetrations and catheter redirections were 1 (95% CI 1-1) and 0 (95% CI 0-0), respectively; and for short-axis, 1 (95% CI 1-1) and 0 (95% CI 0-1), respectively. The median caliber of cannulated vessels in the long-axis was 4.6 (95% CI 4.1-5.5) millimeters and in the short-axis was 5.6 (95% CI 5.1-6.2) millimeters. Median depth of cannulated vessel in the long-axis and short-axis were 8.9 (95% CI 7.4-11.8) and 7.9 (95% CI 7.4-10.2) millimeters, respectively.

The median times to vessel penetration in the long-axis and short-axis are reported in the table for each pair of attempts (i.e., long-axis and short-axis done consecutively). Bivariate analysis comparing long-axis versus short-axis showed that no significant differences existed for time to vessel penetration, skin penetration, or catheter redirection. Differences were present in vessel depth and vessel caliber between long-axis and short-axis with the long-axis approach allowing novice sonographers to penetrate a slightly smaller and deeper vessel, by approximately one millimeter. Both approaches had near-optimal median counts for skin penetrations and catheter redirections, namely one skin penetration and zero catheter redirection prior to successful vessel penetration.

Both long-axis and short-axis had equal success rates of 100% for all 50 attempts in each orientation. For the outcome time to vessel penetration, the final mixed linear model, adjusting for repeated measures, vessel depth, and vessel caliber, showed that the geometric mean of the long-axis attempts was 32% (95% CI 11% to 48%; $p=0.009$) faster than short-axis attempts. For skin penetration, the multivariable generalized linear model using Poisson distribution, adjusting for repeated measures, vessel depth, and vessel caliber, showed that the prevalence of skin penetrations of the long-axis attempts was 20% (95% CI 93% to -843%; $p=0.46$) lower than short-axis attempts. For catheter redirections, the multivariable generalized linear model using Poisson distribution, adjusting for repeated measures, vessel depth, and vessel caliber, showed that the prevalence of catheter redirections of long-axis attempts was 73% (95% CI 58% to 83%; $p<0.0001$) lower than short-axis attempts. A graphical representation of the data for all three outcomes versus vessel depth or vessel caliber, stratified by axis approach is presented in the figure. These graphs show that long-axis attempts tend to cluster more towards the optimal end of the scale for all three outcomes compared to short-axis attempts.

DISCUSSION

Obtaining rapid peripheral IV access is essential for diagnosis and treatment in many ED patients. For patients with difficult IV access, peripheral access using ultrasound guidance has been shown to be an effective alternative to central venous access.[2,12,13] Long-axis and short-axis are the two primary approaches to ultrasound guidance of vessel cannulation; however, the optimal approach remains unclear. Our results show that in novice sonographers proficient in landmark placed peripheral catheters, long-axis was 32% faster than short-axis in time to vessel cannulation. Although

Table. Summary of data for long-axis and short-axis ultrasound-guided approaches stratified by paired long-axis and short-axis attempts.

	Long-axis		Short-axis		Long-axis vs. short-axis		
	Median	95% CI	Median	95% CI	Median difference*	95% CI	p-value
Attempt 1							
Time to vessel cannulation (seconds)	12	9-20	16	8-22	-5	-15 to 10	0.26
Number of skin penetrations	1	1-1	1	1-1	0	0 to 0	1.00
Number of catheter redirections	0	0-2	1	0-4	-1	-2 to 0	0.11
Vessel depth (mm)	9.0	7.1-15.2	10.3	6.9-11.9	0.1	-8.4 to 7.0	0.64
Vessel caliber (mm)	4.9	3.5-6.2	5.8	4.5-7.0	-1.1	-2.3 to 0.2	0.05
Attempt 2							
Time to vessel cannulation (seconds)	14	9-24	6	4-11	5	-5 to 24	0.13
Number of skin penetrations	1	1-1	1	1-1	0	0 to 0	1.00
Number of catheter redirections	0	0-2	0	0-1	0	-1 to 3	0.63
Vessel depth (mm)	11.3	7.4-17.8	7.2	5.2-9.7	5.6	-0.4 to 10.1	0.01
Vessel caliber (mm)	5.9	4.0-6.8	5.9	5.3-6.8	-0.4	-2.1 to 2.1	0.57
Attempt 3							
Time to vessel cannulation (seconds)	10	6-19	16	8-102	-1	-166 to 10	0.39
Number of skin penetrations	1	1-1	1	1-2	0	-2 to 0	0.50
Number of catheter redirections	0	0-2	1	0-9	0	-13 to 1	0.31
Vessel depth (mm)	8.6	4.8-14.1	9.9	5.5-13.3	0.5	-8.1 to 8.3	0.57
Vessel caliber (mm)	4.5	3.8-6.1	5.0	3.7-6.5	-0.1	-2.8 to 1.7	0.58
Attempt 4							
Time to vessel cannulation (seconds)	5	3-19	6	4-10	-1	-4 to 19	0.77
Number of skin penetrations	1	1-1	1	1-1	0	0 to 0	1.00
Number of catheter redirections	0	0-1	0	0-1	0	-1 to 0	0.56
Vessel depth (mm)	4.9	3.8-12.4	7.6	4.8-10.1	-0.4	-7.4 to 9.5	0.92
Vessel caliber (mm)	4.4	3.6-6.0	6.2	5.2-6.6	-1.6	-2.5 to 0.3	0.01
Attempt 5							
Time to vessel cannulation (seconds)	8	5-17	10	6-40	0	-47 to 6	0.51
Number of skin penetrations	1	1-1	1	1-1	0	0 to 0	1.00
Number of catheter redirections	0	0-2	0	0-4	0	-5 to 0	0.25
Vessel depth (mm)	9.9	4.4-16.6	8.1	7.4-14.8	1.9	-7.7 to 8.8	0.77
Vessel caliber (mm)	4.7	3.8-5.7	4.7	4.2-5.9	-0.5	-1.5 to 2.0	0.70

*Difference was defined as long-axis minus short-axis.

statistically significant, a 32% improvement in speed translates to only three seconds improvement if 10 seconds is used as the baseline. This suggests no clinically significant difference in our subject population. Number of skin penetrations and catheter redirections were optimal for both approaches.

Blaivas et al. compared directly long-axis versus short-axis in novice sonographers using a phantom model.[8] This study found that the short-axis approach was almost three minutes faster than the long-axis approach (mean 2.4 minutes short-axis versus 5.0 minutes long-axis), but they noted that average skin penetrations (mean 4 short-axis versus 6 long-axis) and catheter redirections (mean 14 short-axis versus 18 long-axis) were similar. Our results differ in that our time to vessel penetration was within seconds, not minutes, despite similar definitions of the outcome time to vessel penetration; and that the approach did not significantly influence time to vessel penetration. Additionally, our median skin penetrations and catheter redirections were nearly optimal for both long-axis and short-axis approaches. Although model and ultrasound machine differences may have played a part in these differences, one condition of our study was that all novice sonographers were expert in the technique of landmark-based peripheral IV placement. A potential explanation is that our optimal outcomes were a result of

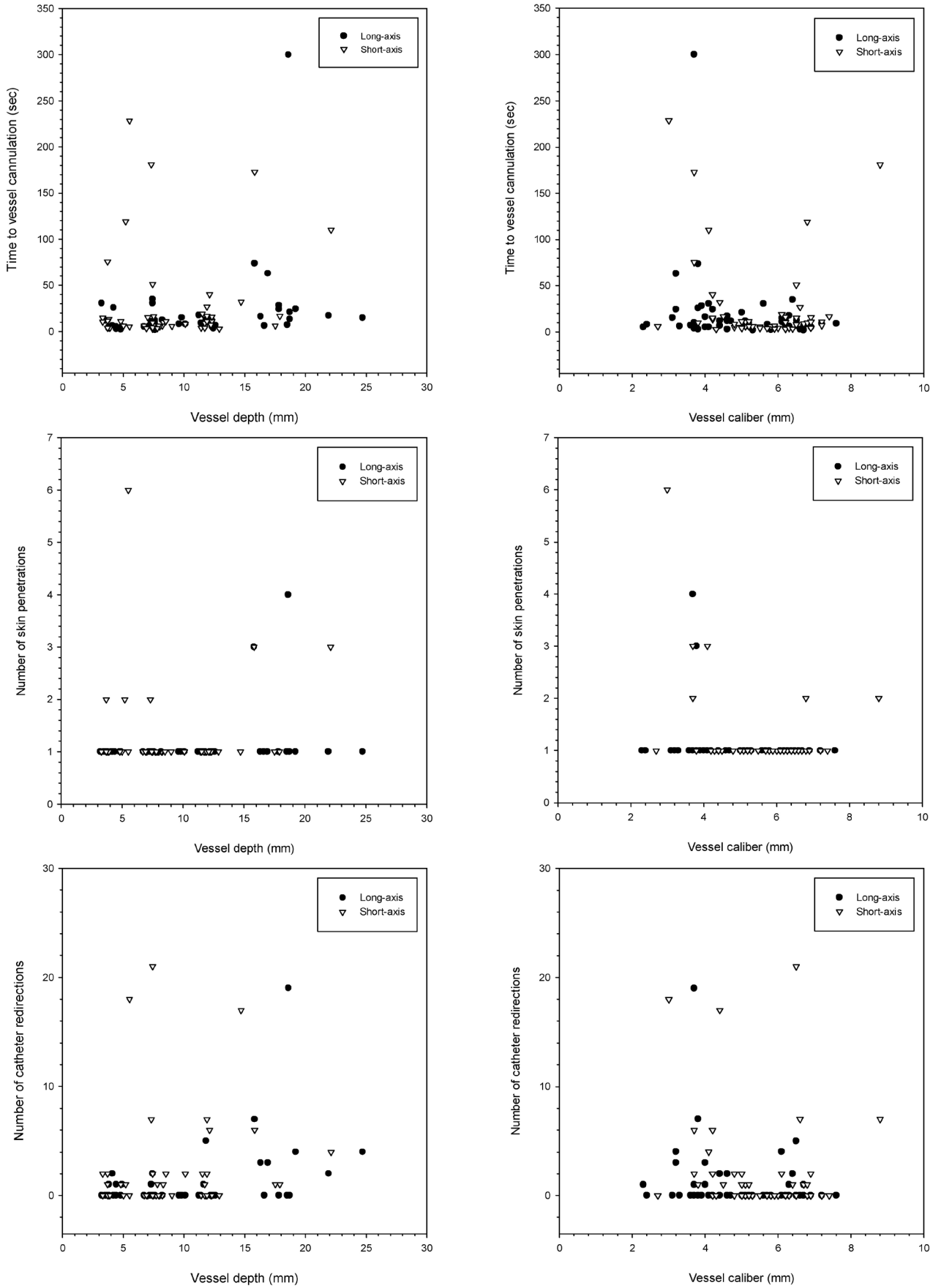

Figure. Individual data for all three outcomes versus vessel depth or vessel caliber, stratified by axis approach.

studying subjects proficient in landmark-based peripheral IV placement. Blaivas et al. used emergency medicine residents, and their technical proficiency with IV placement was unclear.

Mahler et al. published a randomized trial comparing short-axis and long-axis approaches on live patients with four practitioners (half of whom were ED nurses) experienced with ultrasound-guided IV access.[7] Although also not statistically significant, they found that short-axis was faster than long-axis (median 34 seconds short-axis versus 91 seconds long-axis) for insertion time, defined as time from first needle stick to blood return in catheter. Numbers of skin penetrations were similar (mean 1.5 short-axis versus 1.4 long-axis). Perhaps again, one explanation for their results showing faster access times and fewer complications in comparison with Blaivas et al. is the inclusion of ED nurses who were likely proficient in landmark-based peripheral IV placement.[8]

Stone et al. studied long-axis versus short-axis in 22 medical students and 17 emergency medicine interns using similar block phantoms.[9] Their outcomes were time to visible artificial blood in syringe and, separately, needle-tip visibility based on still images taken at the time of initial artificial blood flash. Time to flash was again faster for short-axis (12.4 seconds) versus long-axis (14.8 seconds), though not statistically significant. Different from our study, confirmation of needle-tip visibility in vessel lumen was not necessary for the time outcome. In fact, based on still images needle tip was only visible in 62% of long-axis attempts and 23% of short-axis attempts. Our results, which showed 100% success in visualizing needle tip in vessel lumen, are potentially related to our use of real-time ultrasound and direct observation as opposed to single still images.

We caution that while our study may provide evidence that practitioners proficient in landmark-based peripheral IV placement can perform ultrasound-guided small vessel penetration in both long axis and short axis with similar rates of vessel penetration, it does not provide evidence that proficiency with landmark-based peripheral IV placement is critical for performing ultrasound guided small vessel cannulation. Our study did not directly address this hypothesis; however, we believe this is an important hypothesis that may benefit from future investigation. We also believe the additional studies with a more robust subject population and with live models or patients, potentially classified as "difficult access" patients, would be useful to expand knowledge in the area of ultrasound guided peripheral access.

LIMITATIONS

One limitation is that our study was performed on a simulated model, not live humans. Although our model is commonly used for teaching purposes, it may not fully simulate the comparable human experience. Ultrasound is most frequently used when patients have had numerous attempts to obtain access (i.e., the difficult access patient). The block model may have important differences compared to this specific population. Our sample size of subjects was small, thus may not be representative of novice sonographers proficient with the technical aspect of IV placement. Our observers who performed data collection were ultrasound interested and had completed the residency ultrasound procedure requirement; however, it is possible with highly specialized ultrasound attending physicians that data collection would be more accurate.

There may be additional, important reasons to prefer short-axis or long-axis in the placement of peripheral IV catheters not considered in our study, including but not limited to sonographer preference, patient factors, ability to visualize needle tip.[6,9] Considering additional factors on a per patient basis is important when deciding on the best approach.

It is possible that our definition of successful vessel penetration (an initial "flash" of artificial blood in the catheter chamber and visualization of the needle tip on ultrasound images) may not always represent appropriate placement in the vessel lumen as threading the catheter will increase time to securing a peripheral IV. Specifically, in the short-axis view, sometimes the needle shaft is mistaken for the needle tip within the vessel, and the needle tip has already traveled outside the vessel. It is unclear how frequently this may have occurred. We chose time to vessel penetration because it can be more difficult to thread a small catheter on a phantom model than it is on live subjects; and this is also a potential limitation. This would bias our results by overinflating our success rate and shortening our time to vessel penetration.

CONCLUSION

Novice sonographers, highly proficient with peripheral IV cannulation, can perform after instruction ultrasound-guided small vessel penetration successfully with similar time to vessel penetration in either long- or short-axis approach on phantom models. Optimal technique with ultrasound-guided vessel cannulation may first require proficiency with the technical skill of placing peripheral IV catheters.

Address for Correspondence: Catherine Erickson, Oregon Health and Science University, Department of Emergency Medicine, 3181 SW Sam Jackson Park Road Portland, OR 97239. Email: erickcat@ohsu.edu.

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Ultrasound Distinguishes Ascites from a Large Ovarian Fluid-Filled Cyst

Marissa Camilon, MD
Mikaela Chilstrom, MD

Keck School of Medicine at the University of Southern California, Department of Emergency Medicine, Los Angeles, California

Supervising Section Editor: Mark I. Langdorf MD, MHPE
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A 51-year-old woman with Hepatitis C was referred to the emergency department (ED) for "massive ascites." She reported increasing abdominal girth for six months with intermittent abdominal pain. An outpatient ultrasound performed two weeks prior to ED presentation was interpreted by a radiologist as "massive ascites, no masses within the abdomen" on the paper report the patient brought with her. In the ED, the patient was afebrile with normal vital signs. Her abdomen was distended with mild right upper quadrant tenderness.

The emergency physician performed an abdominal ultrasound expecting to find free intraperitoneal fluid; instead, a large, fluid-filled cystic structure was identified. Further evaluation of Morison's pouch and the left upper quadrant also showed no intraperitoneal fluid outside of the cystic structure (Video). Computed tomography of the abdomen and pelvis demonstrated a large right adnexal mass (33 x 21 x 31cm) without evidence of ascites. The gynecology service scheduled the patient for outpatient surgery, which identified the cystic structure as benign mucinous cystadenoma.

Several conditions can cause abdominal distention and mimic ascites, including hepatosplenomegaly, bowel obstruction, large renal cysts, and pelvic masses.[1-4] The physical examination is of limited value, as it is neither sensitive nor specific for ascites.[1,5,6] Therefore, bedside ultrasound can be instrumental in defining the presence and location of fluid in patients with abdominal distention. However, large cystic masses can be difficult to sonographically distinguish from ascites, as illustrated by the results of the initial outpatient ultrasound in this case. When assessing intraperitoneal fluid, it is essential to confirm that the fluid tracks along fascial planes into dependent areas (e.g., Morison's pouch), as fluid encapsulated in a cyst will not behave in this manner. This case highlights the utility of emergency physician performed ultrasound in the evaluation of abdominal distention and the challenges of sonographically distinguishing free intraperitoneal fluid from fluid within a cyst.

Video. Sagittal and transverse ultrasound images of the pelvis performed with a phased array probe demonstrate a large anechoic fluid collection contained within a cyst. Coronal ultrasound images of the right and left upper quadrants revealed no free fluid in Morison's pouch or around the spleen. Coronal and sagittal CT images of the abdomen and pelvis show a large right adnexal mass (33 x 21 x 31cm) with homogenous attenuation greater than water, but less than muscle, with no ascites.

Address for Correspondence: Mikaela Chilstrom, MD, LAC+USC Medical Center, Department of Emergency Medicine, 1200 N. State Street, Room 1011, Los Angeles, CA 90033. Email: chilstro@usc.edu.

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False Positive Appendicitis on Bedside Ultrasound

Caleb P. Canders, MD*
Angela J. Brown, MD*
Alan T. Chiem, MD, MPH†

* University of California at Los Angeles Medical Center, Department of Emergency Medicine, Los Angeles, California
† Olive View - University of California at Los Angeles Medical Center, Department of Emergency Medicine, Sylmar, California

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CASE

A 27-year-old woman presented with sharp, right lower quadrant abdominal pain for six hours. The pain was colicky, non-migratory, and non-radiating. She reported fevers, anorexia and nausea, and denied dysuria or hematuria. She had no significant past medial history or prior surgeries. Vital signs were notable for a pulse of 110 and an oral temperature of 39.3°C. She had tenderness in her right costovertebral angle and McBurney's point. She had no rebound or guarding. White count was 16.6 x 10^9/L and point-of-care urine pregnancy test was negative. Bedside ultrasound with a 10-5Mhz linear transducer was performed at the point of maximal tenderness (Video).

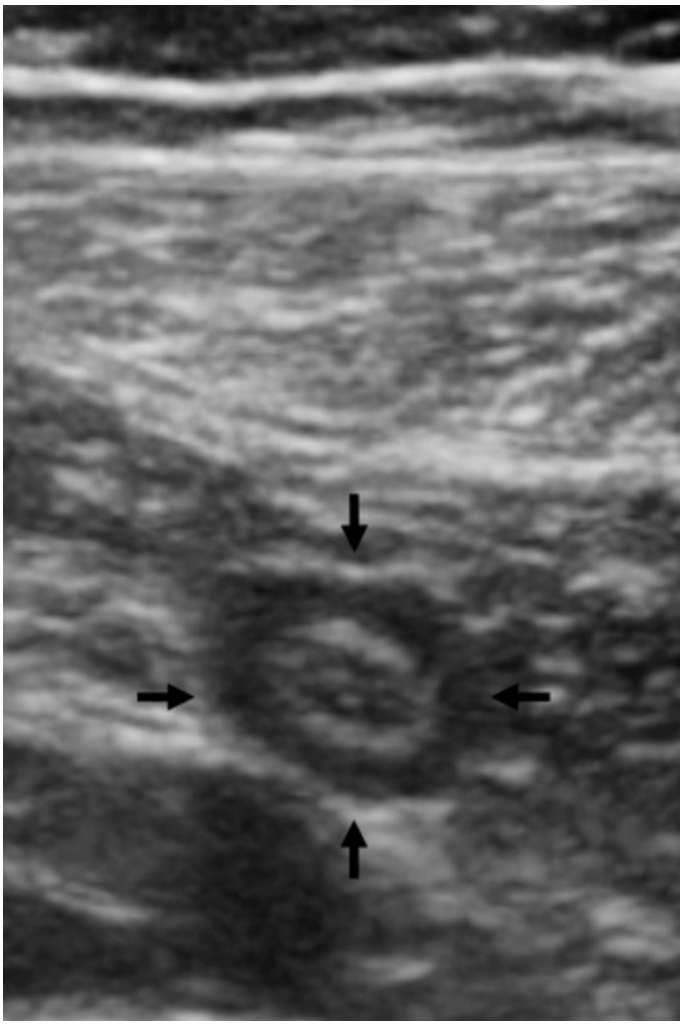

Figure. Cross-section of a tubular structure in the right lower quadrant.

DIAGNOSIS

The elongated and non-compressible tubular structure on ultrasound was initially thought to be the appendix, however an abdominal computed tomography showed right perinephric stranding and ureteritis without evidence of appendicitis. The structure visualized on ultrasound was in fact a dilated and inflamed ureter. Urine analysis revealed 124 white blood cells per high power field. The patient was diagnosed with pyelonephritis, and improved with fluid resuscitation and antibiotics.

Acute appendicitis, the most common abdominal surgical emergency, is a diagnostic challenge, especially in females. Given the perforation rate of 9-35%, an expedited diagnosis is useful to the emergency physician.[1-3] Graded compression ultrasound is noninvasive, radiation-free and can be performed at the bedside. Sonographic findings of appendicitis include a non-compressible tubular structure greater than 6mm in the right lower quadrant, increased blood flow on color-flow Doppler, peri-appendiceal fluid, visible appendicolith, prominent pericecal fat and interruption of the submucosa.[4] Ultrasound can also be used to make alternative diagnoses, such as ovarian cysts, nephrolithiasis, or pyelonephritis.

However, emergency physician-performed ultrasound for appendicitis is 68-90% specific, with a 75-84% positive-predictive value. When performed by specially trained emergency physicians and radiologists, specificity increases to 78-94%.[5-10] Among false-positive appendiceal ultrasound examinations, the most common finding is a non-compressible tubular structure without any other sonographic findings

of appendicitis.[11] As our case demonstrates, this finding alone may lead to an incorrect diagnosis, and an inflamed and dilated ureter may mimic appendicitis on ultrasound. Additional research to determine the specificity of other sonographic findings, as well as how bedside ultrasonography can be incorporated into clinical decision guidelines for appendicitis, would be of benefit to emergency physicians.

Video. A noncompressible, non-peristalsing tubular structure in the right lower quadrant.

Address for Correspondence: Caleb Canders, MD, David Geffen School of Medicine at UCLA, 924 Westwood Boulevard, Suite 300, Box 951777, Los Angeles, CA 90095-1777. Email: ccanders@mednet.ucla.edu.

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Accuracy of a Novel Ultrasound Technique for Confirmation of Endotracheal Intubation by Expert and Novice Emergency Physicians

Michael Gottlieb, MD
John M. Bailitz, MD
Errick Christian, BS, MA
Frances M. Russell, MD
Robert R. Ehrman, MD
Basem Khishfe, MD
Alexander Kogan, MD
Christopher Ross, MD

Cook County Hospital, Chicago, Illinois

Supervising Section Editor: Laleh Gharahbaghian, MD
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Introduction: Recent research has investigated the use of ultrasound (US) for confirming endotracheal tube (ETT) placement with varying techniques, accuracies, and challenges. Our objective was to evaluate the accuracy of a novel, simplified, four-step (4S) technique.

Methods: We conducted a blinded, randomized trial of the 4S technique utilizing an adult human cadaver model. ETT placement was randomized to tracheal or esophageal location. Three US experts and 45 emergency medicine residents (EMR) performed a total of 150 scans. The primary outcome was the overall sensitivity and specificity of both experts and EMRs to detect location of ETT placement. Secondary outcomes included a priori subgroup comparison of experts and EMRs for thin and obese cadavers, time to detection, and level of operator confidence.

Results: Experts had a sensitivity of 100% (95% CI = 72% to 100%) and specificity of 100% (95% CI = 77% to 100%) on thin, and a sensitivity of 93% (95% CI = 66% to 100%) and specificity of 100% (95% CI = 75% to 100%) on obese cadavers. EMRs had a sensitivity of 91% (95% CI = 69% to 98%) and of specificity 96% (95% CI = 76% to 100%) on thin, and a sensitivity of 100% (95% CI = 82% to 100%) specificity of 48% (95% CI = 27% to 69%) on obese cadavers. The overall mean time to detection was 17 seconds (95% CI = 13 seconds to 20 seconds, range: 2 to 63 seconds) for US experts and 29 seconds (95% CI = 25 seconds to 33 seconds; range: 6 to 120 seconds) for EMRs. There was a statistically significant decrease in the specificity of this technique on obese cadavers when comparing the EMRs and experts, as well as an increased overall time to detection among the EMRs.

Conclusion: The simplified 4S technique was accurate and rapid for US experts. Among novices, the 4S technique was accurate in thin, but appears less accurate in obese cadavers. Further studies will determine optimal teaching time and accuracy in emergency department patients. [West J Emerg Med. 2014;15(7)834-839.]

INTRODUCTION

Rapid and reliable confirmation of endotracheal tube (ETT) placement during intubation is essential. The incidence of esophageal intubation during emergency conditions has been reported to be as high as 8-14%.[1,2] Methods of confirmation include direct visualization of passage, chest and abdominal auscultation, esophageal detector devices, pulse oximetry, and end tidal capnography (both colorimetric and quantitative). With the exception of continuous end tidal CO_2 monitoring, each alternative method is fraught with potential problems resulting in poor sensitivities and specificities. Although continuous end tidal CO_2 has become the preferred method,[3] there are still significant risks of false positives with hypopharyngeal placement and false negatives during cardiac arrest.[4-6] Moreover, continuous end tidal CO_2 monitoring is not widely available in many emergency departments (EDs).[7]

As a result, there has been increasing research into the use of ultrasound to visually confirm ETT placement. Multiple studies assessing the use of transcricoid ultrasonography to confirm ETT placement have been proposed.[8-10] Of note, all of these studies have utilized a midline approach, which has been suggested to miss the second hyperechoic air-mucosa (A-M) interface in cases where the esophagus is located posterior to the trachea – a situation noted in as many as 16% of patients.[11] Additionally, prior studies have demonstrated that dynamic ultrasonography provides better accuracy than static ultrasonography. However, in a busy emergency department environment, having an ultrasound on top of the patient's neck during the intubation process is an additional impediment that may deter its use by many providers. Hence, current research has yet to describe a reliable method to exclude esophageal intubation without performance of the ultrasound during the actual intubation.

The purpose of this study was to determine the accuracy of a novel, rapid, four step (4S) US technique to confirm correct endotracheal tube placement (Figure 1).

METHODS

This was a two-part, randomized pilot study of a novel technique for airway ultrasonography. Local institutional review committee acknowledgement for the study was obtained. All experts and residents signed an informed consent prior to entering the study.

Study Setting and Selection of Participants

This study was performed in the cadaver lab of an academic hospital in Chicago, IL. The study subjects for part one included an Emergency Ultrasound Director and two Emergency Ultrasound fellows at the end of their fellowship year with prior training in airway ultrasound. The study subjects for part two included 45 postgraduate years two through four (PGY 2-4) emergency medicine residents (EMRs) with no prior training in airway ultrasound.

Two thin (body mass index [BMI] 17.8 and 20.1) and two obese (BMI 33 and 36.5) adult human cadavers were used for all of the intubations. A random number generator was utilized to decide whether the ETT would be placed into the esophagus or the trachea with the goal of equivalent numbers of esophageal and tracheal intubations in order to best define the test characteristics. Each cadaver was carefully intubated by a separate attending emergency physician using a video laryngoscope prior to the entrance of the study subjects into the room. All physicians performing the ultrasound were blinded to the ETT location.

To adequately assess for greater than 90% sensitivity and specificity with 90% power level and a two-tailed alpha error of 0.05, we calculated a total required sample size of 126. In order to better assess the experts for subgroup analysis, we increased the expert scans to 60 and the resident scans to 90 for a total of 150 scans.

Study Design and Data Collection

In part one, the emergency US experts reviewed the existing literature, discussed and practiced previously described techniques, and then developed and refined the rapid four step (4S) technique during a four hour cadaver lab session (Figure 1–5). All scans were performed utilizing a 10MHz linear transducer (GE LOGIQ e series, GE Healthcare, United Kingdom).

After the technique was developed, expert accuracy was assessed as described above. Three blinded emergency US experts each performed ten independent scans on the thin model, followed by ten additional scans on the obese model. The accuracy, operator confidence, and performance time were recorded for all three operators.

In part two, 45 blinded PGY 2-4 EMRs were given a ten minute, hands-on, bedside educational module on the 4S technique by the same US expert (J.B.) during a regularly scheduled EMR cadaver lab (Figure 6). The thin and obese cadavers were then intubated as described in the above methods. The EMRs were assessed for accuracy, operator confidence, and performance time.

A research coordinator recorded the true location of the ETT, study subject prediction of ETT location, and time to ETT prediction. Additionally, operator confidence was assessed by the research coordinator utilizing a Likert scale ranging from 1-5. All descriptive and performance data were arranged by participant with each US expert and EMR having their own unique column for each variable.

Statistical Analysis

All statistical analyses included in this study were performed using Statistical Package for the Social Sciences (Version 21.0. Armonk, NY). In order to determine US expert and EMR accuracy, two-by-two contingency tables were generated comparing each operator's ETT prediction to the ETT true location for each cadaver. Descriptive

Four Step (4S) Technique.

1. As if performing a cricothyrotomy, extend the neck and grasp trachea with the non-dominant hand. Place the transducer in a transverse plane over the larynx to identify the echogenic inverted V formed by the thyroid cartilage anterior to the air column.
2. Slide the transducer caudad to visualize the trachea in between the lobes of the thyroid gland. Slide the transducer slightly to the patient's left and rotate the probe indicator 30 degrees caudad toward the patient's contralateral nipple. Determine if a second air column is present inferior and lateral to the tracheal air column immediately behind the thyroid gland.
3. Rotate the ETT slightly to create a "tube sliding" artifact within the tracheal or esophageal air column based on intubation location.
4. If no tube sliding is seen in either location, move the probe to the patient's right and repeat to detect an esophagus located to the right of the trachea (present in up to 10% of patients).

Figure 1. Four Step (4S) Technique.
ETT, Endotracheal tube

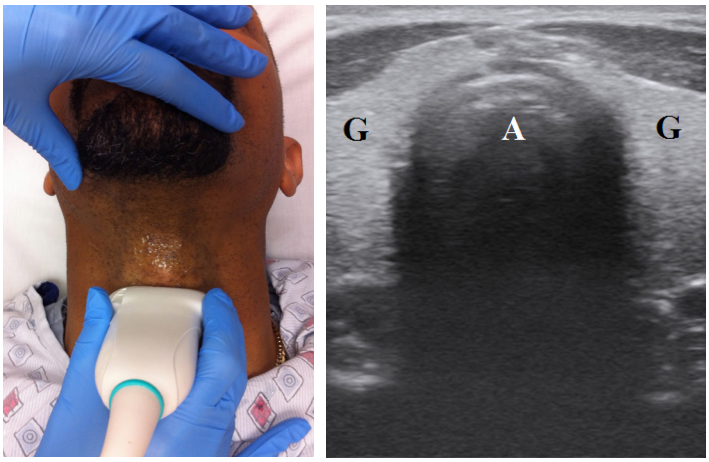

Figure 2. Transverse view of the tracheal air column (A) between the lobes of the thyroid gland (G).

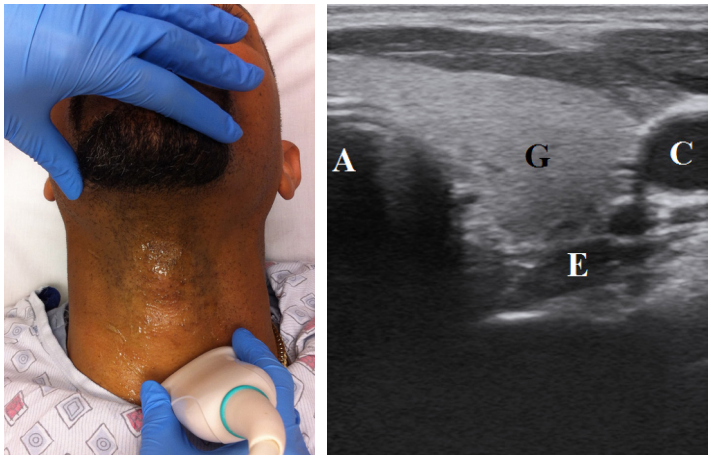

Figure 3. Initial oblique view of the tracheal air column (A), thyroid gland (G), and collapsed esophagus (E) in the typical location between the trachea and carotid artery (C).

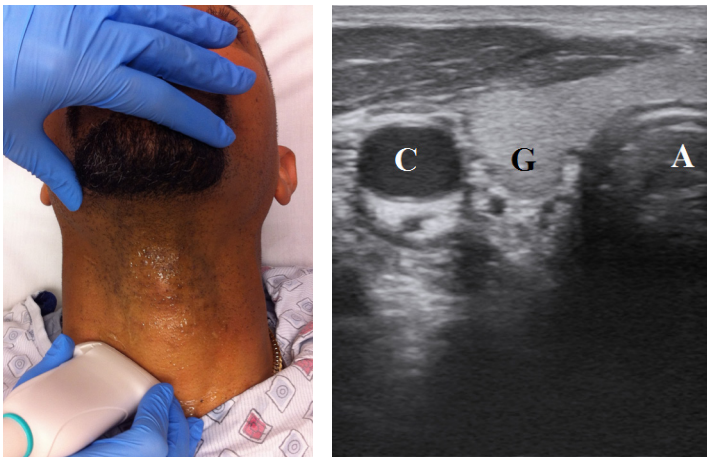

Figure 4. Contralateral oblique view assessing for a right-sided esophagus between the tracheal air column (A) and carotid artery (C). (G) thyroid gland.

statistics, including population estimates at a 95% level of confidence, were also generated for US expert and EMR sensitivity and specificity of endotracheal placement, operator confidence and performance time.

RESULTS

Overall, the four cadavers (two thin and two morbidly obese) yielded 150 intubations. There were a total of 76 tracheal intubations and 74 esophageal intubations.

Among the experts, the overall sensitivity was 96.4% (95% CI = 80.0% to 99.8%) and specificity was 100% (95% CI = 86.7% to 100%). Experts had a sensitivity of 100% (95% CI = 71.7% to 100%) and a specificity of 100% (95% CI = 77.1% to 100%) among the thin cadavers and a sensitivity of 93.3% (95% CI = 66.0% to 99.7%) and a specificity of 100% (95% CI = 74.7% to 100%) among the obese cadavers.

The mean time to detection for US experts was 9.5 seconds (95% CI = 4.4 seconds to 14.6 seconds; range: 2 to 45 seconds) for thin cadavers and 23.7 seconds (95% CI = 19.6 seconds to 27.8 seconds; range: 4 to 63 seconds) for obese cadavers. Operator confidence was 4.9/5.0 (95% CI = 4.8 to 5.0) for the thin cadavers and 4.3/5.0 (95% CI = 4.1 to 4.5) for the obese cadavers.

Among the EMRs, overall sensitivity was 95.5% (95% CI = 83.3% to 99.2%) and specificity was 71.7% (95% CI = 56.3% to 83.5%). The EMRs had a sensitivity of 90.9% (95% CI = 69.4% to 98.4%) and a specificity of 95.7% (95% CI = 76.0% to 99.8%) among the thin cadavers and a sensitivity of 100% (95% CI = 81.5% to 100%) and a specificity of 47.8% (95% CI = 27.4% to 68.9%) among the obese cadavers.

The mean time to detection for EMRs was 21.1 seconds (95% CI = 17.7 seconds to 24.6 seconds; range: 6 to 55 seconds) for thin cadavers and 36.3 seconds (95% CI = 29.9 seconds to 42.7 seconds; range: 12 to 120 seconds) for obese

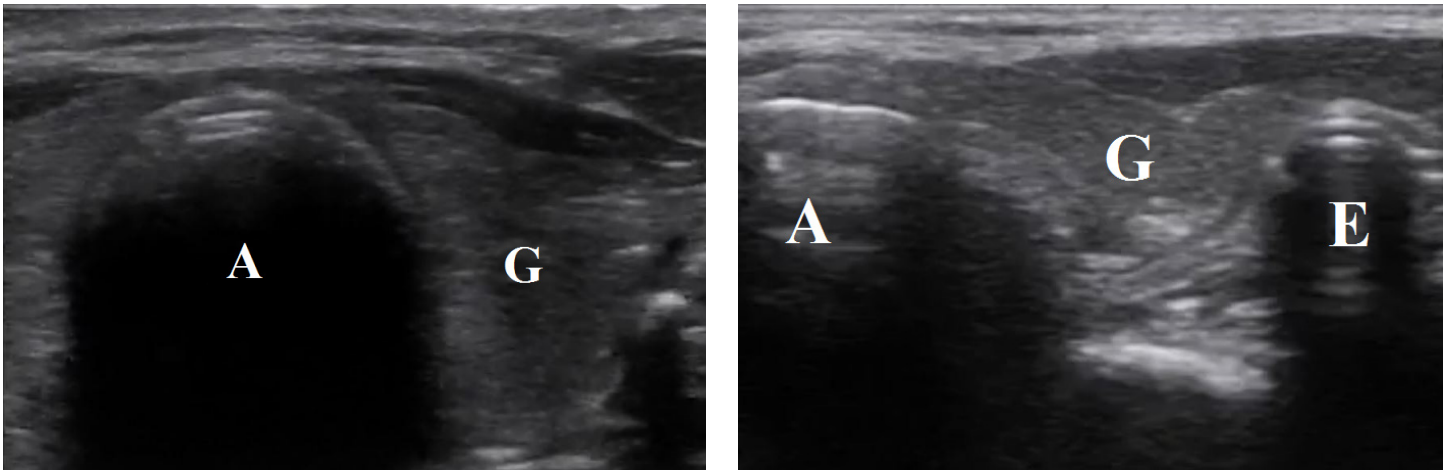

Figure 5. Comparison of tracheal (Left) and esophageal (Right) intubations via the Four Step (4S) Technique.
A, air column; *G,* thyroid gland; *E,* collapsed esophagus (E)

Instructor Methods
1. Instructor explains and performs the 4S Technique with the ETT either in the trachea or esophagus.
2. The ETT location is changed and the EMR explains and performs the above four steps with the tube in a new location as if teaching a medical student. Instructor provides coaching tips on explanations and performance of the US.
3. Questions answered and views repeated as necessary to achieve trainee confidence with material.

Figure 6. Instructor methods.
ETT, endotracheal tube; *EMR*, emergency medicine residents; *US*, ultrasound

cadavers. Operator confidence was 4.6/5.0 (95% CI = 4.4 to 4.8) for the thin cadavers and 4.2/5.0 (95% CI = 4.0 to 4.5) for the obese cadavers.

DISCUSSION

In the ED setting, it is essential to quickly confirm correct ETT placement. Although many tools and clinical examination findings are available, each has limitations. Even colorimetric end tidal CO_2 detectors may have false positives and negatives resulting in accuracy as low as 67.9% during cardiac arrest.[4-6] Moreover, most methods require multiple ventilations, thereby increasing the risk of gastric distension and aspiration if incorrectly placed.

As a result, there has been increasing research into the use of airway ultrasound to quickly confirm ETT placement. Airway ultrasonography utilizes equipment readily available in most EDs without requiring ventilation of the patient. Multiple prior studies assessing the utility of transcricoid ultrasonography to confirm ETT placement have had variable success.[8-10,12-15] However, the majority of these trials have required either the addition of the sliding lung sign with an extra series of steps that may deter providers from performing the exam; or dynamic ultrasonography that requires an additional provider to perform the airway ultrasound at the crowded head of the bed while a separate provider is intubating.

This cross-sectional, randomized trial aimed to assess the accuracy, confidence, and speed of a novel approach to the airway ultrasound exam for ETT confirmation. Building on earlier work, we developed a practical approach to airway ultrasound for endotracheal tube placement confirmation. One unique component of our approach was the use of a paramedian transverse view, rather than a midline longitudinal view, thereby potentially improving the ability to visualize an esophageal intubation when located posterior to the trachea. Additionally, the use of 30 degrees of oblique angulation allowed for greater surface area of the trachea and esophagus, facilitating the detection endotracheal tube movement.[16] Finally, the use of slight tube rotation mimics the motion artifact associated with dynamic ultrasonography, while allowing the exam to be performed after the intubation has occurred. Benefits include the ability to avoid ventilation prior to confirmation, decreased number of instruments near the patient's head and neck during the actual intubation attempt, and the potential ability to perform this when only one provider is present.

Our pilot results suggested that the 4S approach was quite accurate in identifying endotracheal and esophageal intubation in both thin and obese cadavers when performed by expert sonographers. Previous studies by Saglam et al.[8] and Park et al.[13] demonstrated good results, but required the addition of the lung sliding that requires multiple ventilations for confirmation. Ma et al.,[9] Werner et al.,[12] Milling et al.,[14] and Muslu et al.,[15] demonstrated excellent sensitivity and specificity with the dynamic transtracheal approach. However, this requires multiple providers and an ultrasound probe on the trachea during the actual intubation attempt. Finally, a recent study by Chou et al.[10] demonstrated 98.9% sensitivity and 94.1% specificity for endotracheal intubation utilizing a static transtracheal approach. The authors note in their study that the missed esophageal intubations may have been secondary to a posterior esophagus, which is more likely to be identified

correctly with our paramedian approach. Additionally, most of the patients studied were relatively thin with an average BMI of 23, thus limiting its applicability to obese patients.

This study also suggested that the 4S technique is accurate in identifying correct ETT location in thin patients, but appears less accurate in obese cadavers, when performed by novice sonographers. In the study by Chou et al.,[10] the two senior residents were supervised by certified ultrasound experts and had received a one hour lecture and eight hours of practice time prior to the study. The residents in our study demonstrated a slightly lower accuracy. However, our residents included all levels of training and only a short, ten-minute educational session. Additionally, the nine hour training session performed by Chou et al.[10] may not always be feasible for all locations. Our study was performed during a regularly scheduled cadaver lab and demonstrated only slightly lower accuracy with the ten minute training session. This suggests that the ideal training time may, in fact, be sometime between ten minutes and nine hours.

LIMITATIONS

The primary limitation of this pilot study was the use of a cadaver model. Although fresh cadavers were used, this may not completely mimic the anatomy or experience in a live patient in the ED environment. As a pilot study of a novel technique, the cadaver model provided a safe research and educational environment. Moreover, the cadaver model allowed for a significantly increased number of esophageal intubations when compared to an ED-based population. This provided the opportunity to determine a more accurate assessment of the detection of both endotracheal and esophageal intubations than would be possible in an ED environment. Another limitation was the pooling of expert sonographers with EMRs for assessing the primary outcome. It became apparent by subgroup analysis that the lower overall specificity was strongly influenced by the EMR obese cadaver group. Finally, due to a busy cadaver lab agenda, teaching sessions were limited to 10 minutes which may have been a significant contributing factor to the lower accuracy. In subsequent studies, we will confirm the accuracy of the 4S technique in ED patients as well as the optimal teaching time required.

CONCLUSION

In conclusion, our results suggest that the 4S US technique provides an accurate and rapid bedside technique to confirm endotracheal intubation in a cadaver model. Amongst emergency ultrasound experts, the 4S US technique is accurate and rapid. Amidst novice ultrasonographers, the 4S US technique is accurate in thin patients, but appears less accurate in obese patients. Further studies will determine the optimal teaching time required and the accuracy of the 4S technique in emergency department patients.

Address for Correspondence: Michael Gottlieb, MD, Cook County Hospital, Department of Emergency Medicine, 1900 W. Polk St, 10th Floor, Chicago, IL 60612. Email: mgottlieb2@cookcountyhhs.org.

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Sydenham Chorea: Rare Consequence of Rheumatic Fever

Paul J. Myers, DO*
Kathleen E. Kane, MD*
Bernadette G. Porter, BS*
Richard J. Mazzaccaro, MD, PhD †

* Lehigh Valley Health Network/USF MCOM, Department of Emergency Medicine, Allentown, Pennsylvania
† Lehigh Valley Health Network, Department of Pediatrics, Allentown, Pennsylvania

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CASE REPORT

Sydenham Chorea (SC) is an acute rheumatic fever complication. SC is the most common acquired childhood chorea, usually affecting children five to fifteen years of age.[1] It occurs following an untreated group A streptococcal infection and a latent period of one to six months.[1,2] Despite rheumatic fever diminishing, 18% to 36% of acute rheumatic fever patients develop SC.[3] Full recovery often takes several months; some patients suffer permanent neurologic sequelae.[1]

An 11-year old male presented to the Emergency Department with two days of uncontrolled body twitching. The movements affected his right arm and leg, with occasional lip twitches; he experienced intermittent confusion and hyperactivity. The patient denied recent illness, but recalled a fever with headache and vomiting several months prior. Besides the above findings, his physical examination was normal.

The patient's rapid streptococcal antigen test was negative, but his throat culture was positive for group A beta hemolytic Streptococcus. An anti-streptolysin O (ASO) titer resulted at 503 (reference range, <240 IU/mL). Symptoms progressed to include slurred speech, head jerking, awkward gait, and decreased right eye vision.

Several motor manifestations are pathognomonic: "Milkmaid's grip" occurs when patients are unable to clench their fists, displaying as intermittent relaxation and tightening of hand grip.[1] "Choreic hand" is "spooning" of the hand by wrist flexion and extension of the digits.[1] The linked video demonstrates this patient's motor manifestations (Video).

Evaluation of chorea in pediatric patients should include testing for group A streptococcal infection with throat culture and ASO titers. SC is key to diagnosing rheumatic fever and should prompt evaluation for rheumatic heart disease. This patient's brain magnetic resonance imaging and electrocardiogram were normal, but his echocardiogram showed mild mitral regurgitation. Treatment included penicillin for ten days, instructions to get monthly bicillin injections through age twenty-one and a recommendation for lifelong antibiotic prophylaxis.

Video. Motor manifestations of patient.

Address for Correspondence: Bernadette Porter, EM Residency Suite, 2545 Schoenersville Road, Bethlehem, PA, 18017. Email: Bernadette.Gl-Porter@lvhn.org.

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Chikungunya Fever in Los Angeles, California

Katherine R. Harter, MD, MPH
Sanjay Bhatt, MD
Hyung T. Kim, MD
William K. Mallon, MD

Department of Emergency Medicine, Los Angeles County + USC Medical Center, Los Angeles, California

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We report the case of a 33-year-old woman returning from Haiti, presenting to our emergency department (ED) with fever, rash and arthralgia. Following a broad workup that included laboratory testing for dengue and malaria, our patient was diagnosed with Chikungunya virus, which was then reported to the Centers for Disease Control and Prevention for initiation of infection control. This case demonstrates the importance of the ED for infectious disease case identification and initiation of public health measures. This case also addresses public health implications of Chikungunya virus within the United States, and issues related to the potential for local spread and autochthonous cases. [West J Emerg Med. 2014;15(7):841-844.]

INTRODUCTION

Fever in the returned traveler can be a diagnostic challenge. Emergency medicine providers must consider a broad differential diagnosis, which includes infectious diseases native to the areas of travel. Often this differential includes diseases not routinely considered and even at times includes a diagnosis new to the clinical team. In this report, we review a case of a woman complaining of high fever, joint pain, and rash who presented to our urban emergency department (ED) in Los Angeles County shortly after returning from abroad.

CASE REPORT

On June 13, 2014, a 33-year-old Caucasian woman presented to the ED. She complained of one week of fever, joint pain and rapid development of a total body rash. She did note recent travel to visit friends in Port au Prince, Haiti from May 29, 2014, to June 7, 2014. During her trip she noted multiple mosquito bites, and while she had initially been taking antimalarials, due to nausea she stopped taking them shortly after her arrival. Her vaccination history included immunizations to typhoid, hepatitis B and tetanus. On June 6, 2014, she began to feel nonspecific malaise. Concerned about her symptoms, she decided to leave earlier than previously planned. Prior to departure she noted that her friends, now local to Haiti, were having similar symptoms of malaise and fever.

On June 7, 2014, she returned to the United States and noted a fever of 102.0°F. Additionally, she noted a rash over her trunk and extremities. She was initially evaluated at an outside ED on day 2 of her illness. At that time her laboratory workup revealed a leukocyte count of 5900, hemoglobin 12.8 g/dL, hematocrit of 37.1%, and platelet count of 148000/m^3. The remainder of her laboratory work-up, including basic metabolic panel, hepatic function panel and coagulation studies, were all within normal limits. She was diagnosed with cellulitis and sent home on trimethoprim/sulfamethoxazole and clindamycin. After one day of antibiotics, due to nausea she discontinued her medications. She also noted that her fever began to improve. On day 6 of her illness, she noted a returning fever, further spread and intensification of her rash, and diffuse joint pain.

She presented to our ED on day 7 of her illness with a temperature of 100.3°F, a heart rate between 110 and 120 beats per minute, and was otherwise hemodynamically stable and well appearing. Her physical exam was notable for a diffuse blanching maculopapular rash covering her trunk, extremities and face. She complained of joint pain and swelling but had no appreciable effusions; she had full active strength and range of motion in all extremities, with otherwise benign neurologic, cardiopulmonary and abdominal exams.

Given her recent travel history, thick and thin malaria smears were sent along with basic laboratory studies. Her

leukocyte count resulted as 3400 (neutrophils= 76.1%, lymphocytes= 10.9%, eosinophils= 2.8%, monocytes= 10.1%), hemoglobin 13.8 g/dL, hematocrit of 39%, and platelet count 139000/mm^3. Her urinalysis, basic metabolic panel, and hepatic function panel were also within normal limits. Her human immunodeficiency virus (HIV) screen was negative. She remained stable throughout the ED course and was placed in the ED observation unit for further monitoring. There, her BinaxNow malaria antigen detection test and Giemsa stain thin and thick smears were reported negative.

While in the ED observation unit she remained hemodynamically stable. The Centers for Disease Control (CDC) was contacted for further recommendations and for disease reporting. Serologic studies were sent for the evaluation of both dengue and Chikungunya viruses. Additional sets of labs were obtained as shown in table below. She was discharged later that afternoon.

The Chikungunya IgG and IgM serologic studies were reported positive. These positive serology studies were reported to the California Department of Public Health who responded with a notification bulletin to local health facilities and vector control in the patient's neighborhood, which included spraying her neighborhood for Aedes mosquitoes. On follow-up one week after discharge, our patient reported that the majority of her symptoms had resolved by day 10 of her illness. She did endorse persistent mild joint pain in her extremities, much improved from her initial presentation to our ED. Three weeks following her return from Haiti, she endorsed complete resolution of all symptoms, including cessation of arthralgia.

DISCUSSION

Given our patient's recent travel history, the initial differential diagnosis included tropical infections endemic to Haiti. The differential included hepatitis, malaria, primary HIV, Epstein-Barr virus (EBV), typhoid fever, rickettsia, leptospirosis, as well as more common etiologies of fever and rash seen in the ED, including group A streptococcus and drug reactions. Upon discussion with the CDC, the differential extended to include dengue and chikungunya fever.

Dengue and chikungunya fever have similar clinical features, are both spread by the Aedes mosquitos, and can present with a wide range of symptoms, ranging from those of a benign febrile illness to those with severe neurologic and hemorrhagic complications that can result in shock and death. Clinical differentiation of the chikungunya virus from the dengue virus can be difficult; generally arthralgia is more commonly seen in chikungunya fever while myalgia and thrombocytopenia (platelets <118,000/mm^3) are more common to dengue fever.[1,2] Both illness may have a rash, and both may have a saddleback fever profile. A tourniquet test is more likely to be positive in dengue fever; however, this is not consistently seen in the literature.[3]

Chikungunya fever is primarily a mosquito-borne alphavirus endemic to Africa.[4] Humans are the primary viral host and the global spread of the virus occurs when infected humans travel between regions that both support competent Aedes mosquitoes. The *Aedes* A*egypti* and Aedes A*lbopictus* mosquitoes are vectors for both dengue and chikungunya viruses; these mosquitoes were initially thought to be endemic to the tropics; however, they are now known to survive in the Americas and some parts of the United States (U.S.)[4,5] Additionally, recently studied point mutations have resulted in increased infectivity and transmission of the virus.[5,6] Thus, both the breadth of human travel and genetic variation in the virus itself are promoting the spread of the virus.

The viral incubation is quite short, and returned travelers who develop a fever more than 7-10 days after their return are unlikely to have either dengue or chikungunya infections. The incubation period ranges from 2-4 days and symptoms generally present between 3-7 days after the initial mosquito bite.[1,7,8] Serologic surveys indicate that over 75% of those with antibodies to the chikungunya virus have had a symptomatic infection, thus supporting the belief that most of those infected become symptomatic.[2] The spectrum of clinical features of chikungunya fever ranges from asymptomatic patients to those who experience hemorrhage and death.

The most common symptoms are fever and polyarthralgia. Joint symptoms, which are reported in over 85% of symptomatic patients, are usually symmetric and more commonly occur

Table. Laboratory work up throughout emergency department visits of patient with chikungunya fever: complete blood count trend.

	Outside hospital		Within institution	
	6/8/14	6/13/14 at 18:30	6/14/14 at 03:30	6/14/14 at 14:00
Leukocyte	5900	3400	2000	2400
Neutrophil		76.1	58.0	70.7
Lymphocyte		10.9	23.6	16.6
Monocyte		10.1	12.3	9.2
Eosinophil		2.8	5.4	3.2
Hemoglobin	12.8g/dL	13.8g/dL	11.2g/dL	12.6g/dL
Hematocrit	37.1%	39.0%	31.8%	37.0%
Platelet	148,000/mm^3	139,000/mm^3	120,000/mm^3	130,000/mm^3

in the distal joints, most frequently in the hands and ankles.[8,9] Additional symptoms may include cutaneous manifestations, commonly a maculopapular rash over the face, trunk and extremities, headaches, myalgias, conjunctivitis, nausea, vomiting and diarrhea.[2,8] Severe complications are rare, but include uveitis, retinitis, myocarditis, hepatitis, nephritis, bullous skin lesions, hemorrhage, and neurologic complications, including encephalitis, Guillain-Barre syndrome and cranial nerve palsies.[1,2,8,10-12] Patients more likely to experience severe outcomes include neonates, adults over the age of 65, and those with an underlying medical condition or immunodeficiency.[2,8]

In acute infection symptoms generally resolve within 14 days, though occasionally symptoms can persist for many years. Polyarthralgia is the most common chronic manifestation of Chikungunya fever; the most common factors associated with prolonged joint pain or stiffness are pre-existing arthralgia, underlying rheumatologic disorders, female sex, and increased age, though data vary by population studied.[8,9,13]

Chikungunya fever is often diagnosed clinically, especially in resource-limited settings. General laboratory workup often reveals lymphopenia, thrombocytopenia, an elevated creatinine, and elevated hepatic transaminases.[1,2,8] Specific laboratory tests do exist to confirm diagnosis of Chikungunya virus and are available through the CDC and several state health departments. Diagnosis through the viral culture can detect the virus within the first three days of illness. RT-PCR can detect viral RNA in the first eight days of illness, and serology can detect IgM and IgG antibodies towards the end of the first week of illness.[1]

The mainstay of treatment revolves around symptomatic management. As noted above, given the similarities in initial clinical presentation, shared geographic distribution, and Aedes mosquito disease vector for the Chikungunya and dengue viruses, the CDC recommends that all suspected cases of Chikungunya be managed as dengue fever initially; this is particularly true as dengue fever has increased morbidity and mortality.[1] Additionally, they recommend against the use of aspirin and non-steroidal anti-inflammatory drugs given the risk of associated hemorrhage in patients with dengue fever.[1]

Prevention strategies for the Chikungunya virus primarily focus on minimizing exposure to mosquitos and local vector control efforts. There are no specific vaccinations or medications for the prevention or treatment of Chikungunya. In general, epidemics of Chikungunya worldwide have been limited to areas of competent Aedes mosquitos, and until recently no local transmission was noted in or near the U.S. With recent outbreaks in the Caribbean and South America, as well as the first documented cases of autochthonous transmission in Puerto Rico and the U.S. Virgin Islands, it will be important to consider chikungunya in the differential of a patient with recent travel, fever, arthralgias and/or a rash.[14]

California has had seven confirmed cases of Chikungunya fever in 2014, all found in travelers returning to or visiting the U.S.[14] In addition, the California Department of Public Health released a notice on June 13, 2014 that competent Aedes *aegypti* and Aedes *albopictus* mosquitoes have been found in several California cities, including in Los Angeles County, where this case presented, making the possibility of local transmission more realistic as travelers return from endemic countries.[15]

CONCLUSION

Chikungunya fever typically presents within 2-4 days of infection, and is spread primarily from mosquito to human. Until recently cases of Chikungunya fever in or near the U.S. were noted only in travelers returning to or visiting from regions with current epidemics. Chikungunya and dengue fever share many clinical aspects and in suspect patients both diseases should be tested. As of May 30, 2014, the first case of autochthonous transmission was noted in Puerto Rico, and since that time more cases have been reported. With the recent notice regarding competent mosquitoes in California and other areas of the U.S., the index of suspicion must be raised and the differential broadened to include Chikungunya fever, especially as it can lead to the initiation of public health interventions such as vector control.

Address for Correspondence: Katherine Harter, The Department of Emergency Medicine, Los Angeles County and USC Medical Center, Los Angeles, California, USC Medical Center, Department of Emergency Medicine, 1200N. State Street, Los Angeles, CA 90033. Email: krharter@gmail.

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Acute Pulmonary Edema Associated With Propofol: An Unusual Complication

Mian Adnan Waheed, MD
Lavi Oud, MD

Texas Tech University Health Science Center, Department of Internal Medicine, Odessa, Texas

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Propofol is frequently used in the emergency department to provide procedural sedation for patients undergoing various procedures and is considered to be safe when administered by trained personnel. Pulmonary edema after administration of propofol has rarely been reported. We report a case of a 23-year-old healthy male who developed acute cough, hemoptysis and hypoxia following administration of propofol for splinting of a foot fracture. Chest radiography showed bilateral patchy infiltrates. The patient was treated successfully with supportive care. This report emphasizes the importance of this potentially fatal propofol-associated complication and discusses possible underlying mechanisms and related literature. [West J Emerg Med. 2014;15(7):845–848.]

INTRODUCTION

Propofol (2,6-diisopropylphenol) is an ultrashort-acting intravenous hypnotic and sedative agent formulated as an emulsion containing soybean oil, egg phospholipid and glycerol.[1] It is commonly used for induction of anesthesia in the operating room, as routine sedation in the intensive care setting, and also for procedural sedation in the emergency department (ED). Common adverse effects of propofol include hypotension, respiratory depression, bradycardia and pain during injection. Pulmonary edema after administration of propofol has rarely been reported.[2-5] To our knowledge, we report the first case of propofol-related pulmonary edema in the United States.

CASE REPORT

A 23-year-old man presented to the ED with pain and swelling of his left foot secondary to a work-related accident. He had no preexisting medical problems. The patient was a smoker and denied drug allergies, use of medications or illicit drugs. He was noted to be in severe distress due to pain. His temperature was 36.7°C, heart rate 88 beats/min, blood pressure 133/90 mm Hg, respirations 20 breaths/min, and oxygen saturation by pulse oximetry (SpO_2) 100% on room air. His weight was 66 kg and his physical examination was unremarkable, except for left foot swelling and tenderness. He had a Mallampatti score of 1 and an American Society of Anesthesiologists (ASA) classification of 1. Routine initial laboratory workup, including complete blood count, electrolytes, renal and liver function panel, urinalysis and urine drug screening, was within normal range. A nondisplaced proximal third metatarsal fracture was noted on plain radiography of the left foot. The patient had a low pain tolerance and thus requested sedation and analgesia for any manipulation of his foot. In order to splint his foot, procedural sedation, along with analgesia were provided, including intravenous meperidine 75mg and intravenous propofol in 75mg aliquots up to a total of 350mg over a period of one hour. The patient was under continuous cardiopulmonary monitoring with three-lead electrocardiography and SpO_2 monitoring, as well as close observation by nursing staff to check for signs of respiratory dysfunction or other adverse effects. He tolerated the procedure well, adequately maintaining his airway. His SpO_2 was >95% throughout the procedure, on oxygen at 15 liters per minute through a non-rebreather mask. After the procedure, oxygen supplementation was gradually reduced over 15 minutes.

At 60 minutes following the procedure, the patient was completely awake and oriented, saturating 96% on room air. Ten minutes later, the patient developed acute cough with moderate quantity hemoptysis. Arterial blood gas analysis showed pH of 7.35, PaO_2 44mmHg, $PaCO_2$ 42mmHg

and SaO_2 76%. His temperature was 36.6ºC, heart rate 95 beats/min, blood pressure 128/70mmHg, respirations 18 breaths/min, and SpO_2 80%. Supplemental oxygen through nasal cannula at four liters per minute was initiated with improvement in SaO_2 to 90%. Physical examination revealed bilateral coarse crackles throughout both lung fields with normal heart sounds and normal neck examination. Chest radiography showed patchy bilateral lung airspace infiltrates (Figure), which were confirmed on computed tomography angiography that was otherwise unremarkable. Additional diagnostic studies obtained following development of hypoxemia, including coagulation profile, d-dimer, as well as serial electrocardiograms and troponin I assays, were within normal range. Serum creatinine kinase was 633IU/L.

The patient was admitted to a telemetry unit. Intravenous ceftriaxone 2 grams daily and azithromycin 500mg daily were initiated empirically, along with intravenous furosemide 40mg every six hours. Workup for an infectious etiology, including tuberculosis by interferon-gamma release assay, coccidioidomycosis complement fixation, histoplasmosis antibody, blastomycosis antibody, aspergillus antibody, human immunodeficiency virus antibody, along with sputum and blood cultures, was negative. Echocardiography was unremarkable. A C-reactive protein test was normal and an antinuclear antibody test was negative. A follow-up complete blood count was normal. Over the course of next two days the patient's hypoxia and hemoptysis resolved with no additional treatment. Follow-up chest radiography two days after admission showed near-complete resolution of lung infiltrates, and the patient was discharged from the hospital in stable, asymptomatic condition.

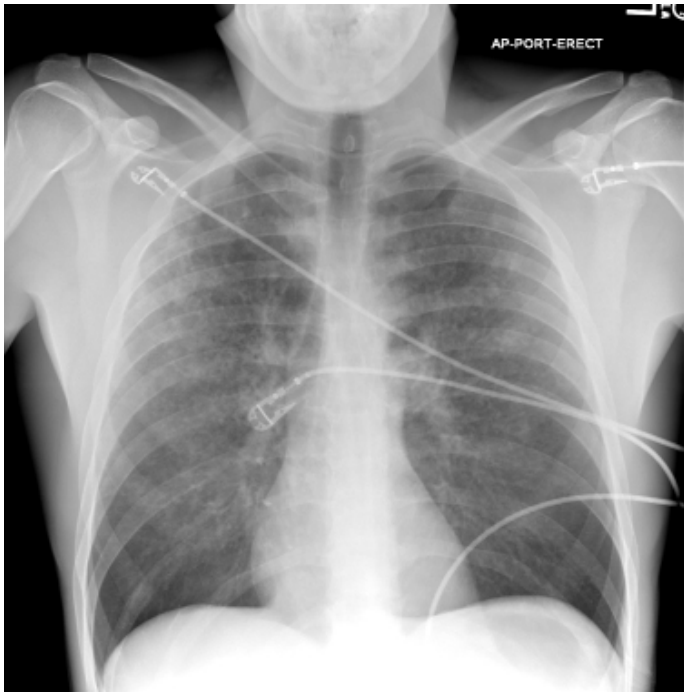

Figure. Chest radiography showing diffuse bilateral patchy infiltrates 60 minutes after propofol administration.

DISCUSSION

Propofol is frequently used for procedural sedation in the ED and is considered to be safe when administered by trained personnel.[6] Typical initial dosage of propofol used for procedural sedation is 1mg/kg intravenously, followed by 0.5mg/kg every 3min titrated to the desired level of sedation. Doses used for induction of anesthesia are around 2-2.5mg/kg.[7]

While not the primary focus of the present report, the care of the reported patient could have been alternatively facilitated by using a regional nerve block, thus avoiding exposure to systemic procedural sedation, its attendant risks, and the associated need for additional monitoring. However, as noted by others,[8] regional anesthesia requires special training and expertise, and may not be consistently available. Our findings underscore the variability in clinical practice among emergency medicine clinicians and the potential for improvement.

We describe development of hemoptysis and pulmonary edema following the administration of propofol for conscious sedation. While hemoptysis is an uncommon manifestation of pulmonary edema, it has been reported previously.[9,10] Anesthesia-related pulmonary edema has been associated with airway obstruction, gas embolism, cardiac failure, fluid overload, acid aspiration, reactions to blood products and drug hypersensitivity reactions.[11,12]

Several alternative causes of hypoxic respiratory failure and lung infiltrates should be considered in our patient. Negative pressure pulmonary edema due to airway obstruction may complicate administration of central nervous system suppressants. However, the latter possibility is unlikely due to lack of signs of airway compromise throughout the closely monitored propofol administration and afterwards. In addition, the timing of hemoptysis does not support a diagnosis of negative pressure pulmonary edema. Cardiogenic pulmonary edema could not explain the findings in our patient as there was no evidence of myocardial damage or cardiac dysfunction. Similarly, fat embolism syndrome is unlikely to occur after a minor foot fracture. Although heroin overdose has frequently been reported to cause opiate-related pulmonary edema, meperidine has not been associated with pulmonary edema on literature review. No evidence of aspiration was noted on close observation, and pulmonary infection is unlikely, given the context of clinical onset, prompt resolution of clinical and radiographic abnormalities over two days, and a negative infection-related workup. Diffuse alveolar hemorrhage can have similar initial presentation. However, diffuse infiltrates without change in hemoglobin and prompt clinical and radiographic resolution with supportive treatment makes this diagnosis implausible.

Acute pulmonary edema as an adverse effect of intravenous propofol has rarely been reported,[2-5] as detailed in the table. Both male and female patients were described with ages ranging between 10 months to 61 years. Pulmonary

Table. Clinical characteristics of patients with propofol-associated pulmonary edema.

	Authors				
Variables	Tsai (2)	Tsutsumi (3)	Inal (4)	Tai (5)	Waheed
Age (years)	35	61	35	10 month	23
Gender	Male	Female	Female	Male	Male
Weight (kg)	NR[a]	49	75	9.5	66
Comorbidities	Nasopharyngeal cancer	Hypertension	None	NR	None
Setting	OR[b]	Psychiatry unit	ICU[c]	ICU	ED[d]
Total propofol dose (mg)	400	80	300	40	350
Indication for propofol	Central venous line insertion	ECT[e]	Caeserean section	Gastrointestinal endoscopy	Splinting of foot fracture
Time to onset[f]	60min	NR	45min	Approx. 30-45min	60 minutes
Tracheal secretions. Key clinical manifestations	Frothy whitish sputum. Hypoxemia, hypotension	Foamy white. Hypoxemia	NR. Hypoxemia, hypotension	Frothy pink fluid. Hypoxemia, tachypnea, bradycardia, skin rash	Hemoptysis. Hypoxemia, cough
Chest Radiography	Bilateral alveolar infiltrates	Butterfly pattern	Bilateral diffuse airspace infiltrates	Butterfly pattern	Patchy bilateral infiltrates
Mechanical ventilation[g]	Yes, initiated	Yes, initiated	Yes, continued	Yes, continued	None
Pharmacological interventions for pulmonary edema	Steroids, dopamine, epinephrine, antibiotics	Diuretics, dopamine	NR	Epinephrine	Diuretics, antibiotics
Time to clinical resolution	5 days	4 days	NR	9 hours	2 days

[a]Not Reported [b]Operating room [c]Intensive Care Unit [d]Emergency Department [e]Electroconvulsive therapy [f]From completion of propofol administration to first manifestation of pulmonary edema [g]During propofol administration, either continued or initiated afterwards.

edema pattern developed within 30 minutes to one hour and was associated with a varying severity of hypoxic and hypercarbic respiratory failure, requiring initiation and continuation of mechanical ventilation. Clinical and radiographic resolution occurred within five days.

The pathogenesis of pulmonary edema associated with propofol remains unclear, although anaphylactoid reaction is the most frequently postulated hypothesis.[2,4,5,13] Propofol contains a diisopropyl chain and a phenol group, both of which have the potential to elicit an allergic reaction.[14] An anaphylactoid reaction may increase vascular permeability and result in acute pulmonary edema. In addition, propofol has been shown to have significant vasodilator activity in the pulmonary vasculature in rats.[15] These mechanisms may contribute to the development of pulmonary edema.

Given the uncertain pathogenesis, with no definite risk factors, no specific preventive steps can be taken beyond contemporary monitoring approach. Increased clinician awareness of this uncommon complication of propofol administration may help improve our understanding of the scope and underlying disease process. Pulmonary edema is a rare complication associated with propofol. Close monitoring and vigilance are required for early recognition and appropriate emergent treatment of associated complications. Further studies are needed to examine the epidemiology of propofol-associated pulmonary edema, its underlying mechanisms, and possible preventive measures.

Address for Correspondence: Mian Adnan Waheed MD, Texas Tech University Health Science Center, Department of Internal Medicine, 701 West 5th Street, Odessa, Texas 79763. Email: Mian.waheed@ttuhsc.edu.

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High Altitude Pulmonary Edema in an Experienced Mountaineer. Possible Genetic Predisposition

Kenneth S. Whitlow, DO[*]
Babette W. Davis, DO, MPH[†]

[*] Kaweah Delta Medical Center, Department of Emergency Medicine, Visalia, California
[†] Baystate Medical Center, Department of Emergency Medicine, Springfield, Massachusetts

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High altitude pulmonary edema (HAPE) is a form of high altitude illness characterized by cough, dyspnea upon exertion progressing to dyspnea at rest and eventual death, seen in patients who ascend over 2,500 meters, particularly if that ascent is rapid. This case describes a patient with no prior history of HAPE and extensive experience hiking above 2,500 meters who developed progressive dyspnea and cough while ascending to 3,200 meters. His risk factors included rapid ascent, high altitude, male sex, and a possible genetic predisposition for HAPE. [West J Emerg Med. 2014;15(7):849–851.]

INTRODUCTION

High altitude illness (HAI) is a spectrum of conditions characterized by the nausea, vomiting, and sleep disturbances typical of acute mountain sickness (AMS), the ataxia and eventual coma seen in high altitude cerebral edema (HACE), and the cough, dyspnea, and eventual death typical of high altitude pulmonary edema (HAPE).[1] Though uncommon, HAPE is a potentially life-threatening non-cardiogenic pulmonary edema that occurs within 2-4 days after rapid ascent above 2,500 meters (8,000 feet) (Figure).[2] Clinically, the patient will be afebrile and have one or more of the following: tachypnea, hypoxemia with an oxygen saturation 10 points lower than expected after correcting for altitude, and inspiratory crackles in the right middle lobe which become diffuse as the process progresses. Known risk factors include male sex, cold environmental temperatures, vigorous exertion, and preexisting conditions.[3] Evidence suggests that genetics may also play a role.[3] HAPE is best treated with simulated or actual descent, nifedipine, or hydralazine. If left untreated, death will ensue.

CASE REPORT

A 25-year-old previously healthy Caucasian male was evacuated from 3,200 meters after experiencing nausea, headache, shortness of breath, and cough. The patient, who frequently enjoyed short mountaineering trips from his home at sea level, had been at altitude the previous weekend with no concerns. On the first day of ascent his group had slept at 1,800 meters and ascended to 3,200 meters on day two. Subsequently the patient felt malaised and experienced a cough. Later on day two he developed nausea and insomnia. By the morning of day three his cough worsened and progressed to frank shortness of breath, but he refused to descend. As the day progressed so did his symptoms, he was

Figure. Incidence and risk factors for high altitude pulmonary edema (HAPE).

no longer able to self-descend and was airlifted to base and transported to a community academic emergency department (ED) approximately one hour away.

During transport he reported complete resolution of his headache and nausea immediately after landing at base altitude but continued to complain of progressively worsening dyspnea despite high-flow oxygen via non-rebreather mask. His vital signs on arrival in the ED were: temperature: 98.6°F, heart rate: 86, blood pressure 131/76, respiratory rate: 20, and oxygen saturation 80% on room air, which represented an improvement from prehospital saturations between 60-70%. On exam he had diffusely coarse breath sounds, audible without a stethoscope, with use of accessory muscles, but was otherwise well appearing. He was given 100% oxygen, albuterol and ipratropium nebulizers, inhaled and intravenous dexamethasone, 5mg of intravenous hydralazine, and 40mEq of intravenous furosemide. Subsequently his oxygen saturations improved to the mid 90s on two liters of oxygen via nasal cannula, and his breath sounds and respiratory effort improved substantially. He was placed in observation, was continued on intravenous dexamethasone, and was successfully discharged the next day. After discharge the patient's father remembered that he had been forced to abort a hiking trip at altitude as a young man due to sudden onset of "asthma," a condition of which he had no prior diagnosis.

DISCUSSION

This patient presented with a near-classical presentation of HAPE. As with 50% of HAPE patients, he also exhibited symptoms of AMS manifesting as nausea and poor sleep,[3] which was a probable manifestation of periodic breathing of altitude, a phenomenon where the hypoxia and alkalosis of altitude result in Cheyne-Stokes respiration that can disrupt sleep.[3,4] His risk factors for HAPE included rapidly attaining high altitude from his baseline of sea level, male sex, and possible genetic predisposition.[3]

HAPE is believed to be precipitated by the hypobaric hypoxemia of ascent resulting in a poor ventilatory response and increased sympathetic tone with mean pulmonary artery pressures above 35mmHg. The resultant pulmonary hypertension is coupled with inadequate production of endothelial nitric oxide and an overproduction of endothelin, resulting in disruption of the alveolar-capillary barrier.[5] High molecular weight proteins, cells, and fluid enter the alveolar space with eventual alveolar hemorrhage. In the patient this is manifested as a non-productive cough, mild dyspnea on exertion, and difficulty ascending.[3] This progresses to dyspnea at rest; pink, frothy sputum that may include frank blood; and drowsiness. Lab studies may show an increased white blood cell count with a normal brain natriuretic peptide, likely ruling out cardiogenic pulmonary edema. The history will most likely differentiate HAPE from pneumonia.

Although this patient had no prior symptoms of HAPE despite his frequent mountaineering, his father described having what he believed was acute asthma while climbing, and genetics appear to be a risk factor for HAPE.[6,7] It is believed that the renin-angiotensin-aldosterone system, nitric oxide pathway, and hypoxia-inducible factor pathway, are controlled by genes that differ in HAPE-susceptible patients.[6] Other studies provide evidence of mitochondrial DNA[8] or heat shock protein[9] polymorphisms in HAPE-susceptible individuals or differences within the major histocompatibility complex.[10] Although the genetic connection is not yet clearly established by the research, these and future studies may help to better explain our patient's risk, protecting his offspring in future generations.

A patient developing any form of HAI is best treated with descent.[2] The goal with HAPE patients, however, is to reduce the pulmonary artery pressure. This is best achieved with supplemental oxygen, which may be available before initiating descent. Rest and limiting cold exposure will also be beneficial.[3] Descent, either with minimal effort by the patient (e.g., via air or ground evacuation versus self-descent) or simulated descent through the use of a hyperbaric chamber, will further reduce pulmonary pressures. Pharmacologic treatment focuses on reducing pulmonary artery resistance. Nifedipine or hydralazine have shown to be of benefit, particularly if oxygen therapy is unavailable. As arterial vasodilators, they will reduce pulmonary vascular resistance, pulmonary artery pressure, systemic vascular resistance and blood pressure while improving arterial oxygenation pressure. Although there is currently evidence for the use of phosphodiesterase inhibitors, dexamethasone, salmeterol, and acetazolamide in HAPE prophylaxis, there is no current evidence supporting their use as treatment once HAPE has developed.

Advice given to any patient with previous HAPE includes gradual ascent with acclimation to elevation. Nifedipine, tadalafil, sildenafil, dexamethasone, acetazolamide, or salmeterol may be used prophylactically. Nifedipine should be carried for potential self-administered treatment.[2] A portable pulse oximeter is a small and relatively inexpensive monitoring device that a previous HAPE patient can easily carry and use for early detection of disease provided they have been instructed in its interpretation at altitude. More complex solutions include portable oxygen and hyperbaric tents. Knowledge of the nearest available oxygen, hyperbaric tent, and evacuation resources may be a more realistic safety plan and exit strategy.

Address for Correspondence: Kenneth S. Whitlow, Baystate Medical Center, Department of Emergency Medicine, 759 Chestnut Street, Springfield, MA 0199. Email: witdavis@gmail.com.

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A Gut Feeling: An Extremely Rare Case of Missed Appendicitis

Ashley Pilgrim, MD*
Rachel Russo, MD†
Aimee Moulin, MD*

* University of California Davis, Department of Emergency Medicine, Sacramento, California
† University of California Davis, Department of Surgery, Sacramento, California

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This case outlines the emergency department and surgical course of a 63-year-old male presenting with acute onset abdominal pain. Appendicitis was high on the differential for the treating physician, but after the computed tomography and laboratory evaluation were unremarkable, the patient was discharged only to return the next day. What ensued was one of the rarest cases of missed appendicitis documented in the medical literature. [West J Emerg Med. 2014;15(7):852-854.]

INTRODUCTION

Acute appendicitis is almost always on the differential for nearly every patient presenting to the emergency department (ED) with abdominal pain. A myriad of decision rules have been created to help guide our diagnostic approach; however, most have proven to be either insensitive, non-specific or too rigorous to be practical in a busy ED setting. Many of us rely on our gestalt and hope that our imaging of choice, often a computed tomography (CT), will help confirm our suspicion. Here we present a case of a 63-year-old male presenting with right lower quadrant pain with a subsequently negative CT found to have an acute ruptured appendicitis on return visit the following day.

CASE REPORT

A 63-year-old male presented to the ED twice in two days with severe abdominal pain. At the first visit, the patient was seen in the ED with initial complaint of acute onset right lower quadrant pain. The pain woke him up from sleep and was described as sharp, 10/10, constant, and worsened by any movement. The patient denied any other associated symptoms, including fevers, vomiting, appetite change, or urinary symptoms. On exam, the patient was afebrile, heart rate of 76, blood pressure of 132/77, and normal respiratory rate and oxygen saturation. He was noted to be grunting due to pain, diffusely tender to palpation in the abdomen but worse in the right lower quadrant, and had a positive obturator sign. He also had a partially reducible, non-tender umbilical hernia.

The patient's past medical history was significant for atrial fibrillation on Warfarin, obesity, diabetes mellitus, and peptic ulcer disease.

Laboratory findings were unremarkable, including a normal white blood cell count, liver function tests, lipase, and urinalysis.

A CT abdomen and pelvis with IV contrast was performed to rule out appendicitis. Unfortunately, the radiologist was unable to visualize the appendix; however, he commented that there were no secondary signs of appendicitis. The radiologist also noted an incidental finding of a bowel containing umbilical hernia without evidence of strangulation or bowel obstruction (Figure 1). The patient was discharged home after a five-hour observation period in stable condition.

The patient returned to the ED approximately 25 hours after discharge with acutely worsening abdominal pain now primarily focused in the periumbilical region. Further history was limited as the patient was moaning in pain and appeared to be in extremis. The patient was now tachycardic to 103, but otherwise vital signs were within the normal range. On exam, the patient was now noted to have a moderately tender, firm umbilical hernia with overlying skin erythema.

Acute Care Surgery was immediately consulted for concerns of a strangulated umbilical hernia. They were at the bedside within minutes and elected to take the patient to the operating room urgently following Warfarin reversal with fresh frozen plasma.

In the operating room, the hernia sac was opened and found to contain a perforated appendix with abscess formation. The patient was found to have a very long appendix with the tip lying within the umbilical hernia sac,

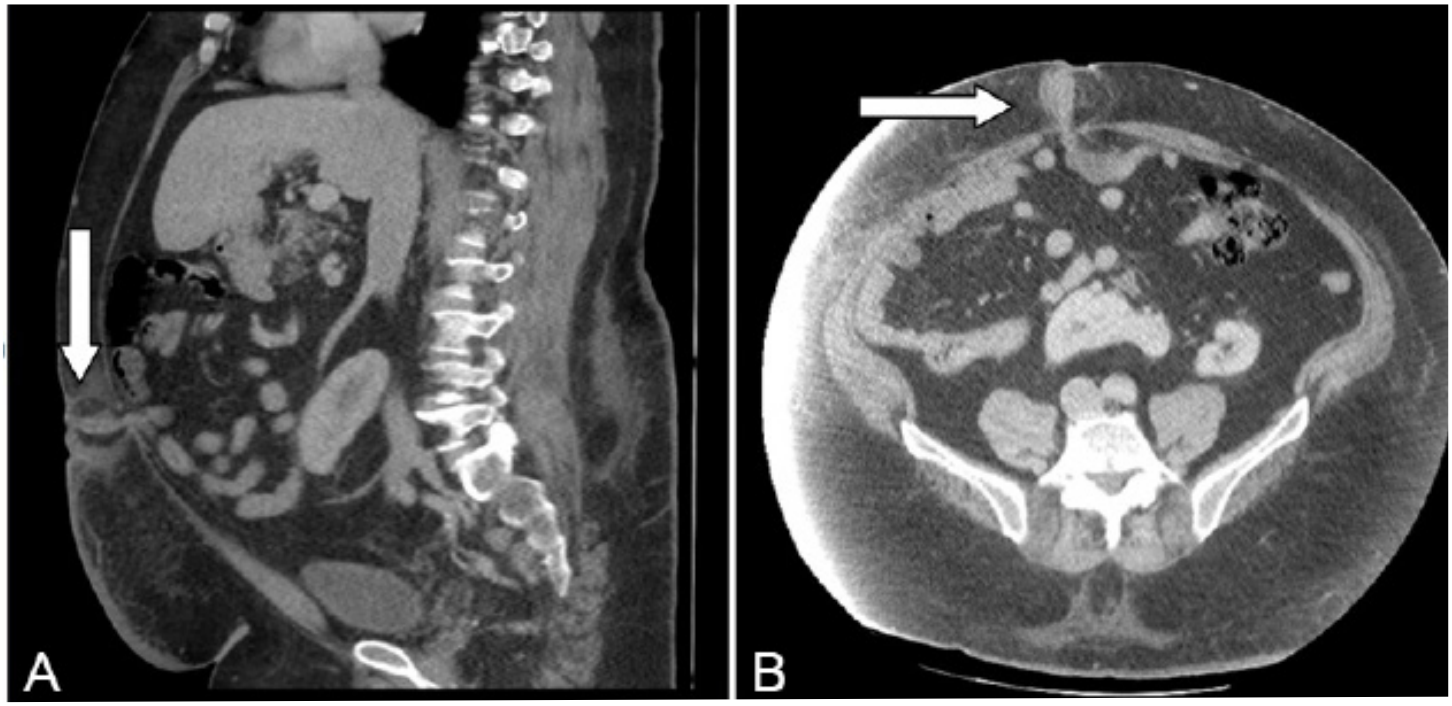

Figure 1. A & B, Arrows illustrating sagital and axial views of appendix entering umbilical hernia sac.

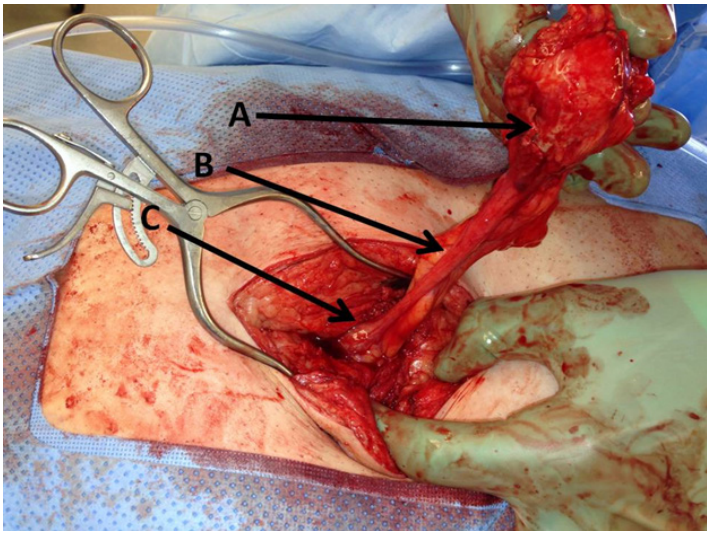

Figure 2. Limited midline laparotomy revealing umbilical hernia sac containing the perforated tip of the appendix. A, Perforation at the tip of the appendix with inflamed mesoappendix within the hernia sac. B, Body of appendix. C, Base of the appendix, joining the cecum.

surrounded by thickened omentum (Figure 2). The patient next underwent an open appendectomy with umbilical hernia repair without the use of mesh. The incision was left open to heal by secondary intention. Intraoperative wound cultures were obtained and enterococcus raffinosus and streptococcus anginosus were isolated.

The patient had a relatively uneventful post-operative course. The patient was discharged five days later with a wound vacuum assisted closure (VAC) in place and given a 10-day course of ciprofloxacin and flagyl. In the following several weeks, the patient was reportedly doing well, but wound VAC remained in place to promote wound healing.

DISCUSSION

The presence of an appendix within a hernia sac is a relatively rare phenomenon. This was described first by Jacques Croissant de Garengeot in 1731 after discovering a vermiform appendix located within a femoral hernia.[1] Claudius Amyand four years later described the first known instance of an appendix within an inguinal hernia sac on an 11-year-old boy.[2] Appendices located within a femoral hernia or an inguinal hernia sac are now more commonly referred to by their eponyms, de Garengeot and Amyand's hernias, respectively. The presence of acute appendicitis within an inguinal hernia is reported to be as low as 0.08%.[3] The presence of appendicitis within a umbilical hernia is even rarer. To the best of our knowledge, there have been less than a handful of case reports in adults describing the presence of appendicitis within an umbilical or paraumbilical hernia sac. It was first described by Doig[4] in 1970, later by Al-Qahtanit[5] in 2003, and most recently by Agarwal[6] in 2013. All were single-patient case reports. There is only one reported occurrence in the English literature in a child, described in 2008 by Atabek,[7] in which he found an acute appendicitis within an umbilical hernia sac in a 25-day-old infant.

The finding of appendicitis within a hernia sac is almost always found in the operating room. Patients usually present with acute onset abdominal pain with exam findings highly suspicious for a strangulated hernia.

Hernias are often tender, firm, and may have overlying skin changes. However, if imaging is obtained, there will not be radiologic evidence of a bowel obstruction. Now with the increased use of high resolution CT scanners, it is possible to diagnose appendicitis within a hernia sac prior to the operating room. The first CT radiographic evidence of appendicitis within an umbilical hernia was described by Arnaiz[8] in 2006. Unfortunately, this was not the case for our patient whose appendix was not identified on CT from the day prior. Park et al.[9] reports the overall sensitivity of CT for diagnosis of acute appendicitis is 96.4%, meaning nearly 4% of acute appendicitis will be missed with CT alone. This highlights not only the importance of a thorough history and physical, but also the importance of providing strict and detailed return precautions for our patients being considered for discharge. Retrospective analysis of the CT on our patient did in fact reveal malrotation, colon isolated to the left hemi-abdomen, and the appendix entering the umbilical hernia with a very small amount of free fluid (Figure 1). It has been hypothesized that external compression of the appendix by the hernia leads to ischemia and subsequent appendicitis. Despite the initial delay in diagnosis, our patient is recovering well.

Address for Correspondence: Ashley Pilgrim, MD, 3018 Donner Way, Sacramento, CA 95817. Email: pilgrimashley@gmail.com.

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Diphenhydramine Overdose with Intraventricular Conduction Delay Treated with Hypertonic Sodium Bicarbonate and IV Lipid Emulsion

Amin Abdi, MD*
Emily Rose, MD*†
Michael Levine, MD*

*University of Southern California, Department of Emergency Medicine, Los Angeles, California
†University of Southern California, Department of Pediatrics, Los Angeles, California

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Diphenhydramine toxicity commonly manifests with antimuscarinic features, including dry mucous membranes, tachycardia, urinary retention, mydriasis, tachycardia, and encephalopathy. Severe toxicity can include seizures and intraventricular conduction delay. We present here a case of a 23-year-old male presenting with recurrent seizures, hypotension and wide complex tachycardia who had worsening toxicity despite treatment with sodium bicarbonate. The patient was ultimately treated with intravenous lipid emulsion therapy that was temporally associated with improvement in the QRS duration. We also review the current literature that supports lipid use in refractory diphenhydramine toxicity. [West J Emerg Med. 2014;15(7):855–858.]

INTRODUCTION

Diphenhydramine (DPH) overdoses are relatively common and frequently present with classic anticholinergic toxicity. In severe overdoses, seizures and intraventricular conduction delay can occur due to sodium channel blockade. Sodium bicarbonate has been the mainstay for DPH-induced sodium channel blockade. Recently an animal study demonstrated intravenous lipid emulsion therapy was equivalent to sodium bicarbonate in the treatment of DPH toxicity.[1] In addition, a single, confirmed case of DPH toxicity treated with intravenous lipid emulsion therapy has been reported.[2]

CASE REPORT

A 23-year-old male with no significant past medical history presented to the emergency department (ED) for evaluation of a witnessed ingestion of 2000-2500mg of DPH. Emergency medical services (EMS) was called approximately thirty minutes post ingestion. Upon arrival of EMS, the patient was obtunded. Ventilation was assisted by placement of a supraglotic airway. He had a witnessed, generalized tonic clonic seizure that lasted approximately thirty seconds, prompting the administration of 5mg of intravenous midazolam. His pre-hospital glucose was 122mg/dL.

Upon arrival in the ED, he was normothermic and had a blood pressure of 73/32mmHg with a heart rate of 145 beats per minute. Notable findings on his exam included pupils that were 6mm and sluggish bilaterally. He was unresponsive to painful stimuli and had no gag reflex and absent corneal reflexes but preserved occulo-cephalic reflex. He had normal muscle tone without pathologic plantar reflexes. His skin was dry.

His initial electrocardiogram (ECG, Figure 1) demonstrated sinus tachycardia with evidence of intraventricular conduction delay (QRS width of 172 msec,) along with a prolonged corrected QT interval (QTc of 577 msec). A venous blood gas revealed a pH of 6.83 with a pCO2 of 57mmHg. Serum chemistries were notable for the following: sodium 144 mmol/L, bicarbonate 10mmol/L, and chloride 111mmol/L (anion gap 19). A venous lactic acid was >20 mmol/L. His serum salicylate and acetaminophen concentrations were non-detectable. A urine drug screen was negative for cocaine or amphetamines, and a serum DPH level ultimately returned at 4100ng/mL (therapeutic range 50-100ng/mL).

Initially the patient underwent synchronized cardioversion twice for a hemodynamically unstable wide complex tachycardia. In addition, during the initial resuscitation the patient received 500mEq of sodium bicarbonate along with 4 liters 0.9% normal saline, 2g of magnesium sulfate, 10cc of 10% calcium gluconate, and was started on a bicarbonate infusion.

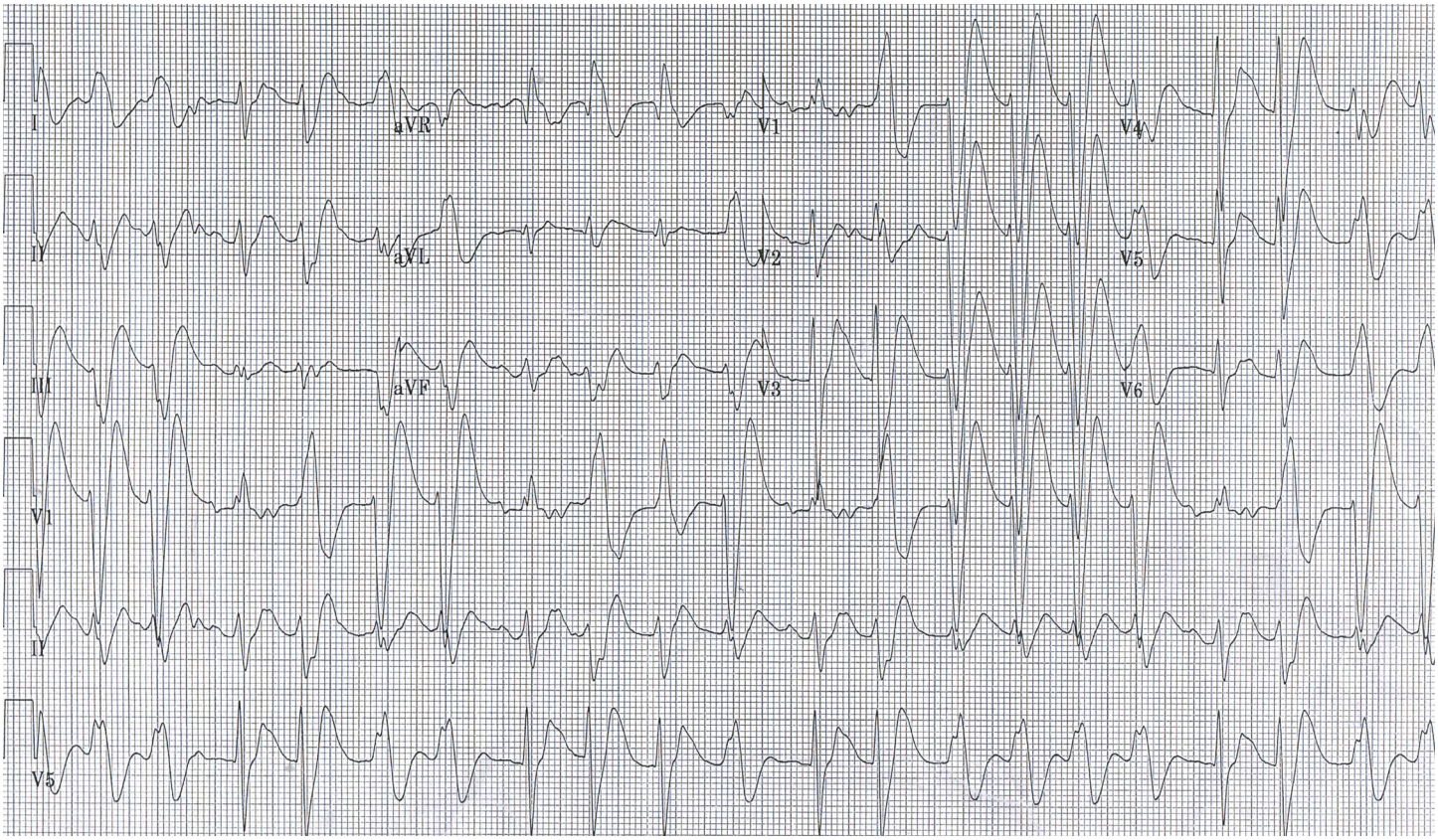

Figure 1. Initial electrocardiography on arrival of patient with probable diphenhydramine toxicity. Of note, the patient had significant intraventricular conduction delay.

Following the 500mEq sodium bicarbonate, an arterial blood gas revealed a pH of 7.44 with pCO2 of 45mmHg, PO2 of 334mmHg, and a bicarbonate of 32mmol/L. The sodium was 149mmol/L, potassium was 2.9mmol/L, and the lactic acid was improving to 13.8mmol/L. Because the ECG revealed continued intraventricular conduction delay (QRS 140msec), he was given additional 100mEq of sodium bicarbonate without effect. Despite this intervention, however, the patient began to have increased ventricular ectopy. He subsequently received 1.5cc/kg of 20% intravenous lipid emulsion without significant change in hemodynamics or QRS width. Approximately twenty minutes later, a second bolus of 1.5cc/kg of 20% lipid emulsion was administered. Approximately five minutes after the bolus, there was an abrupt discontinuation of the wide complex tachycardia, which narrowed to a sinus rhythm with a rate of 115 beats per minute and a QRS width of 106msec (Figure 2).

The patient's girlfriend arrived and confirmed the history of an ingestion of DPH. The patient was admitted to the intensive care unit. He was successfully extubated on hospital day 3. He had developed an elevated lipase without concurrent symptoms of pancreatitis. He was evaluated by psychiatry, and ultimately discharged from the acute-care setting.

DISCUSSION

Diphenhydramine is a widely available over-the-counter medication commonly used as a nocturnal sleep aid and a cold/allergy medication due to its anti-histaminergic and anti-cholinergic effects. While commonly thought of as an antagonist of the H1 receptors, it is more accurately considered an inverse agonist since it induces a conformational change in the receptor and stabilizes the inactive form of the receptor.[3,4]

In mild overdoses DPH can cause sedation and symptoms attributable to the classic antimuscarinic toxidrome, namely tachycardia, mydriasis, urinary retention, dry mucosal membranes with flushed skin, and hypoactive bowel sounds. Moderate or severe ingestions can have central antimuscarinic features as well, including agitation, delirium, hallucinations, or coma.[5] In addition, DPH toxicity can induce rhabdomyolysis.[6-8] However, in severe overdoses DPH inhibits sodium channels, similar to Vaughan Williams 1a antiarrhythmics.[9,10] This inhibition typically manifests as a wide complex tachycardia.[10,11] Infrequently, DPH-induced sodium channel blockade can manifest as a Brugada pattern.[12,13]

Despite the antimuscarinic properties of DPH, the use of phyostigmine was contraindicated because of both the history of the seizure, as well as the intraventricular conduction delay. Similar to all drug-induced sodium channel blockade, the intraventricular conduction delay associated with DPH overdose should be treated with intravenous sodium bicarbonate.[10,11] This patient had received 500 mEq

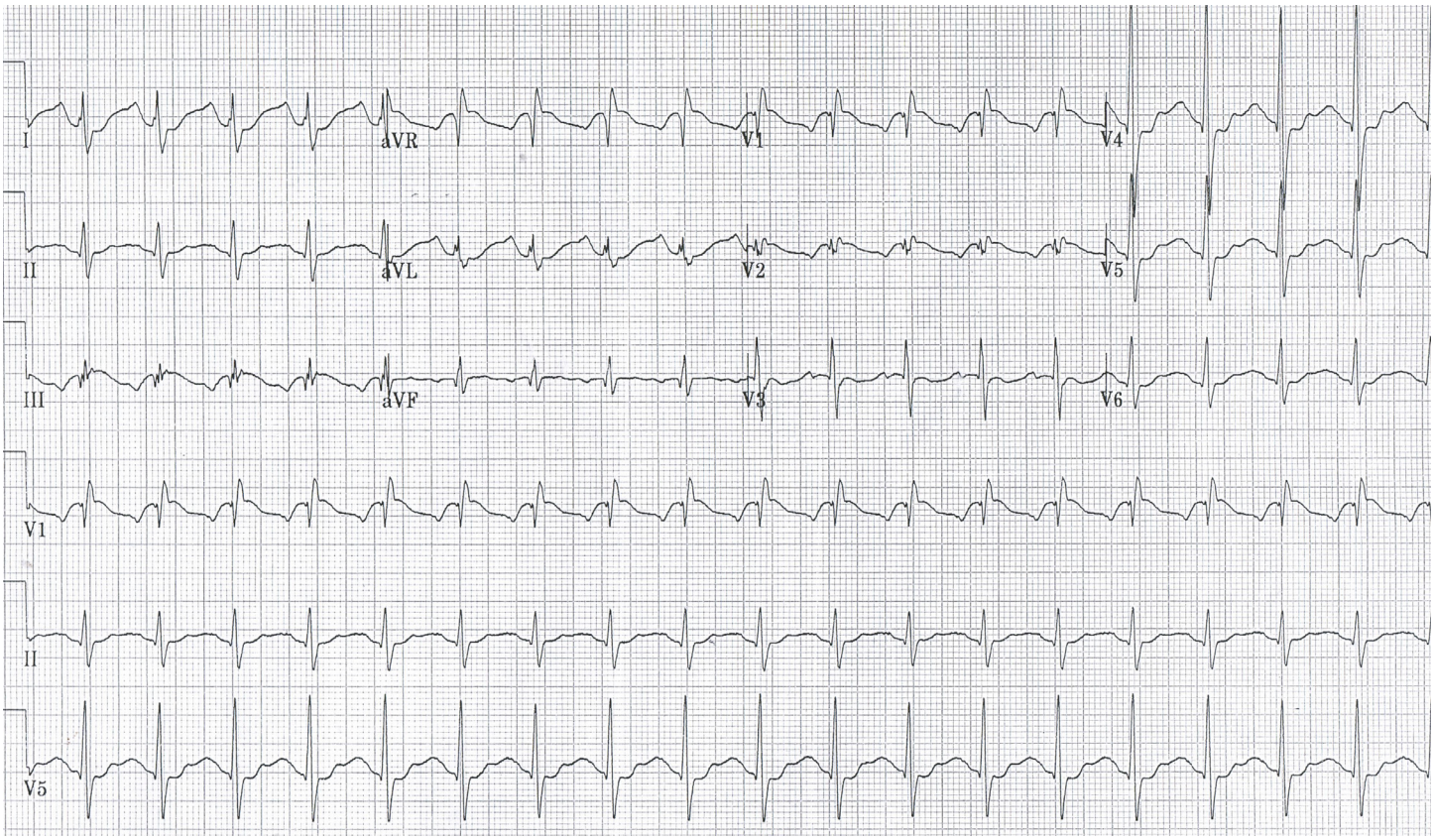

Figure 2. Electrocardiography following the second bolus of ILE. There is significant narrowing of the QRS complex.
ILE, intravenous lipid emulsion

of sodium bicarbonate and had documented hypokalemia. Additional bicarbonate was administered, and increased ectopy occurred, prompting concern that additional sodium bicarbonate might induce further hypokalemia and thus more ectopy. Consequently, the decision was made to administer intravenous lipid emulsion therapy.

Lipid emulsion therapy has been used as an adjunctive therapy in the management of lipophilic drug toxicity. It is postulated that intravenous lipid emulsion therapy provides a "lipid sink" that partitions the toxic, lipophilic drug, effectively sequestering the drug out of the periphery.[5,14,15]

Intravenous lipid emulsion (ILE) therapy for DPH has only rarely been described. Varney and colleagues performed an animal study in which DPH toxicity was created in 24 swine.[1] Twelve were randomized to receive 7ml/kg bolus of ILE followed by a continuous infusion of 0.25ml/kg/min or 2mEq/kg of sodium bicarbonate plus an equal volume of normal saline. No significant difference was observed between ILE and sodium bicarbonate with regards to cardiac output, systemic vascular resistance, or QRS intervals. It should be noted that the patient in this report received much more sodium bicarbonate but less ILE compared with the doses administered in Varney's study. It is not clear if the dose discrepancy accounted for beneficial effects seen in this patient, but not in their study.

Two published abstracts describe ILE use for a reported DPH ingestion. Jolliff and colleagues published a case of a 42-year-old female who presented in cardiac arrest after ingesting acetaminophen/DPH tablets (estimated 1250-2500mg DPH).[16] The patient was hypoglyocemic (glucose 28mg/dL) and received multiple standard medications, including epinephrine and atropine. The patient received 50 mEq of sodium bicarbonate without effect and ultimately ILE was administered with transient return of spontaneous circulation, although the patient ultimately died. No confirmatory testing was reported. A second case of DPH toxicity treated with ILE was published by Schwarz in which a 30-year-old female was found altered after a presumed overdose. She was tachycardic and appeared anticholinergic.[2] She developed status epilepticus, hypotension, and wide complex tachycardia resistant to cardioversion and amiodarone, followed by cardiac arrest which responded to epinephrine, lidocaine, and 200mEq of sodium bicarbonate. She was hypotensive requiring norepinephrine infusions. She received ILE followed by improved hemodynamics.

The use of ILE has been increasing. While its exact mechanism of action has yet to be determined, one of the prevailing theories involves increasing the lipid concentration intravascularly, with a subsequent shift of lipophilic drugs from the periphery into the vascular compartment.[17] This theory, often referred to as the lipid sink theory, explains

the apparent improvement in clinical toxicity from a variety of lipophilic drugs following the administration of ILE. However, its use is not without side effects, which include laboratory interference, pancreatitis, and possibly acute respiratory distress syndrome (ARDS).[18]

This case has several potential limitations. While the history of isolated DPH ingestion was obtained, and the serum DPH level is consistent with overdose, it is possible other sodium channel blocking agents were not detected, and contributed to the wide complex tachycardia. However, the girlfriend's history of DPH ingestion, along with an empty pill bottle of DPH and the elevated level, makes this less likely. There was a temporal improvement in the intraventricular conduction delay after ILE; this improvement can only be considered to be temporally associated, and causality cannot be determined. Other interventions were being administered to this patient as well. However, the magnesium had been completed almost thirty minutes prior to the first dose of ILE, and no additional sodium bicarbonate was given immediately before or after the ILE. Thus, it is unlikely that either the bicarbonate or the magnesium were the cause of the reduction in the QRS duration.

CONCLUSION

This report describes a case of DPH toxicity treated with sodium bicarbonate and ultimately ILE. To our knowledge, this is only the second case of ILE for DPH toxicity (with confirmed levels) described. Intravenous lipid emulsion therapy may be a viable treatment option in cases with DPH toxicity persisting despite the treatment with sodium bicarbonate.

Address for Correspondence: Michael Levine, MD, Department of Emergency Medicine, Section of Medical Toxicology. University of Southern California, 1200 North State Street, Room 1011, Los Angeles, CA 90033. Email: mdlevine@usc.edu

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Diagnosing Appendicitis: Evidence-Based Review of the Diagnostic Approach in 2014

Daniel J. Shogilev, MD*
Nicolaj Duus, MD†
Stephen R. Odom, MD‡
Nathan I. Shapiro, MD, MPH§

* Duke University, Division of Emergency Medicine, Duke University, Durham, North Carolina
† Beth Israel Deaconess Medical Center, Department of Emergency Medicine, Boston, Massachusetts
‡ Beth Israel Deaconess Medical Center, Department of Surgery, Boston, Massachusetts
§ Beth Israel Deaconess Medical Center, Department of Emergency Medicine and Center for Vascular Biology, Boston, Massachusetts

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Introduction: Acute appendicitis is the most common abdominal emergency requiring emergency surgery. However, the diagnosis is often challenging and the decision to operate, observe or further work-up a patient is often unclear. The utility of clinical scoring systems (namely the Alvarado score), laboratory markers, and the development of novel markers in the diagnosis of appendicitis remains controversial. This article presents an update on the diagnostic approach to appendicitis through an evidence-based review.

Methods: We performed a broad Medline search of radiological imaging, the Alvarado score, common laboratory markers, and novel markers in patients with suspected appendicitis.

Results: Computed tomography (CT) is the most accurate mode of imaging for suspected cases of appendicitis, but the associated increase in radiation exposure is problematic. The Alvarado score is a clinical scoring system that is used to predict the likelihood of appendicitis based on signs, symptoms and laboratory data. It can help risk stratify patients with suspected appendicitis and potentially decrease the use of CT imaging in patients with certain Alvarado scores. White blood cell (WBC), C-reactive protein (CRP), granulocyte count and proportion of polymorphonuclear (PMN) cells are frequently elevated in patients with appendicitis, but are insufficient on their own as a diagnostic modality. When multiple markers are used in combination their diagnostic utility is greatly increased. Several novel markers have been proposed to aid in the diagnosis of appendicitis; however, while promising, most are only in the preliminary stages of being studied.

Conclusion: While CT is the most accurate mode of imaging in suspected appendicitis, the accompanying radiation is a concern. Ultrasound may help in the diagnosis while decreasing the need for CT in certain circumstances. The Alvarado Score has good diagnostic utility at specific cutoff points. Laboratory markers have very limited diagnostic utility on their own but show promise when used in combination. Further studies are warranted for laboratory markers in combination and to validate potential novel markers. [West J Emerg Med. 2014;15(7):859–871.]

INTRODUCTION

Acute appendicitis is the most common abdominal emergency requiring surgery with an estimated lifetime prevalence of 7%.[1] Despite its high prevalence, the diagnosis of appendicitis remains challenging. The diagnosis of appendicitis embodies Sir William Osler's spirit when he

stated, "Medicine is a science of uncertainty and an art of probability." The clinical presentation is often atypical and the diagnosis is especially difficult because symptoms often overlap with other conditions.[2] The fundamental clinical decision in the diagnosis of a patient with suspected appendicitis is whether to operate or not. Ideally, the goal is to expeditiously treat all cases of appendicitis without unnecessary surgical interventions. A 2001 study reported negative appendectomy rates between 15% and 34% with approximately 15% being commonly accepted as appropriate to reduce the incidence of perforation.[3,4]

The meaningful evaluation of acute appendicitis balances early operative intervention in hopes of preventing perforation against a more restricted approach with the hope of reducing the risk of unnecessary surgery. Additionally, physicians must consider the accuracy, delay-to-surgery, and radiation risks of using computed tomography (CT) imaging, as well as the reliability of laboratory results and clinical scoring systems. Lastly, physicians' actions are often unfortunately influenced by malpractice litigation as appendicitis is one of the most frequent medical conditions associated with litigation against emergency department (ED) physicians with claims paid to patients in up to one third of cases.[5,6]

The goal of this article is to present the reader with an update on the diagnostic approach to appendicitis by providing an evidence-based review of radiological imaging, clinical scoring systems, laboratory testing, and novel biomarkers for appendicitis.

METHODS

We did a broad PubMed search using the follow key phrases: "diagnosis of appendicitis", "imaging AND appendicitis", "CT AND appendicitis", "US AND appendicitis" , "laboratory markers in appendicitis", "Alvarado score" and "novel markers in appendicitis." We searched meta-analysis, systematic reviews, reviews and clinical trials dating back to 2000. Only published research was used in our paper. We also conducted a secondary source search on the most relevant articles. Since many meta-analyses are available, we focus on these, but also include relevant single publication data. Our focus is on bringing the reader up to date in this rapidly evolving field.

Radiological Imaging

Technological advances and an increase in availability of CT have fundamentally changed the approach to appendicitis. In a 2011 study of 2,871 patients, multi-detector CT had a sensitivity of 98.5% and a specificity of 98%.[7] Similarly, another 2006 meta-analysis consisting of data from 31 studies and 4341 patients yielded both a sensitivity and specificity of 94%.[8] A 2011 meta-analysis made up of 28 studies comprising 9,330 patients found that the negative appendectomy rate was 8.7% when using CT compared to 16.7% when using clinical evaluation alone.[9] Similarly, this study also demonstrated a significantly higher negative appendectomy rate during the pre-CT era compared to the post-CT era (10% vs. 21.5%).[9] Interestingly, the incidence of appendiceal perforation, the most significant complication of appendicitis, was reported as unchanged by the use of CT.[9]

A 2007 systematic review (25 studies and 9,121 patients) examining ultrasound (US) in the diagnosis of equivocal acute appendicitis yielded a sensitivity of 83.7% and a specificity of 95.9%.[10] Similarly, a 2006 meta-analysis found similar results in both children and adults.[8] A long-standing criticism of US use in the diagnosis of appendicitis is that it is less accurate than CT and user-dependent. This criticism was evident in a pooled study of surgeon-performed US imaging in cases of suspected appendicitis where considerable inter- and intra-observer heterogeneity was seen. While this was largely attributed to the operator-dependent variability of US, it also likely reflected the resolution spectrum seen in bedside ultrasound machines compared to higher-resolution machines in radiology departments.[11]

The improvement in diagnostic accuracy with widespread adoption of CT for appendicitis comes with the concerns over increased radiation exposure and long-term cancer risks. One study estimated that there would be approximately 29,000 future cancers related to CTs performed in the year 2007, alone, with the largest proportion coming from scans of the abdomen/pelvis, the scan of choice in suspected appendicitis.[12] Another study estimated that there would be the development of a radiation-associated cancer for every 620 males and every 470 females who received abdomen/pelvic CT with contrast at the age of 20. For those undergoing this type of CT at the age of 60, it was estimated that 1 in 1,250 males and 1 in 1,320 females would develop CT radiation-associated cancers.[13]

Efforts to avoid the disadvantages of CT while maintaining diagnostic accuracy are warranted. One popular strategy, particularly in the pediatric population, is to perform US as the initial radiologic step in the diagnosis of appendicitis because of ability to "rule in" appendicitis if positive. If clear signs of appendicitis are present, then surgery is performed without the need for CT. Due to US's limited sensitivity, a negative or equivocal result cannot be used to "rule out" appendicitis, and CT is employed. Poortman et al. followed this protocol in their study of 151 patients with suspected appendicitis. US was positive for 79 patients, and 71 of them had acute appendicitis. Those who had a negative or inconclusive US, underwent CT, of which 21 were positive for appendicitis (verified in surgery).[14] In a large pediatric study of 620 children with equivocal US findings, some patients received a follow-up CT while others were observed. Here, there were no known missed diagnosis of appendicitis.[15] More recently, a 2014 study of 662 patients under 18 with suspected appendicitis compared CT with a radiation free US-magnetic resonance imaging (MRI) protocol (similar to that of US-CT protocol). They found this US-MRI protocol and CT to have no significant differences in time to antibiotic

administration, time to appendectomy, negative appendectomy rate, perforation rate or length of stay.[16] In-depth research to help discern an optimal strategy combining US, CT and even MRI is warranted since it has the potential of reducing costs and radiation exposure while maintaining a low negative appendectomy rate.

Efforts have also been made to limit CT's high radiation levels with low-dose CT imaging. Kim et al. examined the use of this low-dose abdominal CT for evaluating suspected appendicitis. In their single-center study of 891 adolescents and young adults, they demonstrated that low dose CT (which used 1/4th of the standard radiation) and standard CT had a similar negative appendectomy rates and no major differences in perforation rates.[17] Other smaller studies have yielded similar results,[18,19] and there is currently at least one large, multicenter randomized control trial underway.[20]

The Alvarado Scoring System

The Alvarado score is a clinical scoring system used to stratify the risk of appendicitis in patients presenting with abdominal pain. Alvarado's original work was published in 1988 and is based on his retrospective data analysis of 305 patients presenting with abdominal pain suggestive of acute appendicitis. This study found eight predictive factors of diagnostic value in acute appendicitis and assigned each factor a value of 1 or 2 based on their diagnostic weight. A score of 1 was given for each of the following: elevated temperature >37.3°C, rebound tenderness, migration of pain to right lower quadrant (RLQ), anorexia, nausea or vomiting, and leukocyte left shift. A score of 2 was given for RLQ tenderness and leukocytosis >10 000. The likelihood of appendicitis and specific management recommendations are given based on the total score. A score of 5 or 6 is "compatible" with the diagnosis of acute appendicitis and recommends the clinician observe or serially examine the patient. A score of 7 or 8 is "probable" appendicitis and a score of 9 or 10 is "very probable" appendicitis and recommends surgical intervention.[21]

Ironically, the results in subsequent validation studies of the Alvarado score largely outperform the original study's findings and provide the major support for consideration of the rule in clinical practice. In a meta-analysis by Ohle et al.[22] conducted in 2011, a review of 29 studies including 5,960 subjects revealed that for a cutoff of 5 (criteria to observe/admit) there was a sensitivity of 99% (95% CI: 97-99%) and specificity of 43% (36-51%). At a cutoff of 7 (criteria to proceed directly to surgery) sensitivity was 82% (76-86%) and specificity was 81% (76-85%). Based on these results, the authors argue that using a cutoff score of 5 or lower provides a good "ruling out" score, while a cutoff of 7 is not sufficiently specific enough to provide an adequate "ruling in" score.[22] However, several other smaller studies did not find such a high sensitivity. A 2007 retrospective study of 150 patients aged 7 and older who presented to the ED with abdominal pain found that 5% of patients with a score of 3 or less had appendicitis, as did 36% of patients with a score between 4-6.[23] Similarly, in a retrospective study of 215 adults and children who presented with acute abdominal pain, Gwynn et al.[1] found that 8.4% (12 of 143) of subjects with appendicitis had an Alvarado score below 5. Another retrospective study of 156 children found that 9% of subjects with complicated appendicitis would have been overlooked with the use of the Alvarado score.[24]

What can we conclude from this? Based on the results of the aforementioned 2011 meta-analysis we can conclude that since an Alvarado score of ≥5 had a sensitivity of 99%, this is a promising strategy for ruling out patients who are clinically at low risk for appendicitis. These patients may be observed clinically or with outpatient warnings as opposed to receiving an ED CT. Conversely, the specificity of the Alvarado score does not reliably determine the need for surgery without further clinical assessment and testing. While some smaller studies call into question the accuracy of the Alvarado score, this approach does seem to be a reasonable starting point in the assessment of a patient with suspected appendicitis.

One main critique of the Alvarado score is its applicability in pediatric populations. A meta-analysis revealed that at a cutoff of 5 (observe/admit criteria) for 1,635 pediatric patients there was a sensitivity of 99% and specificity of 57%, similar to that of the adult subjects. At a cutoff of 7 (surgery criteria) sensitivity was 87% and specificity was 76%.[22] Thus, similar clinical prediction rules can be prescribed as above. This meta-analysis did not give a clear definition of what constitutes a "child," and thus, it is not clear whether these results apply to all pediatric populations. The Alvarado score requires children to identify migration of pain, nausea and anorexia, variables that are not easily identified by very young children.[25]

Laboratory Markers

White Blood Cells (WBCs):

The degree of white blood cell (WBC) elevation in acute appendicitis has been extensively studied. It is very commonly elevated in patients with acute appendicitis. However, it is not a specific marker and is commonly elevated in patients with other inflammatory conditions included in the differential diagnosis.[26] Table 1 lists 19 publications including two meta-analyses of WBC sensitivity, specificity, likelihood ratios and accuracy. Part of the difficulty in drawing precise conclusions from these data is that there is great variability in the WBC concentration cut-offs. A WBC cut-off of greater than 10-12 000 cell/mm^3 yielded a range of sensitivity between 65-85% and specificity between 32-82%.[2,25,27-36] A 2003 meta-analysis including 14 studies (3,382 patients) likely gives a representative approximation of the true sensitivity and specificity of a WBC>10 000 cell/mm^3 measured at 83% and 67%, with a positive and negative likelihood

Table 1. Operating characteristics for the white blood cell count as a predictor of appendicitis.

Author	Subjects	WBC count (10,000 cell/mm^3)	Sensitivity (%)	Specificity (%)	+LR	-LR	AUC (Accuracy)	Study type	Comments
Agrawal et al.[27] (2008)	145	≥11	79	55	1.76	0.38		Prospective	
Al-gaithy[37] (2012)	456	≥9.4	77	66	2.26	0.35	0.70	Retrospective	
Andersson et al.[28] (1999)	502	≥10	78	68	2.44	0.33	0.80	Observational	
Andersson[2] (2004)	3382	≥10	83	67	2.52	0.26		Meta-Analysis: 14 studies	
		≥15	25	93	3.57	0.81			
Deballon et al.[41] (2008)	135	≥9.6	86	43	1.51	0.33	0.75	Prospective	
Fergusson et al.[39] (2002)	1013	≥12	74	72	2.64	0.36	0.80	Retrospective	
Keskek et al.[29] (2007)	540	≥10.5	84	53	1.79	0.30		Retrospective	
Khan et al.[30] (2004)	259	≥11	83	62	2.18	0.27		Retrospective	
Kharbanda et al.[40] (2011)	280	≥14.6	68	80	3.4	0.4	0.78	Prospective	Patients age 3-18
Mentes et al.[31] (2012)	201	≥11.9	72	77	3.13	0.36	0.72	Retrospective	
Ng et al.[32] (2002)	282	≥11	82	39	1.34	0.46		Retrospective	
Sengupta et al.[33] (2009)	98	≥11	65	72	2.32	0.49		Prospective	
Shaw et al.[45] (2011)	297	≥11	70, 71	82, 55	3.9, 1.6	0.37, 0.53		Retrospective Cohort	Study performed at 2 different hospitals. Results listed for each hospital
Wu et al.[25] (2012)	144	≥11	80	71	2.76	0.28		Retrospective	
Xharra et al.[34] (2012)	173	≥10	85	68	2.66	0.22	0.83	Prospective	
Yang et al.[47] (2006)	897	10.4	86	32	1.26	0.44		Retrospective	
Yidrim et al.[42] (2006)	85	≥12.4	87	64	2.42	0.2	0.84	Retrospective	
Yu et al.[36] (2012)	1011	Elevated (pooled)	62	75	2.48	0.51	0.72	Meta-analysis: 7 studies	

WBC, white blood cell; *LR*, likelihood ratio; *AUC*, area under curve

ratio of 2.52 and 0.26.[2] Thus, on its own, a WBC>10 000 cell/mm^3 is insufficient as a diagnostic modality. The discriminatory power of an elevated WBC count, expressed as area under the curve (AUC), is shown in Table 1. The AUC values range from 0.72 to 0.8 reflecting WBC's modest discriminatory power.[28,31,34,36-42] The likelihood ratio values are also shown in Table 1. While these values are statistically significant, it is generally agreed that clinically significant values for likelihood ratios are either greater than 10 or under 0.1. Thus, these values only alter the probability of the diagnosis to a modest degree, and thus, do not change the diagnostic workup on its own.

C-Reactive Protein (CRP):

CRP is an acute phase reactant. Its diagnostic significance is largely based on both its kinetic properties and its utility as a marker for complicated/advanced appendicitis. CRP levels show an increase between 8-12 hours after the onset of inflammatory processes with a peak between 24 and 48 hours, which is later than that of WBC.[43,44] Consequently, CRP contributes little diagnostic utility early in the case of simple appendicitis. Table 2 lists 12 studies including two large meta-analyses on CRP levels in appendicitis. A CRP cut-off of >10 mg/L yielded a range of sensitivity between 65-85% and a specificity between 59-73%.[2,28,33,34,36,45] In a study of 542 people the AUC of CRP on day 1 was only 0.60 compared to 0.77 on day 2 and 0.88 day 3. In cases of perforated appendicitis, the AUC was 0.90 on day 1, 0.92 on day 2 and 0.96 on day 3.[44] Thus, CRP serves as a strong predictor for appendiceal perforation but is quite limited for appendicitis in general.[44,46]

Granulocyte Count and Proportion of Polymorphonuclear (PMN) Cells:

Table 3 lists 10 publications including one meta-analysis of granulocyte count and proportion of polymorphonuclear (PMN) that document their sensitivity, specificity, likelihood ratios and accuracy. A normal granulocyte count ranges between 2500-6000 cells. A modestly elevated PMN greater than 7-7.5 x10^9 cells/L yielded a range of sensitivity of 71-89% and a specificity of 48-80% in diagnosis of acute appendicitis.[2,28,37,39,45] Andersson's 2003 meta-analysis of several laboratory variables in acute appendicitis showed that a granulocyte count greater than 11×10^9/L had a larger likelihood ratio than any other lab marker measured and was one of the strongest laboratory discriminators of appendicitis.[2] Yet, the likelihood ratios were not even increased to near clinically significant levels unless the PMN was very elevated to >13 x 10^9 cells/L. At this level, 2 studies of 502 and 1013 patients found a likelihood ratio of 7.09 and 6.67, respectively.[2,39]

Similarly, as detailed in Table 3, PMN ratio>75%, was also a discriminator of acute appendicitis but had limited clinical significance due to a sensitivity of 66–87% and specificity of 33-84%.[2,28,32,34,39,41,47] Again, the likelihood ratios were not high enough to significantly change the probability of appendicitis.

Assessing "left shift," defined as a band form count >700/microL, a 2002 retrospective study of 1013 subjects found a sensitivity of 28%, a specificity of 87%, and an AUC of 0.58.[39] In this study the presence of "left shift" provided a likelihood ratio of 2.17 which has limited clinical significance. In another study of 722 patients with a mean age of 9.7 years who presented to the pediatric ED, a "left shift" had a total sensitivity of 59% and a specificity 90%.[48] Here the likelihood ratio was 5.7. Thus, while possibly providing some diagnostic clues, "left shift" did not yield any absolute conclusions.

Temperature:

History of fever provides very little diagnostic significance in acute appendicitis.[2,28,38,49] In a study of 492 patients, a temperature of greater than 37.7°C had a sensitivity of 70% and a specificity of 65%.[28] In a meta-analysis consisting of 570 patients with suspected appendicitis, history of fever only gave a likelihood ratio of 1.64.[2] A meta-analysis of 502 patients reported that the average measured temperature in non-surgical abdominal pain was 37.7°C versus 37.8°C in cases of appendicitis on first measurement.[28] However, the diagnostic significance of the variable increased significantly on serial examination and was an important discriminator of advanced appendicitis. The receiver operating characteristic (ROC) curve for all appendicitis on primary examination was 0.56 increasing to 0.77 after serial assessment.[28] Thus, although initial temperature does not provide much diagnostic value initially, it still remains a parameter worth looking at when observing someone with suspected appendicitis.

Lab Values in Combination:

Perhaps a multi-marker approach is necessary for the diagnosis of appendicitis. While the individual elements of clinical and laboratory data carry limited diagnostic value, many studies show an exponential increase in the predictive and discriminatory power when multiple markers are combined.[35,41,50-54] The major limitation of these publications is that some of the data may have been over-fit and the product of post-hoc analyses.

Table 4 shows many of the different combinations of lab markers evaluated. A study of 502 patients over the age of 10 years found that the combined inflammatory parameters (including WBC, PMN cells, PMN ratio, body temperature and CRP) had an accuracy of 0.85, which was similar to the total accuracy of clinical findings (0.87) and greater than all elements of disease history (0.78).[28] The largest study identified included 897 patients and gave a sensitivity of 99% and specificity of 6% when any one of CRP≥8 mg/L, WBC≥10.4 x 10^3 cells/mm^3 *or* PMN Ratio >74% was present, and a sensitivity of 98% and specificity of 12% when either WBC or CRP was elevated.[47] Thus, while the absence of all of these laboratory markers can potentially "rule out" the diagnosis of

Table 2. Operating characteristics for C-reactive protein as a predictor of appendicitis.

Author	Subjects	CRP (mg/L)	Sensitivity (%)	Specificity (%)	+LR	-LR	AUC (Accuracy)	Study type	Comments
Andersson et al.[28] (1999)	481	>10	80	60	2	0.33		Observational	
Andersson[2] (2004)	1889	Appendicitis: >10	81	59	1.98	0.32	0.75	Meta-analysis: 9 studies	
	521	Perforated: >10	91	79	4.33	0.11	0.87		
Deballon et al.[41] (2008)	135	>6	91	74	3.5	0.12	0.85	Prospective	
Khan[30] (2004)	259	17	76	84	4.75	0.29		Retrospective	
Ng et al.[32] (2002)	282	≥8	68	36	1.06	0.89			
Noh[67] (2012)	307	>5	86	35	1.32	0.4		Retrospective	Hazard Ratio: 2.53 – highest marker for complicated appendicitis
Sengupta et al.[33] (2009)	98	>10	65	68	2.03	0.51		Prospective	
Shaw et al.[45] (2011)	297	≥10	65,68	73,64	2.41, 1.89	0.48, 0.5		Retrospective cohort	Study performed at 2 different hospitals. Results listed for each hospital
Wu et al.[44] (2005)	542	Appendicitis: >15	38	81	2.00	0.77	0.60	Retrospective	
		Perforated: >10	77	89	7.12	0.26	0.90		
Xharra et al.[34] (2012)	173	>10	85	72	3.04	0.21	0.83	Prospective	
Yang et al.[47] (2006)	897	8	77	26	1.04	0.88		Retrospective	
Yu et al.[36] (2012)	1011	Elevated (pooled)	57	87	4.38	0.49	0.75	Meta-analysis: 5 studies	

CRP, C-reactive protein; *LR*, likelihood ratio; *AUC*, area under curve

Table 3. Operating characteristics for polymorphonuclear (PMN) count and ratio as a predictor of appendicitis.

	Author	Subjects	PMN count (x10^9/L)	Sensitivity (%)	Specificity (%)	LR+	LR-	AUC (Accuracy)	Study type	Comments
PMN Count	Al-gaithy[37] (2012)	456	≥7.5	71	66	2.09	0.44	0.68	Retrospective	
	Andersson et al.[28] (1999)	502	≥11	48	92	6	0.57	0.80	Observational	
	Andersson et al.[2] (2004)	882	≥7	85	48	1.64	0.31	0.77	Meta-analysis: 3 studies	
			≥9	66	75	2.64	0.45			
			≥13	29	96	7.09	0.74			
	Fergusson et al.[39] (2002)	1013	≥7	89	59	2.17	0.19	0.83	Retrospective	
			≥11	59	88	4.91	0.47			
			≥13	40	94	6.67	0.64			
	Kharbanda et al.[40] (2011)	280	≥11	69	75	2.76	0.41	0.78	Prospective	
	Shaw et al.[45] (2011)	297	≥7.5	80, 75	80, 50	4, 1.5	0.25, 0.5		Retrospective cohort	Study performed at 2 hospitals. Results listed for each hospital
			PMN Ratio (%)							
PMN Ratio	Andersson et al.[28] (1999)	502	≥70	93	49	1.82	0.14	0.79	Observational	
			≥85	52	88	4.33	0.55			
	Andersson et al.[2] (2004)	1494	≥75	66	84	4.13	0.41	0.78	Meta-analysis: 5 studies	
			≥85	50	87	3.85	0.57			
	Deballon et al.[41] (2008)	134	≥75	83	46	1.54	0.37	0.69	Prospective	
	Fergusson et al.[39] (2002)	1013	≥70	87	61	2.23	0.21	0.78	Retrospective	
			≥85	32	90	3.2	0.76			
	Ng et al.[32] (2002)	282	≥80	60	77	2.61	0.52		Retrospective	
	Xharra et al.[34] (2012)	173	≥75	79	68	2.47	0.31	0.78	Prospective	
	Yang et al.[47] (2006)	897	≥74	87	33	1.3	0.39		Retrospective	

Table 4. Operating characteristics for a combination of markers to predict appendicitis

Author	Subjects	Combination of markers	Sensitivity (%)	Specificity (%)	+LR	-LR	Study type	Comments
Deballon et. al[41] (2008)	135	CRP ≥ 6 mg/L and WBC ≥ 9.6 x 10^3 cells/ mm^3	86	37	1.37	0.38	Prospective	
Sengupta et. al[33] (2009)	98	CRP ≥ 10 mg/L and WBC ≥ 11 x 10^3 cells/ mm^3	50	90	5	0.56	Prospective	NPV: 88%
		CRP ≥ 10 mg/L *OR* WBC ≥ 11 x 10^3 cells/ mm^3	100	51	2.04	0		NPV: 100%
Shaw et. al[45] (2011)	297	Hospital Centre A:					Retrospective	Study performed at 2 different hospitals. Results listed for each hospital
		CRP ≥ 10 mg/L and WBC ≥ 11 x 10^3 cells/ mm^3 and PMN Count ≥7.5 x 10^9/L	46	89	4.18	0.61		
		CRP ≥ 10 mg/L or WBC ≥ 11 x 10^3 cells/ mm^3 or PMN Count ≥7.5 x 10^9/L	94	60	2.35	0.1		
		Hospital Centre B:						
		CRP ≥ 10 mg/L and WBC ≥ 11 x 10^3 cells/ mm^3 and PMN Count ≥7.5 x 10^9/L	53	77	2.30	0.61		
		CRP ≥ 10 mg/L or WBC ≥ 11 x 10^3 cells/ mm^3 or PMN Count ≥7.5 x 10^9/L	92	64	2.56	0.13		
Van Dieijen-Visser et. al[55] (1991)	258	CRP ≥ 12 mg/L and WBC ≥ 10 x 10^3 cells/ mm^3	56	93	8	0.47	Retrospective	
		CRP ≥ 12 mg/L or WBC ≥ 10 x 10^3 cells/ mm^3	97	55	2.16	0.05		PPV: 94%
		CRP ≥ 12 mg/L and WBC ≥ 10 x 10^3 cells/ mm^3 and PMN Ratio > 70%	22	99	22	0.79		NPV: 98%
		CRP ≥ 12 mg/L or WBC ≥ 10 x 10^3 cells/ mm^3 or PMN Ratio > 70%	99	50	1.98	0.02		
Yang et. al[47] (2006)	897	WBC ≥ 10.4 x 10^3 cells/mm^3 or PMN Ratio > 74%	95	17	1.14	0.29	Retrospective	
		CRP ≥ 8 mg/L or WBC ≥ 10.4 x 10^3 cells/ mm^3	98	12	1.11	0.17		
		CRP ≥ 8 mg/L or WBC ≥ 10.4 x 10^3 cells/ mm^3 or PMN Ratio > 74%	99	6	1.05	0.17		

CRP; C-reactive protein; *WBC*; white blood cells; *PMN*, polymorphonuclear leukocytes; *LR,* likelihood ratio; *PPV,* positive predictive value; *NPV*, negative predictive value

appendicitis, the complete lack of specificity severely limits its application. In a smaller study of 98 patients, Sengupta et al.[33] calculated a sensitivity of 100%, a specificity of 50% and a NPV of 100% when either CRP≥10 mg/L *or* WBC≥11 x 10^3 cells/mm^3. Vaughn-Shaw et al.[45] replicated Sengupta's study in 297 patients and found a lower sensitivity of 92-94% and a specificity of 60-64%. In another prospective study of 102 patients (49 who had appendicitis), the combined AUC of a WBC>10^9 cells/L *and* CRP>6 mg/L was 0.96 with a likelihood ratio of 23.32 when all variables were present, 0.53 when at least one variable was present and 0.03 when all variables were absent.[2] Many of these studies used different cut-off points so it is difficult to compare them. However, based on these results, acute appendicitis is very unlikely when WBC, CRP and PMN ratio are all within normal limits. As such, if a patient presents with clinical findings of appendicitis but no elevation of any of these lab markers, based on a collection of very small studies, the diagnosis of appendicitis is unlikely. While these studies are further limited by secondary and post-hoc analyses, they do provide some empiric evidence for a multi-marker approach. However, further validation is warranted.

Table 4 also shows the sensitivities and specificities when both CRP *and* WBC or CRP, WBC *and* PMN ratio are all elevated. Again, different combinations and cut-off values were used making it difficult to compare individual studies. The data show a specificity that ranges from 77-99%.[33-35,45,55] Thus, because of this wide range of measured values, the current studies do not show a consistently high enough specificity to "rule in" appendicitis and warrant surgery without further clinical and/or imaging workup.

Interestingly, in a 1999 study by Gronroos et al.,[52] none of the 200 consecutive adult patients with acute appendicitis had both CRP and WBC within normal range. However, Gronroos[53] also reported that in the same study done on children, normal values of both WBC *and* CRP were found in 7 of 100 consecutive children. Therefore, the sensitivity and specificity of combined laboratory markers may vary in different age demographics.

This analysis is limited by the relative scarcity and small sample sizes of the literature examining the combined use of markers. Small studies have shown enhanced diagnostic potential and utility but much larger sample sizes are needed before any absolute recommendations can be made. Furthermore, evaluation of this multi-marker approach in different patient demographic groups, most notably children, adults and the elderly is warranted.

Novel Markers – Diagnostic Markers of the Future?

In response to the difficulty of making the accurate diagnosis of appendicitis and to decrease CT utilization and negative appendectomy rates, there has been much effort to search for novel markers. Table 5 lists several of these markers, which we will now briefly discuss. While some of these markers have shown early promise, the power of these studies is limited due to the small sample size.

Interleukin 6 (IL-6) is a cytokine that plays a focal role in the activation of the acute inflammatory response.[40,56,57] A 2011 prospective study of 280 patients aged 3-18 with suspected appendicitis showed the IL-6 levels increase early appendicitis, and mean concentration also increases with the degree of inflammation.[40,56,57] The sensitivity and specificity at different cut-off points are shown in Table 5. In a small prospective study of 80 patients, Paajanen et al.[43] found the sensitivity, specificity and accuracy of IL-6 to be higher than that of WBC or CRP. While these studies show a clear relationship between IL-6 levels and acute appendicitis, they did not show that IL-6 improved the diagnosis of appendcitis.[40,43,58,59]

Serum Amyloid A (SAA) is a non-specific inflammatory marker. A small 2005 study of 42 patients with a mean age of 10.6 years and confirmed appendicitis on surgery calculated a sensitivity of 86%, a specificity of 83% and an AUC of 0.96 at a cutoff of SAA>45 mg/L. All 42 patients with acute appendicitis had elevated SAA levels, whereas only 14/42 had normal WBC values and 9/42 had normal CRP values.[60] They also found that SAA had an early and more dynamic increase in inflammatory conditions compared to that of WBC and CRP. Thus, SAA may be useful in early appendicitis.

Muenzer et al..[61] studied leukocyte gene expression (Riboleukograms) and cytokine profiles in children being evaluated for appendicitis. In a training cohort of 20 patients, they first identified 28 genes and five cytokines that were strongly associated with the diagnosis of appendicitis. They subsequently tested the diagnostic potential of these genes and cytokines in eight patients. Four out of the five patients with confirmed appendicitis would have been correctly diagnosed using riboleukograms alone. Out of the three patients without appendicitis, there would have been one false-positive result. Using the five identified plasma cytokines alone, only one out of four patients with appendicitis was correctly identified. However, all three patients without appendicitis were correctly identified here. Thus, riboleukograms showed potential for being a sensitive marker and plasma cytokines as a specific marker for acute appendicitis. Some of the major limitations of this study are the very small sample size, cost and real-time technical feasibility.

Allister et al.[62] tested the utility of Granulocyte colony-stimulating factor (G-CSF) in the diagnosis of acute appendicitis in 32 patients with a mean age of 12 years. G-CSF is over-expressed in acute appendicitis and acts on the bone marrow to stimulate the production and release of granulocytes into the peripheral blood. Using a cut-off of 28.3 pg/ml yielded a sensitivity of 91% and a specificity of 51%. Additionally, serum levels of G-CSF closely correlated with the severity of inflammation and thus have the potential to complement other diagnostic measures while also helping to determine the severity of acute appendicitis.

Another promising novel marker in acute appendicitis is

Table 5. Operating characteristics for novel markers in predicting appendicitis

Novel marker	Author	Subjects	Cut-off	Sensitivity (%)	Specificity (%)	AUC (Accuracy)	Study type
Interleukin 6	Kharbanda et al.[40] (2011)	280	11.3 pg/mL	82	69	0.78	Prospective
	Paajanen et al.[43] (2002)	80	14 pg/mL	84	79	0.80	Prospective
	Eriksson et al.[58] (1995)	165	15 pg/mL	66	31		Prospective
Serum Amyloid A	Lycopoulou et al.[60] (2005)	42	45 mg/L	86	83	0.96	Prospective
Riboleukograms	Muenzer et al.[61] (2010)	8	N/A	80	66		Prospective
Plasma Cytokines				25	100		
Granulocyte colony-stimulating factor	Allister et al.[62] (2011)	32	28.3 pg/mL	91	56	0.76	Prospective
Leucine-rich α-2-glycoprotein in the urine	Kentsis et al.[63,64] (2010 and 2012)	49	3.9 ug/mL			0.99	Prospective
Calprotectin (S100A8/A9)	Bealer et al.[65] (2010)	181	20 Elisa units	93	54	0.71	Prospective
	Mills et al.[66] (2012)	843	14 Elisa units	96	16	0.66	Prospective

AUC, area under curve

urine Leucine-rich α-2-glycoprotein (LRG). LRG is believed to be shed earlier in the urine of patients than locally activated neutrophils. A 2010 and 2012 study by Kentsis et al.[63,64] of 49 patients found LRG detected more than 100-fold in the urine of patients under 18 years with appendicitis compared to those without. It was found to be elevated in the urine of some patients with acute appendicitis even in the absence of macroscopic changes. (Two patients had a pathologic appendix but had negative imaging were identified by elevated LRG levels.) It is also likely increased in pyelonephritis and other bacterial infections. Direct measurement of urine LRG using a select ion monitoring mass spectrometry assay yielded an AUC of 0.99, but using a commercially available LRG-ELISA the AUC was only 0.80 due to an immunoassay interference effect. One of the major focuses moving forward is to see if elevated urine LRG is sufficiently sensitive and specific enough to effect the clinical decision making of ED physicians. Furthermore, more effort is required in order to develop a standard widespread available laboratory technique that is able to accurately measure LRG.

Calprotectin (also known as S100A8/A9) is a calcium-binding protein associated with acute inflammation, specifically of gastrointestinal origin. The relationship between Calprotectin as a diagnostic tool in acute appendicitis was first studied by Bealer et al.[65] in 2010. In a preliminary study of 181 patients, Bealer found a sensitivity of 93% and a specificity of 54% at a cut-off of 20 Elisa units. Their promising results persuaded the investigators to undergo a larger ongoing study examining this relationship. In 2012, Mills et al.[66] conducted a similar study with 843 patients. Using a cut-off of 14 Elisa units yielded a sensitivity of 96% and a specificity of 16%. One major problem in this study was that the measured value of ELISA for Calprotectin showed a 13-43% increase in actual levels due to a shipping effect whereby the test values were inflated due to delay in analysis. Thus, the next step in development of Calprotectin as a lab marker for acute appendicitis is to create an accurate real-time laboratory analyzer. In short, Calprotectin is a promising new marker of appendicitis that may help differentiate acute appendicitis from non-inflammatory causes of acute abdominal pain.

CONCLUSION

The purpose of this article was to present the reader with an update on the diagnostic approach to suspected appendicitis by providing an evidence-based review of radiological imaging, clinical scoring systems, laboratory testing, and novel biomarkers for appendicitis. CT remains the best

radiological modality for diagnosing appendicitis but radiation exposure and long term cancer risks are a major concern. The alternative use of ultrasound may help decrease the use of CT in certain circumstances. In adults, an Alvarado score up to five shows promise at ruling out appendicitis. Laboratory markers all contribute to the presentation of appendicitis but are unable to change the diagnostic management of suspected appendicitis on their own. When used in combination they show greater promise. Lastly, there are several novel markers that have showed early promise in diagnostic capability of suspected appendicitis. Further exploration of some of these markers, as well as potential others, is warranted.

Address for Correspondence: Daniel Shogilev, MD, 4130 Garrett Rd. Apt. 1014, Durham, North Carolina, 27707. E-mail: dshogilev@gmail.com.

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Old Man with Groin Bruising

Basak Bayram, MD
Nese C. Oray, MD
Cagdas A. Acara, MD

Dokuz Eylül University School of Medicine, Department of Emergency Medicine, İzmir, Turkey

Supervising Section Editor: Sean O. Henderson, MD
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A 67-year-old man presented to the emergency department with abdominal pain and groin bruising. He had no history of any disease or drug use. In his breaf story he had a heavy cough five days ago and bruises appeared on the abdomen skin and groin in the last two days. Ecchymosis extends in the midline from umblicus to the penis and scrotum in physical examination (Figure 1). Laboratory evaluation revealed normal hemoglobin level, platelet count, prothrombin time, and activated partial thromboplastin time. [West J Emerg Med. 2014;15(7):872–873.]

DIAGNOSIS

Abdominal rectus muscle hematoma was detected on abdomen computed tomography (Figure 2). We thought that rectus sheath hematoma appeared after heavy coughing. The patient was given a supportive treatment and after twenty days of follow up, the hematoma was disappered without any complications.

Heavy cough can cause rectus sheath hematoma.[1] Rectus sheath hematoma should be considered in elderly patients on anticoagulant treatment with abdominal pain.[2] The frequent clinical findings are abdominal mass and pain.[1-3] The patients should be followed up for loss of blood and enlargement of the hematoma. Fatal complications are rarely seen and supportive treatment is adequate.

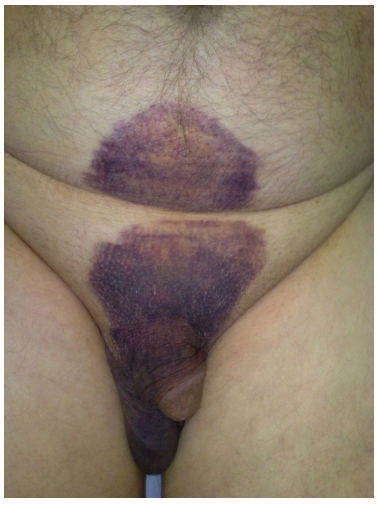

Figure 1. Appearance of the patient's abdomen and groin.

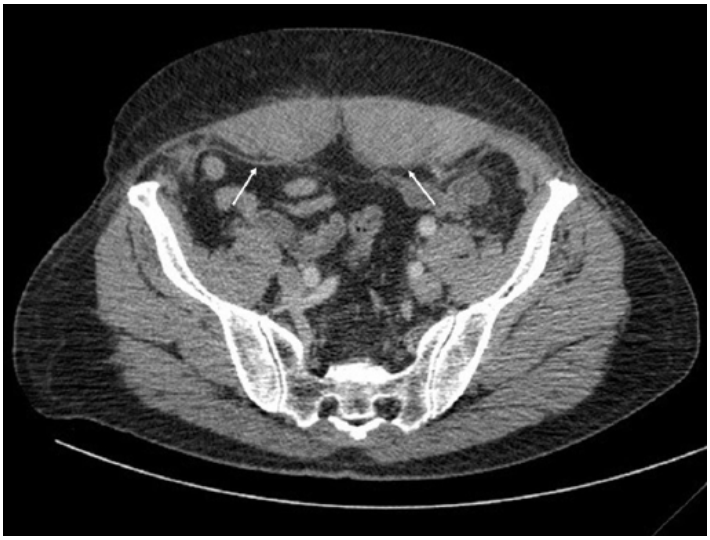

Figure 2. Abdomen computed tomography showing rectus sheath hematoma (arrows).

Address for Correspondence: Başak Bayram, MD, Dokuz Eylül University School of Medicine, Department of Emergency Medicine, Inciralti, 35340 Izmir, Turkey. Email: basakdr@yahoo.com.

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Hip Pain Secondary to Small Bowel Fistula to Pelvis

Chris Cruz, MD
James Liang, DO
David Heltzel, MD
Kimberly Liang, PharmD

US Naval Hospital Okinawa, Department of Emergency Medicine, Okinawa, Japan

Supervising Section Editor: Sean O. Henderson, MD
Submission history: Submitted July 15, 2014; Accepted August 20, 2014
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A 26-year old man presented to the emergency department for two months of worsening right hip and thigh pain. He complained of radicular pain from his buttocks to his calf and has difficulty bearing weight on his right leg. He denies a history of trauma, fever, prior surgery, or arthritis. In addition, he was being evaluated by a gastroenterologist for recurrent diarrhea. In the middle of his encounter, the radiologist called to discuss a result of his computed tomography (CT) performed three days prior. CT images showed inflamed loops of bowel involving the distal ileum and rectum. A fistula is seen from the rectum, extending into the distal ileal loop and the posterior pelvis (Figures 1 and 2). An abscess was found between the piriformis and gluteus medius. He was admitted for intravenous antibiotic therapy, including a consultation with general surgery for Chrohn's Disease (CD). He responded well to antibiotics and was discharged six days later.

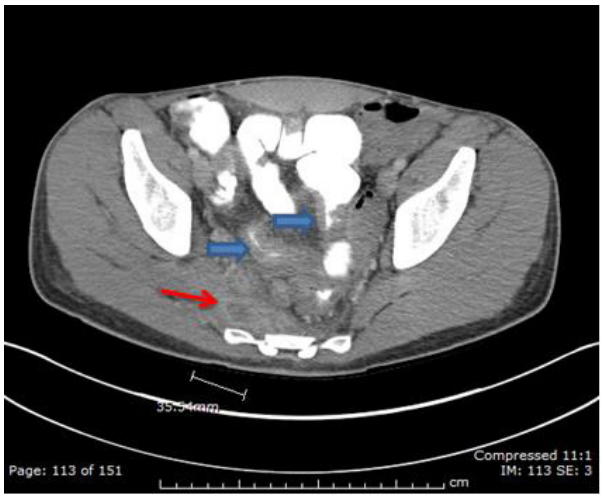

Figure 1. Axial computed tomography of the pelvis with oral and intravenous contrast material, at the level of the greater sciatic foramen, demonstrating a sinus tract extending to the right piriformis (red arrow), originating from a segment of the distal ileum (not shown). Segmental, transmural distal ileal wall thickening is also shown (blue arrows). Patient also has multiple ileocolic fistulae (not shown).

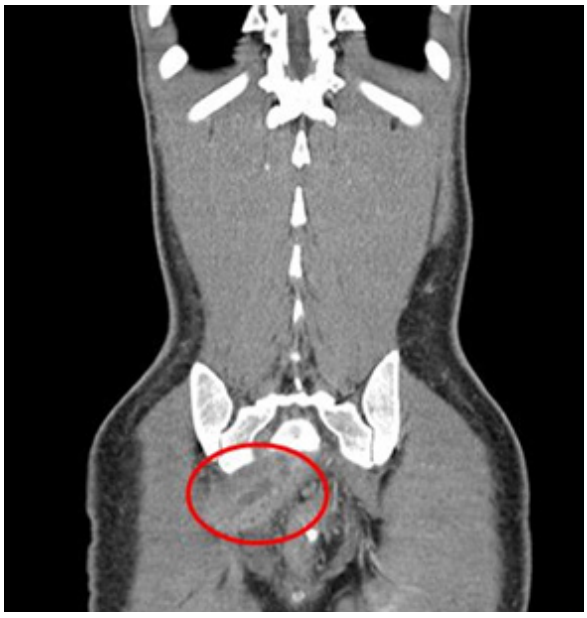

Figure 2. Coronal reformat better demonstrating the oblique, presacral course of the sinus tract along the piriformis (circle).

Extraintestinal manifestations of CD are known to occur with arthropathies occurring in twenty percent of patients.[4] Common among this group are sacroilitis, or ankylosing spondylitis. Purulent musculoskeletal complications, while rare, have been described.[1] In this study, twenty-three of 552 patients were found to have a musculoskeletal abnormality in CT scans during a 7-year period. Only four of the patients presented with gluteal muscle abscess/fistula. However, twenty-two of these patients were known to have CD at the time of the abnormality. Solitary involvement of the piriformis has also been identified in a patient with a known case of CD.[2] Similar to the case above, this patient developed difficulty walking and bearing weight. Purulent complications can extend further from the abdominopelvic area with fistula communicating along fascial planes of the thigh into the knee compartment.[3] Unfortunately, the patient died from complications and CD was diagnosed post-mortem.

Address for Correspondence: James Liang, DO. Department of Emergency Medicine, United States Naval Hospital Okinawa, PSC 482 FPO AP 96362-1600. Email: jmcl73@yahoo.com.

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Tracheal-Mediastinal Fistula Post-chemoradiation Therapy

Joseph McCarthy, DO
Jason Hamel, MD

Lakeland Regional Medical Center, Department of Emergency Medicine, St. Joseph, Michigan

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INTRODUCTION

A 52-year-old male presented to the emergency department with chest pain, shortness of breath and hemoptysis that had been worsening over the past two days. Past medical history included a history of non-small cell lung carcinoma, which he had completed radiation therapy approximately four months prior and was currently undergoing chemotherapy. Significant vitals upon presentation included a respiration rate of thirty-six breaths/min and peripheral oxygen saturation measuring 80%. Physical examination revealed a cachectic male appearing older than his actual age, alert and oriented to person, place and time with rhonchi throughout his lung fields and decreased breath sounds on the right. He was started on non-invasive biphasic positive airway pressure with mild improvement of clinical status. An anteriorposterior chest radiograph was preformed and prior computed tomography of the chest was reviewed (Figures 1, 2). Computed tomography of the chest was also repeated on the day of presentation (Figure 3).

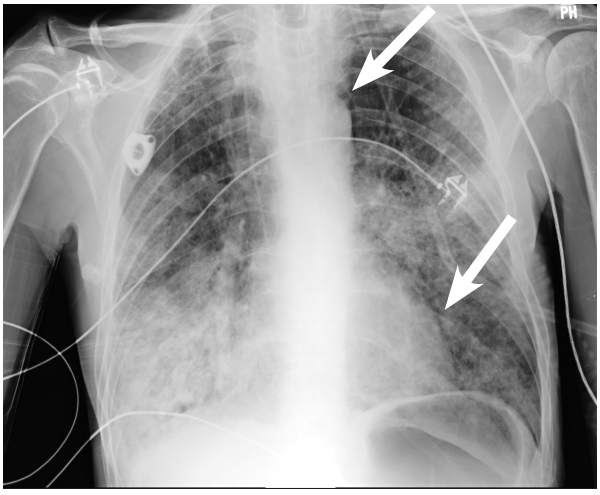

Figure 1. Anteriorposterior chest radiograph displaying lucency adjacent to the aortic knob (arrow) and left cardiac border (arrowhead) consistent with pneumomediastinum.

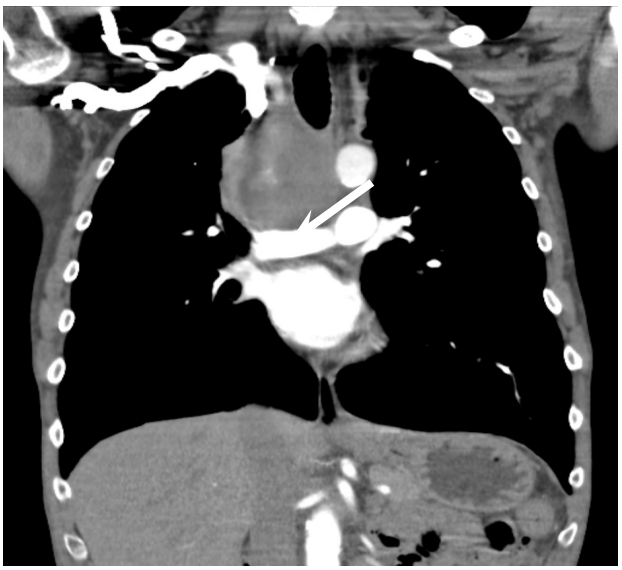

Figure 2. Coronal computed tomography of paratracheal mass with right anterolateral trachaeal involvement.

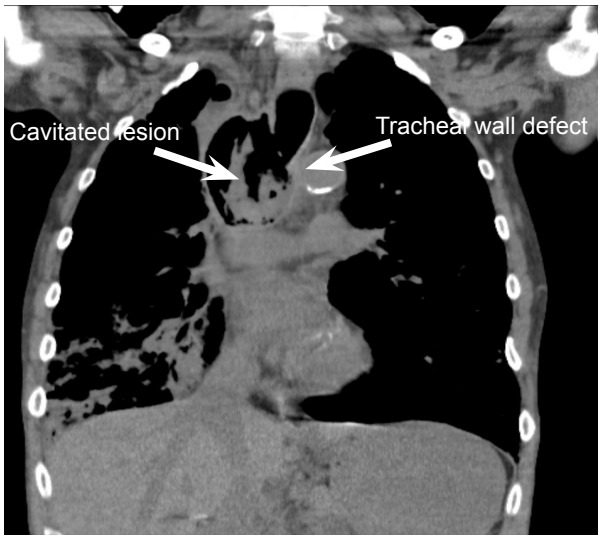

Figure 3. Coronal computed tomography exhibiting a deficit in the right tracheal wall with a cavitary space previously occupied by the large soft tissue mass seen in Figure 2.

DISCUSSION

There are reports of high incidences of tracheoesophageal fistula formation in patients being treated for lung cancers with the combination of radiation therapy and chemotherapies, notably bevacizumab,[1] but tracheal-mediastinal fistulas are rare.[2] Patient's presentation can vary from acute tension pneumothorax and asphyxiation from pulmonary flooding secondary to hemorrhage, to insidious wasting, malaise, fever, or chronic cough.[3] Acquired fistulas of the tracheobronchial airways are associated with high rates of morbidity and mortality, with many patients dying from hemorrhage resulting from progression of the fistula into the blood vessels.[2] Emergent intubation is often required with the understanding that this may cause or worsen hemoptysis leading to possible cardiovascular and respiratory failure. There is lack of consensus for optimal definitive therapy, but options include open surgery, bronchoscopically placed expandable stents, fibrin glue, and even autologous adipose-derived stem cells.[2,3]

After discussion with the patient and family regarding the diagnosis, he preferred not to be intubated and requested only supportive care. He was admitted to the hospital on biphasic non-invasive positive airway pressure and expired from respiratory failure shortly thereafter.

Address for Correspondence: Joseph McCarthy, DO. Lakeland Regional Medical Center Emergency Medicine Residency Program, 1234 Napier Avenue, St. Joseph, MI 49085. Email: jmccarthy@lakelandregional.org.

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Intragastric Balloon Rupture

George Lim, MD
Braden Hexom, MD

Icahn School of Medicine at Mount Sinai, Department of Emergency Medicine, New York, New York

Supervising Section Editor: Sean O. Henderson, MD
Submission history: Submitted August 18, 2014; Accepted August 28, 2014
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A 38 year old obese female presented to the emergency department with 1 hour of nausea and blue colored urine. She endorsed recent flatus and bowel movement but denied abdominal pain, dysuria, fevers, or toxic ingestions. She presented a urine cup on arrival with obviously blue tinged urine (Figure). Her exam revealed a comfortable appearing female with no abdominal or costovertebral tenderness. She reported having an Orbera™ intragastric balloon placement 15 months prior in Brazil (Apollo Endosurgery, Inc., Austin, TX). The patient was admitted to the hospital for urgent endoscopic retrieval. However, as the device is not approved for use in the U.S., attempts to find a local physician familiar with the procedure or the appropriate retrieval equipment were unsuccessful. Open surgical removal was offered to the patient, who declined and instead returned to Brazil for removal there. The patient was lost to follow up.

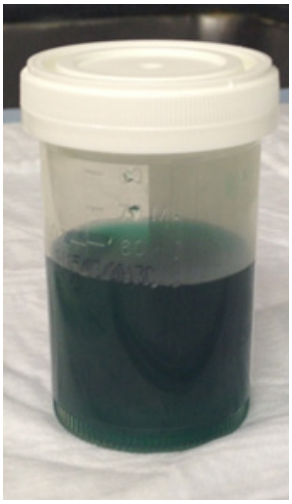

Figure. Patient's blue urine after intragastric balloon rupture.

DISCUSSION

Obesity is a prevalent disease with treatment options including diet, behavioral modification, medication and surgery. Patients, who are not candidates for more traditional bariatric surgeries may benefit from endoscopically placed intragastric balloons (IGB).[1] Once in the stomach, the balloon is filled with 500-700mL of saline and 10mL of methylene blue (to identify leakage or rupture). The balloon displaces stomach volume which produces a sense of early satiety when eating.[2] Severe adverse complications include gastric perforation (more likely in those with previous upper GI surgeries), gastric obstruction, gastric ulcer, esophagitis, and esophageal perforation.[3] IGBs are only designed to remain in the stomach for a maximum of 6 months, while this patient had her device for several more months than is recommended. Increased balloon rupture and displacement with occasional intestinal obstruction are associated with patients who retain IGBs for more than 6 months.[4] Treatment for ruptured and displaced IGBs is endoscopic retrieval using proprietary equipment, or possible laparotomy.

Address for Correspondence: George Lim, MD, Mount Sinai Medical Center, Dept. of Emergency Medicine, 1 Gustave L. Place, Box 1149, New York, NY 10029. Email: georgelim3@gmail.com.

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Osteomyelitis Pubis: A Rare and Elusive Diagnosis

Justin Yax, DO, DMTH
David Cheng, MD, DMTH
Case Western Reserve University, University Hospitals/Case Medical Center, Department of Emergency Medicine, Cleveland, Ohio

Supervising Section Editor: Joel Schofer, MD, MBA
Submission history: Submitted July 27, 2014; Revision received August 19, 2014; Accepted August 20, 2014
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Osteomyelitis pubis is an infectious inflammation of the symphysis pubis and accounts for 2% of hematogenous osteomyelitis. This differs from osteitis pubis, a non-infectious inflammation of the pubic symphysis, generally caused by shear forces in young athletes. Both conditions present with similar symptoms and are usually differentiated on the basis of biopsy and/or culture. A case of osteomyelitis pubis is presented with a discussion of symphisis pubis anatomy, clinical and laboratory presentation, etiology and risk factors, and optimal imaging studies. [West J Emerg Med. 2014;15(7):880–882.]

INTRODUCTION

Infection of the symphysis pubis, or osteomyelitis pubis, and non-infectious inflammation of the same joint, or osteitis pubis, are distinct entities that present similarly. The diagnosis of osteomyelitis pubis is often missed or delayed due to the infrequency of the disease and its variable presentation. Because many patients with this condition report sudden onset of pelvic pain, they are often seen in the emergency department (ED). The emergency physician can make a difference in the course of the disease by recognizing the condition early, and starting the patient on the road to definitive workup and treatment, which involves pain control and long-term intravenous (IV) antibiotic therapy.

CASE PRESENTATION

A 39-year-old woman with a history of genital herpes and normal vaginal delivery eight months ago presented with nine days of severe pelvic pain. Initially she experienced a spontaneous peri-vaginal "pressure sensation" that was five out of ten in intensity. She denied vesicles in her perineum or vulva, fever, or chills. Seven days prior to presentation, she developed a temperature to 100.3ºF and went to another hospital where a pelvic exam, pelvic ultrasound and a computed tomography (CT) of the pelvis with oral and IV contrast were performed. All tests were normal except for a leukocytosis of 14,000 cells/mcL. She was discharged with a diagnosis of leukocytosis of unclear etiology and discharged on hydrocodone/acetaminophen for pain control. On follow-up with an obstetrician a few days later, another pelvic exam was unremarkable and no vesicles were seen. She was started on valaciclovir for suspected herpes sine herpete, an atypical presentation of genital herpes without obvious lesions.

Three days prior to presentation, our patient had increasing difficulty walking secondary to her pain. She presented to another hospital where a repeat CT of the pelvis was negative. She was discharged on oxycodone/acetaminophen and ibuprofen and was to follow up with her obstetrics pelvic floor specialist. Prior to her follow-up appointment, however, her pain was so great she presented to our institution unable to ambulate without a walker and now had pain that radiated into her right buttock.

At presentation, she denied loss of bowel or bladder function, but had soiled herself due to her difficulty reaching the bathroom and her limited mobility. She denied trauma. She was febrile to 101.3ºF and the remainder of her vital signs were normal. Her exam revealed severe suprapubic tenderness and her lower extremity exam revealed severe pain with hip flexion bilaterally and normal bilateral patellar and Achilles reflexes. Saddle hyperestheia was noted and otherwise sensation was normal. Rectal tone was normal and examination of her back showed no spinal step-offs or lesions. She was exquisitely tender over the right gluteus region. Her white blood cell count was 12,600 cells/mcL, C-reactive protein (CRP) was 37.1mg/L, and erythrocyte sedimentation rate (ESR) was 114mm/hr. The laboratory abnormalities caused the treating physicians to order a magnetic resonance imaging (MRI) of the pelvis, which was consistent with osteomyelitis pubis. She was admitted for pain control and further workup. Blood cultures drawn on admission grew methicillin-sensitive *Staphylococcus aureus,* and the patient was discharged on four weeks of IV ceftriaxone and gradually improved.

DISCUSSION

The pubic symphysis is classified as an amphiarthrodial (slightly movable) joint and shares this classification with the intervertebral disks of vertebral bodies, the distal tibiofibular articulation, and sacroiliac joint articulation with pelvic bones.[5,6] The pubic symphysis consists of an intrapubic fibrocartilage disk sandwiched between thin layers of hyaline cartilage.[5] The hip adductors originate inferiorly on the pubic symphysis and the pectineus, rectus, and the inguinal ligament insert superiorly while muscles of the pelvic floor insert posteriorly, helping to explain the extensive distribution of pain throughout the pelvis in our patient.

Osteitis pubis, a non-infectious inflammation of the pubic symphysis, is caused by shear stresses to the joint and is not an infectious process. Athletes are more predisposed to this condition given the insertion and origin of several muscle groups on the pubic rami. In particular, athletes in sports involving twisting and cutting motions such as rugby, American football, soccer, ice hockey, tennis, basketball and endurance running are at higher risk.[7-9] One study showed that 76% of players on an English professional soccer team had symphyseal abnormalities on pelvic radiographs, suggestive of repetitive stress injury.[10] This is thought to be due to shear forces transmitted along hip adductors by repetitive kicking.[11] Younger patients are thought to be at higher risk for hematogenous bacterial seeding of a sterile, inflamed amphiarthrosis given their ligamentous laxity. In older patients, these joints become sclerosed and ossified, probably reducing the risk of bacterial seeding.[12-14] Therefore, theoretically, in young patients osteitis pubis may become hematogenously seeded by bacteria, creating osteomyelitis pubis.

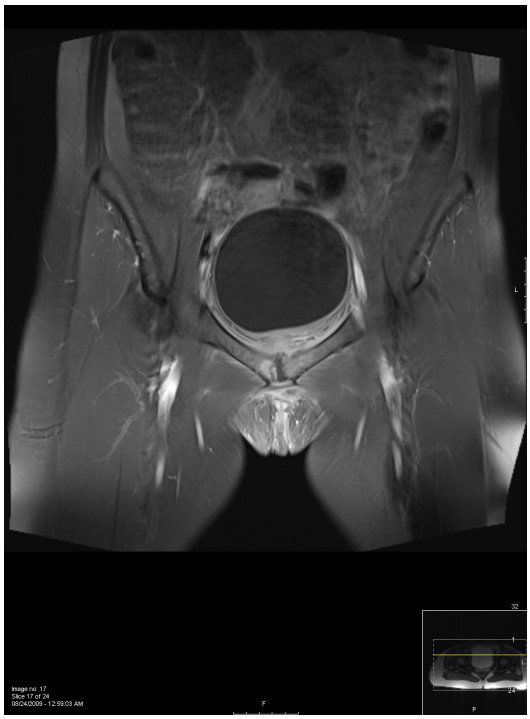

Figure. Axial T2 weighted image of the pelvis with fat saturation reveals bone marrow edema (white) on the right ischial spine just adjacent to the symphysis pubis suggesting osteomyelitis. Blood cultures grew Methicillin-sensitive Staphylococcus aureus and patient was treated with a prolonged course of intravenous ceftriaxone by the inpatient infectious disease team and improved.

Osteomyelitis pubis by definition is infectious in nature and its clinical and laboratory manifestations can vary. In a study of 100 patients with laboratory-confirmed osteomyelitis pubis, only 74% had fever, 59% had painful gait and 45% had pain with hip motion.[15] Laboratory values were not always abnormal, as in the same study leukocytosis was observed in only 35% of patients. ESR and CRP may be abnormal but are nonspecific. Bacteremia, not a useful marker in the ED, was present in 73% of patients with blood culture results reported. Cultures of needle aspirates of the symphysis pubis were more sensitive with 86% positive. Finally, in 89% of cases requiring surgical debridement, surgical specimens were the only positive culture result.[14]

Emergency physicians need to be aware of the risk factors that predispose to osteomyelitis pubis. The major risk factors in this study were female incontinence surgery (24%), being an athlete (19%), history of pelvic malignancies (17%), and IV drug use (15%). The remainder of the risk factors included vaginal delivery, male incontinence surgery, cardiac catheterization, and herniorraphy. Ten percent of the patients in the study had no identifiable risk factors.[15] *Staphylococcus aureus* was the most common etiologic agent in athletes, whereas polymicrobial infection and enteric pathogens were most often responsible in patients with pelvic malignancies. *Pseudomonas aeruginosa* was a common etiology in intravenous drug users prior to 1983, but its incidence is decreasing.[2]

Our patient underwent CT of the pelvis twice at outside facilities and plane radiographs once prior to an MRI finally revealing her diagnosis (Figure). Studies have shown that MRI is 100% sensitive for detecting cases of osteomyelitis pubis, but are not readily available at all institutions.[15] CT is another option, but false negative rates as high as 10% have been reported in the literature[15] and this should be considered if clinical suspicion is high despite a negative CT of the pelvis. These patients should be admitted for further workup or referred urgently for MRI if the diagnosis is still suspected.

Osteomyelitis pubis should be added to the emergency physician's differential diagnosis for acute onset pelvic pain of unclear etiology, and MRI may be needed for definitive diagnosis. Despite the complicated workup and treatment of this disease, the emergency physician can make a significant difference in the timely diagnosis and early treatment in these patients if the diagnosis is considered in patients presenting with severe pelvic pain.

Address for Correspondence: Justin Yax, DO, DMTH, 11100 Euclid Ave, Wearn B-17, Cleveland, OH 44106. Email: Justin.Yax@uhhospitals.org.

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Patellar Sleeve Fracture

Scott Sullivan, MD
Kevin Maskell, MD
Tristan Knutson, MD

Madigan Army Medical Center, Department of Emergency Medicine, Tacoma, Washington

Supervising Section Editor: Sean O. Henderson, MD
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PRESENTATION

A 10 year-old male presented to the ED with knee pain after falling off his bicycle. He landed on his flexed knee with an audible "pop." He could not extend his knee or walk. Physical examination revealed an effusion and high riding patella with a palpable inferior pole defect. He was neurovascularly intact, and the remaining examination of his lower extremity was unremarkable. His radiographs are shown in Figure 1.

DIAGNOSIS / DISCUSSION

Patellar Sleeve Fracture (PSF)

Patellar fracture and tendon rupture are uncommon occurrences in skeletally immature children. In this population, the most common form of this injury is the PSF, which should be considered in patients with an exam concerning for patellar tendon rupture.[1] During secondary ossification, the patella is surrounded in a layer of protective cartilage. Forced loads on the contracted quadriceps with knee flexion results in an avulsion fracture. Since much of the fragment is unossified peripheral cartilage, these sleeve fractures are difficult to detect on radiographs. If there is clinical suspicion for PSF, magnetic resonance imaging can visualize this fragment.[2] Identifying sleeve fractures is critical as prompt surgical correction is required for recovery of function.[3] Delay may result in complications such as reduced knee flexion, ectopic bone formation, or avascular necrosis.[3,4]

This patient's x-rays (Figure 1) reveal patella alta and a 1.3cm ossific fragment representing an avulsion with partial rupture of the patellar sleeve. He had an ORIF the next day. At 15 week follow up, his patellar tendon remained intact and he was progressing in physical therapy. His post-operative radiograph is displayed in Figure 2.

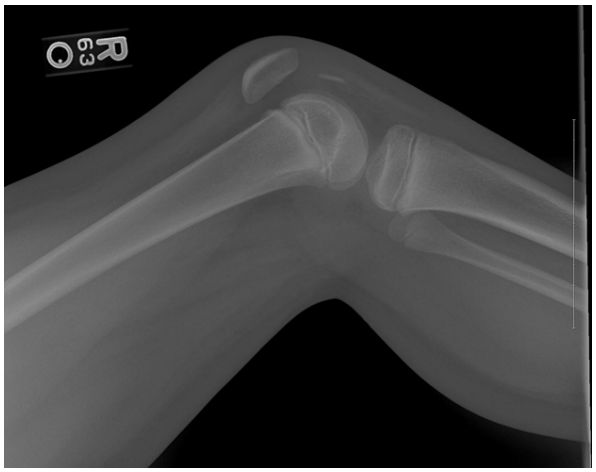

Figure 1. This is the initial lateral view of the patient's knee demonstrating patella alta and a 1.3cm ossific fragment representing an avulsion with partial rupture of the patellar sleeve.

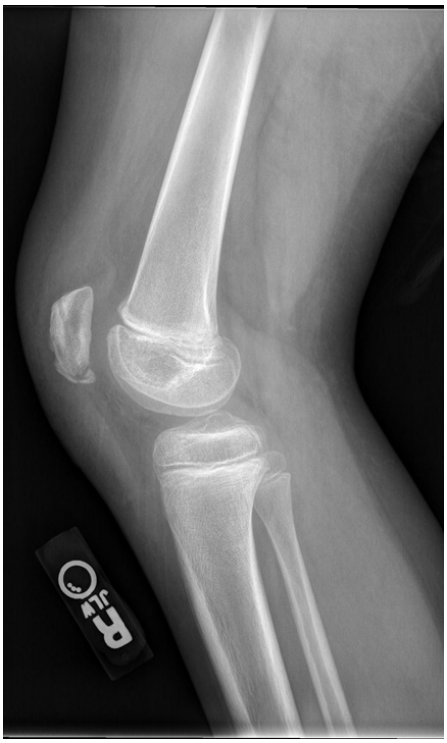

Figure 2. This is the post-surgical fixation lateral view of the patient's knee demonstrating resolution of patella alta and fixation of the ossific fragment.

Address for Correspondence: Scott Sullivan, MD, 3086 O'Brien St, DuPont, WA 98327. Email: scott.b.sullivan1@gmail.com.

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Diagnosis of Spinal Epidural Abscess by Abdominal Plain-Film Radiography

Brent Felton, DO
Tam Dao, MD
Brett Gerstner, DO
Shawn Letarte, MD

Michigan State University, Sparrow Health System, Department of Emergency Medicine, Lansing, Michigan

Supervising Section Editor: Sean O. Henderson, MD
Submission history: Submitted May 8, 2014; Revision received June 9, 2014; Accepted August 31, 2014
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A 57-year-old male with a history of diabetes mellitus, hepatitis C, and intravenous drug abuse presented to the emergency department complaining of abdominal pain of three months duration that had worsened in the week prior to presentation. Review of systems was significant for back pain, nausea, and fever. The patient's physical examination demonstrated a diffusely tender abdomen in addition to bilateral costo-vertebral angle tenderness, bilateral lower extremity weakness, and decreased rectal tone. An acute abdominal series was ordered to evaluate for bowel perforation (Figure). After review of this radiograph, magnetic resonance imaging (MRI) of the thoracic spine was ordered to confirm the suspected diagnosis of epidural abscess (Figure). The patient was transferred to the operating room for successful thoracic hemi-laminectomy and discharged home on post-op day seven.

The incidence of spinal epidural abscess has been estimated to account for 0.2-2.0 per 10,000 admissions, although recent studies report that the incidence is rising owing to increased rates of intravenous drug abuse and spinal surgical instrumentation.[1,2] While the utility of plain film radiography is limited in the initial evaluation of suspected epidural abscess, abnormalities suggesting the presence of the disease in the form of end plate erosions or findings suggestive of osteomyelitis should not be ignored as these findings may be present in up to 89% of cases.[3-5] In contrast, MRI with gadolinium contrast has a reported sensitivity of 91% with an associated specificity of 100%, rendering it the imaging modality of choice.[5-7] Timely diagnosis of this relatively rare condition is paramount as the associated mortality of 5-16% is significant.[8,9]

Address for Correspondence: Brent Felton, DO, 2370 Robins Way, Okemos, MI 48864. Email: feltonbr@gmail.com.

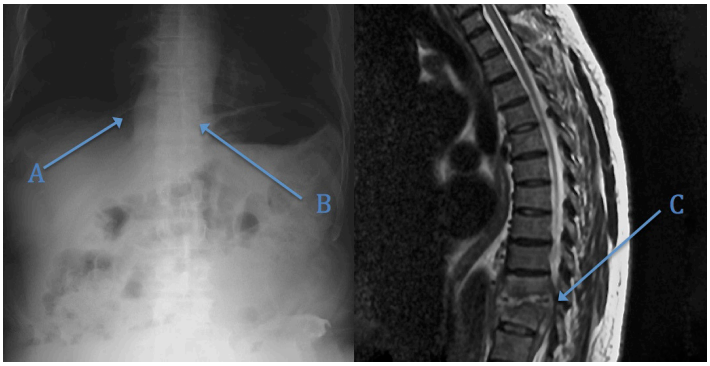

Figure. Magnetic resonance imaging of thoracic spine. Upright abdominal image demonstrating (A) paraspinal soft tissue density at the T10-T11 level worrisome for the possibility of paraspinal abscess, (B) poor visualization of the T10-T11 disc interspace, and (C) MRI demonstrating findings consistent with diskitis and associated sub-ligamentous abscess extending into the spinal canal at T11 and T12 with cord compression and severe central canal stenosis at these levels.

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Egg Shell Sign: Rare Finding in Acute Aortic Dissection

John Ashurst, DO
Kevin Weaver, DO
Lehigh Valley Health Network, Allentown, Pennsylvania

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A 77 year-old woman presented with a one day history of central chest pressure that radiated to the neck and right upper extremity. She had a history of hypertension and chronic obstruction pulmonary disease. Her blood pressure was 86/47 with a heart rate of 87 beats per minute. A grade 2/6 systolic ejection murmur was auscultated over the left sternal border. An electrocardiogram showed ST elevation in lead III with ST depression I, AVL, V4-V6 and a chest radiograph was obtained which showed an "egg shell sign" as compared to previous radiograph (Figures 1 and 2). The patient was diagnosed with a type A aortic dissection and taken to the operating room for emergent repair but died during the procedure.

DISCUSSION

Aortic dissection was first described more than 200 years ago by Morgagni and since then has become the most common aortic emergency requiring surgical intervention.[1,2] Aortic dissections are currently classified by their location with the Stanford Type A dissection involving the ascending aorta, and the Type B dissection occurring distal to the left subclavian artery.[2]

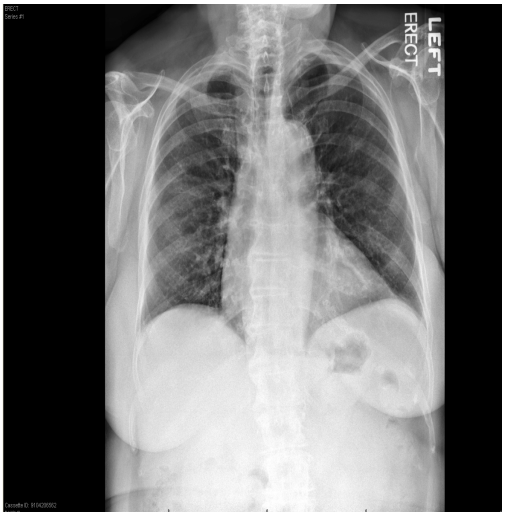

Figure 1. Previous radiograph with no acute disease process.

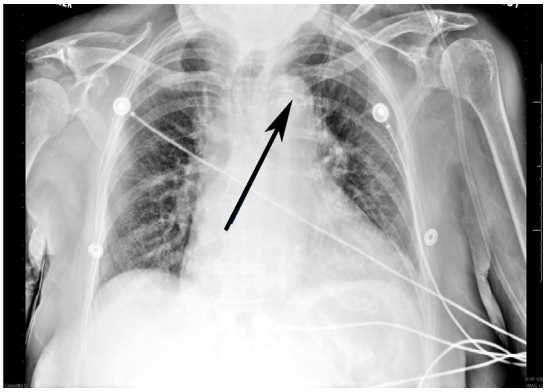

Figure 2. Egg shell sign (arrow), defined as a distance greater than 6mm from the aortic calcification to the lateral soft tissue margin of the aorta, with a widened mediastinum indicating aortic dissection.

A meta-analysis showed that acute onset of pain had a sensitivity of 84% and that severe pain had a sensitivity of 90% for aortic dissection.[3] A new diastolic murmur does little to change the pretest probability but pulse deficits or a blood pressure differential has a high pre-test probability of aortic dissection.[3] Chest radiography is abnormal in 90% of patients with an acute aortic dissection.[3] In Figure 2, the patient had both a widened mediastinum and an "egg shell" sign indicative of an aortic dissection. The "egg shell" sign is reported in only 14% of patients with aortic dissection and is described as displacement of the soft tissue greater than 6mm from an aortic calcification.[2,4]

Address for Correspondence: John Ashurst, DO, Lehigh Valley Health Network, 2545 Schoenersville Rd, Bethlehem, PA 18017-7300. Email: ashurst.john.32.research@gmail.com.

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Estimation of Laceration Length by Emergency Department Personnel

Christina L. Bourne, MD*
M. Adams Jenkins, MD†
Kori L. Brewer, PhD‡

*Medical University of South Carolina, Department of Medicine, Division of Emergency Medicine, Charleston, South Carolina
†Northcrest Medical Center, Department of Emergency Medicine, Springfield, Tennessee
‡Brody School of Medicine at East Carolina University, Department of Emergency Medicine, Greenville, North Carolina

Supervising Section Editor: Eric Snoey, MD
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Introduction: Documentation and billing for laceration repair involves a description of wound length. We designed this study to test the hypothesis that emergency department (ED) personnel can accurately estimate wound lengths without the aid of a measuring device.

Methods: This was a single-center prospective observational study performed in an academic ED. Seven wounds of varying lengths were simulated by creating lacerations on purchased pigs' ears and feet. We asked healthcare providers, defined as nurses and physicians working in the ED, to estimate the length of each wound by visual inspection. Length estimates were given in centimeters (cm) and inches. Estimated lengths were considered correct if the estimate was within 0.5 cm or 0.2 inches of the actual length. We calculated the differences between estimated and actual laceration lengths for each laceration and compared the accuracy of physicians to nurses using an unpaired t-test.

Results: Thirty-two physicians (nine faculty and 23 residents) and 16 nurses participated. All subjects tended to overestimate in cm and inches. Physicians were able to estimate laceration length within 0.5 cm 36% of the time and within 0.2 inches 29% of the time. Physicians were more accurate at estimating wound lengths than nurses in both cm and inches. Both physicians and nurses were more accurate at estimating shorter lengths (<5.0 cm) than longer (>5.0 cm).

Conclusion: ED personnel are often unable to accurately estimate wound length in either cm or inches and tend to overestimate laceration lengths when based solely on visual inspection. Abstract [West J Emerg Med. 2014;15(7):889–891.]

INTRODUCTION

Approximately 8.2% of emergency department (ED) visits in the United States are for lacerations, resulting in more than 90 million ED visits for lacerations annually.[1] One of the descriptive factors included in the documentation and used for billing is the wound length, which is often estimated rather than measured. Despite this common practice, there is very little published research into wound length estimation.[2-4] One previous study looked at estimation of wound length based on two-dimensional line drawings.[2] The current study examines the ability of medical personnel to estimate the lengths of simulated lacerations using real tissue. This study was designed to test the hypothesis that ED personnel can accurately estimate wound lengths without the aid of a measuring device. We compared the accuracy of wound length estimations in inches versus centimeters and also compared accuracy across different groups of health care professionals.

METHODS

This prospective observational study was carried out

at a single-center academic ED affiliated with a Level I Trauma Center. The local institutional review committee approved the study.

Seven wounds of varying lengths were simulated by creating lacerations on pigs' ears and feet obtained from a local grocery store. Theatrical blood was applied to each wound to better simulate a real laceration, but the blood did not obscure the edges of any of the wounds. Two independent observers measured the lacerations prior to the study and determined the actual lengths by averaging these two measurements if any discrepancy was noted. The actual lacerations created ranged from 1.4 - 9.5cm (1.4, 2.5, 3.5, 5.2, 6.0, 7.1, 9.5cm). Healthcare providers, defined as nurses and physicians working in the ED, were asked to participate in the study. Participants were given a survey in which they were asked their occupation, years of experience in that occupation, and their estimate of the lengths of the simulated lacerations in both inches and cm out to one decimal place. Participants were not permitted to touch the lacerations and therefore determined their estimated length on visual inspection alone. The surveys were obtained on two separate days and with two different sets of simulated lacerations.

We calculated the difference between actual length and estimated length of each laceration in both inches and cm,as well as whether estimates were an overestimation or underestimation of length.

Estimated lengths were considered correct if the estimate was within 0.5cm or 0.2 inches of the actual measured length. We placed the data in an Excel Worksheet and analysed it using the Statview Statistical Program (SAS, Inc.). Descriptive statistics are provided for wound length estimates for physicians. We compared the difference between estimated and actual wound lengths in the physician group to that of nurses using an unpaired t-test with $p<0.05$ indicating a significant difference.

RESULTS

Twenty-three resident physicians, nine attending physicians, and 16 nurses participated in the study. Physicians were only able to estimate wound length accurately as defined before the study within 0.5cm 36% of the time and within 0.2 inches 29% of the time (Figure 1 and 2). Physicians consistently overestimated laceration length with 70% of estimates being too long when using cm and 87.9% being too long when using inches. Accuracy was significantly better on lacerations less than 5cm in length, with 46% being estimated accurately within 0.5cm for these lacerations compared to 21% when the lacerations were over 5cm (p=0.002) (Figure 3). The same was true when estimating in inches; where lacerations less than 5cm in length were estimated accurately to be within 0.2 inches 36.7% of the time compared to 17.7% of the time for lacerations over 5cm (p=0.001) (Figure 4). Physician estimates of laceration length were consistently more accurate than those provided by nurses with a mean difference in cm of -0.86 +/- 0.075 for physicians versus -2.73 +/- 0.391 for nurses (p<0.0001; 95% CI = -4.2 to -2.9) and a mean difference in inches of -0.731 for physicians versus -0.909 for nurses (p=0.032; -1.8 to -1.4). Similar to physicians, nurses also tended to overestimate in both cm and inches, as well as being more accurate at estimating lacerations of shorter lengths (<5.0cm).

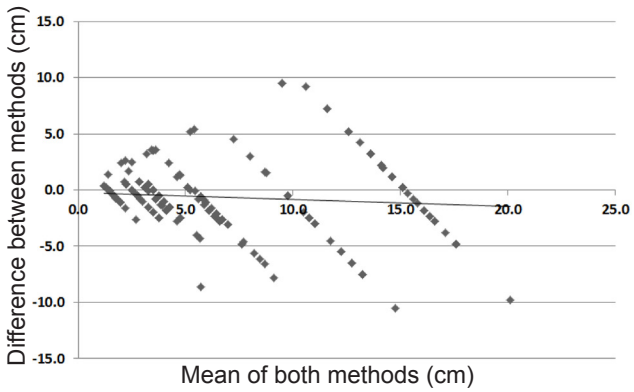

Figure 1. Bland-Altman Plot of data obtained from paired measurements of seven different wound simulations (estimations provided in centimetres). Correlation R = 0.1025 (p-value=0.11). Slope = -0.06 (p-value=0.11). Intercept = -0.24 (p-value=0.47).

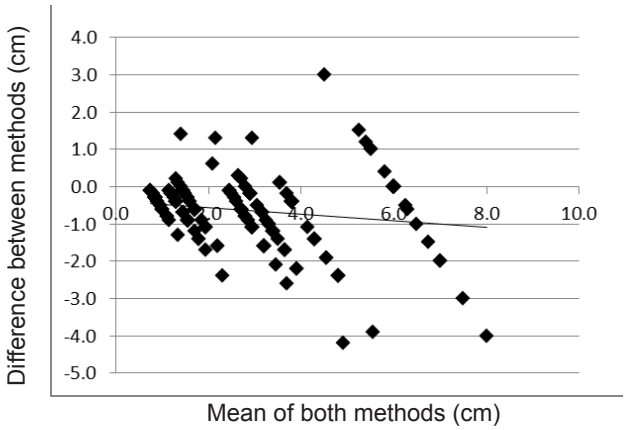

Figure 2. Bland-Altman Plot of data obtained from paired measurements of seven different wound simulations (estimations provided in inches). Correlation R = 0.1625 (p=0.01). Slope = -0.08 (p=0.01). Intercept = -0.40 (p<0.01).

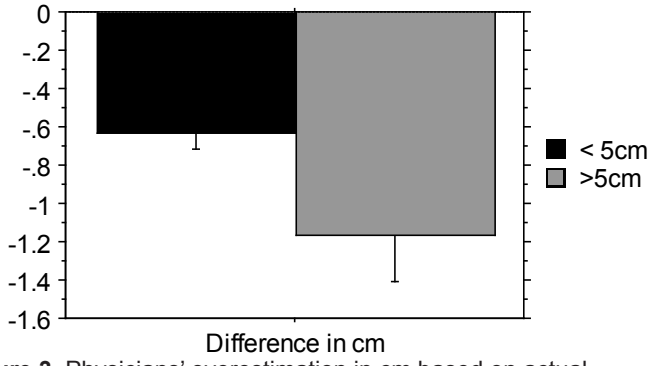

Figure 3. Physicians' overestimation in cm based on actual wound length.

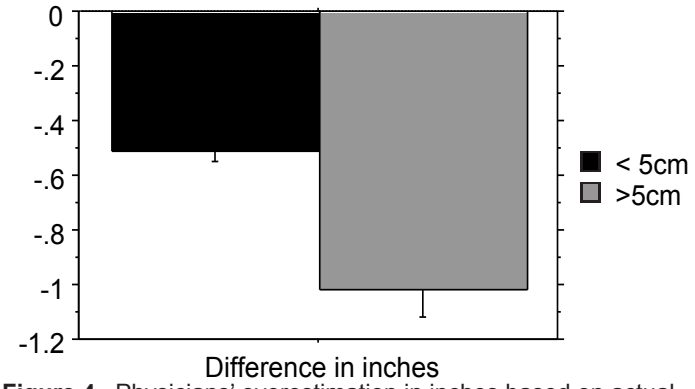

Figure 4. Physicians' overestimation in inches based on actual wound length.

DISCUSSION

This study found that ED personnel are not able to accurately estimate wound length based on visual inspection. Accuracy was low when laceration length was estimated in cm or inches, and both ED physicians and nurses tended to overestimate. This is important to both physicians and patients as this could result in incorrect billing for repair of lacerations.[4,5] These findings imply that we should be measuring our lacerations rather than estimating their length, as most of the time we overestimate.

LIMITATIONS

This study was not designed as a comprehensive look at the multiple factors associated with billing for lacerations. Billing not only includes laceration length but also location and complexity. The study did not look at the most complex lacerations or at multi-layer closure lacerations but did attempt to get some variety as far as jagged lacerations and Y-shaped lacerations. However, it could be presumed that if we are not able to accurately estimate simpler lacerations, then we undoubtedly do worse with more complex lacerations. Similarly, it was not surprising to find that our estimations get worse with longer lacerations.

The study was limited in that there were fairly small numbers of participants. As with any study, it is difficult to get participation; however, when conducting research with perishable items this becomes even more difficult. Multiple sets were obtained on two different days as the model used was perishable. In addition, it was difficult to exactly replicate the same lacerations on two separate days. This could be viewed as a weakness, but as is the case in the ED, no two wounds are exactly the same. A final limitation of this research is that it was based on visual inspection alone. Medical providers may more accurately estimate wound length using techniques that are not purely visual, such as estimating based on finger widths or on number of sutures placed. The subjects were not asked the frequency with which they routinely used these other measuring cues.

CONCLUSION

ED personnel are often unable to accurately estimate wound length in either cm or inches and tend to overestimate laceration lengths when based solely on visual inspection.

Address for Correspondence: Christina L. Bourne, MD, Medical University of South Carolina Emergency Medicine, 169 Ashley Avenue, MSC 300, Room 265B North Tower, Charleston, SC 29425. Email: bournec@musc.edu.

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Middle Cerebral Artery Arrow Sign

Zachary D. Levy, MD*
Richard E. Temes, MD†
Amir R. Dehdashti, MD‡

* Hofstra North Shore-LIJ School of Medicine, Department of Emergency Medicine, Hempstead, New York
† Hofstra North Shore-LIJ School of Medicine, Department of Neurology, Hempstead, New York
‡ Hofstra North Shore-LIJ School of Medicine, Department of Neurosurgery, Hempstead, New York

Supervising Section Editor: Sean O. Henderson, MD
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A 54-year-old woman presented to the emergency department with sudden onset severe headache, nausea and vomiting upon waking that morning. On examination, she was alert and oriented, with a mild right facial droop and a right upper extremity pronator drift. A non-contrast computed tomography (CT) of the head revealed diffuse subarachnoid blood, with a prominent triangular focus projecting into the left Sylvian fissure (Figure).

DIAGNOSIS

Patients with aneurysmal subarachnoid hemorrhage often present with acute headache and evidence of blood in the basilar cisterns on non-contrast CT.[1] When aneurysms of the middle cerebral artery rupture, blood may pool in the area around the insular cortex and ipsilateral Sylvian cistern. The resulting hemorrhage takes on the appearance of an arrow pointing towards the side of the lesion, also known as the middle cerebral artery (MCA) arrow sign.[2]

Following non-contrast CT, the patient underwent cerebral angiography, which did indeed demonstrate an aneurysm at the distal M1 segment at the origin of the left anterior temporal branch. The patient subsequently underwent craniotomy and successful clipping of her aneurysm. She had normal post-operative neurologic function.

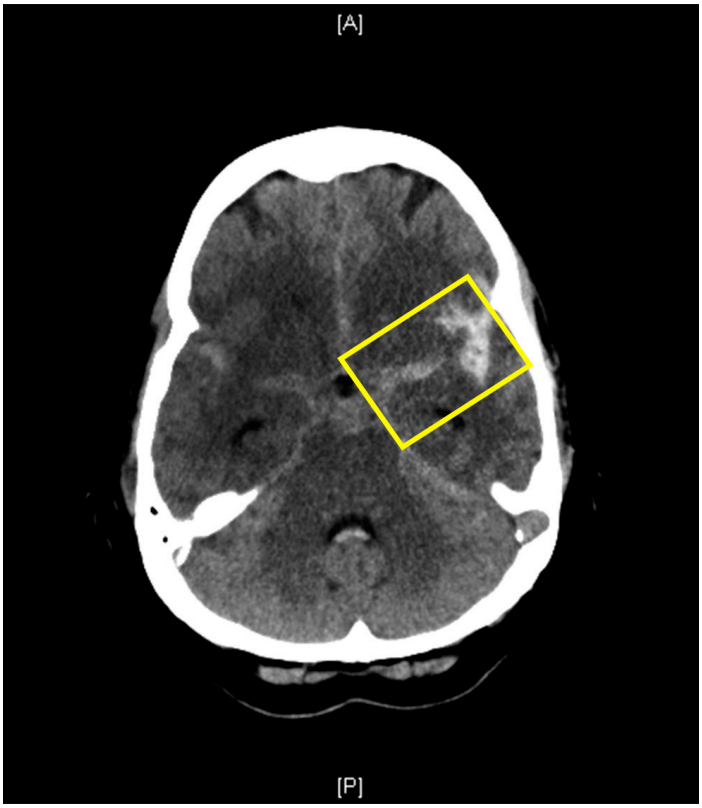

Figure. Left MCA arrow sign.
MCA, middle cerebral artery

Address for Correspondence: Zachary Levy, MD. 300 Community Drive, Manhasset, NY 11030. Email: zlevy@nshs.edu.

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Hepatic Portal Venous Gas: Findings on Ultrasound and CT

Kristin Berona, MD
Kevin Hardiman, DO
Thomas Mailhot, MD

Los Angeles County + University of Southern California Medical Center, Department of Emergency Medicine, Los Angeles, California

Supervising Section Editor: Sean O. Henderson, MD
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A 76-year-old female with a history of Parkinson's, dementia, and hypertension presented to the emergency department with non-bilious, non-bloody vomiting and abdominal pain for 2 days. Her exam was significant for borderline hypotension without tachycardia, abdominal distension and a palpable ventral hernia. An emergency physician performed ultrasound showed free intraperitoneal air and gas in the liver (Video). A computed tomography showed pneumoperitoneum, pneumatosis intestinalis, and hepatic portal venous gas (HPVG) (Figure). At laparotomy, she was found to have a sigmoid colon perforation from adenocarcinoma, ischemic small bowel, and a colovesicular fistula. Post-operatively her clinical status worsened, and she was transitioned to comfort care and expired on hospital day 2.

HPVG was first reported in infants with necrotizing enterocolitis.[1] In adults, it is most commonly associated with mesenteric ischemia and pneumatosis intestinalis, accounting for 43% of HPGV cases[2] and an associated mortality of 75%.[2-3] It has been reported with other diseases such as diverticulitis, inflammatory bowel disease, obstructive pyelonephritis, pancreatitis, cholangitis, uterine gangrene, and severe shock.[4] HPVG is attributed to either bacterial gas production in bowel entering mesenteric circulation[4] or intraluminal air entering capillaries from impaired mucosal barrier or increased intraluminal pressure.[5] HPVG spreads to the periphery of the liver whereas pneumobilia collects centrally, in the direction of bile flow. Treatment is always aimed at the underlying etiology of HPVG.

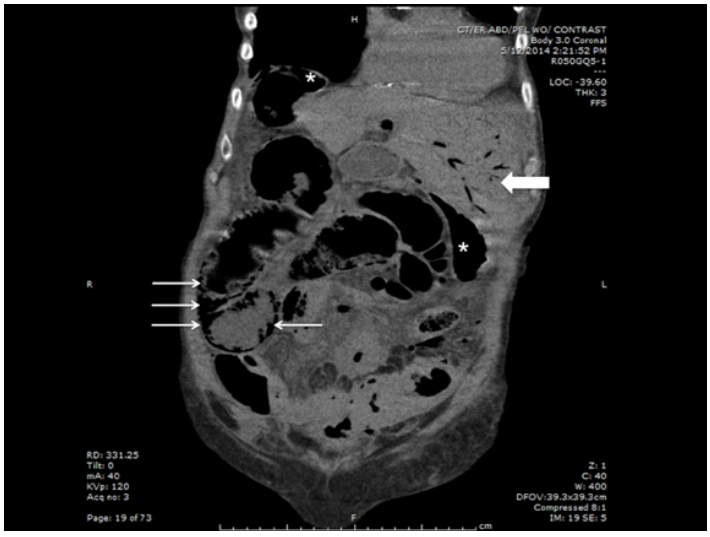

Figure. Computed tomography without contrast of the abdomen and pelvis showing free air (asterisks), pneumatosis intestinalis (thin arrows), and hepatic portal venous gas (large arrow).

Video. Ultrasound videos in epigastrium and right upper quadrant showing pneumoperitoneum and hepatic portal venous gas.

Address for Correspondence: Kristin Berona, MD, LAC+USC Medical Center, 1200 N. State St. Room 1011, Los Angeles, CA
Email: kberona@gmail.com.

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Post Transapical Aortic Valve Replacement (TAVR) Pseudoaneurysm

Michael W. Manning, MS
Leonel Diaz, Jr., DO
Michael B. Weigner, MD
Colin L. Donnelly, DO
Marna R. Greenberg, DO, MPH

Department of Emergency Medicine, Lehigh Valley Hospital, Allentown, Pennsylvania
Department of Emergency Medicine, University of South Florida College of Medicine, Tampa, Florida

Supervising Section Editor: Sean Henderson, MD
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A 63-year-old female presented to the emergency department with complaints of her "heart beating out of my chest," palpitations, and shortness of breath. She was three months postoperative a #23 Edwards Sapien Transapical Aortic Valve Replacement (TAVR). On exam she was surprisingly comfortable in appearance with an easily visible pulsatile mass on her left anterior chest.

A computed tomography revealed a large, high density collection extending from the apex of the left ventricle through the left anterior fifth-sixth intercostal space into the left anterior chest wall (Figure). The pseudoaneurysm measured approximately 9.7cm by 6.5cm. The heart appeared mildly enlarged and a percutaneously placed aortic valve was noted. There was atherosclerotic calcification in the coronary arteries and thoracic aorta. No pleural or pericardial effusion was present. A healed medial sternotomy and a sternal plate were also noted.

A 2D Echocardiogram (Video) showed a large pseudoaneurysm located at the apex of the left ventricle associated with a large apical pulsatile collection. The "neck" of the pseudoaneurysm measured 1cm. There was large and turbulent flow between the left ventricle and the large collection of the pseudoaneurysm. The left ventricular (LV) chamber size and systolic function were normal. Moderate concentric LV hypertrophy was present and the LV ejection fraction was visually estimated to be 60% (in pseudoaneurysm setting). The right ventricle was enlarged with reduced systolic function. Both atria were dilated (moderately on the left, mildly on the right). The aortic valve showed a #23 Edwards Sapien TAVR with no regurgitation. The mitral valve showed thickened leaflets, annular calcification, and moderate regurgitation. The tricuspid valve showed mild regurgitation but no stenosis.

Reports of false or pseudo aneurysms as complications of

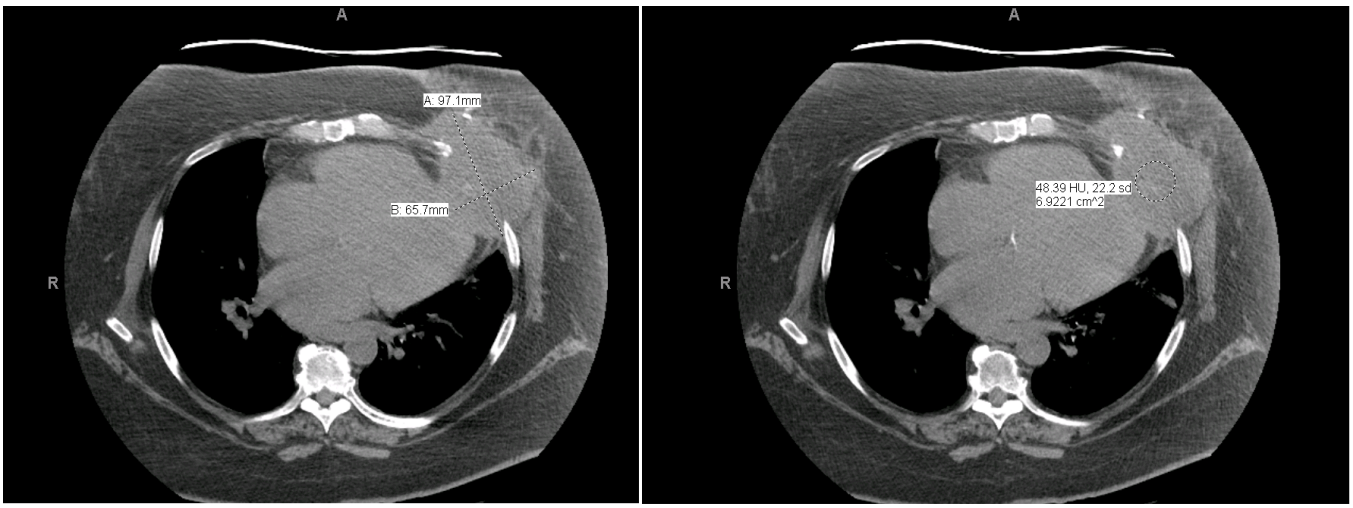

Figure. LVI-CT of the chest without contrast.
LVI-CT, left ventricular index-computed tomography

TAVR are rare, and only a handful ranging from two weeks to five months postoperatively have been reported. 1-4 Surgical repair is necessary.

Video. Echocardiogram.

Address for Correspondence: Marna R. Greenberg, DO, MPH, FACEP. 1909 Earls Court, Allentown, PA 18103. Email: mrgdo@ptd.net.

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A Woman with Dyspnea and Hemoptysis

Steven G. Schauer, DO*
Justin C. Eisenman, DO†

*Bayne-Jones Army Community Hospital, Department of Emergency Medicine, Fort Polk, Louisiana
†Blanchfield Army Community Hospital, Fort Campbell, Kentucky

Supervising Section Editor: Sean O. Henderson, MD
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A 55-year-old female presented to the emergency department at a small community hospital with cough, fever, dyspnea and blood-streaked sputum. A chest radiograph was ordered. She was diagnosed with pneumonia and discharged home with antibiotics. She returned three days later, afebrile, with worsening dyspnea and gross hemoptysis. She was found to have a murmur reported as chronic but had never been evaluated by echocardiography. A computed tomography chest and echocardiography were performed (Figure). She was diagnosed with a left atrial myxoma (Video). She was transferred and underwent tumor excision. [West J Emerg Med. 2014;15(7):897-898.]

DISCUSSION

Primary cardiac tumors are rare with an incidence of 0.05%.[1] The overwhelming majority of cardiac myxomas are located in the left atrium, followed by the right atrium and then in the ventricles.[2,3] Like most cardiac myxomas, the histology in this presentation is benign. The myxoma triad consists of obstructive symptoms (heart failure, shortness of breath), malaise, and embolic events. Physical exam may reveal a murmur known as "tumor plop" that often mimics mitral stenosis.[4] The diagnosis is often made when evaluating for etiologies of similar presentation. Echocardiography, chest computed tomography (CT), cardiac magnetic resonance imaging (MRI), and cardiac angiography have all been described. Echocardiography has the advantage of being able to evaluate size, shape, location and mobility in a dynamic fashion with reported sensitivities of 95% and nearly 100% for transthoracic and transesophageal, respectively.[5] MRI and CT appear to have lesser reliability when determining tumor origin.[6] The prognosis is good with a 96% 10-year survival rate.[3]

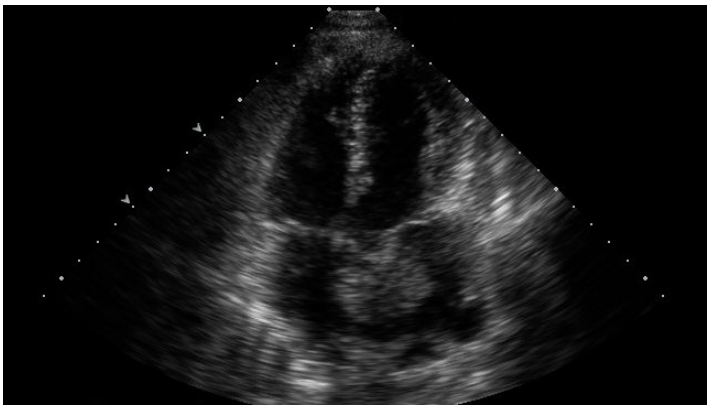

Figure. Echocardiography of patient diagnosed with left atrial myxoma.

Video. Video demonstrates the dynamic left atrial myxoma denoted by arrow.

Address for Correspondence: Steven G. Schauer, DO, Bayne-Jones Army Community Hospital, 1585 3rd Street, Fort Polk, LA 71459. Email: sgschauer@gmail.com.

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Medical Identity Theft in the Emergency Department: Awareness is Crucial

Michelino Mancini, DO Lakeland Healthcare, Department of Emergency Medicine, St. Joseph, Michigan

Supervising Section Editor: Rick McPheeters, DO
Submission history: Submitted April 24, 2014; Revision received July 24, 2014; Accepted August 15, 2014
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Medical Identity theft in the emergency department (ED) can harm numerous individuals, and many frontline healthcare providers are unaware of this growing concern. The two cases described began as typical ED encounters until red flags were discovered upon validating the patient's identity. Educating all healthcare personnel within and outside the ED regarding the subtle signs of medical identity theft and implementing institutional policies to identify these criminals will discourage further fraudulent behavior. [West J Emerg Med. 2014;15(7):899–901.]

INTRODUCTION

The crime of medical identity theft is a growing concern in healthcare institutions. Medical identity theft is a practice in which someone uses another individual's identifying information, such as health insurance or social security number, without the individual's knowledge or permission, to obtain medical services or goods, or to obtain money by falsifying claims for medical services and falsifying medical records to support those claims.[1]

According to the Federal Trade Commission (FTC), medical identity theft accounted for 3% of identity theft crimes, or 249,000 of the estimated 8.3 million people who had their identities stolen in 2005.[2] More recently, the Ponemon Institute calculated that there were 1.84 million victims of medical identity theft in 2013.[3] These numbers were not specific to particular institutional departments, and emergency departments (EDs) may have a higher percentage of cases due to the growth in ED visits and the obligation to provide treatment in most emergency situations.

Numerous parties are negatively impacted by medical identity theft, including healthcare providers and payers. But, the stakeholder most adversely affected is the healthcare consumer. Consumers may receive inappropriate medications or treatment, which in some instances may be life-threatening. They can also suffer financial burdens when healthcare services provided to the medical identity thief are billed to the consumers or their insurance carriers.

The following cases illustrate common emergency medical encounters that were eventually exposed as incidents of medical identity theft. These incidents were discovered with the combined efforts of multiple healthcare associates, including registration clerks, nursing staff, security officers and physicians, and they were handled without compromising patient care or Emergency Medical Treatment and Labor Act (EMTALA) regulations.

CASE REPORTS

Case 1

An 18-year-old male presented to the ED with a chief complaint of a headache after a fall twelve hours prior. The patient reported that while walking down the last couple stairs in his house, he slipped and struck his head on the floor. Since the event he had experienced a persistent 6/10 sharp frontal headache. He denied any other associated symptoms including loss of consciousness, blurred vision, gait instability, neck pain, nausea, vomiting, or confusion.

The patient did not have a medical history and denied illicit drug or substance abuse. He answered all questions appropriately and had stable vital signs. His Glasgow Coma Scale was fifteen, and the remainder of his exam including neurological was negative. The patient was given hydrocodone/acetaminophen 5-325mg for his pain.

Upon reentering the patient's room to assess his pain, the attending physician encountered the patient being questioned by both the hospital security manager and a local police officer. The patient had presented to the ED without any personal identification cards and no means of validating his identity to the nursing staff or registration clerk. In addition, the security manager noted that his signatures on the hospital's standard financial agreement and

patient identification form did not match previous hospital-encounter signatures. The patient was later discharged from the institution uneventfully and without incarceration. Thirty days later, the information obtained by the hospital security manager and local police officer was used to successfully prosecute the patient for a felony of medical identity theft and insurance fraud.

Case 2

A 19-year-old female presented to the ED with mild lip swelling for two days. The patient denied any associated symptoms, including tongue swelling, shortness of breath, sore throat, voice change or difficulty swallowing. She denied taking any prescribed or over-the-counter medications. She also denied exposure to inhalants or skin irritants.

The patient did not have a medical history, and her vital signs were stable upon presentation. The physical exam was significant for mild lip edema without any tongue or oropharyngeal swelling. The remainder of the exam was negative. The patient was placed on a cardiac monitor and given intravenous diphenhydramine and methylprednisolone.

During her observational period, the registration clerk noted that the patient provided her a maternal insurance card and no personal identification cards. The clerk notified the security manager and, after further investigation, contacted the individual listed on the maternal insurance card. The card holder informed the security manager that she was not related to the patient and was concerned that her insurance card might have been stolen. After the complete resolution of her lip swelling, the patient was discharged and escorted to the local police department for further questioning. As a result of the information obtained by the registration clerk, security manager and local police department, along with the assistance of the victim, 60 days later the fraudulent patient was convicted of a felony for medical identity theft and insurance fraud.

DISCUSSION

In both cases described, the patients provided medical histories identical to their victims. The patient in the first case fraudulently used his brother's identification in order to remit costs of the ED visit to his brother's medical insurance. The patient's brother was found to be the victim and not an accessory to the crime. During the investigation of the second case, the patient was found to have two outstanding warrants for her arrest. These cases only illustrate a few motives for perpetrating medical identity theft. A telephone survey of chief compliance officers in acute healthcare facilities that had policies to counteract this crime revealed a belief that drug-seeking behavior and the presence of law enforcement officials in the ED may compel patients to commit medical identity theft to avoid potential arrest for other, unrelated crimes.[4] Whatever the underlying reason, this simple deceptive act can have significant negative effects on healthcare consumers, providers and payers.

The primary victim is usually an individual consumer (i.e., potential patient). Some individuals, including the disabled, minors, newborns, elderly and recently deceased, are even more susceptible targets for this type of theft. Medical identity theft may continue for years before it is discovered by a consumer who has a reason to scrutinize his or her medical bills or records. This fraudulent information can lead to denial of payments, exhausted health insurance and the inability of the consumer to obtain future health or life insurance. In addition to this financial burden, it may lead to life-threatening situations such as obtaining wrongful medications.

Medical identity theft is difficult to investigate and resolve. Some consumers believe that this crime is not a high priority due to the lack of laws addressing it and limited law enforcement resources. Medical privacy regulations including Health Insurance Portability and Accountability Act (HIPPA) do not address medical identity theft. In addition, this type of crime is treated differently than financial identity theft. The rights of victims of financial identity theft, such as the ability to see and correct credit report errors, obtain documents related to transactions involving their personal information and preventing consumer reporting agencies from reporting information that resulted from this theft, are not given to individuals of medical identity theft.[5] In most cases, victims cannot directly access their medical records and correct errors, and it is nearly impossible to prevent health care providers, medical clearinghouses or insurances from reporting misinformation.[1]

Healthcare providers and payers are usually the secondary victims of medical identity theft. Providers will likely write-off all healthcare expenses incurred as a result of treating fraudulent individuals.[6] Some speculate that ED losses can range from $750,000 to $3,000,000 annually from this theft, which directly affects an emergency medicine physician's compensation.[7] Providers and plans may unknowingly retain inaccurate information and share this information with third parties, such as life insurance carriers. With the proliferation of electronic health records, this information flows quickly and freely to numerous networks, further jeopardizing patient safety. Still unknown are the legal liability issues for healthcare providers and plans that may or may not have a process in place to prevent medical identity theft. In addition, common law is not yet clear on legal actions taken against a provider or plan related to negligence or malpractice with respect to medical identity theft.[6]

In 2008, the FTC issued regulations known as the Red Flag Rules, which required hospital institutions to develop and implement written identity theft prevention programs.[8] Congress later passed the Red Flag Clarification Act of 2010, which eased the requirements, thereby allowing many healthcare organizations to be exempt from this regulation. Consequently, many hospital institutions have

not instituted policies on medical identity theft or provided physician or non-physician staff the needed skills to counteract this type of fraud.

The Red Flag Rules enabled organizations to develop a program that includes four basic elements for responding to medical identity theft. The first is identifying relevant red flags within an institution's day-to-day operations, such as alerts from credit reporting companies, altered or other suspicious documents, mismatched personal identifying information (i.e., incorrect social security number with stated address), fraudulent credit account activity and notices from other sources (i.e., law enforcement). The second element is to detect these relevant red flags through verification and authentication methods. The next element is to prevent and mitigate identity theft. This would include notifying a supervisor or law enforcement in order to monitor and investigate current and existing accounts. Finally, the organization should maintain the program and remain up to date as identity theft tactics change and new technology, such as biometric software for iris scans and facial-recognition, becomes more readily available.

Recommendations

Medical identity theft is a complex crime, and a collaborative effort among individual victims, health information management technologists, institutional security officers, law enforcement, healthcare providers and payers is required to combat its effects. Developing an institutional policy that attempts to prevent and address complaints of medical identity theft must be a priority. In addition, broadening education of this crime to all healthcare associates including registration clerks, nurses and physicians is of great importance. Healthcare organizations that develop a reputation of thoroughly investigating and prosecuting medical identity theft will deter future attempts of this crime by fraudulent individuals. Finally, and most importantly, a heightened awareness of medical identity theft among all healthcare providers will help improve and maintain patient safety.

Address for Correspondence: Michelino Mancini, DO, Lakeland HealthCare, GME department, 1234 Napier Avenue, St. Joseph, MI 49085. Email: mmancini@lakelandregional.org.

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Impact of a Physician-in-Triage Process on Resident Education

Bret A. Nicks, MD, MHA
Simon Mahler, MD
David Manthey, MD

Wake Forest University Health Sciences, Department of Emergency Medicine, Winston-Salem, North Carolina

Supervising Section Editor: John Ashurst, DO
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Introduction: Emergency department (ED) crowding negatively impacts patient care quality and efficiency. To reduce crowding many EDs use a physician-in-triage (PIT) process. However, few studies have evaluated the effect of a PIT processes on resident education. Our objective was to determine the impact of a PIT process implementation on resident education within the ED of an academic medical center.

Methods: We performed a prospective cross-sectional study for a 10-week period from March to June 2011, during operationally historic trended peak patient volume and arrival periods. Emergency medicine residents (three-year program) and faculty, blinded to the research objectives, were asked to evaluate the educational quality of each shift using a 5-point Likert scale. Residents and faculty also completed a questionnaire at the end of the study period assessing the perceived impact of the PIT process on resident education, patient care, satisfaction, and throughput. We compared resident and attending data using Mann-Whitney U tests.

Results: During the study period, 54 residents and attendings worked clinically during the PIT process with 78% completing questionnaires related to the study. Attendings and residents indicated "no impact" of the PIT process on resident education [median Likert score of 3.0, inter-quartile range (IQR): 2-4]. There was no difference in attending and resident perceptions (p-value =0.18). Both groups perceived patient satisfaction to be "positively impacted" [4.0, IQR:2-4 for attendings vs 4.0,IQR:1-5 for residents, p-value =0.75]. Residents perceived more improvement in patient throughput to than attendings [3.5, IQR:3-4 for attendings vs 4.0, IQR:3-5 for residents, p-value =0.006]. Perceived impact on differential diagnosis generation was negative in both groups [2.0, IQR:1-3 vs 2.5, IQR:1-5, p-value = 0.42]. The impact of PIT on selection of diagnostic studies and medical decision making was negative for attendings and neutral for residents: [(2.0, IQR:1-3 vs 3.0,IQR:1-4, p-value =0.10) and (2.0, IQR:1-4 vs 3.0, IQR:1-5, p-value =0.14 respectively].

Conclusion: Implementation of a PIT process at an academic medical center was not associated with a negative (or positive) perceived impact on resident education. However, attendings and residents felt that differential diagnosis development was negatively impacted. Attendings also felt diagnostic test selection and medical decision-making learning were negatively impacted by the PIT process. [West J Emerg Med. 2014;15(7):902–907.]

INTRODUCTION

Emergency department (ED) crowding and operational constraints are common in countries across the globe. ED crowding occurs when the demand for services outstrips available resources within a health system – routinely impacting the patient care. Patients often wait for hours before being seen by a provider, or wait to be transferred to an inpatient hospital bed after ED care is provided – not merely an inconvenience but rather a degradation in the quality of care, patient safety, staff morale, patient satisfaction, and

cost of care.[1-5] In 2006, the Institute of Medicine highlighted the near breaking point of the U.S. emergency care system citing crowding as a systemic sign of failure – an institutional problem that goes well beyond the ED.[6]

Since that report, many high-impact solutions have been developed and tested to assuage ED crowding.[7-12] One such solution is a provider in triage (PIT) to improve front-end ED patient flow. This provider (physician or advanced practice clinician) performs a brief initial assessment and initiates necessary testing and treatment directly in the triage space when patients cannot be immediately placed in a main ED treatment area bed. The goal of the PIT process is to increase the efficiency and timeliness of initial patient contact with a licensed medical provider. Patients with only minor complaints can often be discharged directly after this evaluation in triage. For more ill patients, triage physician interventions are initiated – assuming a bed is not immediately available, and patients are placed in a waiting room queue until an ED bed is assigned. Once the patient is bedded to the ED, a comprehensive evaluation is performed, usually by a different provider. The PIT concept can be expanded into a "team triage" concept where an emergency physician, nurse, registrar, technician, and scribe, or some variation thereof, initiate an initial evaluation and treatment of a patient on presentation to the ED. Prior studies have demonstrated that a PIT process increases patient satisfaction, decreases the number of patients who leave without being seen (but perhaps not those leaving without completion of treatment or AMA), and in some settings decreases total length of stay (LOS).[16-22]

While a PIT process can reduce crowding, its applicability at academic medical centers, which balance the missions of patient care and education, is unclear because of concerns regarding its impact on resident education. At present, few peer-reviewed studies have looked at the relationship between crowding and resident education. However, none have focused on the interventional impact on resident education related to having a PIT process in place.[23] Therefore, the primary objective of this study is to determine the impact of a PIT process on ED resident education as measured by resident and attending perception while recognizing the balance of patient care and resident education. Secondary measures, including perceived quality of care, patient satisfaction, throughput and others were included.

METHODS

We performed a prospective cross-sectional study over a 10-week period from March to June 2009, at Wake Forest Baptist Medical Center (WFBMC). WFBMC is a Level I Trauma Center, burn center, and academic tertiary care facility located in Winston-Salem, NC. The ED has an annual volume of 104,000 patient visits per year with thirty-four adult beds during the study period. It also has a three-year emergency medicine (EM) residency training program with fifteen residents per year currently. This study was institutional review board approved.

During the ten-week study period a PIT process was piloted at WFBMC ED. The focus of this pilot project was to assist in the initial evaluation and care needs of those patients presenting during times of ED over-capacity. The PIT team consisted of an ED physician, ED nurse, and ED technician or nursing assistant. They provided initial medical screening examinations for all patients awaiting care in the Adult Acute Care area of the ED when beds were not immediately available. Initiation of laboratory tests and/or radiographic images and concurrent documentation were provided while the patient awaited ED bed availability.

All EM residents and faculty were aware of the PIT process pilot and the desire to address ED crowding but were not made aware of the research objectives. Only attending physician volunteers participated in the PIT. All providers continuing patient care from the PIT during the pilot received a study questionnaire at the end of the study period. The questionnaire was secure, anonymous, and was completed online using SurveyMonkey. Following completion of the online questionnaire, we collated responses and created a secure electronic database, which could only accessed by study investigators.

Questionnaire respondents were asked to evaluate the impact of the PIT process on resident education, quality of patient care, patient throughput, and patient satisfaction. All definitions were provided in an educational session prior to the survey dissemination. All answers were recorded on a 5-point Likert scale: (1-5) with 1 being negative, 3 no impact, and 5 being positive. Resident education was further delineated into these common process steps: history, physical examination, differential diagnosis development, testing and treatment, medical decision making, documentation, consultation, and disposition decision.

We analyzed data from each questionnaire item in two ways: 1) in aggregate and 2) separately for attending and resident physicians. Given the non-parametric nature of the data, we calculated median and IQR to describe questionnaire responses. Mann-Whitney U tests were used to compare questionnaire responses of residents versus attendings. We calculated descriptive statistics for patient satisfaction survey responses, including median and IQR. Statistical analysis was performed using SAS 9.2 (SAS Institute, Cary, North Carolina).

RESULTS

During the study period 54 residents and faculty were identified as having worked a shift in which the PIT was operational. The questionnaire (Figure) was completed by 42/54 physicians, a response rate of 78%. Level of training of the respondents included EM First-years (19.0%), Second-years (21.4%), Third-years (16.7%), and faculty (42.8%) (Table 1).

There was no perceived impact of PIT on resident

Question 1: We just completed our physician-in-triage (PIT) Pilot Project. Did you work clinically during a shift in which the PIT was operational? (If YES, survey continued)
Question 2: What is your current level of training? (1st, 2nd, 3rd year resident, attending)
Question 3: Based on your perception, the PIT pilot had the following impact on:

	Strongly negative	Negative	No Impact	Positive	Strongly positive
Resident education					
Quality of patient care					
Patient satisfaction					
Patient throughput					

Question 4: Based on your perception, what impact did the PIT pilot have on the following areas of resident education?

	Strongly negative	Negative	No impact	Positive	Strongly positive
Patient rapport	0	2	4	2	0
History taking	0	2	4	2	0
Physical examination	0	1	6	1	0
Generating differential diagnoses	0	4	1	2	1
Selecting diagnostic studies	0	4	2	2	0
Medical decision making	0	4	2	1	1
Documentation	0	1	5	2	0
Consultation	0	0	5	3	0
Disposition decisions	0	2	4	2	0
Faculty teaching	0	1	4	3	0

Figure. Questionnaire.

Table 1. Questionnaire response rate by Emergency Medicine participants in physician-in-triage study.

Physician	Participants
First-year residents	8
Second-year residents	9
Third-year residents	7
Attendings	18

education between the attending and resident survey respondents [3.0 (2-4) vs 3.0 (2-4), p-value =0.18]. Residents perceived the quality of care to be better while attending perceived no difference, but this was not statistically significant [3.0 (2-4) vs 4.0 (3-4), p-value =0.22] (Table 2). Both groups perceived patient satisfaction to be positively impacted [4.0 (2-4) vs 4.0 (1-5), p-value =0.75] although residents perceived the overall patient throughput to notably improved [3.5 (3-4) vs 4.0 (3-5), p-value =0.006]. Perceived impact on the components of patient care was negative in both groups for differential diagnosis generation [2.0 (1-3) vs 2.5 (1-5), p-value =0.42] and attendings perceived the impact on selection of diagnostic studies and medical decision making to be negative [2.0 (1-3) vs 3.0 (1-4), p-value =0.10] and [2.0 (1-4) vs 3.0 (1-5), p-value =0.14] respectively (Table 3).

DISCUSSION

In this study, a PIT process improved the ED providers' perception of patient satisfaction without negatively impacting the overall perception of resident education at an academic medical center. This result is significant, because academic medical centers have a bipartite mission to provide high-quality patient care while simultaneously delivering an excellent educational experience for trainees. Our results, suggest that a PIT process can be implemented at academic

Table 2. Attending and resident perceived impact of physician in triage on resident education, quality of care, patient satisfaction and throughput.

	Attending (median/IQR)*	Resident (median/IQR)*	p-value
Resident education	3.0 (2-4)	3.0 (2-4)	0.18
Quality of care	3.0 (2-4)	4.0 (3-4)	0.22
Patient satisfaction	4.0 (2-4)	4.0 (1-5)	0.75
Patient throughput	3.5 (3-4)	4.0 (3-5)	0.006

*Likert scale: 1-5 with 1 = strongly negative impact, 5 = strongly positive impact.

Table 3. Attending and resident perceived impact of physician in triage on patient rapport, history taking, physical exam, differential diagnosis, diagnostic ordering, medical decision making, documentation, consultation, disposition, and faculty teaching.

	Attending (median/IQR)*	Resident (median/IQR)*	p-value
Patient rapport	3.0 (3-4)	3.0 (2-4)	0.26
History	3.0 (2-3)	3.0 (2-4)	0.22
Physical exam	3.0 (2-3)	3.0 (2-4)	0.38
Differential diagnosis	2.0 (1-3)	2.5 (1-5)	0.42
Diagnostic studies	2.0 (1-3)	3.0 (1-4)	0.10
Medical decision making	2.0 (1-4)	3.0 (1-5)	0.14
Documentation	3.0 (3-4)	3.0 (2-4)	0.86
Consults	3.0 (3-4)	3.0 (3-5)	0.023
Disposition	3.0 (3-4)	3.0 (2-5)	0.63
Faculty teaching	3.0 (2-3)	3.0 (2-4)	0.083

*Likert scale: 1-5 with 1 negative impact, 5 positive impact.

medical centers to improve patients' ED satisfaction without compromising the residents' or attendings' perceptions of the educational mission.

Prior to this study, no investigations looked at the effect of a PIT process on the education of residents in an academic ED. The results of our study directly address some of the criticisms against PIT in a teaching institution. Many educators believe that a PIT process decreases residents' opportunities to develop an unbiased differential diagnosis. They are concerned that testing and interventions ordered by the physician in triage prior to the assessment will bias resident assessments and short-circuit learning. In addition, because the initial evaluation documentation may be completed before the resident evaluates the patient, some are concerned the resident's focus may shift from a more complete patient care process to a disposition-only focus. Furthermore, some purport that the PIT process may disrupt and negatively impact the resident-attending educational processes already in place.

In this study, there was no perceived impact of PIT on resident-attending education processes. Perhaps this was due to the heightened awareness of the care team that these patients had already been assessed by a physician-in-triage, or that current care processes and dialogue were maintained despite the process change. While not statistically significant, residents believed the quality of care to be better overall while attendings perceived no difference. Both groups believed the PIT process enhanced patient satisfaction based on their interactions when receiving PIT patients. Comments related to this perception resonated with the idea of eliminating delays in the care process and improved communication (including care updates) with the patients through the PIT. The residents also perceived patient throughput to be notably improved, which likely reflected the impact of having orders and perhaps tests completed for prior to the resident evaluation in the ED.

Regarding potential negative impacts from the PIT process, both groups believed there was a negative impact on differential diagnosis generation – an important skillset for any emergency provider. In addition, attendings perceived the impact on selection of diagnostic studies and medical decision making to also negatively impact the resident education process. However, it was suggested by several providers that perhaps changing the communication process with residents caring for PIT patients would encourage renavigation of differential and care considerations. In doing so, this may assuage some of the educational concerns noted in this study.

Our study demonstrated improved patient satisfaction from a PIT process. Prior to the onset of our study in 2011, there was a relative absence of quality data related to the impact of providers-in-triage, except for anecdotal information from facilities that have reached over-capacity based on system failures. Review of current literature on the topic appropriately recognizes the complex multi-factorial aspects impacting ED crowding and the subsequent impact on access to and quality of patient care. As such, most systems recognize and recommend a system-wide approach to quality, efficient patient care while specific process changes are being piloted or implemented.

Currently, limited data exist in the literature with similar project foci – the educational impact of implementing this operational change.[23] In a study by Partovi et al., the LWBS rate was reduced by 46% with a faculty physician in triage during peak volume and capacity periods.[17] Another showed that placing a physician in triage during similar time periods significantly reduced patient waiting time.[15] In another publication, Choi et al., summarized current data to conclude that having a physician in triage may be an effective intervention for ED crowding under certain circumstances – that require further clarification.[18] However, further analyses appropriately recognized that many of the previously-performed studies were not sufficiently rigorous to support a widespread implementation of the PIT model or one similar to it.

LIMITATIONS

This study is limited by a small sample size, short duration of the pilot period, and a survey response rate slightly below 80%. This study was isolated to a single academic ED, which may limit generalizability to other academic medical centers. Although the process was uniformly implemented on the days the PIT was in place and participating faculty received the same process training, variances in approach may have influenced the downstream perception of both residents and supervising faculty in the ED. It also does not address the difference between the perceived impact and the actual educational paradigm. The questionnaire was also completed at the end of the study period and therefore may have incurred some recall bias for those only participating at the beginning of the 10-week period. In addition, prior to the start of the study, there were many vocal discussions and established opinions around the PIT concept that may have instilled bias prior to its initiation. Resource limitations in the PIT may have also restricted providers that would otherwise have ordered greater testing upfront. However, all attendings participating in the PIT were voluntary, received equal pre-PIT process education and came from varying perspectives on the PIT concept.

CONCLUSION

Placing a physician in triage did not negatively impact the perceived resident educational experience. However, while residents didn't perceive the PIT process negatively impacting their educational involvement with attendings, both groups perceived differential diagnosis development was negatively impacted. Attendings also felt diagnostic test selection and medical decision making may be negatively impacted. For academic centers looking to implement a PIT process, ensuring appropriate educational reinforcement of these areas of concern may be helpful.

Address for Correspondence: Brett A. Nicks, MD, MHA. Wake Forest Baptist Medical Center, Medical Center Blvd, Winston-Salem, NC 27157. Email: bnicks@wakehealth.edu.

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Osteopathic Emergency Medicine Programs Infrequently Publish in High-Impact Emergency Medicine Journals

Sean M Baskin, MA*
Christina Lin, DO†
Jestin N Carlson, MD, MS*†‡

* Department of Medicine, Division of Emergency Medicine, Lake Erie College of Osteopathic Medicine, Erie, Pennsylvania
† Department of Emergency Medicine, Allegheny Health Network, Erie, Pennsylvania
‡ Department of Emergency Medicine, University of Pittsburgh School of Medicine, Pittsburgh, PA

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Introduction: Both the Accreditation Council for Graduate Medical Education (ACGME) and the American Osteopathic Association (AOA) require core faculty to engage in scholarly work, including publication in peer-reviewed journals. With the ACGME/AOA merger, we sought to evaluate the frequency of publication in high-impact peer-reviewed EM journals from authors affiliated with osteopathic emergency medicine (EM) programs.

Methods: We performed a retrospective literature review using the Journal Citation Report database and identified the top five journals in the category of 'Emergency Medicine' by their 2011 Impact Factor. We examined all publications from each journal for 2011. For each article we recorded article type, authors' names, position of authorship (first, senior or other), the author's degree and affiliated institution. We present the data in raw numbers and percentages.

Results: The 2011 EM journals with the highest impact factor were the following: *Annals of Emergency Medicine*, *Resuscitation*, *Journal of Trauma*, *Injury,* and *Academic Emergency Medicine*. Of the 9,298 authors published in these journals in 2011; 1,309 (15%) claimed affiliation with U.S.-based EM programs, of which 16 (1%) listed their affiliations with eight different osteopathic EM programs. The 16 authors claimed affiliation with 8 of 46 osteopathic EM programs (17%), while 1,301 authors claimed affiliation with 104 of 148 (70%) U.S.-based allopathic programs.

Conclusion: Authors from osteopathic EM programs are under-represented in the top EM journals. With the pending ACGME/AOA merger, there is a significant opportunity for improvement in the rate of publication of osteopathic EM programs in top tier EM journals. [West J Emerg Med. 2014;15(7):908-912.]

INTRODUCTION

Currently, graduate medical education in the United States is governed by two different organizations: the Accreditation Council for Graduate Medical Education (ACGME) for allopathic programs and the American Osteopathic Association (AOA) for osteopathic programs. Both organizations have expectations of faculty, including scholarship activity. The ACGME's listing of scholarship activities includes publication of original work, obtaining grant funding and presentation at national meetings.[1] The AOA requires "major activity," which includes publication of original work, along with other avenues such as national board membership and exam item writing.[2] Given the recent announcement that all United States (U.S.) graduate medical education programs are to be accredited by the ACGME, osteopathic residencies must examine the impact this merger may have on their academic involvement.

Previous work has identified several barriers to successfully completing scholarly work across a range of medical specialties, including emergency medicine (EM);

however, these have focused on allopathic programs.[3-7] Limited data exist comparing the research endeavors and publication rates of core faculty, either in or between allopathic and osteopathic EM residencies. We sought to determine the frequency of research publications in high-impact EM journals for osteopathic EM residency programs.

METHODS

Study Design

Using the Journal Citation Report database, we identified the top five journals in the EM category by their 2011 impact factor (IF), as 2011 was the most recent year with complete impact factor results.[8] We accessed and cataloged each article and collected article type, authors' names, authorship position, author's highest degree (MD, DO, PhD, etc.) and affiliated institution. All journals listed the affiliated institution except for the *Journal of Trauma* for which we cross-referenced the articles with www.PubMed.org to identify the corresponding author's institution. No institutional review board approval was sought, as this was a literature review from publicly available data.

Study Protocol

We accessed all published volumes for each of the top five journals. We subdivided affiliation into EM or other (e.g surgery), and further subdivided EM into U.S. or international for each author. U.S. EM authors who only claimed affiliation with industry, public service organizations or other non-clinical organizations were categorized as lacking academic affiliation. We checked author affiliation against the 2011 listings of ACGME and AOA affiliated EM residencies.[2] We designated authors who claimed affiliation with only U.S. military training programs as ACGME programs unless either the program's website or the AOA indicated dual accreditation. When authors claimed affiliation with a hospital or health system, we determined ACGME or AOA designation by departmental or hospital affiliations with their respective training programs. We included any author affiliated with a dual ACGME/AOA accredited program in both cohorts. Given that neither the ACGME nor the AOA qualify scholarly work to include or exclude publication type (original work, case reports, etc), we included all publications and stratified by type.

Measurements

We determined the number of published articles containing at least one U.S.-based EM physician claiming affiliation with either an ACGME or AOA EM residency. We also determined the raw percentage of osteopathic and allopathic programs that published in the identified journals.

Data Analysis

We present the data in both percentages and raw numbers computed using Stata v. 12 (Statacorp, College Station, TX). We also compared publications per program between allopathic and osteopathic programs using Wilcoxon-Mann-Whitney test.

RESULTS

The 2011 EM journals with the highest impact factor (IF) were: *Annals of Emergency Medicine* (4.133), *Resuscitation* (3.601), the *Journal of Trauma* (2.478), Injury (1.975) and *Academic Emergency Medicine* (1.861). We identified 1,992 manuscripts published by 9,298 authors. Of these, 1,309 (15%) claimed affiliation with U.S.-based EM programs, of which 16 (1%) listed their affiliations with osteopathic EM programs (Figure 1).

The 1,309 authors represent 418 publications, with only 10 publications listing at least one author from an osteopathic institution (five original works, four case reports, and one letter to the editor). The 418 publications included 217 original works, 30 case reports, 81 editorials, 12 review articles, 31 letters to the editors, 39 policy statements, seven book reviews and one perspective paper.

The 16 osteopathic-affiliated authors claimed affiliated with eight different osteopathic EM residencies and represent 17% of the 46 AOA-accredited programs in 2011. There were 1,301 authors who claimed affiliation with 104 U.S.-based allopathic programs representing 70% of the 148 programs in 2011. Figure 2 shows the frequency of publications per program for both allopathic and osteopathic programs. Allopathic programs published a median (IQR) of two papers (0, 5.5) while osteopathic published a median (IQR) of zero papers (0, 0) in the selected journals in 2011 ($p<0.001$). Of the 217 original works, five were from four of the 46 osteopathic programs (8.7%), while the remainders were from 63 of 148 allopathic programs (42.6%).

DISCUSSION

Although previous efforts have attempted to quantify research in EM in the United States, there are limited data describing osteopathic EM research, specifically the frequency of publishing authors based on their affiliated institution.[9-11] Our results show that authors affiliated with osteopathic EM programs and osteopathic programs are underrepresented in high-impact EM journals.

There are several possible explanations for the low rate of publication from osteopathic programs. Barriers to completion of research projections, such as lack of time, interest, and not having an established research curriculum, have been well published.[4,12,13] While these were identified in prior studies in allopathic programs, it is likely these are also present in osteopathic programs and would not result in such a discrepancy. Another possibility is that the authors are publishing their work outside of EM journals, targeting specific audiences.[6,9]

Additionally, the limited publication rates for osteopathic programs may be the result of limited time and resources at the disposal of osteopathic researchers. While we were unable to identify prior studies that compared the extent of work and resources required to publish in the highest-impact journals, these journals publish works most likely to affect practice change. Academic institutions, which are historically allopathic programs,

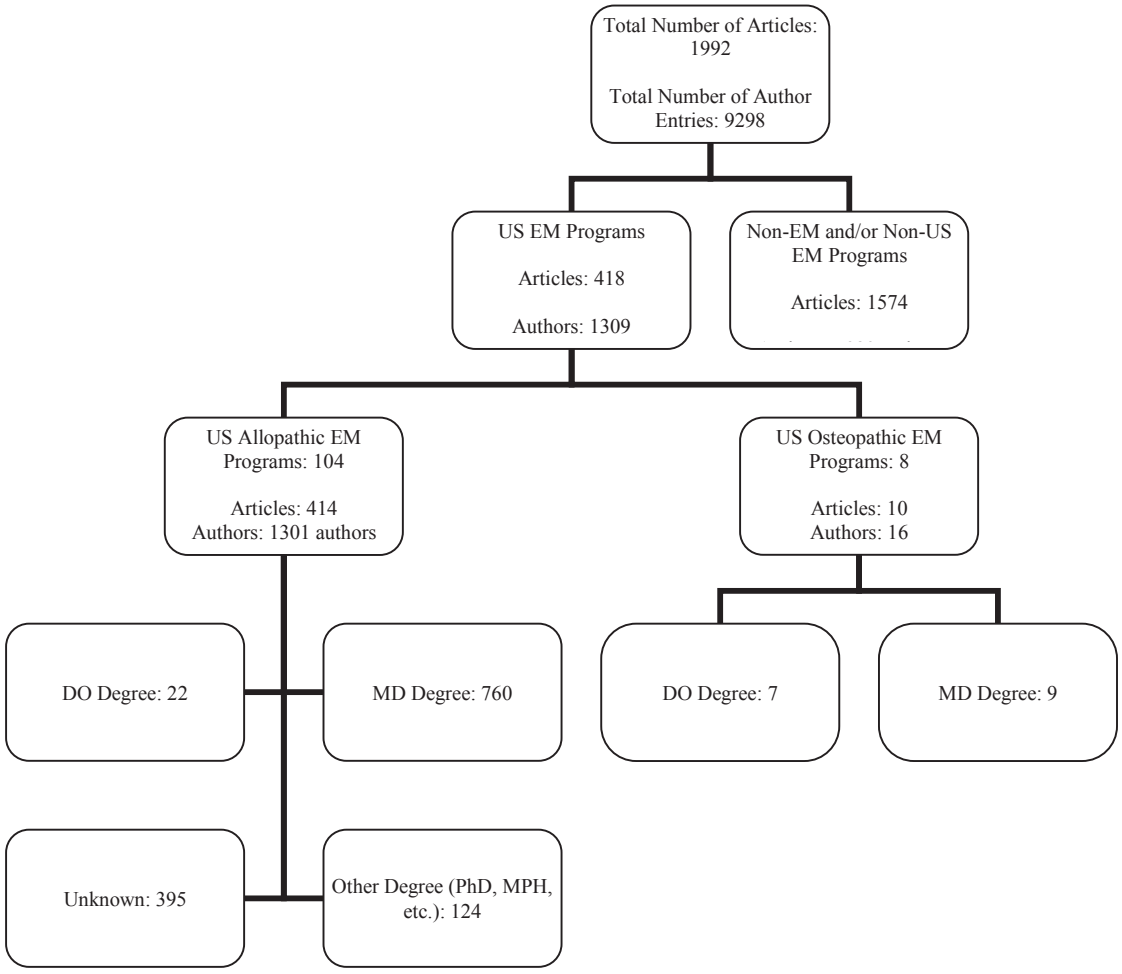

Figure 1. Consort diagram of all manuscripts. Three articles are the result of multi-centered studies and are included in both allopathic and osteopathic categories. Eight authors, affiliated with dual ACGME/AOA accredited residencies, are both included in both categories. *US*, United States; *EM,* Emergency Medicine; *DO*, Doctor of Osteopathic Medicine; *MD*, Medical Doctor; *PhD*, Doctor of Philosophy; *MPH*, Masters of Public Health

may have more opportunities for multi-centered trials, statistical support and "protected time" for faculty, allowing for more impactful research compared to osteopathic EM residencies, which tend to be based out of community teaching hospitals.[5] Future efforts may help to identify academic differences between osteopathic and allopathic programs, such as statistical support, faculty with formal research training and funding opportunities, which may help to explain these differences.

Previous work has suggested techniques for improving research productivity, which include designated faculty mentors, increased resources (financial and time), guidance in project selection and support for national meeting attendance.[3,4,12,14,15] For osteopathic EM programs that cannot support an increased research department internally, partnering with regional academic institutions may provide access to university resources while allowing for the included authorship from osteopathic-affiliated researchers. Additionally, recruitment of faculty with prior published research experience may be an avenue by which programs could support an increased research curriculum and simultaneously provide mentorship to current and future faculty with less research experience.

The recently announced merger of graduate medical education states that all current AOA residencies must adhere to the standards of and receive accreditation from the ACGME. While the AOA and ACGME may continue to adapt to changing graduate medical education requirements, it appears that the ACGME's listing of scholarship activities (including publication of original work, obtaining grant funding and presentation at national meetings) will be the benchmark for research requirements after the merger has been implemented.

Although accreditation may change, it is unlikely that the majority of the aforementioned barriers will be resolved. Current osteopathic programs will need to consider ways to increase their research output if they are to reach the standards required of the ACGME. Through professional organizations such as the American College of Osteopathic Emergency Physicians (ACOEP) and the Foundation of Osteopathic Emergency Medicine (FOEM), seminars are offered in the areas of faculty development and research infrastructure

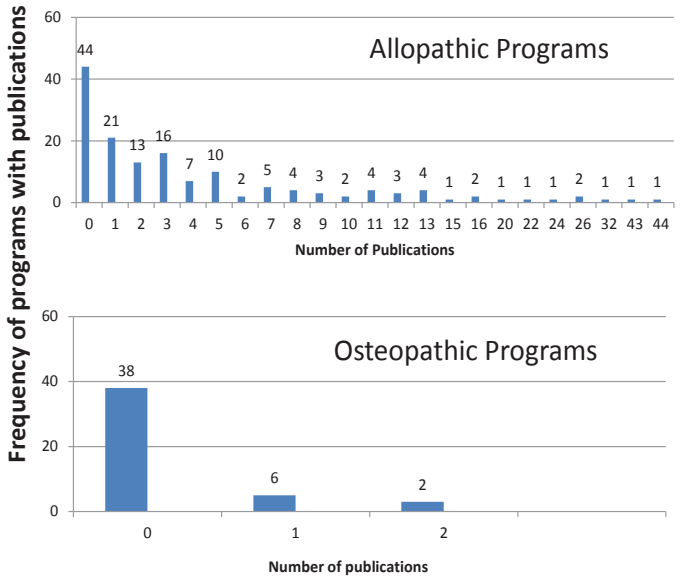

Figure 2. Publication frequency for emergency medicine residencies. The top graph shows the frequency of publications per program for allopathic programs. The lower graph shows the frequency of publications per program for osteopathic programs.

to prepare osteopathic faculty for the ACGME's Common Core Standards. Additionally, FOEM's Research Quality Improvement Initiative seeks to assist faculty and residents to increase both the caliber and quantity of academic output.[16]

Limitations

There are several limitations with our study. We do not know the rate of submission and/or rejection by the journals that we studied. We did not determine the rank of the author (attending vs. resident) at the time of acceptance or publication. Our study was limited to EM journals, whereas authors may have published in other specialty journals. We did not evaluate all EM journals. There are 23 EM journals listed in Journal Citation Report.[8] We selected the top five as we feel these are likely to be the most impactful and likely to drive emergency care. Future efforts may evaluate the rate of osteopathic publications in lower impact journals.

While we did identify publications listed in each of the journals, we did not contact individual programs to identify their publications during the determined time period. Because of concerns for potential biases in response rates (e.g. programs with greater numbers of publications may be more likely to return the survey), we objectively evaluated the publications listed in the selected journals.

The *Journal of Trauma* did not list the authors' affiliation, and cross-referencing articles with PubMed only provided the affiliation for the corresponding author. We do not believe this would dramatically alter the data as only 2.63% (11 of 418 manuscripts) of all publications were from the *Journal of Trauma*, of which all corresponding authors claimed affiliation with allopathic programs. We did search the authors' names via department websites and verified that all EM authors are currently affiliated with allopathic EM programs; however, they may not have been affiliated at the time of publication.

We identified articles by journal impact factor. While other metrics including immediacy index and cited half-life have been suggested for assessing journal rank, impact factor remains a key metric for assessing journal influence.

CONCLUSION

Osteopathic EM programs rarely publish in the high-impact EM journals. With the pending ACGME/AOA merger, there is a significant opportunity for improvement in the rate of publication of osteopathic EM programs in top tier EM journals.

Address for Correspondence: Jestin Carlson, MD, Allegheny Health Network, Department of Emergency Medicine, Saint Vincent Hospital, 232 West 25th St, Erie, PA 16544. Email: jcarlson@svhs.org.

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Randomized Trial of a Novel ACLS Teaching Tool: Does it Improve Student Performance?

Nicholas Nacca, MD
Jordan Holliday
Paul Y. Ko, MD

SUNY Upstate Medical University, Department of Emergency Medicine, Syracuse, New York

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Introduction: Mounting evidence suggests that high-fidelity mannequin-based (HFMBS) and computer-based simulation are useful adjunctive educational tools for advanced cardiac life support (ACLS) instruction. We sought to determine whether access to a supplemental, online computer-based ACLS simulator would improve students' performance on a standardized Mega Code using high-fidelity mannequin based simulation (HFMBS).

Methods: Sixty-five third-year medical students were randomized. Intervention group subjects (n = 29) each received a two-week access code to the online ACLS simulator, whereas the control group subjects (n = 36) did not. Primary outcome measures included students' time to initiate chest compressions, defibrillate ventricular fibrillation, and pace symptomatic bradycardia. Secondary outcome measures included students' subjective self-assessment of ACLS knowledge and confidence.

Results: Students with access to the online simulator on average defibrillated ventricular fibrillation in 112 seconds, whereas those without defibrillated in 149.9 seconds, an average of 38 seconds faster [p<.05]. Similarly, those with access to the simulator paced symptomatic bradycardia on average in 95.14 seconds whereas those without access paced on average 154.9 seconds a difference of 59.81 seconds [p<.05]. On a subjective 5-point scale, there was no difference in self-assessment of ACLS knowledge between the control (mean 3.3) versus intervention (mean 3.1) [p-value =.21]. Despite having outperformed the control group subjects in the standardized Mega Code test scenario, the intervention group felt less confident on a 5-point scale (mean 2.5) than the control group. (mean 3.2) [p<.05]

Conclusion: The reduction in time to defibrillate ventricular fibrillation and to pace symptomatic bradycardia among the intervention group subjects suggests that the online computer-based ACLS simulator is an effective adjunctive ACLS instructional tool. [West J Emerg Med. 2014;15(7):913–918.]

INTRODUCTION

Simulation has advanced rapidly over the past decade with more innovative and realistic tools being incorporated to educate healthcare providers on a daily basis.[1-4] The body of literature investigating the effectiveness of medical simulation has struggled to keep pace with the developments in simulation technology. Many authors have called for quality research regarding the use of simulation in medical education.[5-8]

Advanced cardiac life support (ACLS) is a collection of skills and interventions intended to direct healthcare providers during treatment of cardiac arrest and other life-threatening emergencies. Currently, many medical schools do not require ACLS certification for graduation.[9,10] Many medical school graduates feel underprepared and lack the

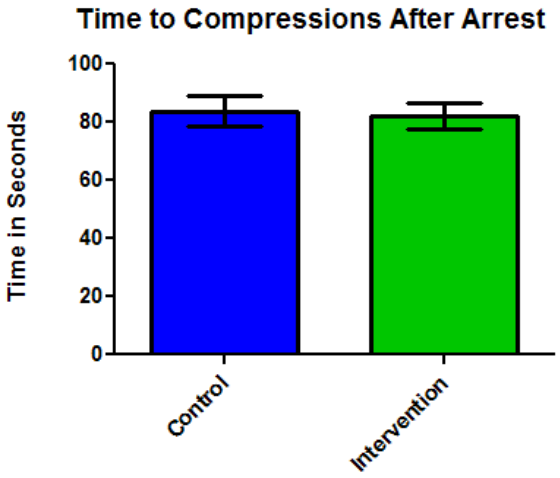

Figure 1. Students with access to computer based simulation did not initiate compressions in the ACLS Megacode faster than students without access.
ACLS, advanced cardiac life support

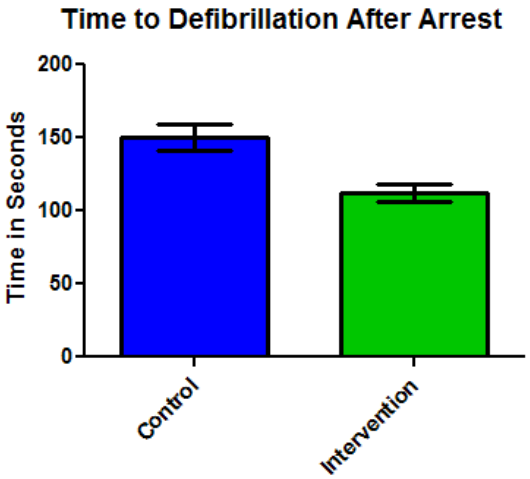

Figure 2. Students with access to computer based simulation defibrillated Ventricular Fibrillation in the ACLS Megacode 38 seconds faster than students without access [t(63=3.36, p<0.5].
ACLS, advanced cardiac life support

confidence and skills to effectively participate in resuscitative efforts as interns beginning their residency programs.[10-14] The necessity for high-quality education of ACLS at the medical student level cannot be overstated. The integration of high-fidelity mannequin-based simulation (HFMBS) into existing ACLS curricula as a supplemental instructional tool has been advocated.[10,15-21] A recent study of medical students using HFMBS in ACLS training showed significantly improved knowledge and psychomotor skills.[22] The costs associated with acquiring and maintaining an HFMB simulator may be impeding its use in many ACLS training programs.[3,10,23]

The department of emergency medicine at the State University of New York (SUNY) Upstate Medical University uses two different ACLS curricula to train approximately 650 healthcare providers annually. The first is a traditional two-day American Heart Association (AHA) ACLS course, which uses didactic lectures, AHA-approved instructional videos, and low-fidelity simulation in small-group sessions.[10] The second is a three-day HFMBS course, which is used to teach third-year medical students ACLS during their two-week internal medicine rotation. Third-year medical students enrolled in the HFMBS course demonstrated higher proficiency in learning ACLS than students enrolled in the traditional course.[10] This is consistent with previous studies, which revealed improved educational outcomes, retention of ACLS skills and knowledge, and adherence to ACLS guidelines.[24-26]

The majority of the early literature on HFMBS as an educational tool for training healthcare providers stemmed from residency programs, and there was little data on the use of simulation at the medical student level.[27] Not until recently have educators studied the utility of HFMBS at the undergraduate medical education level.[10,27-29] In an effort to further increase student proficiency in ACLS, we noted reports of ACLS-specific computer-based simulators dating back to 1991.[30,31] Advances in computer technology have facilitated the development of many high-quality computer-based simulation programs that are efficacious instruction tools.[13,23,32] A more recent study suggested that a computer-based simulation program improved retention of ACLS guidelines as a standalone teaching tool.[33] We hypothesized that a computer-based simulation program used as an adjunct to HFMBS ACLS training would result in improved ACLS proficiency.

METHODS

At SUNY Upstate, each third-year emergency medicine resident serves as a certified AHA ACLS instructor during their administrative month. They train groups of 4-6 third-year medical students in ACLS using HFMBS. During their two-week rotation, the medical students undergo three days of HFMBS ACLS training, which consists of an introduction to ACLS material using partial task trainers, followed by simulated management of five ACLS scenarios including ventricular fibrillation, ventricular tachycardia, symptomatic bradycardia, pulseless electrical activity, and asystole. The details of this curriculum have been previously published.[10]

At the conclusion of the course students were assessed by running a "Mega Code" on the high-fidelity mannequin simulator (SimMan®, Laerdal Medical Corporation, Wappingers Falls, NY, USA). The "Mega Code" scenario consisted of a 40-year-old male patient complaining of chest pain who becomes unresponsive after 40 seconds of conversation. The student must first recognize and treat ventricular fibrillation using the appropriate electrical and pharmacologic interventions, in addition to directing team members on proper cardiopulmonary resuscitation. After the third defibrillation attempt, the patient converts to symptomatic sinus bradycardia, which the student must recognize and treat appropriately. Failure to initiate and carry out the proper interventions would result in simulated patient death.

A novel, online, computer-based ACLS simulator

(SimCode ACLS™,Transcension Healthcare LLC) teaches the user to direct nurses, diagnose, and appropriately treat ACLS cases. Student accounts can be monitored by a manager account, with student use and performance assessed and trended over time. Transcension Healthcare LLC, provided student accounts for participants of this study.

Groups of third-year medical students were randomized. Both groups underwent a two-week ACLS course taught by a third-year emergency medicine resident, which used HFMBS. The intervention group (n=29) each received a two-week access code to the online ACLS simulator as a supplemental resource, whereas the control group (n=36) did not. A run's test was performed to confirm true randomization. The students in the intervention group were instructed to complete the computer-based tutorial on the first day of their ACLS instruction. They were then asked to complete the online ventricular tachycardia and symptomatic bradycardia cases during their two-week ACLS course. We used the manager account feature to verify qualitative usage of the computer-based ACLS simulator for students in the intervention group. On the last day of the ACLS course, informed consent was obtained from both groups prior to any data collection.

Each student's simulated "Mega Code" was recorded using audio, video, and Laerdal recording software. Prior to the assessment, students were asked to rate their subjective knowledge and confidence of ACLS material and practice. Following the "Mega Code" assessment, students were again asked to rate their subjective knowledge and confidence. Students in the intervention group were asked various additional questions regarding their use of the computer-based ACLS simulation program.

Data collected by review of video and software recording included the time to initiate chest compressions during cardiopulmonary resuscitation and time to defibrillation, which were calculated for each student from the beginning of the simulation. The time to pace symptomatic bradycardia was calculated from the onset of the rhythm change. We used these times as our primary outcome measures. The post mega code subjective knowledge and confidence surveys were used as secondary outcome measures. We entered the collected data into spreadsheet format, and we used a statistical software package (GraphPad Prism Version 4.0®, GraphPad Software, Inc., San Diego, CA, USA) to run a Student's t-test for each of the variables. The SUNY Upstate Medical University Institutional Review Board granted exemption status for this study.

RESULTS

We obtained complete data from the recorded "Mega Code" and surveys of 65 third-year medical students. During the study period four groups (three assigned to intervention and one to control) were not consented and therefore data was not collected. This accounted for approximately 24 missed participants. An additional two groups (one assigned to control and one to intervention) were consented, but video recording was unavailable. This accounted for seven consented students that were excluded from analysis for lack of data. Only one student in the intervention group refused participation. Ten students assigned to the intervention group never accessed the online simulator and thus were excluded from analysis.

Of the 65 participants with complete data (36 controls and 29 Intervention), there was not a statistically significant difference between the time required to initiate chest compressions on the unresponsive, pulseless high-fidelity mannequin in the control versus the intervention group (Figure 1). A statistically significant difference was noted between the two groups in time to defibrillate ventricular fibrillation, where those students who had used the computer-based simulator defibrillated on average in 112 seconds versus those without access defibrillated on average in 149.9 seconds, on average 38 seconds faster. $[t(63)=3.36, p<.05]$ (Figure 2). Additionally, students in the intervention group paced symptomatic bradycardia in an average time of 95.14 seconds versus the average time of 154.9 seconds in the control group. Thus, the intervention group was on average 60 seconds faster than the control, which was statistically significant $[t(63)=3.71, p<.05]$ (Figure 3).

There was not a statistically significant difference between students' perceived ACLS knowledge following the Mega Code assessment between the control and intervention groups (Figure 4); however, analysis of the students' subjective confidence following the Mega Code assessment revealed a statistically significant difference $[t(63)=4.19, p<.05]$, where students in the intervention group reported lower confidence levels on a 5-point scale (Figure 5). Students in the intervention group provided many positive subjective responses indicating satisfaction with the computer-based simulation program. Sixty-six percent of students reporting that the program "Very Much Improved" or "Extremely Improved" their ability to effectively manage an ACLS code. Additionally, 34% reported that they would "Definitely" and 62% reported that they would "Probably" use the online, computer-based simulator in the future.

DISCUSSION

The data demonstrated that the addition of an online computer-based simulation program to an HFMB ACLS training program did not influence the time to initiate chest compressions in a simulated scenario requiring cardiopulmonary resuscitation. It did, however, reduce the time to defibrillate ventricular fibrillation and pace symptomatic bradycardia. Though the primary outcome measurements have not been systematically validated to reflect improved ACLS performance, the authors interpret these as valuable indicators of comfort and fluency in ACLS protocols.

Perhaps the most interesting finding was that, despite outperforming students in the control group, students in

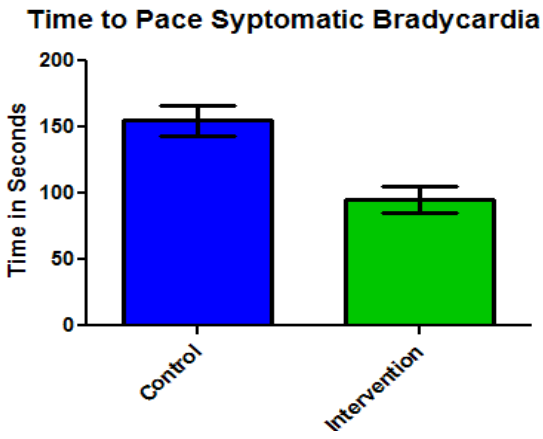

Figure 3. Students with access to computer based simulation paced Symptomatic Bradycardia in the ACLS Megacode 60 seconds faster than students without access [t(63)=3.71, p<0.5].
ACLS, advanced cardiac life support

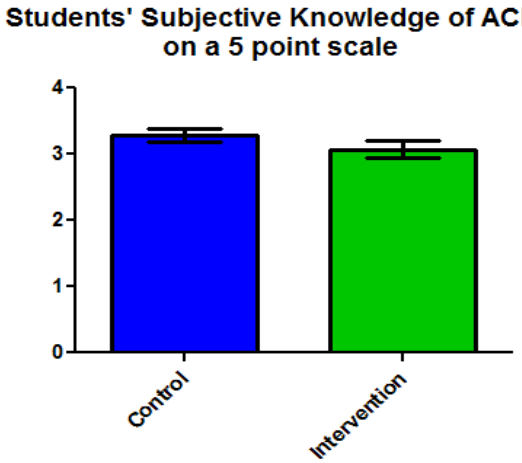

Figure 4. Students with access to computer based simulation did not assess their knowledge of ACLS guidelines differently than those without access.
ACLS, advanced cardiac life support

the intervention group reported feeling less confident. Additionally, the students in the intervention group did not rate their knowledge level higher than did the students in the control group. These findings were unexpected and in stark contrast to much of the available literature that discusses participants' self-confidence following an educational intervention.[10,24,34] A proposed explanation for this finding is that the online, computer-based simulation program exposed students in the intervention group to many ACLS simulation cases in excess of the five HFMB simulation scenarios in which both groups participated. Due to the structure of the online computer-based simulation program, these additional simulation cases could not have been completely ignored by students in the intervention group, even thought they were only tasked with completing the ventricular fibrillation and symptomatic bradycardia cases. The exposure to additional cases may have added to the complexity of the material and

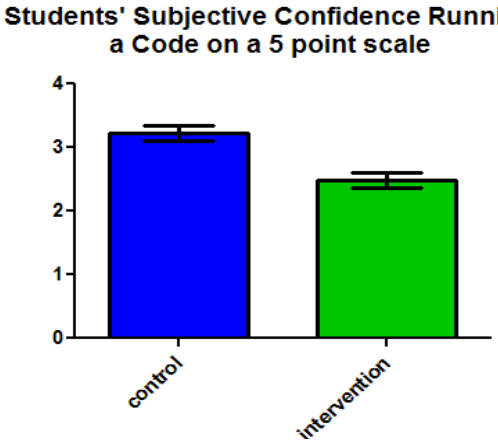

Figure 5. Students with access to computer based simulation had significantly lower subjective confidence in running a code than those without access [t(63)=4.19, p<.05].

contributed to the lower subjective confidence ratings despite superior performance on the primary outcome measures.

Managing resuscitations and other medical crises, whether simulated or real, elicits emotional stress and anxiety as individual and team performance may be compromised.[35,36] The stress and anxiety encountered during such situations may enhance memory encoding, consolidation, and retrieval, thereby improving retention.[19,37,38] The reported effects of the stress and anxiety induced during participation in simulations are contrasting, with a group of anesthesia trainees reporting enhanced learning and clinical experience and a group of nursing students reporting hindered learning.[19,39,40] Anxiety is characterized as demotivating and detrimental to perceived self-efficacy within the psychological literature.[41,42] We did not include a real-time measure of student anxiety in this study. It could be that students in the intervention group experienced more anxiety in ACLS learning than did students in the control group.

The improvement in performance demonstrated by students in the intervention group during the HFMB "Mega Code" assessment is consistent with previous studies supporting the use of computer-based simulation as an educational tool.[13,23,32,33]

LIMITATIONS

Our study has several clear limitations. The most notable limitation was that the third-year emergency medicine resident who taught the HFMB ACLS course was not consistent. At least eleven different instructors participated in the training of students whose performances on the Mega Code assessment were included in this analysis. Thus, the authors were unable to control for this confounding variable in the analysis. In addition, blinding the instructors to the intervention group students was not enforceable. We did not perform a power analysis due

to the difficulty in predicting an expected improvement in performance based on the implemented educational intervention. Incomplete data collection resulting from a combination of computer and human error led to the exclusion of several cohorts of third-year medical students enrolled in the ACLS course, comprised of both intervention and control groups, from data analysis. The authors were unable to monitor the amount of self-study time of students in the control group and were thus unable to determine if students in the intervention group may have spent more time with ACLS material in general than did those in the control group. The authors did not record the duration or frequency of use of the program. Students' usage of the online, computer-based simulation program was not enforceable, which necessitated that students had to be self-motivated to use the program. Given the nature of this curriculum analysis study, the authors were unable to enforce use of the program with course failure or grade demotion. In practical application of this program, such enforcement would be feasible. Several students in the intervention group neglected to use the program and were thus excluded from the subsequent analysis. Additionally, intention to treat analysis was purposely abandoned based on the premise that a course instructor using the computer-based simulator would have the ability to monitor and enforce the use of the program. A post hoc intention to treat analysis yielded persistent statistically significant results. Students did record the number of previously run ACLS codes in the post megacode data collection form. Only one student in the control group had prior experience as a seasoned paramedic, and was thusly excluded from analysis. The authors did not collect any data regarding ultimate career goals. This may be a source of a confounding variable as those students going into acute care specialties may have not been randomly allocated to intervention and control groups. Finally, it is unclear whether the above listed findings are generalizable to other online, computer-based simulation programs.

CONCLUSION

We interpret the data to reflect the validity of the online, computer-based simulator as a valuable adjunctive ACLS teaching tool. Students with access to the simulation program outperformed students without access in both time to defibrillate ventricular fibrillation and time to pace symptomatic bradycardia. Notably, the students in the intervention group felt less confident than did the students in the control group. We speculate that the students in the intervention group may have felt less confident managing resuscitations due to their broadened perspective of ACLS material that was gained from their access to a multitude of ACLS scenarios within the computer-based simulation program. This would require further investigation to be confirmed.

Address for Correspondence: Paul Y. Ko, MD. Department of Emergency Medicine, SUNY Upstate Medical University, EmSTAT Building, 550 East Genesee Street # 103C, Syracuse, NY 13202 Email: kop@upstate.edu.

Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. SimCode ACLS, Transcension Healthcare LLC provided student accounts free of charge for the study, but was not involved in the design, data collection, drafting or any other aspect of the study.

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Pilot Study of Ultrasound-Guided Corticosteroid Hip Injections by Emergency Physicians

Erik S. Anderson, MD*
Evan Hodell, BS†
Daniel Mantuani, MD*
Jahan Fahimi, MD* ‡
Ingrid Pampalone, PA§
Arun Nagdev, MD* ‡

*Alameda County Medical Center, Highland Hospital, Department of Emergency Medicine, Oakland, California
†University of California, San Francisco School of Medicine, San Francisco, California
‡University of California, San Francisco, Department of Emergency Medicine, San Francisco, California
§Alameda County Medical Center, Highland Hospital, Department of Orthopedics, Oakland, California

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Introduction: Our objective was to assess the efficacy of ultrasound-guided hip injections performed by emergency physicians (EPs) for the treatment of chronic hip pain in an outpatient clinic setting.

Methods: Patients were identified on a referral basis from the orthopedic chronic pain clinic. The patient population was either identified as having osteoarthritis of the hip, osteonecrosis of varying etiologies, post-traumatic osteoarthritis of the hip, or other non-infectious causes of chronic hip pain. Patients had an ultrasound-guided hip injection of 4ml of 0.5% bupivacaine and 1ml of triamcinolone acetate (40mg/1ml). Emergency medicine resident physicians under the supervision of an attending EP performed all injections. Pain scores were collected using a Likert pain scale from patients prior to the procedure, and 10 minutes post procedure and at short-term follow-up of one week and one month. The primary outcome was patient-reported pain score on a Likert pain scale at one week.

Results: We performed a total of 47 ultrasound-guided intra-articular hip injections on 44 subjects who met inclusion criteria. Three subjects received bilateral injections. Follow-up data were available for 42/47 (89.4%) hip injections at one week and 40/47 (85.1%) at one month. The greatest improvement was at 10 minutes after injection with a mean decrease in Likert pain score from pre-injection baseline of 5.57 (95% CI, 4.76-6.39). For the primary outcome at one week, we found a mean decrease in Likert pain score from pre-injection baseline of 3.85 (95% CI, 2.94-4.75). At one month we found a mean decrease in Likert pain score of 1.8 (95% CI, 1.12-2.53). There were no significant adverse outcomes reported.

Conclusion: Under the supervision of an attending EP, junior emergency medicine resident physicians can safely and effectively inject hips for chronic pain relief in an outpatient clinical setting using ultrasound guidance. [West J Emerg Med. 2014;15(7):919-924.]

INTRODUCTION

Hip pain is a common complaint with a wide variety of etiologies. These range from the benign and chronic, such as osteoarthritis, to the acutely joint-threatening, such as septic arthritis. Chronic hip pain has an estimated prevalence of up to six percent and is a common cause of pain in patients presenting to orthopedic clinics and emergency departments (EDs).[1] Joint injections with corticosteroids are first-line recommended therapy by the American College of Rheumatology,[2] and the European League Against Rheumatism recommends intra-articular hip injections for flares of chronic hip osteoarthritis.[3] A 2007 randomized controlled trial has also demonstrated clear efficacy without any complications.[4]

Ultrasound (US) guidance for either hip arthrocentesis

or hip injections has since been described in the radiology, rheumatology, and orthopedic literature.[5-9] Three trials in emergency medicine (EM) literature have shown efficacy of US to aid in diagnosis of hip effusions,[10-12] but no EM trials to date have demonstrated US-guided hip injections as efficacious in the treatment of chronic hip pain. US-guided hip injections have been shown to be more safe and efficacious as compared to blind injections.[6,7,13] However, these procedures are rarely performed in an ED setting, and many front-line practitioners who encounter patients with hip pain from degenerative diseases of the hip may not have the training to perform the procedure. Frequently the intra-articular corticosteroid hip injections are performed only in specialty clinics, limiting the access for optimal pain control in patients with non-infectious hip pathology. With adequate training and coordinated follow-up, clinicians could facilitate timely pain control (without overreliance on standard opioid and anti-inflammatory therapies) for these patients.

In a prospective cohort pilot study, we aim to analyze the effect of US-guided corticosteroid hip injections on pain scores as performed by EM trainees.

METHODS

Study Design and Setting

This is a prospective pilot study of US-guided intra-articular hip injections performed by EM trainees with bupivacaine and triamcinolone for hip pain due to osteoarthritis, avascular necrosis, and other chronic conditions. Patients were consecutively enrolled from an orthopedic surgery clinic at a busy, urban hospital and trauma center. The Institutional Review Board of Alameda County Medical Center approved this study.

Selection of Participants

Enrollment occurred from September 2012 to February 2013. Adult patients (age>18) were eligible for inclusion if deemed to have chronic hip pain related to osteoarthritis, avascular necrosis, post-traumatic degenerative changes, late sequelae of septic arthritis, or hip dysplasia as determined by the referring orthopedic surgery attending. All patients were consented for the procedure and enrollment into the study. Exclusion criteria were any signs of systemic infection such as fever, recent illnesses in the past two weeks, contraindication or allergy to the injection agents, anti-coagulant therapy other than aspirin, previous hip injection within the last four months, planned total hip arthroplasty in the coming four months, if an interpreter was not available for the consent process, or if the patient was receiving a diagnostic injection as part of a hip or back pain work up. Patients found ineligible for the study or who declined study enrollment still had the opportunity to receive a hip injection.

Interventions

All patients received the study injection solution of 4ml of 0.5% bupivacaine and 1ml of triamcinolone (40mg). The dosing and medication selection for analgesia and steroid injection were selected based on prior research on fluoroscopically-guided hip injections.[4] An EM attending physician, fellowship trained in emergency US, supervised all procedures. First and second-year EM resident physicians performed all procedures after receiving an instructional handout and a standardized five-minute bedside training session. All trainees had completed a one-month US rotation that included instruction on needle-guided procedures, such as US-guided central lines, peripheral venous access, and nerve blocks. They also received a five-minute bedside tutorial on the anatomy of the femoral neck and anterior synovial recess. Trainees had also completed a one-month orthopedics rotation during which they performed landmark-based knee and shoulder injections as part of their clinical rotation. None of the residents had performed hip injections prior to this study, and each resident performed 1-2 injections during the clinic. An ultrasound fellowship-trained EM attending physician supervised all procedures.

Procedure

An ultrasound system (Sonosite M-Turbo; Bothell, WA) with a low frequency curvilinear probe (2-5MHz) was used to identify the hip joint. Local anesthesia over the injection site was applied using ethyl chloride spray. Using standard sterile procedure and local analgesia, a 10cc syringe filled with a 5cc mix of bupivacaine and 40mg of triamcinolone attached to a 20g 3.5 inch spinal needle was guided into the joint space with real-time in-plane ultrasound guidance (Figure 1) (Video). This solution was then injected after ultrasonographic confirmation that the needle tip was in the joint space (Figure 2). Patients were observed for a period of twenty minutes after the procedure.

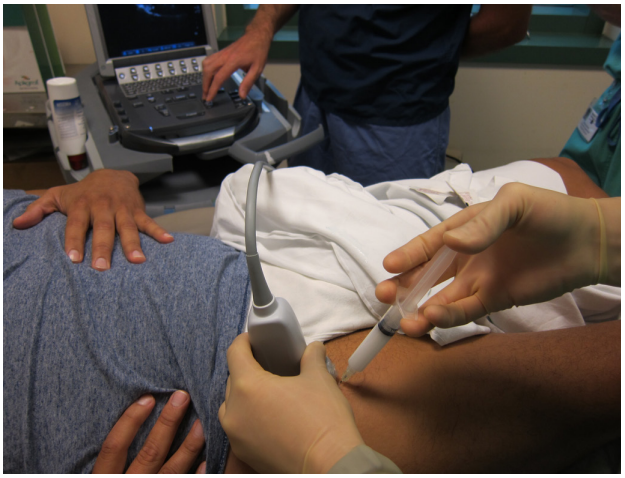

Figure 1. Set-up of ultrasound machine and patient for injection.

Methods and Measurements

We used a standardized data collection tool to collect demographic and clinical information of all enrolled subjects, including age, sex, race, etiology for pain, whether or not the patient previously had a hip injection performed, and whether or not there were any complications or adverse events as

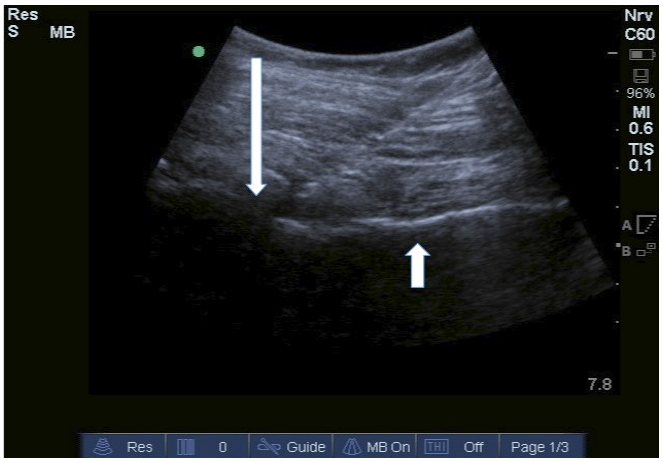

Figure 2. Real-time ultrasound view of needle insertion. The needle tip in the anterior synovial recess just distal to the femoral head is indicated with the long arrow. The femoral neck identified is indicated with the shorter arrow.

described by the patient. Pain scores before and at various times after the hip injection were collected using a 0 to 10 Likert scale. A research assistant performed telephone follow-up to obtain pain scores after clinic discharge and determine whether or not any complications occurred according to a standardized questionnaire.

Outcomes

Our primary outcome was decrease in pain score at one week. We chose this as the primary outcome interval because the effect of local anesthetics will have worn off and the corticosteroid effect should have become evident. We additionally collected pain scores at five minutes, 10 minutes, and one month after the procedure.

Analysis

We collected descriptive statistics for our cohort and report median pain scores, with interquartile range (IQR), pre-injection, then post-injection at five minutes, 10 minutes, one week, and one month. We calculated mean change in pain scores within a 95% CI, from the pre-injection score to the post-injection intervals. Graphical and statistical methods were used to assess for normality of the pain score and pain score change distributions. Additionally, we determined mean changes in pain score stratified by pre-injection pain levels (mild<4, moderate 4-7, or severe >8). Finally, we used a multivariate linear regression model to assess whether covariates (age, sex, race, etiology of hip pain, or pre-injection pain score) were associated with reduction in pain score at one week. Statistical analyses were performed with Stata SE version 11 (StataCorp LP, College Station, TX).

RESULTS

We performed a total of 47 US-guided intra-articular hip injections on 44 subjects who met inclusion criteria. Three subjects received bilateral injections. Follow-up data were available for 42/47 (89.4%) hip injections at one week and 40/47 (85.1%) at one month. The median age was 56 years (IQR 45-62), and the majority of patients were female (63.6%). The age of patients ranged from 19 to 75 years. Additional demographic and clinical information of the cohort are available in Table 1. Osteoarthritis was the most common cause of chronic hip pain, present in 37/47 (78.2%) of included patients, followed by avascular necrosis 5/47 (10.6%), hip dysplasia 2/47 (4.3%), and other causes 3/47 (6.4%). Previous injections had been performed in 5/47 (10.6%) of patients.

Median pain scores at all-time intervals and mean changes in Likert pain score at the follow-up intervals are available in Table 2. We found clinically and statistically significant decreases in pain scores at all-time intervals, with the greatest improvement at 10 minutes after injection. For the primary outcome at one week, we found a mean decrease in Likert pain score from the pre-injection baseline of 3.85 with a 95% CI from 2.94-4.75. Additionally at one month, there was a mean decrease in Likert pain score from pre-injection baseline of 1.8 with a 95% CI from 1.12-2.53.

Table 1. Demographic features of 44 patients enrolled in ultrasound-guided corticosteroid hip injection study.*

Characteristics	n (%)
Mean age (years +/- SD)	53.02 +/- 11.5
Male sex	28 (63%)
Race/ethnicity	
Black	17 (37%)
White	14 (31%)
Latino	9 (20%)
Asian	4 (9%)
Etiology of hip pain	
Osteoarthritis	37 (79%)
Avascular necrosis	5 (11%)
Hip dysplasia	2 (4%)
Unclear etiology	2 (4%)
Post-infectious arthritis	1 (2%)

*44 patients, 47 hips injected.

Graphical representation of individual pain scores for the 42 patients available for follow-up at the primary outcome of one week appears in Figure 3. Patients with both high and low levels of pre-procedural pain had improvement in their pain scores at one week. At one week follow-up one patient had an increase in his pain, three patients had no change in their pain, and seven patients had no pain at all after one week.

One patient reported transient dizziness after the procedure (lasting one minute). No other complications were

Table 2. Pain scores and differences at established intervals.

Outcome	N (hips)	Median pre-injection Pain score (IQR)	Mean decrease in pain score from pre-injection baseline (95% CI)
Pre-injection	47	8 (7-10)	-
5 minutes	47	2 (0-5)	4.98 (4.18-5.78)
10 minutes	47	1 (0-4)	5.57 (4.76-6.39)
1 week	42	4 (1-5)	3.85 (2.94-4.75)
1 month	40	5 (4-8)	1.8 (1.12-2.53)

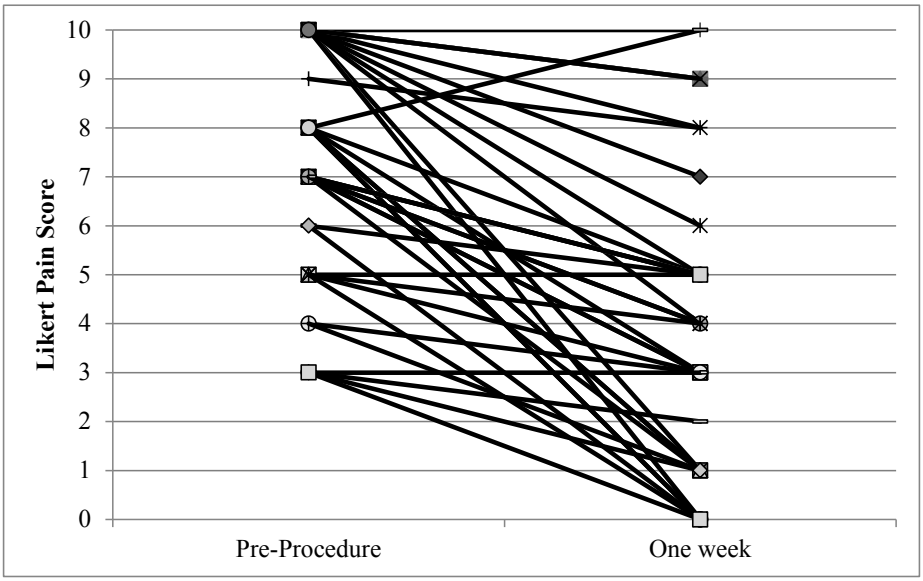

Figure 3. Individual patient pain scores from pre-injection to one week after hip injection.*
*Includes 42/47 injections available for follow up at one week.

reported or noted.

Multivariate analysis did not identify an association between age, sex, race, etiology of hip pain, or pre-injection pain score and change in hip pain at one week.

DISCUSSION

Our study demonstrates that EM trainees can effectively perform US-guided corticosteroid hip injections as a method for the treatment of chronic hip pain. We noted a statistically significant reduction in pain scores at one week, and while the effect waned somewhat, patients continued to have modest pain relief at one month.

Our analysis demonstrates that US-guided corticosteroid intra-articular hip injection as performed by EM trainees is effective at decreasing chronic hip pain acutely and over a one-week period. This is a well-established and safe procedure practiced in various settings,[4-9] and has been reported in the ED setting.[14] In our study, junior EM providers with modest comfort with point-of-care US were able to successfully perform a US-guided hip injection after a brief tutorial.

Our results suggest that the technical difficulty of the procedure is low. The trainees performing the study were supervised, though the attending physician did not intervene during any of the procedures. Successful performance of the procedure was evident due to the dramatic improvement in pain after just ten minutes consistent with expected analgesia using bupivacaine.

The American College of Rheumatology advises corticosteroid injections as a first-line therapy for osteoarthritis of the hip.[2] To our knowledge, the American College of Emergency Physicians has no comment on intra-articular steroid injections. Integration of this treatment to the care of ED patients should be considered for a number of reasons. Degenerative diseases of the hip, as well as other painful chronic musculoskeletal conditions, may be treated primarily in the ED setting with non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, opioid pain medications, and referral to specialists. There are significant risks associated with long-term use of NSAIDs and a growing concern over opioid drug abuse.[15-17] In settings where access to primary care, pain management, and orthopedic specialists are limited, wait-times to see a practitioner may exceed months.[18-20] This temporizing procedure may assist with chronic pain management, but, nonetheless, should only be performed in conjunction with appropriate consultation and referral to providers who will ultimately care for these patients. With this in mind, providing timely corticosteroid injections are an appealing approach to pain

management for degenerative diseases of the hip to decrease repeat ED visits for chronic pain and opioid prescriptions. More specifically, similar attempts at moving towards multi-modal approaches to pain management have been shown to decrease the need for opioids, and ultimately may help curb the adverse effects and abuse associated with these and other controlled drugs.[22]

Integration of intra-articular hip injections into practice in the ED may not be successful without careful planning. The scope of this study does not assess the efficacy or feasibility in an ED and it if it is implemented the higher acuity and undifferentiated patient population needs to be considered. As with any procedure, clinicians should be adequately trained and comfortable and require the necessary credentialing. They should screen for patients with any signs of septic arthritis and should not perform the procedure in patients with signs of an infectious etiology for their pain, prosthetic hip joints, allergies to the medications, or overlying cellulitis.[13] We would suggest that any patient with suspicion of a septic joint and a visualized effusion should have their joint aspirated using this same US-guided technique. In cases where the risks or benefits of an intra-articular hip injection are not clear, providers should not perform it or should obtain expert consultation. Additionally, patient consent is paramount. Known rare but significant complications of this procedure include avascular necrosis, post-procedural septic joint, and increased risk of post-operative septic joint when performed in proximity to surgery,[13] and as such, patients must be informed and appropriately counseled. Finally, coordination of care beyond the ED is important, specifically with primary care and specialty clinic follow-up. Again, we reiterate that this procedure should not be done in lieu of appropriate referral. Rather, it can serve as an effective temporizing intervention for pain reduction, and should be followed by referral to an orthopedic surgeon, general practitioner, physical therapist, and/or pain specialist. Similarly, an understanding by the community of physicians who will be caring for these patients should be reached. It will be important, for example, that orthopedic surgeons seeing these patients in follow-up are aware of and comfortable with the performance of this procedure by emergency providers. In our experience at our medical center, there has been wide acceptance of intra-articular steroid injections of the hip by emergency providers, orthopedic specialists, and primary care physicians.

LIMITATIONS

There are inherent limitations to our study. Our non-blinded and uncontrolled method does not show that this method is superior compared to placebo, though this has already been established.[2-6] As in most ultrasound studies, the issue of operator dependence is a limitation; however, EM providers may have extensive experience with US-guidance during procedures. There is no doubt that this procedure is unique as compared to vascular access or nerve blockade, and, as such, our training module and supervision by ultrasound fellowship-trained attending physicians was aimed at ensuring familiarity with the anatomy, needle insertion approach and angle, as well as appropriate injection of anesthetic and steroid. Training of providers on the unique technical aspects of this procedure will be paramount before adoption into clinical practice.

Additionally, for the purposes of this study, we enrolled patients directly from an orthopedic clinic. While it remains unclear if the benefit of this procedure would be as evident in ED patients, its benefit has been shown in various settings performed by providers of different specialties,[4-9,13] suggesting that the benefit would also be realized in the ED setting. ED patients with hip pain are likely a more heterogeneous and higher acuity population in terms of presenting complaint, etiology of pain, or reliability for follow-up. While our clinic's patient population represented a more heterogeneous population than previous studies in terms of etiology of disease, it may not approximate the heterogeneity likely to be seen in the ED. The patients in our study were identified by an orthopedic attending and selected as patients who would safely benefit from such a procedure, and as such we must temper our results in light of this limitation. Taken together, this limitation stresses the importance of careful ED patient selection and screening, and, in some instances, may support the use of consultation prior to performing the procedure.

CONCLUSION

This current study suggests that intra-articular hip injections for chronic pain conditions can be reliably taught to EM providers and, similar to previous studies, we have shown that it is safe and effective. It is entirely possible, however, that intra-articular hip injections may not be a feasible, efficient, or effective intervention when introduced into clinical practice in the ED. Prospective observational or randomized trials in this setting are warranted prior to wider acceptance of this procedure.

Future research should study the efficacy of this procedure in a larger population of ED patients. Analyses should specifically focus on proper patient selection, and identification of factors associated with higher efficacy (i.e., which etiology of hip pain benefits more from the injection). Meanwhile, educational resources should be made available to emergency providers who wish to learn this skill for their practice or study its use.

Address for Correspondence: Erik Sorem Anderson, MD, 1411 E 31st Street, Oakland, CA 94602. Email: esoremanderson@gmail.com.

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Video. Hip Injection.

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Management of In-Flight Medical Emergencies: Are Senior Medical Students Prepared to Respond to this Community Need?

Robert J. Katzer, MD, MBA* [*] University of California, Irvine, Department of Emergency Medicine, Irvine, California
David Duong, MD, MS† [†] University of California, San Francisco, Department of Emergency Medicine, San Francisco, California
Matthew Weber, MD*
Amy Memmer, BS‡ [‡] University of California, Irvine, School of Medicine, Irvine, California
Ian Buchanan, BS§ [§] University of California, San Francisco, School of Medicine, San Francisco, California

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Introduction: In-flight medical emergencies on commercial aircraft are common in both domestic and international flights. We hypothesized that fourth-year medical students feel inadequately prepared to lend assistance during in-flight medical emergencies. This multicenter study of two U.S. medical schools obtains a baseline assessment of knowledge and confidence in managing in-flight medical emergencies.

Methods: A 25-question survey was administered to fourth-year medical students at two United States medical schools. Questions included baseline knowledge of in-flight medicine (10 questions) and perceived ability to respond to in-flight medical emergencies.

Results: 229 participants completed the survey (75% response rate). The average score on the fund of knowledge questions was 64%. Responses to the 5-point Likert scale questions indicated that, on average, students did not feel confident or competent responding to an in-flight medical emergency. Participants on average also disagreed with statements that they had adequate understanding of supplies, flight crew training, and ground-based management.

Conclusion: This multicenter survey indicates that fourth-year medical students do not feel adequately prepared to respond to in-flight medical emergencies and may have sub-optimal knowledge. This study provides an initial step in identifying a deficiency in current medical education. [West J Emerg Med. 2014;15(7):925–929.]

INTRODUCTION

In-flight medical emergencies are not uncommon occurrences on commercial aircraft. There is no required reporting for all incidents, but it has been estimated that at least 20,000 of these events occur in the United States annually.[1] One study estimated the incidence of emergencies on U.S. flights to be one per 753 flights,[2] while another estimated one per 604 flights.[3] A retrospective study of one year for a single airline found that one in 11,000 passengers experienced an in-flight emergency.[4] An estimated 40-90% of commercial aircraft flights in the U.S. have a physician among the passengers.[5,6] Physicians have noted that the loud, confined space environment of an aircraft cabin can make it challenging to render aid.[7] The reduced humidity and atmospheric pressure and loss of personal mobility present specific pathophysiologic considerations for physicians who respond to a passenger in need.[8-10] At the same time, the population of air travelers has transitioned to a demographic that is older with more comorbidities.[10]

The general public relies on Good Samaritan physicians of all specialties to respond to in-flight emergencies, yet there are no medical school curriculum

requirements specific to this community need.[11] As noted in prior research, "the provision of medical assistance to passengers during flights aboard commercial aircraft is a matter of concern to most physicians."[13] We are interested in the knowledge and confidence of fourth-year medical students because they will soon be licensed physicians, and physicians of all specialties may be called upon to assist with in-flight emergencies. We believe that medical school serves as an appropriate venue for this training, and it will equip students with a skillset that is important to serve their communities when they become licensed physicians. A heterogeneous pilot project on medical students in different stages of training suggested that a deficit in this skillset exists, and that a focused curriculum, including simulation, could improve their attitudes and fund of knowledge.[12]

To further explore the issue and to ultimately develop curriculum around in-flight medical emergencies, we employed the first two steps of the six-step approach to curriculum development proposed by Kern et al.[14] In this framework, the educational issue can be analyzed first through problem identification and a needs assessment of the learners. We hypothesize that fourth-year (senior) medical students do not feel comfortable assisting during an in-flight medical emergency, nor do they have an adequate fund of knowledge in this area. We structured a multi-site needs assessment study, as there is no documentation to this point of medical student knowledge or present instruction received on inflight emergencies.

METHODS

This study is an observational, cross-sectional investigation of medical student comfort levels and fund of knowledge regarding responses to in-flight medical emergencies. We used questionnaires and fund of knowledge evaluations to examine both comfort and knowledge. The sponsoring medical schools' institutional review boards approved this study as exempt from written consent. As such, researchers used verbal consent for enrollment of all participants.

We distributed the survey to a convenience sample of fourth-year medical students during scheduled class meetings at two medical schools in the U.S., the University of California, Irvine School of Medicine and the University of California, San Francisco School of Medicine. All full-time students in their fourth year of medical education attending the sponsoring medical schools were eligible for inclusion. Prior to participating, students received a mass email containing the study information sheet, and a copy was available during the day of the survey administration. Investigators administered surveys in a break room and lecture hall and collected them in a confidential manner. Completion of the survey was completely optional, and researchers collected no identifying data in the survey.

The primary outcome was descriptive analysis of the survey data, including mean scores of questions on knowledge and self-assessment of competency for in-flight emergencies. The survey consisted of a demographic section with questions that assessed age, gender, year of training, previous healthcare training such as emergency medical technician-basic, previous employment as a healthcare provider, previous training for in-flight emergencies, possession of a pilot's license, and whether they had been aboard an aircraft during an in-flight medical emergency. The survey contained a section to measure perceived confidence and comfort level of students in responding to in-flight medical emergencies with questions using a 5-point Likert scale. The third section of the survey involved 10 fund-of-knowledge questions (Table 1). These questions addressed flight physiology, common in-flight medical emergencies, and logistical considerations when managing in-flight medical emergencies. They were independently reviewed and approved by a former airline medical director, who is an expert in ground-based medical command of in-flight medical emergencies and currently works in the ground-based medical advisory industry. This expert is not a coauthor of this paper.

We calculated descriptive statistics for the demographic questions, responses to the self-assessment questions, and scores of the fund of knowledge questions using a commercially available spreadsheet program (Microsoft Excel 2011, Microsoft Corp., Redmond, WA).

RESULTS

The survey was distributed to 304 fourth-year medical students, 126 from one medical school and 178 from the other. Two hundred thirty-two (76%) students filled out and returned the survey instrument, and 229 (75%) completed all of the subjective and objective questions. Three students indicated that they were third-year medical students. These were excluded from analysis. The majority (54%) of respondents were female, with a mean age of 27 years. Demographic responses to the survey indicated that the vast majority (85%) of respondents had taken a basic life support course, but only a minority (12%) had previously worked as a healthcare provider. A minority of respondents reported previous training on flight physiology or in-flight emergencies (11%). Although 21% of responders had previously been on an aircraft during a medical emergency, only 10% of those (2% of the total sample) had helped manage an in-flight medical emergency. The baseline mean response to each in-flight self-assessment question was less than three, corresponding to disagreement or strong disagreement with statements of comfort with in-flight medical emergencies (Table 2). The mean responses for whether the students felt confident in their ability to respond to general medical emergencies was greater than the mean response to their ability to respond to in-flight medical emergencies ($p<0.0005$).

The answers to the initial fund-of-knowledge questions yielded a mean correct percentage of 64% (range of 10%-

100%, median of 60%, 95% CI of 62.1%-65.9%). The most commonly missed question was "With respect to the enhanced medical kit, flight crew members are required to…" (28% correct). The question most frequently answered correctly was "U.S. flight crews are all trained in the use of the automated external defibrillator" (94% correct). When analyzing the subgroup of participants that had previously worked as a healthcare provider the mean correct percentage for the fund-of-knowledge questions was not significantly different compared to all respondents at 63% (CI of 57.9%-68.1%) vs. 64% (CI of 62.1%-65.9). Those who had worked as healthcare providers also exhibited a baseline response less than three for all the in-flight self-assessment questions, similar to those participants without prior experience working as healthcare providers.

Table 1. Fund-of-knowledge questions related to in-flight emergencies, with correct answers starred.

Question	Percent answered correctly (%)
1. The percentage of oxygen in the atmosphere decreases as your altitude or elevation increases. True False*	31
2. The humidity in cabin air on a commercial airline flight is typically relatively _____ when compared to typical ground level building interiors. a. Low* b. High	87
3. Commercial airplane cabins are typically pressurized to an altitude of _____ a. Sea level b. 2,000 feet c. 8,000 feet* d. 15,000 feet e. Not pressurized	31
4. The most common in-flight medical emergency is. a. Stroke b. Myocardial Infarction c. Seizures d. Vasovagal (syncope, fainting, dizziness)*	86
5. Licensed physicians are required to respond to in-flight medical emergencies on domestic US flights. True False*	62
6. All of the following equipment is required by the FAA as part of the enhanced emergency kit, EXCEPT (Choose only one). a. Laryngoscope* b. Inhaled bronchodilator c. Epinephrine 1:10,000 d. Aspirin e. Nitroglycerin	85
7. US Flight crews are all trained in the use of the automated external defibrillator. True* False	94
8. With respect to the enhanced medical kit, flight crew members are required to. a. Take it out only on request* b. Always take it out c. Always open it d. Know the indications of its medications	28
9. Who has the final say on whether the plane will be diverted because of an in-flight medical emergency? a. the responding physician b. the pilot in charge (captain)* c. the patient d. Ground based medical control	52
10. Only a minority of in-flight medical emergencies result in the diversion of the plane. True* False	85

Table 2. Mean response to self-assessment questions.

Self-assessment questions	Mean response (1-strongly disagree 2-disagree 3-neither agree nor disagree 4-agree 5-strongly agree) (95% CI)
My medical education has given me adequate knowledge and skill to render assistance during a medical emergency.	3.34 (3.21-3.47)
My medical education has given me adequate knowledge and skill to render assistance during an in-flight medical emergency.	2.68 (2.54-2.82)
I have an adequate understanding of what medical supplies are required on commercial airplanes.	1.78 (1.65-1.91)
I have an adequate understanding of the level of training of commercial air crew in managing in-flight medical emergencies.	1.59 (1.48-1.70)
I have an adequate understanding of the manner in which the air crew, ground based medical control, and the on board volunteer healthcare provider work together to manage an in-flight medical emergency.	1.66 (1.55-1.77)
I would currently feel confident responding to an in-flight medical emergency.	2.19 (2.06-2.32)
I would currently provide competent care while responding to an in-flight medical emergency.	2.26 (2.14-2.38)

DISCUSSION

Education addressing logistics and environmental considerations for managing in-flight medical emergencies is not a required component of medical school curriculum in the U.S. This is despite the fact that any physician who travels by

air may be asked to render care in such a situation. Our study indicates that approximately one in five medical students have already been on a flight with a potential medical emergency. Our results also confirmed that medical students, even in their final year of training, do not feel confident or competent in the management of in-flight medical emergencies. The participants' responses to both subjective and objective questions indicated that they were not sufficiently capable of responding during in-flight medical emergencies.

These results build on the limited available previous research. When compared to the only other known publication on discrete medical student training in this specific topic, our study demonstrates that a lack of perceived competence and knowledge exists consistently among senior medical students at more than one medical school.[12] The need for this knowledge base by practicing physicians can be further inferred by several review articles and case reports on in-flight medical emergencies.[1,2,4,5-10] In addition, the literature has demonstrated that discrete simulation training improves response to medical emergencies.[15,16] Given these findings, medical schools should consider ways to include material on the subject within their curricula.

LIMITATIONS

Our study has several limitations. First, response performance to in-flight medical emergencies is challenging to measure and Likert scale questions may not capture actual student perception of competency levels. Although Likert scales may incur central tendency bias, such bias would likely falsely elevate students' confidence ratings, since the most common responses to the self-assessment questions corresponded to disagree or strongly disagree. Likert scales supply results that are similar to those of traditional formats of measurement.[17] Second, our study used multiple-choice questions to evaluate the topic-specific fund of knowledge. We attempted to find questions on the topic with existing external validation, but were unable to. As the process of creating validated questions alone would have been much more complex than the design of this study, we moved forward with that limitation. Although the fund-of-knowledge questions were not externally validated, we attempted to select questions that addressed key concepts of in-flight medical emergencies. Additionally, these questions were vetted by an expert in providing online medical command during these events. Third, while successful performance on these objective questions is expected for individuals with appropriate expertise, it is by no means sufficient to demonstrate an adequate understanding and performance of the required skills during actual in-flight medical emergencies. Fourth, as with any convenience sample, the potential for bias exists. This was mitigated by including a study population that was both homogenous and advanced in training (senior medical students), and by administering the survey in person during scheduled activities that involve the entire class, not certain sub segments. Two separate universities were involved to reduce the bias from any one institution, with an adequate overall response rate. The use of only two universities may not result in a national representation of curricular preparedness and curricular need, but did function at decreasing the bias that may occur when looking at only one school.

It is not entirely clear why three of the 235 responders indicated that they were third-year medical students, as the surveys were administered at functions attended solely by fourth-year medical students. These students might have circled the third-year indicator in error or they may have been third-year medical students who chose to attend the activity.

CONCLUSION

This multicenter study demonstrates that fourth-year medical students do not feel adequately prepared to respond to in-flight medical emergencies and may have sub-optimal knowledge in this area of medicine. A training gap likely exists in the U.S. medical school curriculum to address the response to and management of in-flight medical emergencies aboard commercial aircraft. This study provides an initial step in identifying and potentially improving a deficiency in current medical education.

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Address for Correspondence: Robert Katzer, MD, MBA. UC Irvine, Department of Emergency Medicine, 101 The City Dr. S, Orange, CA 92868. Email: rkatzer@uci.edu.

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Learning Curves for Direct Laryngoscopy and GlideScope® Video Laryngoscopy in an Emergency Medicine Residency

John C. Sakles, MD*
Jarrod Mosier, MD*
Asad E. Patanwala, PharmD†
John Dicken, BS‡

*University of Arizona, Department of Emergency Medicine, Tucson, Arizona
†University of Arizona College of Pharmacy, Department of Pharmacy Practice and Science, Tucson, Arizona
‡University of Arizona College of Medicine, Tucson, Arizona

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Introduction: Our objective is to evaluate the resident learning curves for direct laryngoscopy (DL) and GlideScope® video laryngoscopy (GVL) over the course of an emergency medicine (EM) residency training program.

Methods: This was an analysis of intubations performed in the emergency department (ED) by EM residents over a seven-year period from July 1, 2007 to June 30, 2014 at an academic ED with 70,000 annual visits. After EM residents perform an intubation in the ED they complete a continuous quality improvement (CQI) form. Data collected includes patient demographics, operator post- graduate year (PGY), difficult airway characteristics (DACs), method of intubation, device used for intubation and outcome of each attempt. We included in this analysis only adult intubations performed by EM residents using a DL or a standard reusable GVL. The primary outcome was first pass success, defined as a successful intubation with a single laryngoscope insertion. First pass success was evaluated for each PGY of training for DL and GVL. Logistic mixed-effects models were constructed for each device to determine the effect of PGY level on first pass success, after adjusting for important confounders.

Results: Over the seven-year period, the DL was used as the initial device on 1,035 patients and the GVL was used as the initial device on 578 patients by EM residents. When using the DL the first past success of PGY-1 residents was 69.9% (160/229; 95% CI 63.5%-75.7%), of PGY-2 residents was 71.7% (274/382; 95% CI 66.9%-76.2%), and of PGY-3 residents was 72.9% (309/424; 95% CI 68.4%-77.1%). When using the GVL the first pass success of PGY-1 residents was 74.4% (87/117; 95% CI 65.5%-82.0%), of PGY-2 residents was 83.6% (194/232; 95% CI 76.7%-87.7%), and of PGY-3 residents was 90.0% (206/229; 95% CI 85.3%-93.5%). In the mixed-effects model for DL, first pass success for PGY-2 and PGY-3 residents did not improve compared to PGY-1 residents (PGY-2 aOR 1.3, 95% CI 0.9-1.9; p-value 0.236) (PGY-3 aOR 1.5, 95% CI 1.0-2.2, p-value 0.067). However, in the model for GVL, first pass success for PGY-2 and PGY-3 residents improved compared to PGY-1 residents (PGY-2 aOR 2.1, 95% CI 1.1-3.8, p-value 0.021) (PGY-3 aOR 4.1, 95% CI 2.1-8.0, p<0.001).

Conclusion: Over the course of residency training there was no significant improvement in EM resident first pass success with the DL, but substantial improvement with the GVL. [West J Emerg Med. 2014;15(7):930-937.]

INTRODUCTION

Emergency physicians are expected to be able to manage the airways of critically ill and injured patients presenting to the emergency department (ED). As such, emergency medicine (EM) residents have to be trained, knowledgeable and skilled with a variety of intubation devices. These include both the conventional direct laryngoscope (DL) and indirect laryngoscopes such as the GlideScope® video laryngoscope (GVL). The intubation techniques of these two devices are considerably different.

With DL, the operator must compress and displace the tissues of the upper airway so that a direct line of sight to the airway can be achieved.[1] This can be technically challenging and thus achieving an adequate laryngeal view can often be difficult. However, once an adequate view is achieved directing the tube to the laryngeal inlet is usually fairly easy.

With the GVL, the hyperangulated blade and the presence of a micro video camera on the blade allow the operator to look around the structures that would impede a direct view and thus obviate the need to displace the tissues of the upper airway. An excellent view of the laryngeal inlet is almost always achieved when using the GVL.[2,3] However, directing the tube to what the operator is seeing on the video screen can be quite challenging, as the operator must direct the tube along the curved path of the hyperangulated blade. To facilitate this process, the manufacturer of the GVL has produced a specially designed rigid stylet (GlideRite®) that matches the curvature of the GVL blade.[4]

The techniques employed in using these two intubating devices are very different, so one might expect that their learning curves would likely also be different. The goal of this investigation was to compare the learning curves for DL and GVL over the course of an EM training program.

METHODS

Study Design

This was a retrospective analysis of intubations performed on adults in the ED by EM residents with the DL or the standard reusable GVL over the seven-year period between July 1, 2007 and June 30, 2014. This project was granted exemption from informed consent requirements by the university's institutional review board (IRB) prior to conducting the study.

Study Setting and Population

This study was conducted at a tertiary care academic ED, which currently has 61 beds and approximately 70,000 annual ED visits. We collected data on all patients requiring intubation in this ED. Only adult patients (age 18 or older) who underwent an initial intubation attempt by EM residents using the DL or the standard GVL were included in this study (Figure 1).

This ED is a Level 1 trauma center with a three-year EM residency program and a five-year combined emergency medicine/pediatrics (EM/Peds) residency program. For the purposes of this study, we included only categorical EM residents (post-graduate year [PGY]-1, 2, 3) in the analyses. The typical EM class size is 15 per year (range 11-16) for a total of approximately 45 residents (range 40-47) in the EM program at any given time. Over the seven-year study period, 129 EM residents have performed intubations. An EM resident, over the course of training in our program, performs an average of 21 adult intubations in the ED. All intubations performed by EM residents are supervised by an EM attending.

During the study period, there were between two and four GVL units available at any given time, as well as a full range of available Macintosh, Miller, and GrandView™ DL blades. Both standard malleable stylets and GlideRite® rigid stylets were available in the ED throughout the entire study period. The decision regarding the method of intubation and initial device selection were at the discretion of the EM resident and EM attending.

EM residents in this program receive formal instruction on the use of multiple airway devices and techniques. These include DL, GVL, C-MAC, flexible fiberoptic scope, intubating laryngeal mask airway, and cricothyrotomy. Resident training involves both didactic material as well as hands on experience in the simulation lab. All interns complete a mandatory rotation in anesthesiology where they perform roughly 25 intubations on stable patients, which are primarily performed using DL. The technique taught to EM residents regarding GVL intubation has been previously described in detail.[5] Briefly, residents are instructed to insert the device in the midline and navigate slowly towards the airway as they systematically identify landmarks as they advance the blade. They are strongly encouraged to use the GlideRite® stylet for all GVL intubations.

Study Protocol

After each intubation, a continuous quality improvement (CQI) form was completed by the operator to document clinically important information. Data collected included patient age and sex, operator PGY, difficult airway characteristics of the patient, indication for and method of intubation, drugs used for intubation, device used and reason for device selection and outcome of each attempt.

Difficult airway characteristics assessed by the operator included the following: cervical immobility, facial or neck trauma, airway edema, small mandible, obesity, large tongue, short neck, restricted mouth opening, blood in airway, vomit in airway.

The three different intubation methods were classified on the form as rapid sequence intubation (RSI) in which a paralytic agent was used, oral intubation in which only a sedative agent was used (SED), and oral intubation in which no medications were used (NO MEDS).

Options for the reason for device selection were "standard" (routine airway, no suspected difficulty), "difficult" (difficult airway anticipated) or "education" (device selected for educational reasons).

Primary outcome was the first pass success of DL and GVL per PGY. We defined an intubation attempt as the insertion of the laryngoscope blade into the mouth of the patient, regardless whether an attempt was made to insert a tracheal tube. First pass success was defined as tracheal intubation with a single laryngoscope blade insertion.

The senior author reviewed every CQI form for completion, and in the case of an incomplete form, the operator was interviewed to complete the data collection. To ensure complete compliance, missing data forms were identified through a cross-referencing system. We used various methods throughout the study period to identify missing forms, including cross referencing billing records, pharmacy records, and a customized intubation report in the electronic medical record. If an intubation was performed in the ED that was missing a form, the operator was given a blank CQI form to complete.

Data Analysis

Patient and intubation characteristics are presented descriptively in the DL and GVL groups for each PGY of training. We reported continuous variables as means, and categorical variables as percentages. For categorical data we included 95% confidence intervals (CI) calculated using the "exact" method. The proportion of cases with first pass success was reported as a percentage for each year of residency training. We used a logistic mixed-effects model to determine the association between PGY of residency training and first pass success. A mixed-effects model was used because the data are clustered according to the resident performing each intubation. Thus, the individual resident was added to the model as a mixed effect. The primary predictor of interest was PGY of residency training, categorized as PGY-1, PGY-2 and PGY-3. There was a significant interaction between PGY and device (DL versus GVL) with regard to the effect on first pass success, meaning the effect of PGY on first pass success depended on the device used. Thus, we constructed models separately for DL and GVL. Based on previous investigations the following confounders were selected a priori and included in each model: reason for intubation (cardiac arrest versus non-cardiac arrest) and number of difficult airway characteristics (included as an ordinal variable).[5,6] These variables have been shown to be significantly associated with first pass success. We also included calendar year as a possible confounder, given the possibility for improvement over time with continued use of the devices in the ED. We performed all statistical analyses with STATA version 13 (College Station, Texas).

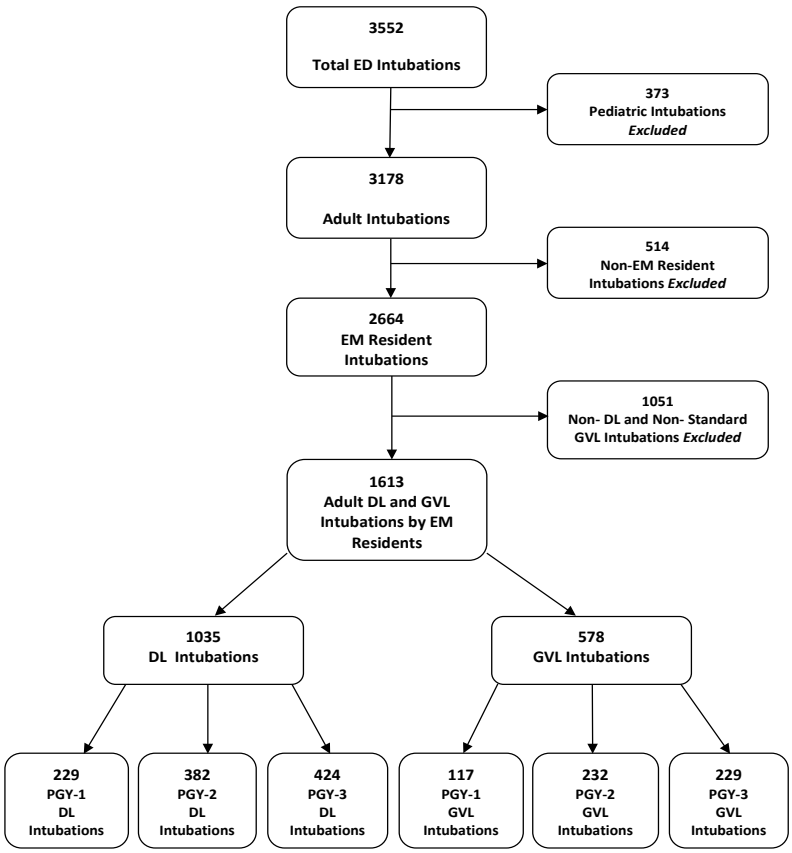

Figure 1. Flow diagram of patients in DL and GVL cohorts.
ED, emergency department; *EM,* emergency medicine; *DL*, direct laryngoscope; *GVL*, GlideScope® video laryngoscope; *PGY,* post-graduate year

RESULTS

Over the seven-year study period, EM residents performed a total of 1,613 intubations using the DL or the GVL. Of these, 1,035 were initially attempted using the DL and the 578 were attempted with GVL (Figure 1). Patient and intubation characteristics of each cohort are reported in Table 1a and Table 1b. In the GVL cohort, more patients were trauma patients and more patients had difficult airway characteristics.

For DL, the first past success of PGY-1 residents was 69.9% (160/229; 95% CI 63.5%-75.7%), for PGY-2 residents 71.7% (274/382; 95% CI 66.9%-76.2%), and for PGY-3 residents 72.9% (309/424; 95% CI 68.4%-77.1%). For GVL the first pass success of PGY-1 residents was 74.4% (87/117; 95% CI 65.5%-82.0%), for PGY-2 residents 83.6% (194/232; 95% CI 76.7%-87.7%), and for PGY-3 residents 90.0% (206/229; 95% CI 85.3%-93.5%) (Figure 2).

In the mixed-effects model for DL, first pass success for PGY-2 and PGY-3 residents did not improve compared to PGY-1 residents (PGY-2 aOR 1.3, 95% CI 0.9-1.9; p-value 0.236) (PGY-3 aOR 1.5, 95% CI 1.0-2.2, p-value 0.067) (Table 2a). However, in the model for GVL first pass success for PGY-2 and PGY-3 residents improved compared to PGY-1 residents (PGY-2 aOR 2.1, 95% CI 1.1-3.8, p-value 0.021; PGY-3 aOR 4.1, 95% CI 2.1-8.0, p<0.001) (Table 2b). Also, for each calendar year increment, the odds of first pass success did not increase with DL (aOR 1.0, 95% CI 0.9-1.1, p-value 0.878). However, GVL performance improved over time with continued use in the ED (aOR 1.2, 95% CI 1.1-1.4, p-value 0.009).

DISCUSSION

In this study we sought to determine the learning curves for two commonly used intubating devices in the ED, the direct laryngoscope and the GlideScope® video laryngoscope. Our results show that the first pass success for DL was approximately 70% for PGY-1 residents and increased to 73% for PGY-3 residents. This difference was not statistically significant or clinically meaningful. The first pass success for GVL was approximately 75% for PGY-1 residents, a value that was similar to DL for the same level of training. However, this improved significantly to 90% for PGY-3 residents. To account for potential confounders we developed a logistic mixed-effects model, which demonstrated that there was no significant improvement in DL performance (aOR 1.5) between PGY-1 and PGY-3 residents, but considerable improvement in performance with GVL (aOR 4.1). This suggests that the learning curve for DL is fairly flat, with little improvement in success with training over time. On the other hand, GVL has a very steep learning curve with significant improvement over the course of residency training. This was true despite the fact that EM residents performed many more DL than GVL intubations in the ED during the study period.

The difference in the learning curves between the DL and the GVL is remarkable and may be related to inherent differences in their design and use. When performing DL, obtaining a view of the laryngeal inlet requires great skill and technically can be very challenging, but once that view is achieved intubation is usually straightforward. On the other hand, when performing GVL, an excellent view can usually be easily attained, but directing the tube to the image of the laryngeal inlet that is visualized on the video monitor can be very challenging. For DL, optimizing the laryngeal view requires subtle changes in technique and positioning, and with the experience a resident receives during their training, they may not be able to acquire this skill. With GVL, achieving an excellent view is usually easy, and the learning curve is primarily dependent on acquiring the skill of directing the tube to the image that is seen. This skill appears to be more easily acquired over the course of residency training.

Another possible explanation for the lack of DL improvement over training is the rapid abandonment of DL. In the past, if DL failed, there were no other options for rescue intubation, so DL was attempted again. This allowed the operator to learn from the initial DL failure and receive another learning experience on the additional DL attempt. Currently there are multiple airway devices available for rescue intubation attempts, particularly video laryngoscopes, and operators are more likely to abort the use of DL after a failed intubation and switch to video laryngoscope (VL). Thus the opportunity for residents to learn from their mistakes and advance their DL skills after failed first intubation attempts is lost.

Our results are supported by other studies that have evaluated the learning curves for DL and GVL. Ambrosio et al. conducted a randomized trial comparing DL and GVL intubation performance on a difficult airway manikin among novice physicians with little to no prior intubation experience.[7] These novice physicians had 47.4% success with DL and 100% success with GVL. Nouruzi-Sedeh et al. also compared the success of DL to GVL in untrained medical personnel performing intubations on stable patients in the operating room.[8] They found that these novices had success of only 51% with DL but 90% with GVL.

Our results, considered in the context of previous research, suggest that for operators with less experience, the GVL is more quickly learned and is associated with higher first pass intubation success than DL.

LIMITATIONS

There are several limitations to this study. First, because it was observational the selection of operators and devices was not randomized. There was likely some selection bias regarding the choice of airway devices with user preference and comfort dictating which devices were selected. Also, patient characteristics could impact the device selection, as demonstrated by the high use of the GVL in patients with difficult airway characteristics. We attempted to control for these confounders by using a logistic mixed-effects model. A randomized controlled study would be ideal and would

Table 1a. Patient and intubation characteristics by PGY in DL cohort.

Patient characteristic	PGY-1 (%)	95% CI*	PGY-2 (%)	95% CI*	PGY-3 (%)	95% CI*
Mean age, years	52.9	50.3-55.6	51.0	47.5-54.5	49.6	47.6-51.6
Sex						
Male	60.7	54.1-67.1	68.3	63.4-73.0	65.6	60.8-70.1
Medical/trauma						
Trauma patients	18.3	13.6-24.0	36.7	31.8-41.7	42.2	37.5-47.1
Difficult airway characteristic						
None	51.5	44.9-58.2	37.7	32.8-42.8	38.4	33.8-43.3
≥1	48.5	41.8-55.2	62.3	57.2-67.2	61.6	56.7-66.2
Cervical immobilization	12.7	8.7-17.7	21.5	17.5-25.9	31.1	26.8-35.8
Blood in airway	16.6	12.0-22.1	22.3	18.2-26.8	22.9	19.0-27.2
Vomit in airway	12.7	8.7-17.7	13.9	10.6-17.8	12.5	9.5-16.0
Facial/neck trauma	4.4	2.1-7.9	8.1	5.6-11.3	10.1	7.4-13.4
Obesity	14.4	10.2-19.6	18.6	14.8-22.9	16.3	12.9-20.1
Short neck	11.8	7.9-16.7	11.8	8.7-15.4	11.3	8.5-14.7
Large tongue	9.2	5.8-13.7	10.5	7.6-14.0	13.0	9.9-16.6
Airway edema	2.6	1.0-5.6	1.6	0.6-3.4	3.1	1.6-5.2
Small mandible	6.6	3.7-10.6	4.7	2.8-7.4	5.4	3.5-8.0
Restricted mouth opening	0		0		0.2	0-1.3
Reason for intubation						
Airway protection	62.5	55.8-68.7	63.9	58.8-68.7	58.3	53.4-63.0
Respiratory failure	19.7	14.7-25.4	16.8	13.2-20.9	18.4	14.8-22.4
Cardiac arrest	10.5	6.8-15.2	10.0	7.1-13.4	14.9	11.6-18.6
Patient control	5.2	2.7-9.0	8.6	6.0-11.7	6.8	4.6-9.7
Hypoxia	2.2	0.7-5.0	0.8	0.2-2.3	1.7	0.7-3.4
Reason for device selection						
Standard	95.2	91.6-97.6	94.2	91.4-96.4	92.9	90.1-95.2
Difficult	2.2	0.7-5.0	1.8	0.7-3.7	3.3	1.8-5.5
Education	2.6	1.0-5.6	3.9	2.2-6.4	3.8	2.2-6.1
Method of intubation						
Rapid sequence intubation (RSI)	89.1	84.3-92.8	88.0	84.3-91.1	83.3	79.4-86.7
Sedative agent was used (SED)	0		0.8	0.2-2.3	0.7	0.2-2.1
No medications were used (NO MEDS)	10.9	7.2-15.7	11.3	8.3-14.9	16.0	12.7-19.9
Paralytic agent						
Succinylcholine	48.9	42.3-55.6	41.9	36.9-47.0	39.6	34.9-44.5
Rocuronium	40.2	33.8-46.8	46.1	41.0-51.2	43.2	38.4-48.0
Induction agent						
Etomidate	84.7	79.4-89.1	83.8	79.7-87.3	79.0	74.8-82.8
Ketamine	0.9	0.1-3.1	1.8	0.7-3.7	2.4	1.1-4.3
Propofol	0.9	0.1-3.1	0.8	0.2-2.3	0.7	0.2-2.1

PGY, post-graduate year*; DL*, direct laryngoscope; *RSI,* rapid sequence intubation; *SED*, sedative agent was used; *NO MEDS*, no medications were used

*95% CIs calculated with the "exact" method.

Table 1b. Patient and intubation characteristics by PGY in GVL cohort.

Patient characteristic	PGY-1 (%)	95% CI*	PGY-2 (%)	95% CI*	PGY-3 (%)	95% CI*
Mean age, years	49.4	45.7-53.1	47.3	44.8-49.8	48.6	46.0-51.2
Sex						
Male	70.9	61.8-79.0	69.4	63.0-75.3	68.1	61.7-74.1
Medical/trauma						
Trauma patients	47.0	37.7-56.5	58.2	51.6-64.6	62.5	55.8-68.7
Difficult airway characteristic						
None	25.6	18.0-34.5	24.1	18.8-30.2	21.4	16.3-27.3
≥1	74.4	65.5-82.0	75.9	69.8-81.2	78.6	72.7-83.7
Cervical immobilization	42.7	33.6-52.2	48.7	42.1-55.3	50.2	43.6-56.9
Blood in airway	26.5	18.8-35.5	29.3	23.5-35.6	27.1	21.4-33.3
Vomit in airway	14.5	8.7-22.2	11.6	7.8-16.5	12.2	8.3-17.2
Facial/neck trauma	24.8	17.3-33.6	25.4	20.0-31.5	22.7	17.5-28.7
Obesity	19.7	12.9-28.0	20.3	15.3-26.0	17.5	12.8-23.0
Short neck	18.8	12.2-27.1	19.0	14.1-24.6	15.7	11.3-21.1
Large tongue	15.4	9.4-23.2	11.2	7.5-16.0	13.5	9.4-18.7
Airway edema	4.2	1.4-9.7	4.7	2.4-8.3	4.4	2.1-7.9
Small mandible	3.4	0.9-8.5	8.2	5.0-12.5	9.2	5.8-13.7
Restricted mouth opening	1.7	0.2-6.0	12.9	0.3-3.7	1.8	0.5-4.4
Reason for intubation						
Airway protection	65.8	56.5-74.3	65.5	59.0-71.6	62.0	55.4-68.3
Respiratory failure	12.0	6.7-19.3	14.7	10.4-19.9	14.4	10.1-19.6
Cardiac arrest	8.6	4.2-15.2	10.8	7.1-15.5	14.9	10.5-20.1
Patient control	9.4	4.8-16.2	7.3	4.3-11.5	8.3	5.1-12.7
Hypoxia	4.3	1.4-9.7	1.7	0.5-4.4	0.4	0-2.4
Reason for device selection						
Standard	29.9	21.8-39.1	39.7	33.3-46.3	31.0	25.1-37.4
Difficult	54.7	45.2-63.9	52.6	46.0-59.2	63.3	56.7-69.6
Education	15.4	9.4-23.2	7.8	4.7-12.0	5.7	3.1-9.5
Method of intubation						
Rapid sequence intubation (RSI)	89.2	82.8-94.6	83.6	78.2-88.1	82.5	77.0-87.2
Sedative agent was used (SED)	3.4	0.9-8.5	2.2	0.7-5.0	1.8	0.5-4.4
No medications were used (NO MEDS)	6.8	3.0-13.0	14.2	10.0-19.4	15.7	11.3-21.1
Paralytic agent						
Succinylcholine	47.0	37.7-56.5	44.0	37.5-50.6	43.7	37.2-50.4
Rocuronium	42.7	33.6-52.2	39.2	32.9-45.8	38.9	32.5-45.5
Induction agent						
Etomidate	81.2	72.9-87.8	78.0	72.1-83.2	76.9	70.9-82.2
Ketamine	5.1	1.9-10.8	3.0	1.2-6.1	3.1	1.2-6.2
Propofol	1.7	0.2-6.0	2.2	0.7-5.0	1.3	0.3-3.8

PGY, post-graduate year; *GVL*, GlideScope® video laryngoscope; *RSI,* rapid sequence intubation; *SED*, sedative agent was used; *NO MEDS*, no medications were used
*95% CIs calculated with the "exact" method.

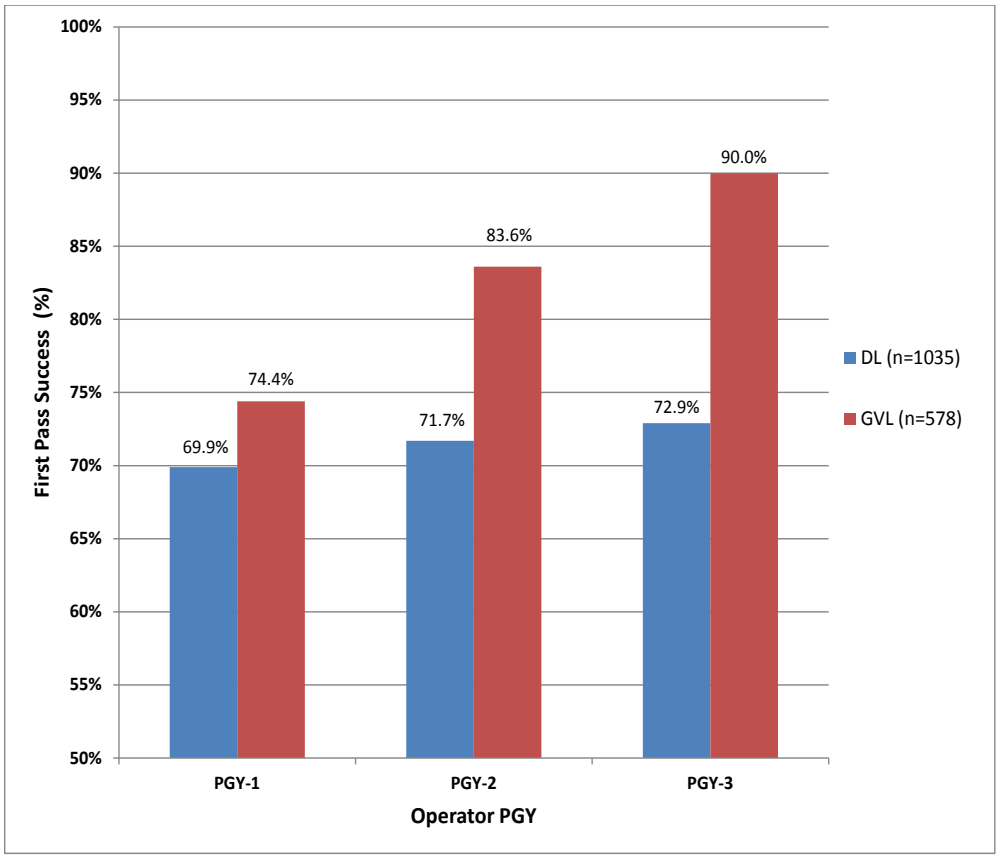

Figure 2. First pass success by PGY in DL and GVL cohorts.
PGY, post-grad year; *DL*, direct laryngoscopy; *GVL*, GlideScope® video laryngoscope

Table 2a. Mixed-effects model for improvement in first pass success with DL.

Variable	Adjusted odds ratio	95% CI	p-value
Reason for intubation			
Non-cardiac arrest	[Reference]		
Cardiac arrest	0.7	0.5-1.2	0.178
Difficult airway characteristics	0.6	0.6-0.7	<0.001
Operator PGY			
PGY-1	[Reference]	0.9-1.9	0.236
PGY-2	1.3	1.0-2.2	0.067
PGY-3	1.5		
Calendar year	1.0	0.9-1.1	0.878

DL, direct laryngoscopy; PGY, post-graduate year

Table 2b. Mixed-effects model for improvement in first pass success with GVL.

Variable	Adjusted odds ratio	95% CI	p-value
Reason for intubation			
Non-cardiac arrest	[Reference]		
Cardiac arrest	0.3	0.1-0.5	<0.001
Difficult airway characteristics	0.7	0.6-0.9	<0.001
Operator post-graduate year (PGY)			
PGY-1	[Reference]		
PGY-2	2.1	1.1-3.8	0.021
PGY-3	4.1	2.1-8.0	<0.001
Calendar year	1.2	1.1-1.4	0.009

GVL, GlideScope® video laryngoscope; *PGY, post-graduate year*

overcome this limitation; however, the randomization of device selection would be difficult and impractical in the ED setting where intubations are often performed precipitously. Furthermore, randomization may in fact be dangerous by forcing an operator to perform a difficult intubation with a device they feel is not suitable for the patient.

Another study limitation is the use of self-reported data. After each intubation the operator filled out a data form about the procedure. It is possible that information was reported inaccurately and that under-reporting of certain events occurred. However, data collection forms were reviewed as they were received and the operator was interviewed and/or the medical record was reviewed if there appeared to be incongruous information. To overcome this limitation of self-report bias, a designated research observer would need to be present at every intubation to record the data objectively, but this is not practical due to the infrequent and precipitous nature of ED intubations. Recall bias is another limitation that could impact the results; however, this effect is likely to be minimal as the vast majority of forms were filled out by the operators within a few days of the intubation.

Another limitation is that this study was conducted at a single EM residency training program site and aspects of this clinical and learning environment may differ from other training programs. For example, video laryngoscopes have been used in our ED since their introduction in 2001 and multiple video, fiberoptic and optical airway devices are available for use on a routine basis. EM residents in this program have a great deal of exposure and training with video laryngoscopes, which may not be the case in other training programs. Thus, our results may not be generalizable to other academic sites.

Only ED intubations at the primary training site were recorded and analyzed. EM residents have rotations in other EDs, the operating room, the intensive care unit, and on the wards where intubations are performed but are not accounted for in this study. These offsite intubations obviously have an effect on the resident's procedural experience and thus could have impacted the results we obtained.

CONCLUSION

Over the course of a three-year EM residency training program there was very little improvement in the performance of DL by EM residents, but substantial improvement in the performance of GVL. If the trend in VL use in the ED continues to increase at the current rate it is likely that this performance gap between DL and VL will increase over time.

Address for Correspondence: John C. Sakles, MD. University of Arizona, Department of Emergency Medicine, 1501 N. Campbell Avenue, PO Box 245057, Tucson, AZ 85724. Email: sakles@aemrc.arizona.edu.

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The Flipped Classroom: A Modality for Mixed Asynchronous and Synchronous Learning in a Residency Program

Timothy P. Young, MD
Caleb J. Bailey, MD
Mindi Guptill, MD
Andrea W. Thorp, MD
Tamara L. Thomas, MD

Loma Linda University Medical Center, Department of Emergency Medicine, Loma Linda, California

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Introduction: A "flipped classroom" educational model exchanges the traditional format of a classroom lecture and homework problem set. We piloted two flipped classroom sessions in our emergency medicine (EM) residency didactic schedule. We aimed to learn about resident and faculty impressions of the sessions, in order to develop them as a regular component of our residency curriculum.

Methods: We evaluated residents' impression of the asynchronous video component and synchronous classroom component using four Likert items. We used open-ended questions to inquire about resident and faculty impressions of the advantages and disadvantages of the format.

Results: For the Likert items evaluating the video lectures, 33/35 residents (94%, 95% CI 80%-99%) responded that the video lecture added to their knowledge about the topic, and 33/35 residents felt that watching the video was a valuable use of their time. For items evaluating the flipped classroom format, 36/38 residents (95%, 95% CI 82%-99%) preferred the format to a traditional lecture on the topic, and 38/38 residents (100%, 95% CI 89%-100%) felt that the small group session was effective in helping them learn about the topic. Most residents preferred to see the format monthly in our curriculum and chose an ideal group size of 5.5 (first session) and 7 (second session). Residents cited the interactivity of the sessions and access to experts as advantages of the format. Faculty felt the ability to assess residents' understanding of concepts and provide feedback were advantages.

Conclusion: Our flipped classroom model was positively received by EM residents. Residents preferred a small group size and favored frequent use of the format in our curriculum. The flipped classroom represents one modality that programs may use to incorporate a mixture of asynchronous and interactive synchronous learning and provide additional opportunities to evaluate residents. [West J Emerg Med. 2014;15(7):938-944.]

INTRODUCTION

Didactic conference scheduling presents a challenge to the leadership of residency programs in all specialties. Programs that have switched to shift-based schedules to accommodate duty-hour requirements are finding that residents' attendance at conference is impacted.[1] Emergency medicine (EM), with its inherent shift-based schedule, is no stranger to this dilemma. Not only does shift work impact EM residents' ability to attend conference, but EM faculty are challenged with finding a balance between preparing for and delivering didactics and managing their own clinical shift schedules. Residents at our institution have commented that they would like greater participation by faculty in didactic sessions. At the same time, the implementation of the Accreditation Council for Graduate Medical Education (ACGME) milestones project in the United States has increased the importance of opportunities for face-to-face evaluation of a resident's medical knowledge.

Over recent years, the methods and information sources that

residents use to learn have changed. The availability of online material in the EM community has exploded, with residents increasingly making use of blogs, podcasts, and social media for learning.[2] An entire movement, dubbed FOAM (free open-access "meducation") has emerged in the online EM community.[3] The FOAM concept promotes freely available, "sophisticated, cutting-edge learning resources that enable clinicians and students to update their knowledge and improve their understanding in a fun, motivating and time efficient way."

The increase in online medical education material parallels one that has occurred in secondary education. The Khan academy is a non-profit organization whose website offers thousands of video lectures on multiple subjects.[4,5] Secondary educators have used these and their own videos to create an alternative to traditional didactics that has been called a "flipped classroom."[6] A flipped classroom exchanges the usual process of delivering content synchronously in the form of a classroom lecture and then assigning a problem set for students to complete at home. The didactic is viewed at home asynchronously, usually in the form of a video lecture, and students use classroom time to work on the problem set in a setting where they can receive help and clarification from an expert. The concept has also been described in undergraduate,[7,8] as well as graduate education.[9] Advantages of the asynchronous video component include the ability of the student to pause, rewind, and fast forward the content to process information at their own pace.[10,11] Suggested benefits of the in-class session include the ability of the educator to guide the application of knowledge.[10,11]

The need for alternatives to traditional didactics in EM has been acknowledged. The Council of Emergency Medicine Residency Directors (CORD) Academic Assembly Conference Alternative Workshop published recommendations in 2008 that included the integration of asynchronous learning activities (also called "individualized interactive instruction") and promoted more flexibility in didactics.[12] The Residency Review Committee (RRC) for EM allows for residents to use individualized interactive instruction for up to 20% of the planned educational experiences or didactics.[13] However, the best method to incorporate asynchronous learning remains unclear.[14] Early efforts, including sending residents tasks and receiving responses over e-mail,[15] journal article discussion boards,[16] institutional faculty-developed online video lectures[17] and modules,[18] and the adaptation of pre-existing modules,[19] have had mixed results.

We trialed a flipped classroom format in our didactic schedule as a potential means to incorporate 1) an asynchronous component that could allow for more schedule flexibility and appeal to a millennial audience and 2) a synchronous, interactive component with the potential to increase residents' interactions with faculty during our didactic sessions. Our aim was to learn about resident and faculty impressions of the sessions in order to develop them as a regular component of our formal curriculum. We present a description and evaluation of two pilot sessions below. To our knowledge, this is the first comprehensive description of a flipped classroom model in the setting of a residency training program.

METHODS

Study Design

We undertook an evaluation of two flipped classroom sessions developed for EM residents. We created a mixed-methods quantitative and qualitative questionnaire to evaluate the flipped classroom sessions. The questionnaire included a fixed-response (quantitative) component with questions meant to evaluate specific aspects of the format, as well as an open-ended (qualitative) component aimed at exploring participant perspectives in a more in-depth manner. This is known as a convergent design and offers the benefit of observing trends while obtaining more detailed responses (and thus a potentially more complete understanding of a phenomenon) from a small sample size.[20] Responses for quantitative items took the form of either yes/no, fill in the blank, multiple choice, or five-point likert-type items, which were chosen for familiarity. The study was presented to our institutional review board and designated as exempt from review.

Study Setting and Population

Our EM residency is a three-year ACGME accredited program that consists of 13 residents per year, for a total of 39 residents. Our educational conferences are five-hour weekly sessions. Traditionally, this time has been filled by 50-minute lectures, separated by 10-minute breaks.

Study Protocol

The first flipped classroom session took place in December 2012. The topic was syncope and the session was scheduled for two hours. We chose a freely available online lecture about syncope created by Andy Neil and hosted on his website.[21] One week prior to the session, residents were emailed a link to the video with instructions to watch it prior to conference. A reminder email was also sent out on the day prior to the session.

To facilitate the moderated discussion, we created a worksheet of 22 questions on the topic of syncope. The worksheet was a combination of open-ended, multiple-choice, and matching questions. These included questions from EM board review sources such as the Physician's Evaluation and Educational Review in Emergency Medicine (PEER) series of question books,[22] the Council of Residency Directors in Emergency Medicine (CORD-EM) question bank,[23] as well as some written by residency leadership. Questions were selected to reinforce and expand on the topics presented in the video. Question stems were augmented with images of electrocardiograms (ECGs) and ultrasound stills. A corresponding key, with expanded answers and explanations for each question on the worksheet, was distributed in advance to the three faculty members moderating the small groups. The question set was not distributed to residents in advance.

On the day of the session, question sheets were distributed

to the residents in attendance and the group was divided into three small groups. The three faculty moderators each led a small group discussion. Other faculty members in attendance were distributed among the groups. The small groups met at large tables in the same room. Moderators led the residents through the question set. Residents were sequentially asked to each answer a question, taking turns in an "around the table" format until every question had been discussed. The discussion points were at the discretion of the faculty member, although potential "teaching points" were suggested in the answer key. After the session was complete, residents were asked to complete an anonymous evaluation form before leaving the room. The evaluation form had no identifiers other than postgraduate year, and residents placed their own evaluations in a collection box to ensure anonymity.

For the second session in February 2013, we chose the topic of pediatric gastrointestinal presentations. Again, we chose a freely available online video on the topic.[24] Residents were similarly emailed a link one week before the classroom session, with a reminder email the day prior to the session.

In response to concerns from residents in the first session about the additional time required to view the video outside of conference, we altered our plan for the second session. Residents were told that they would be excused from the last hour of conference if they attested that they had viewed the hour-long video prior to conference. They would be given the option to view the video in conference for the last hour of the day if they did not watch the video outside of conference. For this session, two members of the faculty of pediatric EM and a senior pediatric EM fellow were recruited to lead the groups. Again, a 22-item worksheet was developed, along with an answer key. Both were distributed to the faculty moderators in advance. Questions on the worksheet included images of radiographs and key physical findings.

The second session was run like the first, with several small changes. This time, the two-hour session started three hours before the end of conference. When the session was complete, residents were again asked to complete the same evaluation prior to leaving the room. Residents who signed that they had viewed the online video outside of conference were excused. For the last hour of conference, the online video was projected for residents who did not watch the video outside of conference.

To obtain the faculty perspective of the flipped classroom sessions, we surveyed the faculty participants for the two sessions. Faculty were asked to comment on advantages and disadvantages of the flipped classroom format.

Outcome Measures

Our primary outcome was the residents' impression of the value of the session, as measured by the proportion of positive responses ("Agree" or "Strongly Agree") to two Likert items evaluating the assigned video lectures and two Likert items evaluating the flipped classroom format. Our secondary outcomes included the proportion of residents who viewed the video prior to conference, how the residents accessed it, residents' opinion of the ideal group size, their preference for frequency of the format in our curriculum, and the qualitative impressions of the residents and faculty regarding the advantages and weaknesses of the flipped classroom format.

Data Analysis

We compiled survey data using Excel for Mac 2011 version 14 (Microsoft Corporation, Redmond, WA). Proportions, medians and interquartile ranges were calculated and histograms were generated using Stata SE 12.1 (Statacorp, College Station, TX). We calculated 95% confidence intervals for proportions with Stata using the modified Wald technique.

RESULTS

Sixteen residents signed in for the first session, of which 14 (86%) submitted surveys. The most common year of training reported was first year (6/12, 50%). For the second session, 31 residents signed the attendance sheet, and 27 (87%) surveys were collected. The classes were more equally represented for this session, which consisted of eight first-year residents (31%), 10 second year residents (38%), and eight third-year residents (31%). Two survey respondents did not report year of training for the first session, and one did not report year of training for the second session. For the second session, three residents stayed for the last hour of conference to view the video because they had not watched it outside of conference.

The figure displays distributions for Likert item responses to questions regarding residents' perceptions of the video as well as the small group format. For the Likert items evaluating the video lectures, 33/35 residents (94%, 95% confidence interval 80%-99%) responded that the video lecture added to their knowledge about the topic, and 33/35 residents felt that watching the video was a valuable use of their time. For the items evaluating the flipped classroom format, 36/38 residents (95%, 95% confidence interval 82%-99%) preferred the format to a traditional lecture on the topic, and 38/38 residents (100%, 95% confidence interval 89%-100%) felt that the small group session was effective in helping them learn about the topic. Most residents preferred to see the format monthly in our curriculum and chose an ideal group size of 5.5 (first session) and 7 (second session) (Table 1a and Table 1b).

Resident responses to open-ended questions regarding advantages and disadvantages of the flipped classroom are presented in Table 2. Faculty responses to the same open-ended questions are presented in Table 3.

DISCUSSION

We observed a high rate of positive responses from residents to both components of our flipped classroom model. Themes for the perceived advantages of the model in the residents' qualitative evaluations included interactivity, active participation, access to experts, and retention of material. Faculty noted that the sessions

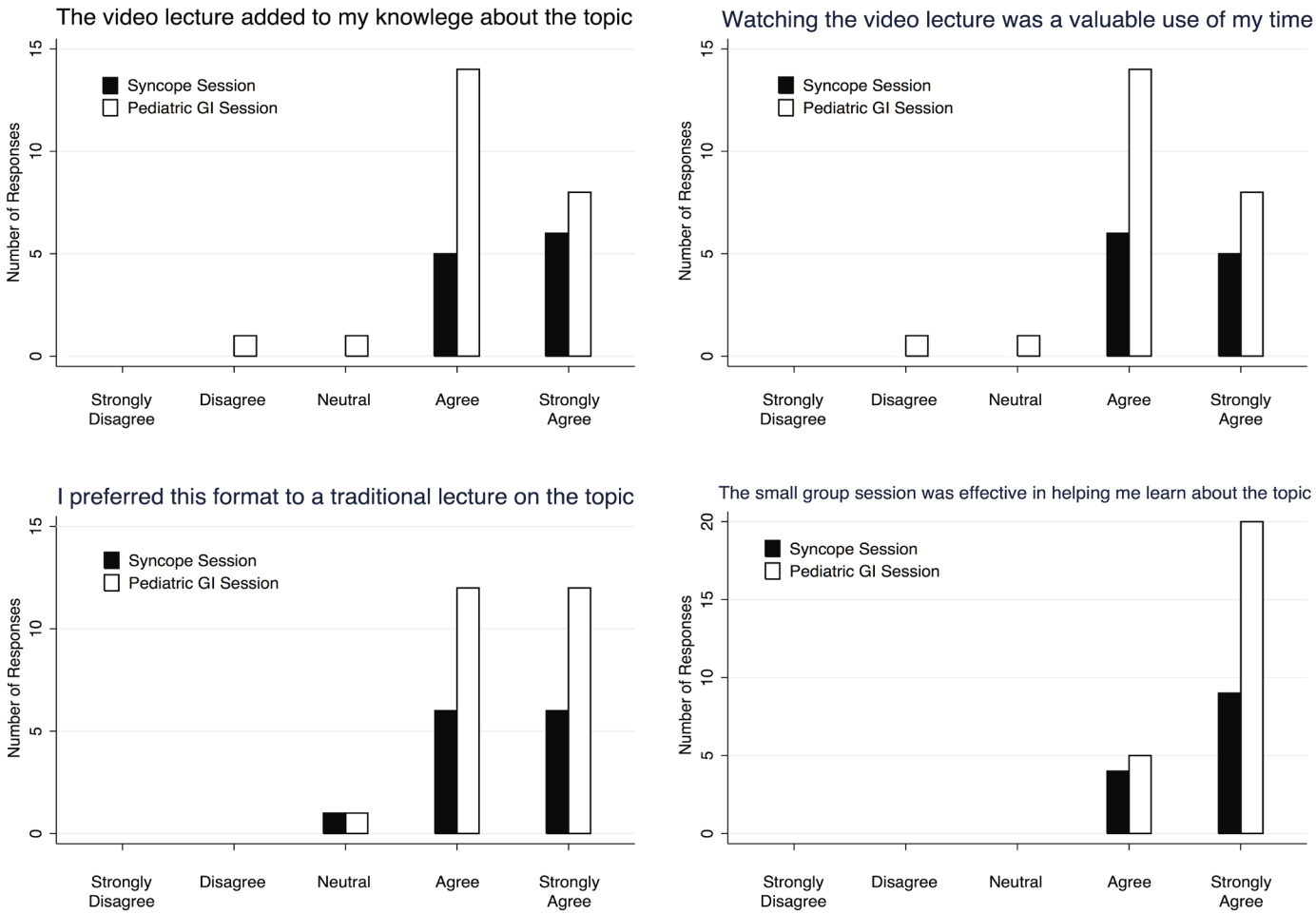

Figure. Distributions for likert item responses for the flipped classroom evaluation survey.
GI, gastrointestinal

Table 1a. Tabulated responses of residents to flipped classroom survey.

	Percentage answering "yes"	
	Syncope session	Pediatric GI session
Did you view the entire video lecture before conference?	9/14 (64%)	23/27 (85%)
Did you watch the video in one sitting?*	7/9 (78%)	16/23 (70%)
Did you use the fast forward, pause, or replay function to enhance your understanding of the content?†	7/13 (54%)	15/25 (60%)

GI, gastrointestinal
*Only responses from those who had watched the entire video are included.
†All responses are included.

Table 1b. Tabulated responses of residents to flipped classroom survey.

	Most frequent answer	
	Syncope session	Pediatric GI session
How did you access the video?†	Tablet computer: 6/13 (46%)	Laptop computer: 10/25 (40%)
Where did you access the video?†	Home: 8/13 (62%)	Home: 20/25 (80%)
How often would you like to see the flipped classroom used in our conference?	Monthly: 8/14 (57%)	Monthly: 17/27 (63%)
What is the ideal group size?‡	5.5 (IQR 5-6)	7 (IQR 5.5-8)

GI, gastrointestinal
†All responses are included.
‡When the response was a range, the average value was used (ie. 5.5 for the range 5-6).

Table 2. Representative resident responses to open-ended questions of flipped classroom survey.

What are the advantages of the flipped classroom format?	What are the weakest aspects of the flipped classroom format?
Group discussion	Finding time to watch the video*
Sharing experiences	Less information covered
Interaction	Takes longer to go through material*
Critical thinking	Can get off topic
Applies more to clinical practice	Time consuming*
Allows for more effective discussion	Poor compliance with the assignment*
Allows for feedback from attendings and peers	It can get too loud in the room†
Better use of conference time	Lack of participation by some
Promotes questions	Should be "turn based" to avoid having the same people answer
Decreases anxiety	It can be hard to hear the speakers†
Reinforces learning points	
Less somnolence	
Active learning	
Helps me remember concepts	
Keeps my attention	
Less boring	
Small group discussion	
Covers more material	
Expert commentary	
Discussion of different approaches to management	
Easier to ask questions	
Ability to ask questions in real time	
More intimate	
Retention of material	

*Comment from first session.
†Comment from second session.

Table 3. Representative faculty responses to open-ended questions of flipped classroom survey.

What are the advantages of the flipped classroom format?	What are the weakest aspects of the flipped classroom format?
Resident/attending interaction Ability to assess residents' understanding/competence	Not all residents are equally prepared (reidents may not have watched the video
Enhanced learning by problem solving together	The quality of the discussion is dependent on the learner's preparation
More time spent discussing difficult concepts	Need to tie to clinical application and evaluation
Better ability to assess critical thinking	Residents get less out of it if they don't watch the videos
Opportunity for interactions in a less intimidating environment	
Senior resident-faculty discussion can facilitate the more novice learner	
The discussion that ensued "off-script"	
Self-scheduling of video viewing	
More interactive	
Residents have better retention of material	
Easier on the attendings	
Ability to provide feedback	

offered the ability to assess residents' critical thinking and provide feedback.

Themes for disadvantages perceived by residents included the increased time necessary to prepare for conference. These comments came from the first session, and we responded by allowing for conference "credit" if the video had been viewed asynchronously before the day of conference. We felt that this was a sustainable practice due to the RRC-EM allowance for 20% asynchronous learning, and seemed to help with the perception that additional work was being assigned. Themes for disadvantages perceived by residents in the second session centered on noise levels. We saw improved attendance at the second session, which was likely due to the first session occurring during the holidays. The improved attendance likely contributed to the increased noise level, as we held the conference in the same single room. We suspect that comments regarding lack of participation and the need to make the session "turn based" were due to faculty not adhering to our suggested protocol.

The shift in the way in which residents accessed the video from the first to second session probably reflects our decision to provide all incoming residents with iPad tablet computers, starting with our first-year class. The larger proportion of first-year residents at the first session probably accounted for the greater use of tablet computers to access the video for that session.

Our residents' perception of the ideal group size was small. A small group size would likely help with the issue of noise level that was commented on in the second, better-attended session. It would also likely accentuate the decrease in anxiety that was cited as an advantage, and increase breadth of resident participation, which was cited as a disadvantage. To accommodate the group sizes that our residents preferred our full residency complement would need to be split into 5-7 small groups. Our residents felt that the ideal frequency of implementation of the flipped classroom in our curriculum was monthly, which would entail the development of 36 unique in order to create a non-repeating three-year curriculum. We were expecting a lower preferred frequency due to the newness of the format, and felt this was a positive endorsement for the format.

The RRC-EM has the following requirements for individualized interactive instruction: the program director must monitor resident participation; there must be an evaluation component; there must be faculty oversight; and the activity must be monitored for effectiveness.[13] The model as we have incorporated it provides the ability to monitor resident participation in the synchronous classroom session. Faculty provide oversight by selecting the content, creating the worksheet, and leading the small group discussions. We plan to monitor the format for effectiveness through evaluations of the sessions and by monitoring residents' performance on in-service exams after its incorporation into our curriculum.

We feel that faculty exposure to residents' patterns of critical thinking during the small group sessions is a strength of the format. When errors in critical thinking are found, residents can be given the opportunity to relearn critical concepts with faculty guidance. We anticipate that this will provide us with a robust platform for faculty to evaluate residents' medical knowledge that will complement evaluations done on clinical shifts. Our faculty commented that senior-level conversations during the sessions facilitated the more novice learners. The classroom small group sessions may allow residents with greater mastery of a topic to take more of a leadership and teaching role in discussions. This may offer faculty a potentially elusive opportunity to evaluate upper-level milestones.

From our experience with these two sessions, the best topics to choose for an EM flipped classroom are those that are broad and complex enough to sustain in-conference discussion, as well as those that lend themselves well to visual stimuli such as ECGs, clinical photos and radiographic images. We have also found that a rate limiting step can be finding a high quality video on such a topic, and suggest that as an early criterion. If the schedule permits (ours did not), it may be beneficial to schedule the "optional" hour in which the video is shown as the first hour of conference, so that those who have not watched the video can come at the usual conference start time and those who have not can come at the start of the flipped classroom session. This option would theoretically allow for more residents to have seen the video prior to the synchronous session.

LIMITATIONS

We report on a small sample size of residents from one institution, which limits the generalizability of our results. We evaluated an additional pilot session in an effort to increase our sample size. While this allowed us to obtain evaluations from a larger pool of residents, repeated measurements also likely biased our results toward the perspectives of residents who are more diligent with conference attendance. While familiar to respondents and easily quantifiable, Likert-type items limit dimensionality of responses, which likely did not capture the full breadth of resident attitudes. We hoped to mitigate this with the addition of open-ended questions. Our pilot sessions did not look at performance indicators or patient care outcomes to evaluate the success of the flipped classroom format. This would be an important future step that could be accomplished by a pre- and post-test comparing the flipped classroom to a traditional lecture format.

Future directions

For future sessions, we plan to place the small groups in separate rooms to address issues with the noise level generated by discussion. We plan to recruit more faculty to lead groups for future sessions in order to decrease group size. We are excited about the possibility of re-using the sessions in the future, allowing a broader base of faculty to participate in didactics without onerous preparation. As we proceed with

the implementation of the ACGME milestones, we plan to incorporate faculty evaluations of residents' performance in the sessions as a means to provide data to our clinical competency committee regarding residents' progress. We are currently developing an online format for the flipped classroom worksheet that will allow for embedded video and audio to augment the problem set.

CONCLUSION

Our flipped classroom model was positively received by EM residents. Residents preferred a small group size and favored frequent use of the format in our curriculum. The flipped classroom represents one modality that programs may use to incorporate a mixture of asynchronous and interactive synchronous learning and provide additional opportunities to evaluate residents.

Address for Correspondence: Timothy P. Young, MD, Loma Linda University Medical Center, 11234 Anderson Street, A108, Loma Linda, California 92354. Email: tpyoung@llu.edu.

Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. The authors disclosed none.

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In Response to "Sensitivity of Emergency Bedside Ultrasound to Detect Hydronephrosis in Patients with Computed Tomography-proven Stones"

Özgür Kızılca, MD
Alp Oztek, MD
Utku Senol, MD

Akdeniz University, Department of Radiology, Antalya, Turkey

DOI: 10.5811/westjem.2014.7.22896
Riddell J, Case A, Wopat R, et al. Sensitivity of Emergency Bedside Ultrasound to Detect Hydronephrosis in Patients with Computed Tomography-proven Stones. *West J Emerg Med*. 2014;15(1):96-100.

Address for Correspondence: Özgür Kızılca, MD, Akdeniz University School of Medicine Department of Radiology 07050 Antalya, Turkey Email: ozgurkizilca82@hotmail.com.

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To the Editor:

We read with great interest the article by Riddell et al. (1) and we believe the study addresses a very important clinical question; however; we have some remarks and questions below.

In Tables 2 and 3, we noticed there were 103 patients with ultrasound (US) evidence of hydronephrosis or stone; but in Table 4, total number of patients with bedside US evidence adds up to 99. Besides that, in Table 1 the number of patients with bedside US evidence of Stone is given to be 98. We could not find information about the missing patients and discrepancy in the number of total patients neither in the results nor discussion, and we feel further clarification is needed.

We also had some questions about the methodology of the study. It is stated that two investigators reviewing charts were blinded to the study hypothesis; however, there is no information regarding whether the emergency physicians performing the ultrasound examination were blinded to computed tomography (CT) results. Similarly, inter-rater reliability was stated to be 100% based on screening of a random sample of study records. We think interrater reliability of the chart reviews is important; however, this is a bit confusing since there is no information given about interobserver variability of the ultrasound examination. We feel including data from the literature about interobserver variability of ultrasound, or evaluating the variability of the performers in another set of patients, would help to give a better sense of real inter-observer variability.

From the perspective of a radiologist, technical details of devices, probes used for ultrasound and protocols used for CT are crucial for external validity, thus including this information would be beneficial.

A result of the study was that, for stones of size >=6 mm, a sensitivity of 100% was reported. Since this is expected to be an SnNout study, we believe this result is very valuable. Also, a sensitivity of 100% was reported for cases with 3 or more stones. However, we think some clarification could be very beneficial regarding how many cases with stones >=6 mm had 3 or more stones, or vice versa.

We think the clarification to our questions above would contribute to the literature in the clinical usefulness of the issue addressed in the study.

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DOI: 10.5811/westjem.2014.10.23864

In Reply:

We thank the authors of the letter for their insightful comments.

There were 98 patients with bedside US evidence of hydronephrosis and 11 patients with evidence of a stone. Only one patient with US evidence of stone had no hydronephrosis. The total number of patients with emergency department (ED) bedside US evidence of stone was 99. This correct number is consistent with Table 4.

The value for Table 1 "bedside US evidence of stone" should also be 99. The "Overall positive finding (hydronephrosis or stone) column in Table 2 should be 99, not 103. This changes the overall sensitivity to 79.2% (95% CI), rather than the 82.4% as published originally, which is consistent with the previously reported sensitivities cited in our paper.

Table 2. Sensitivity of ultrasound in all patients.

N = 125	Ultrasound (US) hydronephrosis	US stone	Overall positive finding (hydronephrosis or stone)
ED bedside US evidence	98	11	99
Sensitivty	78.4%	8.8%	79.2%
95% CI	70.0-85.1%	4.7-15.6%	70.8-85.7%

ED, emergency department; *CI,* confidence interval

The emergency physicians performing the ultrasounds were not formally blinded to the computed tomography (CT) results. However, it is common practice in our emergency department to perform the bedside ultrasound prior to ordering a CT. Though possible that a resident went back and did an US after viewing the CT result, it is unlikely to occur in a busy ED.

Testing of inter-rater agreement is one of the methodologic standards in emergency medicine chart reviews.[1] Our reviewers re-abstracted a sample of charts, blinded to the information obtained by the first reviewer. There were no discrepancies.

Lack of inter-observer variability of the US examination is a limitation. If there were significant interobserver variability, it could have biased the results of the study. There is little in the existing renal ultrasound literature regarding interobserver variability. One study of urologists interobserver agreement was excellent for the grade assessment of hydronephrosis by conventional sonography ($\kappa = 0.82$; $p<0.001$).[2] Goertz and Lotterman studied ED resident and attending physicians performing US and found there was very good interobserver agreement between the degree of hydronephrosis as determined by the performing emergency physician and QA review with $\kappa = 0.847$ (95% confidence interval, 0.777-0.918).[3] A study published in September showed a difference in sensitivity of renal ultrasound performed by emergency medicine residents and fellowship-trained emergency physicians for the detection of hydronephrosis. The authors did not report a kappa statistic for interobserver agreement.[4]

US examinations were performed in the ED with a SonoSite MicroMaxx ultrasound machine with a C60e 2 to 5-MHz curvilinear or P17 1 to 5-MHz phased array ultrasound probe (SonoSite, Bothell, Wash). The CT stone examinations were performed on a single-source 64-detector CT scanner (Aquilion CFX; Toshiba, Tustin, Calif), using the following parameters: 120kVp, 100-500mAs (using dose modulation depending on the size of the patient), gantry revolution speed of 0.5 second, pitch factor of 0.844, beam collimation of 64 x 0.5mm, variable field of view (depending on the size of the patient), standard body kernel. This data is reconstructed into 3mm thick sections in the transverse, coronal and sagittal planes.

Sensitivity was 100% for stones ≥ 6mm when combined with hematuria. Of the 60 patients with stones ≥ 6mm, 7 had 3 or more stones. Put another way, 7 of the 8 cases with 3 or more stones had a stone ≥ 6mm.

We thank the authors for their comments and hope this additional explanation helps readers place this retrospective study in its proper context. It was our hope that it would spur further prospective studies. Many of our questions have since been addressed with publication of the initial results of the STONE trial, a prospective multi-centered study of ED patients with suspected renal colic.[5]

Jeff Riddell, MD
University of California, San Francisco-Fresno, Department of Emergency Mediicne, Fresno, California

Stuart Swadron, MD
University of Southern California, Keck School of Medicine, Los Angeles, California

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Address for Correspondence: Jeff Riddell, MD. University of California, San Francisco-Fresno, 155 N Fresno St., Fresno, CA 93701. Email: jriddell@fresno.ucsf.edu.

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In Response to: "Deliberate Apprenticeship in the Pediatric Emergency Department Improves Experience for Third-year Students"

DOI: 10.5811/westjem.2014.9.23290
Iyer MS, Mullan PB, Santen SA, Sikavitsas A, Christner JG. Deliberate Apprenticeship in the Pediatric Emergency Department Improves Experience for Third-year Students. *West J Emerg Med*. 2014;15(4):424-9.

To the Editor:

Iyer et al. have presented an interesting study of the usefulness of a deliberate apprenticeship model in the pediatric emergency department for third year students.[1] The deliberate apprenticeship model appeared from both the quantitative and qualitative results to show benefits of deliberate apprenticeship. However a closer examination of the methodology reveals potential problems with the quantitative techniques used. Put simply the multiple quantitative comparisons made may have yielded false positive results. By contrast although grounded theory has had its critics, most agree that the constant comparative method is a sound method of qualitative analysis.[2]

However perhaps most concerning is what the learners actually say in the qualitative feedback – or at least what we can see that they say from the selected quotes. One learner talks about being "able to jump from patient to patient" – not behaviour that we would perhaps wish to encourage in our learners. The same learner talks about being given more autonomy in "ordering tests, discharging patients" – activities that are likely to be beyond their competence. Another learner complains that they "didn't get to see as many interesting things" as they would liked – here using language that appears to dehumanize patients. It is interesting to wonder what other learners said in their qualitative feedback. The authors have undoubtedly done a good job in using the constant comparative method to draw conclusions from this feedback but it would be fascinating to see all the raw data. At a time when many leaders in quantitative research are calling for access to all data, should qualitative researchers follow suit and similarly call for access to all qualitative data? It would be too much for journals to publish, but online papers could include a link to an open data repository which interested readers could then access.

Kieran Walsh,
BMJ Learning, London, UK

Address for Correspondence: Kieran Walsh, MD, BMJ Learning, BMJ Knowledge, BMA House, Tavistock Square, London WC1H 9JR, UK. Email: kmwalsh@bmjgroup.com.

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In Reply:

The authors are appreciative of the interest in our study provided by the author(s) of this letter. We found the Deliberate Apprenticeship (DA) model to be useful for third year medical students rotating through our Pediatric Emergency Department in regards to performing more physical exams and also having greater comfort in obtaining histories and creating differential diagnoses. Moreover, we found that this was a feasible and acceptable technique that could potentially be implemented at other institutions.

In response to the first critique of "put simply the multiple quantitative comparisons made may have yielded false positive results," we did explore this in the limitations and agreed that multiple comparisons could have led to a Type 1 error. In fact, we took this a step further and by using Bonferroni Correction discovered that only the comfort in creating differential diagnoses remained statistically significant between the DA and control groups. This was also explicitly stated in the paper.

We also agree that the constant comparison method is a sound tool for analyzing qualitative data and was useful and enlighting in the results of this study. The students comments provide a rich description of their experience from their vantage point. We respectfully disagree that the comments provided by the medical students are concerning in their content itself. The nature of emergency medicine is to manage an ever-changing work load. As stated by Ledrick et al (2009), "part of the skill set needed for [emergency medicine] is being able to treat a large number of patients simultaneously, under pressure, and in a short period of time."[1] We believe that the opportunity for reflection that our study provided created a safe space for students to consider and to articulate their perceptions about the learning envivornment and their roles as students and physicians-in-training. Therefore, the comment from one learner about being "able to jump from patient to patient" is a quality we would hope students are able to acknowledge, consider, and incorporate into their

emergency medicine practice. Furthermore, going from "patient to patient" allows for increased exposure and assists with student learning in an acute care environment. Finally, the comment that this leaner appreciated the autonomy provided by "ordering tests, discharging patients" is not beyond his or her "competence" when the ultimate premise of this study was that these learners were under close supervision of a senior medical resident or faculty member.

It is an interesting idea to create an online repository to allow access to the raw qualitative data in studies. This would be particularly valuable for more extended direct observations over time, yet the implications for institutional review board protection of learners as human subjects would also warrant consideration. Furthermore, we also caution that while such a repository might facilitate further examination of thematic concepts and permit readers to have insight into the spectrum of ideas provided by our learners, providing external access to data opens the door for readers unfamiliar with the study setting to make interpretations not based on deep understanding of the training and practice site.

Maya S. Iyer, MD

Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center, Department of Pediatrics, Division of Emergency Medicine, Pittsburgh, Pennsylvania

Address for Correspondence: Maya Subbarao Iyer, MD. Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center, Department of Pediatrics, Division of Emergency Medicine, 4401 Penn Avenue, AOB 2nd floor, Suite 2400, Pittsburgh, PA 15224. Email: maya.iyer@chp.edu.

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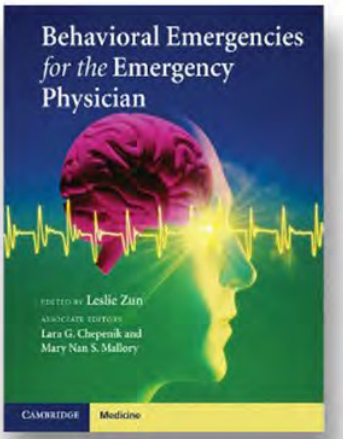

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2015 *Academic Emergency Medicine* Consensus Conference

Diagnostic Imaging in the Emergency Department:
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The 2015 *Academic Emergency Medicine* (*AEM*) consensus conference, **Diagnostic imaging in the emergency department: A research agenda to optimize utilization** will be held on May 12, 2015, immediately preceding the SAEM Annual Meeting in San Diego, CA. Original papers on this topic, if accepted, will be published together with the conference proceedings in the December 2015 issue of *AEM*.

Diagnostic imaging is integral and beneficial to the practice of emergency medicine. Over the last several decades, emergency department (ED) diagnostic imaging has increased without a commensurate rise in identified pathology or improvement in patient-centered outcomes. Unnecessary imaging results in increased resource use and significant exposure risks. ED diagnostic imaging has become the focus of many stakeholders, including patients and various regulatory agencies. This multidisciplinary consensus conference represents the first coordinated effort to further our evidence-based knowledge of ED diagnostic imaging. This consensus conference will formulate the research priorities for emergency diagnostic imaging, initiate a collaborative dialogue between stakeholders, and align this research agenda with that of federal funding agencies.

Consensus Goal:
The overall mission of the 2015 *AEM* consensus conference will be to create a prioritized research agenda in emergency diagnostic imaging for the next decade and beyond. The consensus conference will feature expert keynote speakers, panel discussions including nationally recognized experts, and facilitated breakout group sessions to develop consensus on research agendas by topic. Optimizing diagnostic imaging in the ED is a timely topic that is relevant to all who practice emergency medicine. Furthermore, the conference content spans many other specialties (e.g. radiology, pediatrics, cardiology, surgery, internal medicine), all of which will be invited to participate in the conference to optimize the agenda and for future collaboration in order to improve emergency diagnostic imaging use.

Consensus Objectives:
1. Understand the current state of evidence regarding diagnostic imaging utilization in the ED and identify opportunities, limitations, and gaps in knowledge of previous study designs and methodology
2. Develop a consensus statement that emphasizes the priorities and opportunities for research in emergency diagnostic imaging that will result in practice changes, and the most effective methodologic approaches to emergency diagnostic imaging research
3. Explore and improve knowledge of specific funding mechanisms available to perform research in emergency diagnostic imaging

Accepted manuscripts will present original, high-quality research in emergency diagnostic imaging in areas such as clinical decision rules, shared decision making, knowledge translation, comparative effectiveness research, and multidisciplinary collaboration. They may include work in clinical/translational, health systems, policy, or basic sciences research. Papers will be considered for publication in the December 2015 issue of *AEM* if received by April 17, 2015. All submissions will undergo peer review and publication cannot be guaranteed.

For queries, please contact Jennifer R. Marin, MD, MSc (jennifer.marin@chp.edu) or Angela M. Mills, MD (millsa@uphs.upenn.edu) the 2015 consensus conference co-chairs. Information and updates will be regularly posted in *AEM*, the SAEM Newsletter, and the journal and SAEM websites.

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