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Emergency Department Ultrasound Is not a Sensitive Detector of Solid Organ Injury

John L. Kendall, MD* * Denver Health Medical Center, Department of Emergency Medicine
Jeffrey Faragher, MD† † Providence Everett Medical Center, Department of Emergency Medicine
Gwendolyn J. Hewitt, MD‡ ‡ Lutheran Medical Center, Department of Emergency Medicine
Gregory Burcham, MD# # Swedish Medical Center, Department of Emergency Medicine
Jason S. Haukoos, MD, MSc¥ ¥ University of Colorado at Denver and Health Sciences Center, Department of Preventative Medicine and Biometrics

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Objective: To estimate the sensitivity and specificity of emergency department (ED) ultrasound for the detection of solid organ injury following blunt abdominal trauma.

Methods: A prospective cohort study performed in the ED of an urban Level I trauma center on patients who sustained blunt abdominal trauma. Following initial standard trauma evaluation, patients underwent a secondary ultrasound examination performed specifically to identify injury to the liver or spleen, followed by computed tomography (CT) scan of the abdomen. Ultrasound examinations were performed by emergency medicine residents or attending physicians experienced in the use of ultrasound for detecting hemoperitoneum. Ultrasonographers prospectively determined the presence or absence of liver or spleen injury. CT findings were used as the criterion standard to evaluate the ultrasound results.

Results: From July 1998 through June 1999, 152 patients underwent secondary ultrasound examination and CT. Of the 152 patients, nine (6%) had liver injuries and 10 (7%) had spleen injuries. Ultrasound correctly detected only one of the liver injuries for a sensitivity of 11% (95% CI: 0%-48%) and a specificity of 98% (95% CI: 94%-100%). Ultrasound correctly detected eight spleen injuries for a sensitivity of 80% (95% CI: 44%-98%) and a specificity of 99% (95% CI: 95%-100%).

Conclusion: Emergency ultrasound is not sensitive or specific for detecting liver or spleen injuries following blunt abdominal trauma.
[*West*JEM. 2009;10:1-5.]

INTRODUCTION

Ultrasound is a rapid, portable, real-time study that has become integral to the emergency department (ED) management of blunt trauma. A number of studies have demonstrated that the Focused Assessment with Sonography for Trauma (FAST) examination can effectively detect hemoperitoneum and expedite appropriate patient disposition.[1-4]

A reported limitation of ultrasound in the setting of blunt trauma is poor specificity for determining the source of hemoperitoneum, as well as a limited ability to detect solid organ injury (SOI) in the absence of free fluid.[5] Several studies in the emergency medicine, radiology, and surgery literature have attempted to determine the utility of ultrasound in this setting, but the results have been difficult to evaluate. For example, one study reported sensitivities as low as 41% for the detection of SOI[5] while another documented sensitivities of greater than 90%.[6] Most authors attribute these discrepancies to the sonographer's experience, the affected organ being visualized, the severity of injury, which criterion standard was used for determining the presence of SOI, and when the ultrasound was performed relative to the timing of the injury.

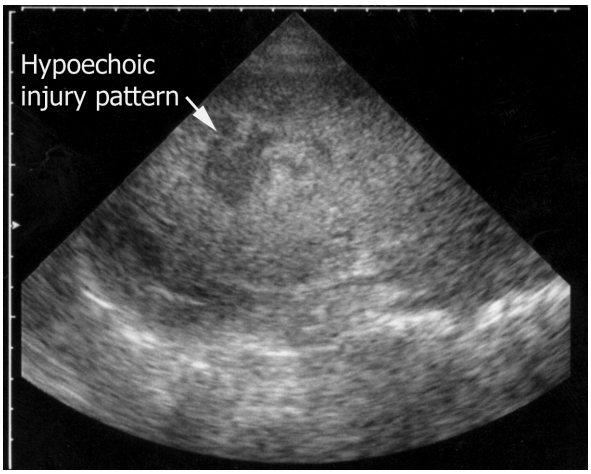

Figure 1. Ultrasound image of a solid organ injury seen as a hypoechoic region within the parenchyma.

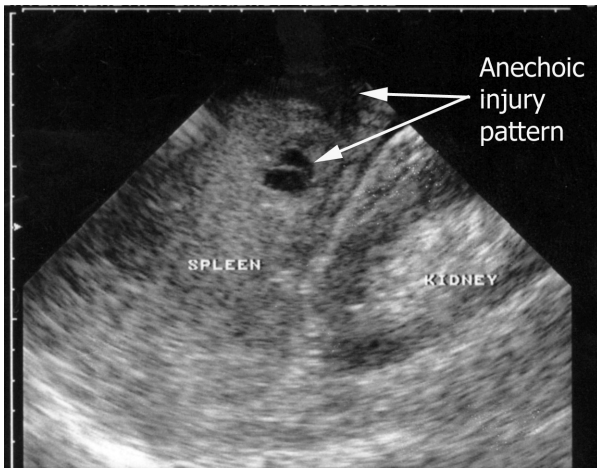

Figure 2. Ultrasound image demonstrating disruption of the splenic architecture representing solid organ injury.

Many of the prior studies also had variable methods, which may account for their conflicting results. Unfortunately, this has made their extrapolation to patient management difficult. To address these issues, we devised a prospective study to control many of the aforementioned variables. The education of the emergency sonographers was standardized, the timing of the ultrasound examination relative to the criterion test was explicitly stated, and the imaging study used for comparison to the ultrasound examination was predetermined. The objective of this study was to estimate the sensitivity of ultrasound performed by emergency physicians for the detection of liver and spleen injuries in patients who suffered blunt abdominal trauma.

METHODS

This study was approved by the Research Committee and the Institutional Review Board from our institution and met criterion for exemption of informed consent.

Study Design and Setting

This was a prospective cohort study performed in the ED at an urban level I trauma center. The annual ED census is approximately 55,000 visits, and the annual major trauma census is approximately 2,500.

Study Population

A convenience sample of patients who presented to the ED following blunt abdominal trauma and who subsequently received computed tomography (CT) scans of the chest or abdomen during their evaluations were included. Following initial trauma evaluation, which includes a four-view ultrasound examination to detect hemoperitoneum or pericardial effusion, eligible patients underwent a secondary ultrasound examination while awaiting CT. The specific purpose of the secondary ultrasound was to evaluate the liver and splenic parenchyma for SOI. The secondary ultrasound consisted of long- and short-axis scans through both organs. Hard-copy images of representative views and any injuries were saved. Studies were performed using a Toshiba SSH-140A (Toshiba, San Francisco, CA) with a 3.75 MHz phased array transducer. Patients were excluded from the study if they were transferred from another facility with known SOI, if the CT was interrupted or not completed, if performing the secondary ultrasound would delay necessary patient care, or if the trauma was not a blunt mechanism.

Resident and attending physicians performed all secondary ultrasound examinations. Both groups had previously completed a standardized eight-hour didactic and practical trauma ultrasound curriculum. This entailed a one-hour lecture on physics and instrumentation, a two-hour lecture on abdominal ultrasound for trauma, and a one-hour lecture on echocardiography. Following this, each participant completed four hours of hands-on instruction. Within the didactic portion of the curriculum, participants were instructed on additional transducer views needed to detect SOI and the appearance of normal and abnormal solid organ architecture. Additionally, each month when new ED residents began their clinical rotations at the study site, they reviewed representative ultrasound images and videotaped examinations of SOI. Solid organ injury was defined as a hyperechoic or hypoechoic region within the organ parenchyma (Figure1), disruption of organ architecture (Figure 2), or a subcapsular fluid collection (Figure 3).[7] The secondary ultrasound was performed just prior to the patient being transported to the CT suite.

Data Collection

Upon completion of the secondary ultrasound, the physician who performed the examination completed a standardized data collection instrument. Recorded information included: patient age and sex; medical record number;

mechanism of trauma; initial vital signs; presence of liver or spleen injury or fluid collection; total number of FAST exams performed by the physician; the length of time to complete the examination; and the presence and location of hemoperitoneum. The criterion diagnostic standard was made using CT. All CT interpretations were performed by attending radiologists who were blinded to the results of the secondary ultrasound examination.

Data Management and Statistical Analyses

All data were entered into an electronic database (MS Excel, Microsoft Corporation, Richmond, WA) and translated in native SAS format using translational software (dfPower/DBMS Copy, Dataflux Corporation, Cary, NC). All statistical analyses were performed using SAS Version 9.1 (SAS Institute, Inc., Cary, NC) or Stata Version 9 (Stata Corporations, College Station, TX). Descriptive statistics were performed for all variables. Continuous variables are reported as medians and interquartile ranges (IQRs) and categorical variables are reported as percentages and 95% confidence intervals (CIs). Sensitivities, specificities, positive predictive values (PPV) and negative predictive values (NPV) are reported, where appropriate.

RESULTS

During the one-year study period, 164 patients were enrolled. Of these, six (4%) had incomplete medical records, two (1%) sustained stab wounds, and one (0.6%) was a non-trauma patient. One (0.6%) patient was transferred after laparotomy from an outside facility with known SOI, and one (0.6%) had a known splenic laceration from a previous ED visit. Lastly, one (0.6%) patient went directly to the operating room and did not receive a CT scan. These patients were excluded from analysis, leaving 152 (92%) patients, which constitute our study sample.

The median age of this cohort was 34 (IQR 25-47, range 6-91 years). Ninety-five (63%) of the patients were male. Of the 152 patients, 98 (65%) were involved in motor vehicle crashes, three (2%) were involved in motorcycle crashes, 21 (14%) suffered falls, 11 (7%) were assaulted, 11 (7%) were involved in auto-pedestrian accidents, and four (2.7%) were involved in bicycle accidents. All but 10 of the secondary ultrasound exams were performed in less than 10 minutes. The experience level of the ultrasound examiner ranged from 27 (20%) having performed 0-25 trauma ultrasounds, 30 (22%) performed 26-50, 18 (13%) performed 51-75, 23 (17%) performed 76-100, and 36 (27%) had performed greater than 101 trauma ultrasounds previously.

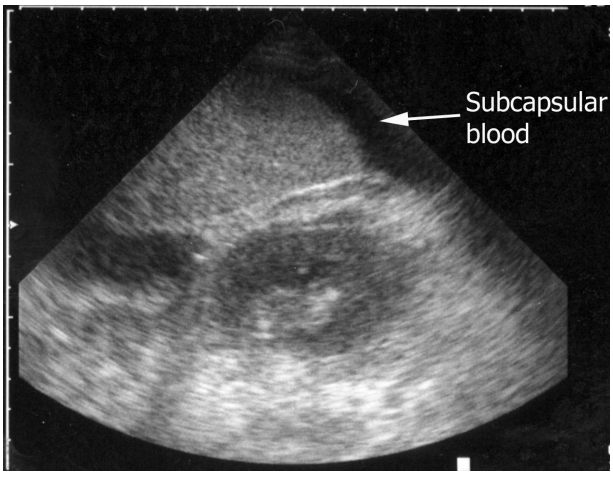

Figure 3. Ultrasound image of splenic subcapsular fluid.

There were nine (5%) liver injuries detected by CT scan. One patient had no identifiable parenchymal injury; however, subcapsular fluid was detected on CT scan, so the patient was classified as having a SOI. None of the parenchymal abnormalities were detected during the secondary ultrasound exam. One patient was noted to have subcapsular fluid on ultrasound and CT confirmed the fluid, as well as the presence of a stellate liver laceration. Thus, the sensitivity of ultrasound for the detection of hepatic injuries was 11% (95% CI: 0%-48%). In total, there were four ultrasound studies interpreted as having either parenchymal injury or subcapsular fluid. Only one of these patients had SOI confirmed by CT scan, yielding a specificity of 98% (95% CI: 94%-100%).

Of the eight liver injuries ultrasound failed to detect, none required transfusion or operative intervention. All of these patients were observed and discharged from the hospital with no immediate complications.

CT scan identified 10 spleen injuries. All had parenchymal injury with seven having corresponding subcapsular fluid. Ultrasound correctly identified eight out of 10 injuries, detecting either the parenchymal abnormality or subcapsular fluid, but not necessarily both. Six out of 10 parenchymal abnormalities were detected during the secondary ultrasound exam. Ultrasound identified five of seven patients with subcapsular fluid collections. There were three patients interpreted by ultrasound to have subcapsular fluid, which was not present on the CT scan. Overall, the sensitivity of ultrasound for detecting either fluid or a parenchymal injury was 80% (95% CI: 44%-98%), and the specificity was 99% (95% CI: 95%-100%).

The two patients with splenic injuries not detected by ultrasound were observed in the hospital and discharged safely. One patient suffered a pulmonary embolus and was successfully anti-coagulated without complications. None required surgery or transfusion.

DISCUSSION

Ultrasound has become an important tool for the management of patients sustaining blunt abdominal trauma. Since the report by Tso et al.,[2] many prospective studies have demonstrated the accuracy of ultrasound in detecting

hemoperitoneum after blunt trauma. The ability of emergency physicians and surgeons to perform ultrasound quickly, accurately, and reliably has led to its nearly universal acceptance in trauma centers. While ultrasound can reliably detect hemoperitoneum, determining the source of bleeding is a much harder proposition. Similarly confounding is the scenario of SOI without intraperitoneal rupture of blood.

The goal of this study was to define an emergency physician's ability to detect SOI after a brief training period. While several groups have previously attempted to determine the utility of ultrasound for this indication, many of the studies have yielded mixed results. For instance, Yoshii et al.[6] reported sensitivities of 92% and 90% for the ultrasound detection of liver and spleen injuries, respectively. In another study, the same group published data using CT and laparotomy as criterion standard tests to compare interpretations from experienced and inexperienced sonographers.[8] In the experienced group, sensitivities for liver and spleen injuries were 87.5% and 85.4%, respectively. In contrast, the inexperienced group had lower sensitivities for detection of liver and spleen injuries at 46.2% and 50%, respectively. One criticism of both studies was the incidence of SOI in the enrolled population was over 30%, which is significantly higher than most United States trauma centers.

Goletti et al.[9] demonstrated a slightly lower sensitivity for liver injuries (80%) but a higher sensitivity for spleen injuries (93%). Similar to the previously mentioned studies, Goletti et al. used an unremarkable clinical course and negative repeat ultrasound to define patients without injury, possibly yielding a falsely elevated true negative rate.

In contrast to the prior studies, McGahan et al.[10] reported detection rates of 14% for liver injuries and 69% for spleen injuries, which are similar to our results. The same group later demonstrated higher sensitivities for both liver and spleen injuries, but this was most pronounced in injuries that were either Grade III and higher.[11,12]

Our study suggests that ultrasound, when performed by emergency physicians, is not a sensitive detector of SOI. There are several reasons this may be true. In an ideal setting, the ability to detect SOI by ultrasound is a difficult examination, even for experienced sonographers. Rothlin et al.[13] showed a 10% increase in sensitivity for detecting SOI between surgeons who had performed 200 examinations and those who had performed 4,000 examinations. The results of the Yoshii et al.[6] study confirm the value of experience in the detection of SOI. Many of the ultrasound examinations in our study were performed by residents or attendings who had relatively little experience with this particular examination (less than 100 prior examinations), which possibly contributed to the low sensitivity of findings.

The ability to detect SOI by ultrasound also relates to the severity of the injury. Grade 4 and 5 liver injuries, for example, are typically easier to visualize than Grade 1 and 2 injuries.[11,12] In our study, all of the missed injuries were either Grade 1 or 2. Furthermore, none of the patients with missed injuries received blood transfusions or required operative intervention. This implies that ultrasound did not miss any clinically significant injuries. It is also possible that several patients with easily detectable injuries during the initial trauma ultrasound exam went directly to the operating room or interventional radiology suite secondary to a grossly positive FAST exam or unstable hemodynamic status and therefore they were not enrolled in this study.

Another potential explanation for our reported low sensitivity of ultrasound to detect SOI was how rapidly the ultrasound was performed after the patient's arrival. All but two of the patients had the secondary ultrasound performed in less than 10 minutes after the patient's arrival to the ED. Perhaps an ultrasound examination repeated later in the patient's clinical course would have detected injury and fluid with greater reliability.

LIMITATIONS

There are several limitations of this study. The small number of injuries hinders our ability to make a more accurate determination of sensitivity and positive predictive value. Second, our study initially intended to enroll patients consecutively, but demands of the ED prevented this from occurring regularly. Subsequently, the study population is best described as a convenience sample, thus allowing for possible selection bias. Since we only included patients who were stable enough to complete a CT scan, our study population likely selected a greater number of minor injuries. It should also be noted that the ultrasound equipment used for this study is outdated by current standards. Consequently, our results may underestimate the ability of ultrasound to detect SOI. Lastly, physicians performing the secondary ultrasound were frequently the same physician treating the patient, and therefore they were not blinded to the results of the initial ultrasound. Knowledge of the presence or absence of hemoperitoneum in the initial ultrasound may have biased the interpretation of questionable findings on the secondary study.

CONCLUSION

Our findings suggest that ultrasound, as performed by ED resident and attending physicians, has a low sensitivity for detecting hepatic injuries. Splenic injuries were detected more successfully when visualization of parenchymal injury or subcapsular fluid was considered a positive examination. CT scanning remains the preferable modality to detect SOI.

Address for Correspondence: John Kendall, MD FACEP. Department of Emergency Medicine, MC 0108, Denver Health Medical Center, 660 Bannock Street, Denver, CO 80204. Email: John.Kendall@dhha.org.

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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Second Impact Syndrome

Tareg Bey, MD[*]
Brian Ostick, MD[†]

[*] University of California, Irvine School of Medicine
[†] Christiana Care Emergency Medicine, Newark, Delaware

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A controversial term first described by Saunders and Harbaugh[1] in 1984, Second Impact Syndrome (SIS) consists of two events. Typically, it involves an athlete suffering post-concussive symptoms following a head injury.[2] If, within several weeks, the athlete returns to play and sustains a second head injury, diffuse cerebral swelling, brain herniation, and death can occur. SIS can occur with any two events involving head trauma. While rare, it is devastating in that young, healthy patients may die within a few minutes. Emergency physicians should be aware of this syndrome and counsel patients and their parents concerning when to allow an athlete to return to play. Furthermore, we present guidelines for appropriate follow up and evaluation by a specialist when necessary.
[*West*JEM. 2009;10:6-10.]

INTRODUCTION

Controversy surrounds Second Impact Syndrome (SIS), a condition so rare that even the frequency of its occurrence is in question. From 1980 to 1993 the National Center for Catastrophic Sports Injury Research in Chapel Hill, NC, identified 35 probable cases among American football players.[2] However, this incidence is called into question by the lack of similar reports from Australian football, despite the high participation rate and a concussive injury rate approximately eight times that of American football. Furthermore, there are no similar reports from the European literature. However, a July 2007 *eMedicine* report summarizing an article in the *American Journal of Sports Medicine* noted:

"A study of American high school and college football players demonstrated 94 catastrophic head injuries (significant intracranial bleeding or edema) over a 13-year period.[3] Of these, only two occurred at the college level. Seventy-one percent of high school players suffering such injuries had a previous concussion in the same season, with 39% playing with residual symptoms."[4]

Ropper and Gorson[5] define concussion as an immediate and transient loss of consciousness accompanied by a brief period of amnesia after a blow to the head. Both anterograde and retrograde amnesia accompany the event.[6] Retrograde amnesia can extend from moments to several days before the head trauma. The extent and period of anterograde memory loss tends to be shorter than retrograde.[5]

SIS is based on rare and mostly disputed cases in which a second mild head injury in children caused massive cerebral edema. McCrory[7] points out that SIS is more likely a condition representing "diffuse cerebral swelling," a consequence of traumatic brain injury with diffuse brain swelling that is well recognized in children. While there is argument over the incidence of SIS, many authors agree that the syndrome is rare.[7,8] While this may be comforting to emergency physicians (EPs), SIS must still be taken seriously as the consequences could be grave.

Epidemiology

The Centers for Disease Control and Prevention estimates about 1.1 million patients with nonfatal traumatic brain injury (TBI) are treated and released from U.S. hospital emergency departments (EDs) annually.[9] An estimated 300,000 TBIs are mild to moderate[10] and some 235,000 require hospitalization.[9] Concussion is not uncommon, affecting about 128 people per 100,000 in the United States yearly. Young children have the highest rates of concussion, with sports and bicycle accidents accounting for the majority of cases in the 5-14 age group. Falls and vehicular accidents are the most common causes of concussion in adults.[5] There is little epidemiological data about SIS. Most of the information comes from case reports or series.[8] The overall incidence of secondary concussion and hence SIS is unknown. One reason for the lack of systematic

epidemiological data comes from the controversy regarding the definition of SIS.[4,5]

Concussion

The word "concussion" comes from the Latin verb *concutere* ("to shake violently").[11] A concussion is defined as an immediate and transient loss of consciousness (LOC) accompanied by a brief period of amnesia after a blow to the head. In post-concussive syndrome, up to three symptoms arise within less than four weeks from the initial LOC.[5] These include headache, dizziness, fatigue, insomnia, irritability and alcohol intolerance, and other symptoms, such as subjective concentration, memory, or intellectual difficulties without neuropsychological evidence of marked impairment.[5] In an article summarizing the Second International Conference on Concussion in Sport (Prague 2004), McCrory et al.[12] differentiate between simple and complex concussions. A simple concussion is an athletic injury that resolves without complications within ten days, whereas a complex one involves persistent symptoms beyond ten days, or additional symptoms of seizures, cognitive impairment or exertional headache or confusion.

The extent of concussive amnesia roughly correlates with the duration of loss of consciousness and the severity of the head injury. Anterograde amnesia is the inability to retain new information. Retrograde amnesia is the inability to remember events preceding a traumatic injury. In some rare cases amnesia can extend backward for several days or longer.[5] Content experts agree that all concussions mandate evaluation by a physician.[12] Repeated brain injuries, including concussions occurring over an extended period of weeks to years, can result in neurologic and cognitive deficit, especially in boxers.[10,13]

Cognitive domain scores are often calculated from executive, attention and memory testing. Newer high technology methods include Diffusion Tensor Imaging (DTI), which is a more recent method of assessing axonal integrity in vivo. DTI characterizes white matter integrity.[14] In a review of 18 cases of young athletes who sustained a second head injury before the first one had resolved Mori et al.[8] found, that ten of the 18 did not lose consciousness. However, after the second traumatic brain injury, eight had a cranial CT scan revealing a subdural hematoma.[8] The symptoms and ED presentation of severe concussion can be identical to SIS. The EP is rarely aware of a preceding concussion days to weeks earlier. Therefore, the evaluation and treatment of these two entities follow the same algorithm.

Pathophysiology of Second Impact Syndrome

A patient who sustains an initial concussion may develop cerebral edema, accounting for loss of consciousness, memory impairment, disorientation and headache. However, the brain's auto regulatory mechanisms compensate for this mechanical and physiologic stress and protect against massive swelling. This is thought to be accomplished by acutely limiting cerebral blood flow, which leads to accumulation of lactate and intracellular acidosis.[15] After the initial phase, a state of altered cerebral metabolism occurs and may last ten days,[16] involving decreased protein synthesis and reduced oxidative capacity.[11] Extensive experimental research suggests that the loss of consciousness after head injuries, the development of secondary brain damage, and the enhanced vulnerability of the brain after an initial insult can be explained largely by characteristic ionic fluxes, acute metabolic changes, and cerebral blood flow alterations that occur immediately after cerebral concussions. Extracellular potassium concentration can increase massively in the brain after concussion, followed by hypermetabolism lasting up to ten days. This makes the brain more vulnerable and susceptible to death after a second sub-lethal insult of even less intensity.[11] Fisher and Vaca[17] hence conclude that when the patient sustains a "second impact," the brain loses its ability to auto regulate intracranial and cerebral perfusion pressures. In severe cases, this may lead to cerebral edema followed by brain herniation. Death has been reported to occur in a matter of two to five minutes, usually without time to stabilize or transport an athlete from the playing field to the ED. This demise can occur far more rapidly than that of an epidural hematoma.[18] Bruce et al.[19] point our that brain swelling in minor head trauma is more significant in small children than in adults. The term "malignant brain edema" has been used to describe this phenomenon. More research in this area is necessary to determine if and when malignant brain edema and SIS are related, or even if they occur by the same process.

Table 1. Data-driven Cantu[4] grading system for concussion

Grade 1 (mild) No loss of consciousness; post-traumatic amnesia* or post-concussion signs or symptoms lasting less than 30 minutes
Grade 2 (moderate) Loss of consciousness lasting less than 1 minute; Post-traumatic amnesia* or post-concussion signs or symptoms lasting longer than 30 minutes but less than 24 hours
Grade 3 (severe) Loss of consciousness lasting more than 1 minute or post-traumatic amnesia* lasting longer than 24 hours; Post-concussion signs or symptoms lasting longer than 7 days

* **Retrograde and anterograde**

Clinical Workup Following Head Trauma

Airway, breathing, and circulation must be assessed and treated following any head trauma seen in the ED

Table 2. Guidelines for the Management of Sport-Related Concussion. These guidelines reflect the latest consensus opinion and are not evidence based. Adapted from the American Academy of Neurology guidelines[24] where newer guidelines are expected to be published in the future. (http://www.aan.com)

Symptoms	First Concussion	Second Concussion
Grade 1: No loss of consciousness, transient confusion, resolution of symptoms and mental abnormalities in <15 min See also Appendix.	Remove from play. Examine at 5-min intervals. May return to play if symptoms disappear and results of mental-function exam return to normal within 15 min	Allow return to play after 1 week if there are no symptoms at rest or with exertion.
Grade 2: as above, but with mental symptoms for >15 min	Remove from play and disallow play for rest of day. Examine for signs of intracranial lesion at sidelines and obtain further exam by a trained person the same day. Allow return to play after 1 week if neurological exam is normal.	Allow return to play after 2-week period of no symptoms at rest or with exertion. Remove from play for season if imaging shows abnormality.
Grade 3: any loss of consciousness	Perform thorough neurological exam in hospital and obtain imaging studies when indicated. Assess neurologic status daily until post-concussive symptoms resolve or stabilize. Remove from play for 1 week if LOC lasts seconds; for 2 weeks if it lasts minutes; must be asymptomatic at rest and with exertion to return to play.	Withhold from play until symptoms have been absent for at least 1 month.

LOC, loss of consciousness.

or in the prehospital setting. Even in the absence of hard signs suggesting cervical spine or spinal cord injury, such as posterior midline pain or tenderness, paresthesias, extremity weakness or depressed consciousness, injury should be assumed and immobilization and radiography routine. A thorough history is imperative and must be taken from the patient, if conversant, or from a witness. Important information includes mechanism of injury, loss of consciousness, previous concussions, seizure history, transient weakness or paresthesias, difficulty walking, bladder or bowel incontinence, and alcohol or drug use. A thorough general physical exam should be performed with special attention to the neurological exam.

Diagnostic Imaging

If there is suspicion of a serious structural brain injury, immediate computed tomography (CT) of the head is needed.[20] CT is usually easier to obtain and more sensitive than magnetic resonance imaging (MRI) to detect acute intracranial bleeding and identify surgically reversible injury.[21] The CT scan should be reviewed for intraparenchymal, extra-axial, intraventricular or subarachnoid bleeding, diffuse cerebral swelling manifested by loss of the grey-white junction, and midline shift. In case of an anatomic abnormality, a neurosurgeon should be consulted.

Treatment

As stated above, true SIS involves brain herniation and death within minutes. Therefore, the odds of seeing acute SIS in the ED are unlikely. If suspected, the patient should be immediately stabilized with special emphasis on airway management, and neurosurgery consulted. Cantu[22] also recommends rapid intubation and mannitol to minimize morbidity. This has not been tested and is based on expert opinion. The use of mannitol in the treatment of intracranial pressure (ICP) shows a small beneficial effect. However, there are insufficient data on the effectiveness of prehospital administration of mannitol.[23] In the management of increased ICP the intubated patient should maintain normocapnic at about 30 mm Hg.[24] The recent literature suggests that hypertonic saline is evolving as a real alternative to mannitol or may be used in otherwise refractory intracranial hypertension. Safety data on hypertonic saline in the treatment of intracranial hypertension are very limited, and the efficacy and duration of ICP-lowering are difficult to predict.[25]

Prevention

Any athlete who still shows signs of concussion should not be allowed to return to play. Such signs include fatigue, headache, disorientation, nausea, vomiting, feeling "in a fog" or "slowed down," as well as other differences from a patient's baseline.[18] If there are any doubts about the severity of injury, the patient or athlete should not be allowed to resume play.

The difficulty lies in deciding the appropriate return to play when the athlete is completely asymptomatic. Parents, teachers and the coach must observe the athlete closely.

High school athletes and those with scholarship possibilities, especially, will try to convince parents and coaches that they feel fine, in order to resume play. There are differences of opinion as to when it is appropriate for a post-concussive patient to resume play. Cantu[18] suggests a grading system to rate the severity of concussions, ranging from Grade 1 through Grade 3 (Table 1)**.** Three widely referenced clinical guidelines advise on the timing and level of participation after a first concussion.[3,4,5] Unfortunately, none are evidence based, and their recommendations differ widely. Some even discuss a stepwise approach to return to play. The EP should focus on the initial stabilization, imaging and the exclusion of a life-threatening or surgically-treatable lesion. The EP should also ensure appropriate outpatient follow up by a neurosurgeon or a sports physician who has expertise with concussive symptoms. Although information on SIS is present in the medical literature, its description in 1984 may leave some non-specialists unaware of the potential danger. Currently the guidelines suggested by the American Academy of Neurology[26] listed in Table 2 are the most widely disseminated and used.

The most sensible approach to prevention is to prevent the first concussion. For soccer, Kangaroo Soccer Headgear, similar to that used in martial arts, is primarily intended to provide protection for children and youth players. Coverage extends around the head, including the ears. The headgear is intended to protect against player-to-player impacts.[27] These headgear models did provide measurable benefit during head-to-head impacts, but not necessarily with ball impact. Experts advise wearing a helmet during high-impact contact sports and preventing or mitigating especially head-to-head contact.

CONCLUSION

More meaningful research is needed to investigate SIS. In light of its rarity, research should focus on observational study of the incidence of primary concussion in similar systems that do and do not employ head protection. Research should be aimed at unifying an algorithm for the work up and treatment of concussions and potential predisposition for SIS, as well as developing guidelines for return to play. At this point, given the limited information on this topic, the prevention of high impacts during sport is the goal for young athletes. When in doubt after a severe concussion, the athletes should not resume play. "When in doubt, sit them out."[11]

Address for Correspondence: Tareg Bey, MD, FACEP. Department of Emergency Medicine, UC Irvine Medical Center, 101 The City Drive, Rte 128, Orange, CA 92868. Email: tbey@uci.edu.

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Appendix. Testing Guidelines for the Management of Sport-Related Concussion.[24] Testing includes:

- orientation
- repetition of digit strings
- recall of word list at zero and five minutes
- recall of recent game events, recall of current events
- finger-to-nose and tandem-gait tests
- Romberg test
- provocative testing for symptoms with a 40-yard sprint
- five push-ups
- five sit-ups
- five knee bends

Devastating Brain Injuries: Assessment and Management Part I: Overview of Brain Death

"To the world you may be one person, but to one person you may be the world."
-Anonymous

Tara D. Dixon, MD
Darren J. Malinoski, MD
University of California, Irvine Medical Center, Department of Surgery

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INTRODUCTION

Perhaps one of the greatest achievements in medicine to date, organ transplantation has transformed the lives of thousands – bringing life to those who would surely have died without it. This achievement is dependent upon a generous gift from another person. From one deceased donor up to 55 lives may be saved or improved.[1] With progressive advances in the trauma system, emergency physicians (EPs) are faced with more severely injured trauma patients, including the potentially brain-dead. The purpose of this three-part series is to present the components of determining brain death, to discuss the pathophysiology unique to brain-dead patients and to outline an algorithm based on that physiology to improve the care of the brain-dead patient. Rather than selectively neglect the brain-dead patient, active management while the patient is still in the emergency department (ED), specialty consultation and critical care can significantly enhance the likelihood of successful organ donation, turning a tragic loss into a rewarding patient encounter.

The majority of transplanted organs come from brain-dead or cadaveric donors. As most of these donors enter the healthcare system through the ED as either trauma patients with brain injuries or medical patients with acute intracranial hemorrhage, EPs are often involved in the diagnosis, referral, and initial stabilization of these patients. When these injuries would not benefit from neurosurgical or neurologic intervention and are deemed to be non-survivable, they are "devastating brain injuries." The EP's goal shifts to maintaining hemodynamic stability to diagnose brain death, should it occur. Furthermore, we must prepare the family for devastating news and allow them to begin the grieving process. EPs and trauma surgeons are often involved in discussions of end-of-life care and intensive care management of critical illness and injury. Therefore, both groups have the ability to impact organ donation, transplant frequency and success.

Table 1. Glasgow Coma Scale

Motor		
	6	Purposeful; follows commands
	5	Localizes to pain
	4	Withdraws to pain
	3	Decorticate posture
	2	Decerebrate posture
	1	No movement
Verbal		
	5	Oriented
	4	Confused
	3	Inappropriate
	2	Incomprehensible
	1	Nonverbal
Eye		
	4	Open spontaneously
	3	Open to voice
	2	Open to pain
	1	No eye opening
Total Score:		**3-15**

Table 2. Brainstem Reflexes

Pupillary response to light
Corneal reflexes
Caloric responses
Gag reflex
Coughing reflex

Table 3. Apnea Test Sequence (Derived from reference 9 and UCI Declaration of Brain Death Policy and Form - see Figure 2)

1. Preoxygenate the patient with 100% FiO_2
2. Ensure the patient is not hypocarbic via ABG
3. Disconnect the ventilator, but supply oropharyngeal oxygen
4. Monitor the patient for any signs of respiration
5. Obtain ABGs at selected intervals (q3-4 min)
6. Stop the test and return to mechanical ventilation if
   - hemodynamic instability occurs, or
   - the patient exhibits attempts to breathe, or
   - the pCO_2 is >60 mmHg or rises > 20 mmHg above baseline in the setting of an arterial pH < 7.3

*FiO_2 fraction of inspired oxygen; *ABG*, arterial blood gas; pCO_2, partial pressure of arterial carbon dioxide

Table 4. Additional Confirmatory Testing for Determination of Brain Death

Cerebral angiography

The contrast medium should be injected under high pressure in both anterior and posterior circulation.

No intracerebral filling should be detected at the level of entry of the carotid or vertebral artery to the skull.

The external carotid circulation should be patent.

The filling of the superior longitudinal sinus may be delayed.

Electroencephalography

A minimum of eight scalp electrodes should be used.

Interelectrode impedances should be between 100 and 10,000 Ω

The integrity of the entire recording system should be tested.

The distance between electrodes should be at least 10 cm.

The sensitivity should be increase to at least 2 μV for 30 minutes with inclusion of appropriate calibrations.

The high-frequency filter setting should not be set below 30Hz, and the low-frequency setting should not be above 1 Hz.

Electroencephalography should demonstrate a lack of reactivity to intense somatosensory or audiovisual stimuli.

Transcranial Doppler ultrasonography

There should be bilateral insonation. The probe should be placed at the temporal bone above the zygomatic arch or the vertebrobasilar arteries through the suboccipital transcranial window.

The abnormalities should include a lack of diastolic or reverberating flow and documentation of small systolic peaks in early systole. A finding of a complete absence of flow may not be reliable owing to inadequate transtemporal windows for insonation.

Cerebral scintigraphy (technetium Tc 99m hexametazime)

The isotope should be injected within 30 minutes after its reconstitution.

A static image of 500,000 counts should be obtained at several time points: immediately, between 30 and 60 minutes later, and at 2 hours.

A correct intravenous injection may be confirmed with additional images of the liver demonstrating uptake (optional).

Organ Donation and Transplantation

Dr. Joseph Murray performed the world's first transplant at Brigham and Women's Hospital in 1954, and since then over 400,000 transplants have been performed.[2] In 2007 there were 21,403 transplants performed in the United States (U.S.) alone.[3] In medically suitable patients, transplantation for end-stage organ failure is the standard of care.[4] The most commonly needed and transplanted organs, in descending order, are the kidney, liver, heart, lung, and pancreas. Kidney transplants made up 60% of all transplants in 2007 in the U.S. and have been shown to improve quality of life and to be cost-effective compared to hemodialysis.[5]

To comprehend the potential impact of organ donation, several statistics are relevant. The five-year survival rates for patients on the transplant waiting list compared to those that are transplanted are 80.3% vs. 91% for pancreas, 66.5% vs. 92% for kidney, and 37.7% vs. 48% for lung. Two-year survival rates for heart transplantation wait-listed patients range from 44-70%, depending on the severity of heart failure, while the five-year survival after heart transplantation is 73%. Similarly, the one-year survival rate for patients awaiting liver transplantation based on severity ranges from 0-60% and the five-year survival after liver transplantation is 73%. It has been estimated that an average of 30 life-years are saved per organ and tissue donor, based on 2002 statistics, and 55 life-years would be saved if all organs were maximally utilized.[6] Despite this potential, there are currently 98,161 people on the United Network for Organ Sharing (UNOS) waiting list[3], 77,758 patients went without transplant in 2007, and approximately 7,000 died waiting.[7]

There are several strategies to address the mismatch between available and needed organs. Education programs increase awareness of transplant needs and thereby increase the number of people who choose to donate, while prevention efforts lessen the burden of chronic diseases that require a transplant. Additionally, UNOS has an extended criteria donor program, which matches high-risk patients with advanced age or chronic diseases such as Hepatitis with high-risk donors. Expanding the donor pool from brain-dead donors to living donors and donors after cardiac death also helps to close

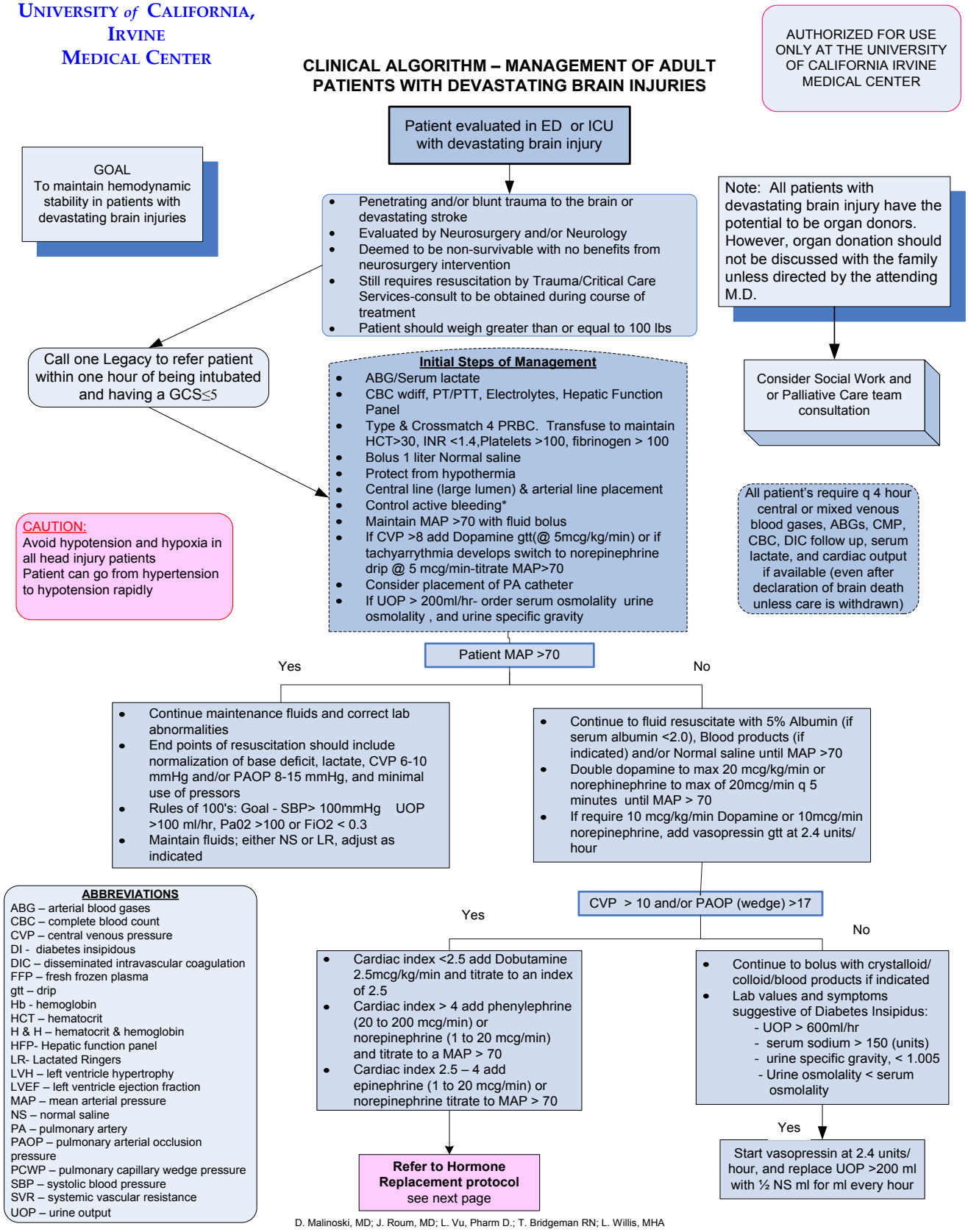

Figure 1. University of California Irvine Medical Center Devastating Brain Injury Pathway
(Included with permission from and only approved for use at UCIMC)

the gap. Finally, this series of articles focuses on improving premortem care of brain-dead donors, which decreases the number who succumb to cardiovascular collapse, and increases the number and function of viable organs procured per donor.[10]

In the first part of this series, we examine the concept and definition of brain death and provide an overview of the organ donation process. We will outline the clinician's role in determining brain death and introduce our Devastating Brain Injury Algorithm, Figure 1, which is the basis of this series.

BRAIN DEATH

The concept of brain death has caused great controversy in medicine and politics. It is debated by ethicists, law professors, government agencies and healthcare workers.[8-11] First introduced by Mollaret and Goulon in 1959, brain death was originally described as a persistent vegetative state or permanent coma.[12] After 1959, the definition evolved until 1968 when a Harvard Medical School ad hoc committee created the current definition, which was later affirmed by the Uniform Determination of Death Act in 1981.[12,13]

In general, brain death is the irreversible loss of all brain function. Most agree that complex mental abilities alone do not singularly constitute being alive, lest those in a vegetative state or with severe cerebral malformations be inappropriately declared devoid of life.[14] Ultimately, the brainstem controls brain function and is responsible for regulating breathing, heart rate, and reflexes such as gagging or coughing when the airway is obstructed, withdrawal from pain, and pupillary function. Without a functioning brainstem, life cannot exist. Therefore, diagnosing brain death requires the absence of brainstem function.

To establish a diagnosis of brain death, the clinician must first identify the underlying causes and determine that they are irreversible.[12] Trauma, stroke, cerebral hypoxia, intracranial hemorrhage, tumors, meningitis, and encephalitis are all well-known causes.[15] All confounding factors must be eliminated, such as hypothermia (< 35°C), hypoxia, intoxication by legal or illegal drugs, shock/hypotension, and severe electrolyte disturbances.[12] Figure 2 shows the brain death declaration form and instruction sheet used at our institution.

The clinical brain death assessment is usually made in the intensive care unit (ICU), but if delayed in the ED, patients may warrant a brain death exam before admission. This evaluation involves three steps: verifying unconsciousness, documenting absent brainstem reflexes, and performing the apnea test. To verify unconsciousness, a Glasgow score of 3 is required (Table 1). The five brainstem reflexes that should be assessed in adults are shown in Figure 3 and Table 2.[12] If all brainstem reflexes are absent, an apnea test is performed. The patient should have a pCO_2 within the normal range and be pre-oxygenated with 100% FiO_2. The apnea test ensures the patient has lost the drive to breathe

Patient Label

UNIVERSITY *of* CALIFORNIA • IRVINE HEALTHCARE

BRAIN DEATH DECLARATION FORM

	RESULTS	
Initial Evaluation	**Check Box**	**Comments**
Mechanism consistent with brain death	☐ Yes ☐ No	
Other causes of death excluded, for example:	☐ Yes ☐ No	
Toxins / drugs (no contributory abnormalities)		
Metabolic parameters (no contributory abnormalities)		
Vital Signs		
Temperature (> 35°C) (record:)	☐ Yes ☐ No	
Blood pressure normal for age (record:)	☐ Yes ☐ No	
Oxygen saturation (> 90%) (record:)	☐ Yes ☐ No	
Neurological Examination		
Response to verbal stimuli absent	☐ Yes ☐ No	
Pupils fixed and dilated	☐ Yes ☐ No	
Corneal reflex absent	☐ Yes ☐ No	
Oculocephalic reflex absent (pt not in C-spine precautions)	☐ Yes ☐ No	
Oculovestibular reflex absent (pt in C-spine precautions)	☐ Yes ☐ No	
Motor response to noxious stimulation absent	☐ Yes ☐ No	
For infants Only		
Sucking/rooting reflexes absent (for infants)	☐ Yes ☐ No	
Apnea Test (no respiratory effort in the setting of):		
pH < 7.30 **AND EITHER**	☐ Yes ☐ No	
pCO2 > 60 mm Hg **OR** ≥ 20 mm Hg over baseline	☐ Yes ☐ No	
Other Confirmatory Tests (as needed)		
4-vessel cerebral angiography	☐ Yes ☐ No	
Radionuclide cerebral blood flow study	☐ Yes ☐ No	
EEG	☐ Yes ☐ No	
Doppler/Ultrasound	☐ Yes ☐ No	

***AFTER ALL CLINICAL CRITERIA ARE MET, EITHER AN APNEA OR OTHER CONFIRMATORY TEST IS REQUIRED TO COMPLETE THE FIRST EXAM. THE SECOND EXAM CAN REFER TO THE APNEA OR OTHER CONFIRMATORY TEST OF THE FIRST EXAM.**

I certify that the above tests have been performed and that according to hospital policy this patient is brain dead.

California Licensed Physician's Signature _____ License Number _____ Date _____ Time _____

Indicate if examination is first or second examination: _____

If second exam, indicate: Identity of the first examiner: _____

Date and time of the first exam: _____

Notes: The second page of this form is for information only and does not need to be placed in the medical record.

All documentation must indicate the specific date and time of entry and a signature complete with identifying credential, title or classification.

88090 (Rev. 4/21/08)

Figure 2. University of California Irvine Medical Center Brain Death Declaration Form and Instruction Sheet (Included with permission from and only approved for use at UCIMC)

and confirms the diagnosis of brain death.

An overview of the procedure and an example of our institution's brain death declaration protocol can be found in Table 3 and Figure 2, respectively. Criteria for a positive apnea test include: no attempt to breathe while disconnected from the ventilator (as oxygen is still delivered to the airway), a pCO_2 greater than 60mmHg or a rise greater than 20mmHg above base-line, and an arterial pH less than 7.3. It usually takes 5-10 minutes of apnea for the pCO_2 to meet criteria, and we recommend drawing blood gasses every three minutes until either brain death is confirmed or the patient becomes hemodynamically unstable, at which point the patient should be reconnected to the ventilator. Some institutions recommend that the clinical exam, including the apnea test, be performed twice, six hours apart for adults and as much as 48 hours apart for neonates, but second assessment remains controversial.[9,12]

If the patient is hemodynamically unstable and would not tolerate even a few minutes off the ventilator for fear

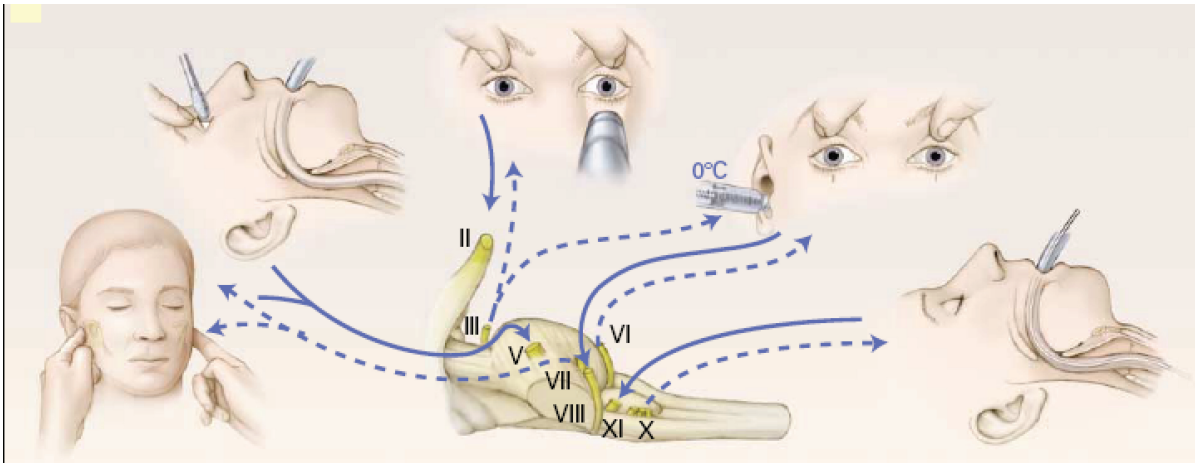

Figure 3. The Steps in a Clinical Examination to Assess Brainstem Reflexes
The tested cranial nerves are indicated by Roman numerals; the solid arrows represent afferent limbs, and the broken arrows efferent limbs. Depicted are the absence of grimacing or eye opening with deep pressure on both condyles at the level of the temporomandibular joint (afferent nerve V and efferent nerve VII), the absent corneal reflex elicited by touching the edge of the cornea (V and VII), the absent light reflex (II and III), the absent oculovestibular response toward the side of the cold stimulus provided by ice water (pen marks at the level of the pupils can be used as reference) (VIII and III and VI), and the absent cough reflex elicited through the introduction of a suction catheter deep in the trachea (IX and X). (*Adapted from Wijdicks[9] and reproduced with permission from Mayo Foundation for Medical Education and Research*.)

of causing cardiopulmonary arrest, other confirmatory tests may be used (Table 4). The most common in the U.S. is cerebral angiography. If the carotid arteries cut off at the base of the skull and there is no blood flow within the calvarium, the patient is brain dead. Recently, clinicians have used magnetic resonance or computed tomography angiograms in lieu of more invasive traditional angiography.[16] Electroencephalography (EEG) is well-validated and frequently used to confirm brain death with absent electrical activity. The disadvantage of EEG is that devices in the ICU may cause artifacts, leading to spurious results.[12] Other tests include transcranial Doppler ultrasound to assess cerebral blood flow and nuclear imaging to assess uptake of tracer in the brain. The latter is preferred for secondary confirmation in our institution. None of these confirmatory tests replaces the clinical exam.

Since children are more resilient than adults, a longer time between assessments has been advocated.[12] Additionally, many institutions require other confirmatory tests, in addition to the apnea test, in children less than one year of age. Deciding who is qualified to determine brain death is another variable. Some centers advocate that at least two clinicians concur on the diagnosis of brain death and that at least one of those clinicians be a neurologist or neurosurgeon. Beyond these minor differences, the declaration of brain death is otherwise similar worldwide.

Once declared brain dead, the patient may become an organ donor with family consent or advanced directive. This may be verified by living wills or, in some states, by registration when obtaining a driver's license.[3] Brain death can be a challenging concept for a patient's family, and it is important to equate brain death with the layperson's understanding of bodily death, which usually means that the heart has stopped. The essential connection between brain function and conscious thought may not be obvious to laypersons, and should be stated explicitly.

It is imperative to separate end-of-life discussions surrounding brain death and the withdrawal of medical support from conversations about organ donation, to avoid any perceived conflict of interest. It is recommended that healthcare providers NOT approach family about organ donation without first consulting with their local organ procurement organization (OPO). In general, representatives from the OPO who are formally trained to talk with families about organ donation make the first, formal approach after end-of-life discussions have taken place. Healthcare providers with a close relationship to the family may be involved in the process as well.

Donor Management

The goal prior to and after the determination of brain death is to maintain perfusion of vital organs. This is, at times, as much the responsibility of the EP as the intensivist. After a family consents to donate organs, the OPO assumes care of the donor, both medically and financially, but physician involvement is still important to perform procedures and provide expert critical care advice. The brain is so central to bodily homeostasis, that once dead, it wreaks havoc on all other organ systems. Preserving organs is quite challenging in the face of brain death, and it is not uncommon to lose donors to the spiral of hormonal and cardiovascular collapse.

Recently, studies have proven that aggressive donor

management (ADM) can improve the quantity and quality of donated organs from brain dead donors.[4,17-19] After a dedicated team of physicians assumed responsibility for the management of all potential organ donors at the Los Angeles County / University of Southern California Medical Center, there was an 82% increase in the number of organ donors and a 71% increase in the number of organs recovered.[4] Furthermore, organizing the care of the brain-dead donor into an evidence-based clinical protocol has been shown to both decrease donors lost to cardiovascular collapse, as well as increase the number of organs procured per brain-dead donor.[17]

The intensive care of the brain-dead donor does increase overall cost of care, but there is no cost to the donor's estate or family.[20] The cost-effectiveness of transplantation has been well established and has been most extensively reviewed for kidney transplantion.[3,20-24] Furthermore, it is imperative to remember that the care of the donor potentially benefits eight patients with end-stage organ failure, and many more who will benefit from tissue donation.[6, 25] Traditionally, 75% of U.S. transplantations have been paid by Medicare.[22] The transplanted patient or the patient's insurance company pay for the remaining 16% and 9%, respectively.[22] Costs incurred while caring for the brain-dead donor are ultimately distributed amongst the patients receiving the donated organs and are usually covered through insurance or Medicare/ Medicaid.[26]

CONCLUSION

The active participation of all healthcare providers involved in the care of patients with severe neurologic insults preserves the option of organ donation for patients and their families. This care often begins in the ED. Recently, our institution implemented a Devastating Brain Injury Pathway – an evidence-based protocol designed to improve care of this unique population. The primary purposes of the pathway are to maintain hemodynamic stability by providing comprehensive critical care in order for brain death to be diagnosed, should it occur; to give families time to come to the hospital and grieve; and to preserve the opportunity of donation for patients and their families. It is imperative to explicitly state that the primary purpose is not to improve the number of organs that can be transplanted, as this would represent a potential conflict of interest for the physician caring for the injured patient. However, the pathway does represent sound neurologic critical care that will improve perfusion to the brain and has the potential to turn a devastating brain injury into a salvageable one. If a patient does regress to brain death, organ perfusion will be maintained should the patient's family decide to donate. In the next two reviews we will discuss the pathophysiology of brain death that causes so many donors to be lost to cardiovascular collapse (part 2) and the resuscitation and management of these donors to preserve the maximum amount and function of organs per donor (part 3).

Address for Correspondence: Darren Malinoski, MD, Department of Surgery, University of California, Irvine, 333 The City Blvd West, The City Tower, Suite 705, Orange, CA 92868. Email: malinosd@uci.edu.

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Periorbital Noise

Philippe Hantson, MD, PhD Université Catholique de Louvain, Brussels, Belgium
Thierry Duprez, MD

Supervising Section Editor: Kurt R. Denninghoff, MD
Submission history: Submitted February 27, 2008; Revision Received June 30, 2008; Accepted September 12, 2008.
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A 54-year-old man presented to the emergency department with a Glasgow Coma Score of 8 after throwing himself out of a window. Right periorbital and conjunctival blood infiltration were noted, with complete ophthalmoplegia and loss of the pupillary light reflex. On the third day, a systolic bruit became audible over the right eyeball [(Figure 1A) Click on image for audio]. The CT with contrast (Figure 1B) demonstrated a wide unilateral enlargement of the right cavernous sinus (white arrow) and of the superior ophthalmic vein (arrowhead), together with multiple bone disruptions, including the sphenoid bone (black arrows). This was consistent with the diagnosis of traumatic carotid cavernous fistula (TCCF). A TCCF arises from direct traumatization of the internal carotid artery within its cavernous course. It is a relatively rare complication of head trauma, with a global occurrence rate ranging from 0.17 to 1.01%.[1] Usually TCCF are found after fractures of the middle third portion of the facial bone. When they are of high-flow type, they develop within a short period after injury.

The diagnosis of TCCF is difficult in comatose patients. Complete ophthalmoplegia, with an ocular bruit, should prompt careful analysis of the head CT scan. High-flow TCCFs should be treated as a relative emergency. They may cause secondary neurological deficits due to flow steal from the intracranial carotid artery or ophthalmologic complications secondary to venous congestion. Endoarterial detachable balloon embolization is the treatment of choice.[2]

Address for Correspondence: Philippe Hantson, MD, PhD. Cliniques St. Luc, Avenue Hippocrate 10, Brussels 1200, Belgium. Email: philippe.hantson@uclouvain.be.

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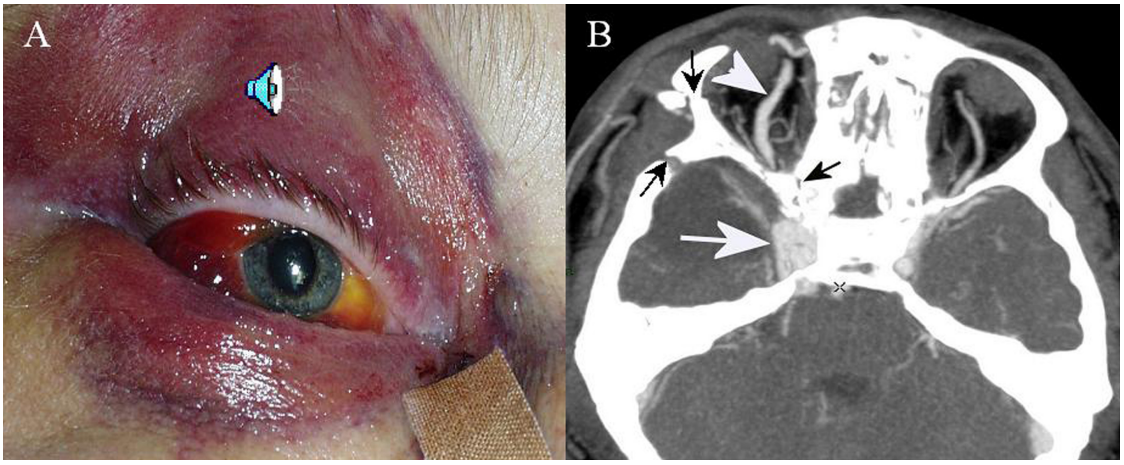

Figure 1. A. Periorbital hematoma, complete ophthalmoplegia and loss of pupillary light reflex. Audible bruit over the eyeball (audio). **B**. Head CT scan with enlarged right cavernous sinus. Click on image for periorbital noise audio (http://repositories.cdlib.org/cgi/viewcontent.cgi?filename=0&article=1291&context=uciem/westjem&type=additional).

Bilateral Cervical Spine Facet Fracture-Dislocation

Shanda Gomes University of California, Irvine School of Medicine
Scott Rudkin, MD, MBA
Fong Tsai, MD
Shahram Lotfipour, MD, MPH

Supervising Section Editor: Rick A. McPheeters, DO
Submission history: Submitted August 20, 2008; Revision Received September 09, 2008; Accepted September 12, 2008.
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An intoxicated 29-year-old male presented to the emergency department after diving into a pool with reported loss of consciousness and complaining of neck pain. On arrival the Glasgow Coma Scale was 15 and vital signs were unremarkable. Physical exam was significant for focal C6 tenderness without step-off deformity, decreased grip strength, biceps hyperreflexia and absent triceps reflexes bilaterally. Lower extremities demonstrated flaccid paralysis, loss of sensation from the T4 dermatome down, urinary retention and no rectal tone. Cervical spine computed tomography (CT) demonstrated bilateral fractured and dislocated facets C6 on C7. The patient was treated with intravenous methylprednisolone and admitted to the Neurosurgical Intensive Care Unit, after undergoing C6-C7 anterior disk excision with subsequent posterior fusion. At discharge he had a C7 functional level with mixed motor deficits inferiorly.

Bilateral facet dislocation occurs when a vertebra's inferior facet dislocates anteriorly over the lower vertebra's superior facet, locking in the intervertebral foramens, creating a severely unstable fracture.[2,3] CT has a higher sensitivity for C-spine injury and is the preferred imaging modality.[2] Sagittal reconstructions best identify the dislocated, locked facets; axial views can demonstrate a "reverse-hamburger-bun sign."[2] While facet dislocation injuries are rare, representing less than 10% of C-spine injuries, the neurologic morbidity is tragically high.[1,3] Common mechanisms for this injury include motor vehicle collisions (61%) and diving accidents (15%), where extreme flexion and axial loading occur.[1] Ivancic et al.[3] reported that the dynamic narrowing of the spinal canal during the dislocation is sevenfold greater than the narrowing observed in the canal immediately post dislocation; thus, CT images may under-appreciate the extent of the injury. Complete spinal cord injury is not uncommon.[1,2]

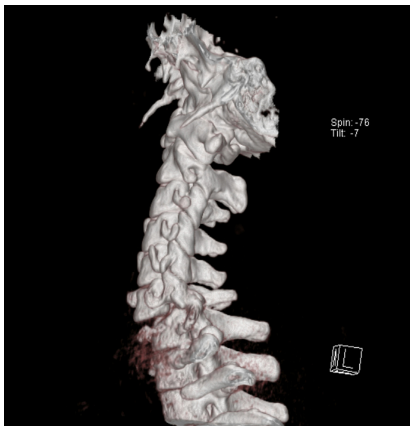

Figure 1. 3D Maximal Intensity Projection (MIP) CT Image of the bilateral dislocated facets (locked facets), C-6 on C-7.

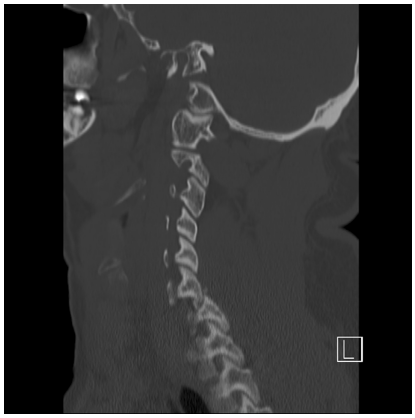

Figure 2. Computer tomography of the bilateral dislocated facets (locked facets). A sagittal reconstruction of the cervical spine demonstrating C-6 dislocated over C-7.

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Address for correspondence: Shahram Lotfipour, MD, MPH. Department of Emergency Medicine, 101 The City Drive, Rte 128-01, Orange, CA 92868. Email: SHL@uci.edu.

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Cauda Equina Syndrome

Joel T. Levis, MD, PhD Kaiser Santa Clara Medical Center, Department of Emergency Medicine

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Submission history: Submitted July 22, 2008; Revision Received September 06, 2008; Accepted October 13, 2008.
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A 26-year-old male with a history of a work-related back injury presented to the emergency department complaining of several weeks of low back pain radiating down his left leg. For the past day, he noticed numbness to his perineal area and feet bilaterally, and difficulty urinating. He denied recent trauma, leg weakness, or fevers. Physical examination revealed perineal anesthesia and decreased rectal tone, as well as decreased sensation to the dorsal and lateral aspects of both feet (L5-S1 dermatomes); his lower extremity strength was 5/5 proximal and distal. Achilles and quadriceps reflexes were absent bilaterally. The patient was unable to urinate, and 550 mL of urine was removed upon post-void bladder catheterization. An MRI was obtained, which showed a large L5-S1 disk herniation with compression of the cauda equina (Figure). The spinal surgeon was consulted, and the patient underwent an L5-S1 laminectomy with diskectomy. The patient was discharged home on hospital day #5 with gradual improvement of his symptoms; his foley catheter was removed post-operative day #10 and the patient was able to urinate without problems.

The adult spinal cord terminates at the level of the L1-L2 vertebrae, with the terminal lumbar and sacral nerve roots within the spinal canal forming the cauda equina distally. Cauda equina syndrome (CES) is most commonly caused by herniation of a lumbar disk, and presents as a complication in 2% of lumbar disk herniation cases.[1,2] Clinical features of CES include perineal anesthesia and other lumbosacral root sensory deficits, lower extremity weakness, difficulty with bladder and bowel control, sexual dysfunction, low back pain, and unilateral or bilateral sciatica.[3] A thorough neurologic examination (including an assessment of perineal sensation and anal sphincter tone) should be performed. Patients with back pain and urinary incontinence should have a urinary post-void residual volume measured; greater than 100-200 mL indicates urinary retention and mandates further evaluation.[4]

MRI should be emergently obtained when the diagnosis of CES is suspected. Treatment with high-dose steroids (dexamethasone 4-100 mg IV) may provide pain relief and improved neurologic function (by reducing edema) while awaiting diagnostic studies and surgical decompression.[4,5] CES is an absolute indication for emergent surgical decompression; laminectomy with gentle traction of the cauda equina and diskectomy is the technique of choice.[1] The outcome for patients with CES is determined primarily by their symptoms at presentation. Patients who can ambulate at presentation will generally remain ambulatory.[5] Patients who present with paresis but are ambulatory with assistance have approximately a 50% chance of walking again, and as many as 79% of patients presenting with urinary retention will continue to require a urinary catheter after treatment.[5]

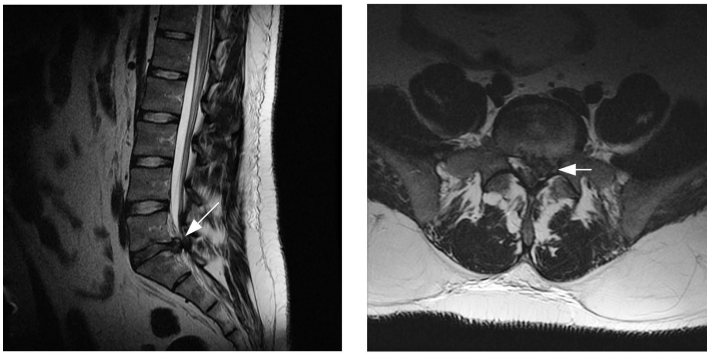

Figure. Sagittal (panel A) and axial (panel B) MRI images demonstrating large central and left paramedian disc extrusion at L5-S1 (arrows) with compression on the cauda equina.

Address for Correspondence: Joel T. Levis, MD, PhD. Kaiser Santa Clara Medical Center, Department of Emergency Medicine, 700 Lawrence Expressway, Santa Clara, CA 95051. Email: joellevis@yahoo.com.

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The Colorado Compendium: An Article-Based Literature Review Program

Jeffrey Druck, MD* * University of Colorado Health Sciences Center, Denver, Colorado
David Pearson, MD, MS† † Carolinas Medical Center, Charlotte, North Carolina
Jonathan Claud, MD, MBA‡ ‡ Legacy Salmon Creek Hospital, Vancouver, Washington

Supervising Section Editor: Michael Epter, DO
Submission history: Submitted June 11, 2008; Revision Received August 25, 2008; Accepted October 10, 2008.
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The immense body of knowledge that emergency medicine (EM) encompasses is constantly growing and ever changing. Textbooks build a strong foundation for the EM resident, but journal articles critical for modifying and improving EM practices are equally important for a well-rounded education. Determining which journal articles are vital to an EM residency education is a challenge. Lacking a formalized list of key articles available to EM residents and realizing that a list of articles without a guide may be difficult and confusing for novice readers, we created the "*Colorado Compendium*": a recommended reading list, limited to 100 articles with accompanying summaries, tailored to emergency medicine residents.
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INTRODUCTION

Internalizing the canon of knowledge in emergency medicine (EM) is a daunting task. As we all know, this knowledge base is not completed during residency. Instead, residency serves as the launching point for a lifetime of medical education. How do residents become familiar with the library of knowledge that will aid them at the bedside? Textbooks are a start. Clinical hours are the mainstay. But journal articles provide the basis for a change in practice. The *Colorado Compendium* is an attempt to identify sentinel articles that are often referred to during clinical rotations. By providing a summary of each article, residents are exposed to the information that lies in these references, while the complete articles remain for further investigation.

METHODS

Attending physicians at the Denver Health Residency in Emergency Medicine were queried via email as to which articles they deemed important for inclusion in the list of "top articles in emergency medicine," with no other caveat listed. In response, we received recommendations for several hundred articles. From this group, we culled for duplication and outdated articles. There were no absolute requirements regarding the characteristics of each article. The litmus test for inclusion was to ask whether an article would fundamentally enhance the clinical expertise of residents practicing EM. The list was narrowed by the authors to 100 articles. Subsequently, the three authors compiled a one-page summary of each article. The summaries were then reviewed and edited by attending physicians at Denver Health Medical Center and the University of Colorado Health Sciences Center with an interest or specialization in the subject area, after which the authors revised each summary.

DISCUSSION

Nationally available lists of articles pose a challenge from a resident education perspective. Using a national poll of "most important" leaves two critical issues that would need to be addressed: first, the issue of influence, and second, the issue of distance. For example, the Lifelong Learning and Self-Assessment (LLSA) articles, chosen by submission from a national audience, may include submissions from specific authors themselves.[1,2] Also, this same pool of articles is subject to a bias towards new, untested modalities, as the inclusion of the nesiritide article in the 2005 LLSA list demonstrates.[3] Lastly, outside influences (drug companies, etc.) can be more apparent in a list that is based on suggestions, with secondary gain of increased knowledge of specific drugs influencing submissions. Through a literature review on PubMed using the search terms "emergency medicine article list,"[4] no other

lists are commonly available. Some commercial sites, such as *eMedicine*, have lists of articles relating to EM, but these articles are not based on published articles themselves, instead acting as a general topic summary.[5] Finally, some web sites organize content based on subject, such as the *New England Journal* collection of EM articles. However, this is a collection of all EM-related articles listed in their publication, with no filter (and currently numbering at more than 250).[6]

That is not to say that some articles or guidelines included in our list are without any taint of influence or possible contradiction. However, we attempted to choose articles that have withstood the test of time in our program and guidelines that did not undergo immediate revision.

The article summaries themselves can be critiqued. As a conglomeration of opinion of three authors and one additional attending physician, there may be inherent bias in comments made. There may also be nuances in each article that are not discussed (or even mentioned) in the summaries that appear in the articles themselves. These summaries are not simply copies of the article abstracts, nor do they serve as adequate substitutes for reading the article itself. They are meant to serve as a brief guide to the associated full-text reference. Hopefully, residents reading the summaries will expand their knowledge base and will be encouraged to go to the original articles for further investigation.

How does one use the *Colorado Compendium*? Does distribution itself equal knowledge acquisition? This remains to be seen. Eighty-three different residency programs recently requested copies of the *Colorado Compendium* to incorporate in their curriculum. As with any educational endeavor, possession of a curriculum does not translate into an effect. At our program, weekly distribution of a single summary was thought to be a method that was best suited to resident interest. Other institutions have distributed the entire *Colorado Compendium* at the beginning of residency. Assessing the *Colorado Compendium* from an educational success standpoint is an ongoing process.

As a final note, our list and summaries are not meant to be a final document for all time. We intended for this *Colorado Compendium* to be a living document, with additions and deletions occurring in an ongoing fashion. To maintain an article-based source for resident education, we encourage others to assist us with updating and editing this list. The article summaries are available online at www.westjem.org as a related file, "*Colorado Compendium*," via this link: http://repositories.cdlib.org/uciem/westjem/vol10/iss1/art7/

CONCLUSION

The *Colorado Compendium* is a starting point for article-based resident education. While textbooks form the basis for a broad knowledge base, the articles with summaries attempt to refine our knowledge of and potentially change our practice in EM.

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Address for Correspondence: Jeffrey Druck, MD. University of Colorado Denver School of Medicine, Division of Emergency Medicine, 12401 E. 17th Avenue, B-215, Aurora, CO 80045. Email: Jeffrey.Druck@uchsc.edu.

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Influence of Assigned Reading on Senior Medical Student Clinical Performance

Lance Hoffman, MD*
Kristine Bott, MD*
Susan Puumala, MS†
Valerie Shostrom, MS†

* University of Nebraska Medical Center, Department of Emergency Medicine
† University of Nebraska Medical Center, College of Public Health

Supervising Section Editor: Michael Epter, DO
Submission history: Submitted June 24, 2008; Revision Received September 25, 2008; Accepted October 03, 2008.
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Objective: This Institutional Review Board-approved, prospective, observational study compared the clinical performance of senior medical students in an emergency medicine (EM) clerkship using a clinical behavioral evaluation tool in which one group had mandatory, topic specific readings and the other did not.

Methods: The study took place in an urban, tertiary referral center emergency department treating 43,000 patients annually and supporting medical student clerkships and an EM residency. The grades of two groups of senior medical students participating in an elective EM clerkship were compared. Those students during the 2002-2004 academic years were not assigned mandatory, topic-specific reading for the clerkship, while those during the 2004-2007 academic years were. The groups were compared on baseline demographic information, prior academic performance, and EM clerkship grade distributions using appropriate statistical techniques, including multinomial logistic regression, chi-square tests, and Fisher's Exact tests.

Results: The control and experimental groups each had 83 subjects and were similar in baseline characteristics, except for the control group performing better than the experimental group during the basic science training of medical school (years 1-2; p=0.01). The experimental group had statistically significant more members in the EM Interest Group (EMIG; p=0.0001) and more members who went on to match in an EM residency (p=0.0007). The difference in grade distributions between the control group and experimental group was not statistically significant (p=0.40). Of note, those student members of the EMIG (p=0.0005) and those later matching to an emergency medicine residency (p<0.0001) were more likely to earn a grade of "honors" for the clerkship.

Conclusion: The addition of uniform, topic-specific reading assignments to an EM senior medical student curriculum does not improve the overall clinical performance of those students as measured using a clinical behavioral evaluation tool.
[*West*JEM. 2009;10:23-29.]

INTRODUCTION

Many medical student clinical clerkships required for graduation assign students a specified reading assignment as part of coursework. This requirement is designed to improve both the student's factual knowledge, especially about disease processes uncommonly encountered in most clinical medical practices, and clinical performance. While it has been demonstrated that factual knowledge improves with implementation of required reading material, it has not been demonstrated that this translates into an improvement in clinical performance. Several educational studies have suggested that the format in which new material is presented is

of less importance to acquiring medical skills than the number of repetitions in which that information is presented.[1-10] If this is indeed true, then the addition of required reading materials to a clinical clerkship might serve as a means to increase the number of times a student is exposed to information about a specific disease process. More importantly, however, it would be useful to know whether this increased exposure to educational materials impacts clinical performance and ultimately patient outcomes.[11] If required reading material improves clinical performance, then it could be argued that topic- specific readings should be included as a part of all clinical clerkships in medical school to supplement the student's clinical experience.

Our senior medical student emergency medicine (EM) clerkship during the academic years of 2002-2003 and 2003-2004 did not require the reading of any EM topics, nor provide any suggested readings on EM topics. At that time the clerkship was purely a clinical experience in an urban emergency department (ED). Starting with the 2004-2005 academic year, the senior clerkship required students to read a textbook dealing with topics specific to senior medical students of emergency medicine. The book was written with the specific goal of providing students with information that would be useful clinically while working in an urban ED. The text , *First Exposure to Emergency Medicine Clerkship*, was published in June 2004.[12] The student evaluation tool used to determine the student's final grade has remained constant since the 2002-2003 academic year. This implementation affords the opportunity to determine whether required textbook readings are influential in improving student clinical performance by comparing grade distributions by year for the clinical portion of the senior EM clerkship. The null hypothesis of this study is that student grade distributions based on clinical behavioral evaluation measures will remain unchanged after the addition of required readings during the clerkship and the knowledge of required written, multiple choice testing at the end of the clerkship.

MATERIALS AND METHODS

Study Design

This study is a single center, prospective, observational study comparing the grade distributions of a consecutive sample of senior medical students assigned topic-specific readings during an EM clerkship and a historical control group of senior medical students without assigned topic-specific readings. This study was reviewed and approved by the Institutional Review Board under exempt status.

Study Setting and Population

This study was conducted at an urban university medical center ED staffed by American Board of Emergency Medicine-certified physicians. The ED has an annual patient census of approximately 43,000 patients comprised of both pediatric and adult populations. A four-week EM clerkship is available as an elective to senior medical students during July through April of each academic year. Study subjects were enrolled consecutively during the 2002-2007 academic years. For any given clerkship month, approximately four senior medical students attending the College of Medicine choose to participate in this elective clerkship. During this clerkship, the students are required to work 15 shifts of nine hours duration distributed equally among day, evening, and night hours. At the completion of a clinical shift, the student presents the supervising physician with a clinical evaluation form, utilizing an anchored Likert scale. The evaluating physician completes and returns this form to the student clerkship director. Each category of these evaluation forms is then averaged to arrive at an overall clinical grade for the clerkship of "Honors, High Pass, Pass, Marginal, or Fail." While the students do not have mandatory didactic sessions, they are encouraged to attend the resident lectures. They do participate in suturing and splinting laboratories, but these activities do not directly impact their clinical grade other than providing them with experiences that may be utilized during clinical shifts. At an orientation session designed to familiarize the students with the ED on the first day of the rotation, the students are encouraged to use the text during ED clinical shifts to help guide their patient management.

The paperback text measures six inches by nine inches so that it may be carried in the pocket of a laboratory coat during clinical duties. It may then be used to correct knowledge deficits during the shift. The text is 455 pages in length and was written by five ABEM-certified emergency physicians at an academic hospital that teaches medical students and resident physicians. The text is divided into four sections. Section I discusses the paradigm of emergency care, the elements of a high-quality patient presentation to a supervising physician, and issues related to emergency medical services. Section II focuses on common emergency procedures, including their indications, contraindications, stepwise approach, and possible complications. Section III describes the generalized evaluation and treatment of patients presenting with chief complaints that are commonly encountered clinically. Section IV discusses specific diseases organized by organ system. The text in its entirety addresses all of the subcategories listed on the student evaluation form.

Study Protocol

Potential subjects were identified by reviewing the class list of senior medical students completing the EM clerkship for the 2002-2007 academic years. This information was available to the principal and secondary investigators in their roles as student clerkship directors for the EM clerkship. After the completion of the student clerkship and the assignment of a final grade, students were sent a cover letter explaining the study and data to be collected as well as a brief survey

Table 1. Baseline Comparison of Groups

	'02-'04 Control (Pre-Intervention)	'04-'07 Experimental (Post-Intervention)	p-value
Mean MS1-MS2 Z-Score	0.1733	-0.2150	0.01
Mean MS3 Z-Score	0.1467	0.0257	0.41
# AOA Members	0 (0%)	0 (0%)	---
# without English as 1st Language	1 (1.2%)	0 (0%)	1.00
# Minority	10 (12.1%)	4 (4.8%)	0.09
# Gender			
Male	60 (72.3%)	53 (63.9%)	
Female	23 (27.7%)	30 (36.1%)	0.24
Median Age	26.0	26.0	0.97
# EMIG Member	11 (13.3%)	33 (39.8%)	0.0001
# EM Match	9 (10.8%)	27 (32.5%)	0.0007

MS, medical student; *AOA,* Alpha Omega Alpha Medical Honor Society; *EMIG*, Emergency Medicine Interest Group; *EM*, emergency medicine

inquiring to the approximate percentage of the reading that was completed during the clerkship and whether they believed the readings to be a useful adjunct to their clinical performance during the clerkship experience. These surveys were returned by mail to the study investigators.

The investigators also provided the Associate Dean of the College of Medicine with a list of students from the 2002-2007 academic years who completed the elective senior EM clerkship. Demographic and prior medical school academic performance characteristics of the experimental and control groups were gathered from the College of Medicine for a baseline comparison of the groups. These data were returned to the investigators without identifiers and in aggregate form according to the academic year in which the clerkship was completed. Baseline comparison characteristics of the groups included the following: number of students completing the clerkship, number of students regarding English as their preferred language, number of under-represented minority members, gender, age at the time the clerkship was completed, number of Alpha Omega Alpha (AOA) honor society members selected during the M3 year of undergraduate medical training, number of members of the Emergency Medicine Interest Group (EMIG), and an overall comparison of academic achievement for the M1-M3 years of training based on a scaled student ranking (Z-scores) provided anonymously by the Associate Dean of the College of Medicine.

This study did not mandate an alteration of the physician interactions with or observation of the medical students during the clerkship. Each student's clinical performance was evaluated based on criteria set forth on the medical student evaluation form. This evaluation form has been utilized since the 2002-2003 academic year continuously through the entire study period. The student's grade for the clerkship was determined by averaging the scores given in each category of the evaluation form for each given shift. Each category was given equal weight. Although the score of a 50-item, written, multiple choice examination based on the information contained in the required reading is weighted as one-third of the student's grade reported to the College of Medicine, this portion of the student's grade was excluded for the purposes of this study's comparison between the group with assigned reading and those completing the clerkship prior to the addition of the assigned reading and written examination. The grade distributions of the two groups were compared to determine whether a statistically significant difference in grade distribution exists between the 2002-2004 academic years group, before the initiation of required reading, and the 2004-2007 academic years group, after the initiation of the required reading.

Measurements

Data were collected by the study investigators and stored without identifiers in aggregate form according to the academic year in which the study subject completed the EM clerkship. The data that was collected represented information on study subject demographics, prior academic performance in medical school, and the clinical grade earned during the EM clerkship.

Data Analysis

Data were analyzed using a multinomial logistic regression model, chi-square test, and Fisher's Exact test. The primary comparison was between students assigned textbook

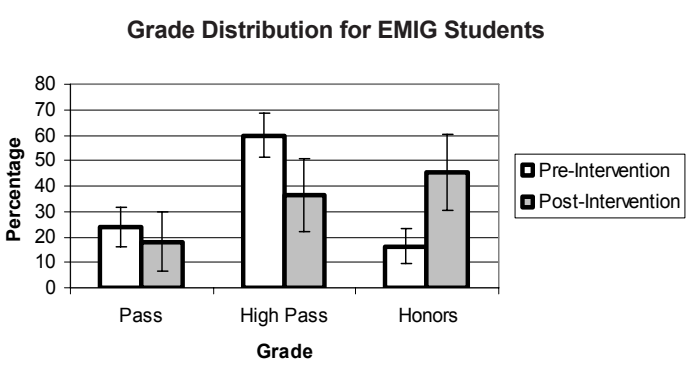

Figure 1.

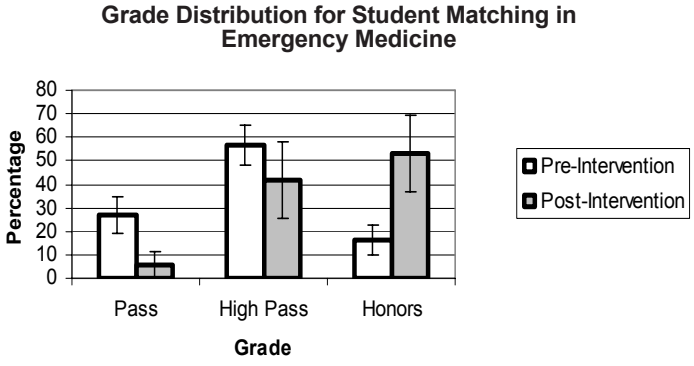

Figure 2.

material and students not assigned textbook material. All of the previously mentioned covariates were included in the model to account for possible differences between the groups. For this multinomial design, sample size was calculated using the S-plus code from Frank Harrell, following the method of Whitehead.[13] With an alpha level of 0.05, to have 80% power to detect an odds ratio of 2.3, 82 subjects in each group were required. In other words, the odds of having a grade of honors in the textbook group is 2.3 times that of the non-textbook group. This odds ratio could be obtained from increasing the percentage in the honors group by 20% and decreasing the pass and high pass groups both by 10%.

Additionally, Chi-square or Fisher's Exact test were used to compare the study groups' grades in each of the subcategories used to compile a given student's overall grade for the clerkship. These subcategories were History and Physical Exam, Patient Presentation, Knowledge Base, Patient Management, Procedural Skills, and Effort/Reliability. When the p-value from the overall test was significant, three 2x2 tables were analyzed (for each pair of grade level). These p-values were adjusted using Bonferroni. In addition, the pass and high pass grades were combined and compared to the honors grades, and the high pass and honors grades were combined and compared to the pass grades. The statistical level of significance used in all analyses was 0.05.

RESULTS

The control and experimental groups each had 83 subjects and were similar in most baseline characteristics of interest (Table 1). While the control group performed better than the experimental group during the basic science training of medical school (years 1-2; p=0.01), the groups were similar in their performance during the first year of clinical training (year 3; p=0.41). In addition, the experimental group had statistically significant more members in the EMIG (p=0.0001) and more members who went on to match in an EM residency (p=0.0007). The group differences did not reach statistical significance in the areas of the number of AOA junior medical student members, the number of individuals without English as their first language, the number of ethnic minority members, gender differences, or median age at the time the EM clerkship was completed.

The difference in the overall grade distributions between the control group and experimental group was not as large as expected (p=0.40); therefore, there was not enough power to detect statistical significance (Table 2). Statistical significance was not reached when the medical students receiving a grade of "Pass" and "High Pass" were combined and compared to the students receiving a grade of "Honors" (p=0.47) or when the medical students receiving a grade of "High Pass" and "Honors" were combined and compared to the students receiving a grade of "Pass" (p=0.19).

Grade distributions of "Honors," "High Pass" and "Pass" for each categorical variable were also compared. Notably, those student members of the EMIG (p=0.0005) and those later matching to an EM residency during the same academic year they completed this EM clerkship (p<0.0001) were more likely to earn an overall grade of "Honors" for the clerkship. These results are represented graphically in Figure 1 and Figure 2.

The difference in the subcategory grade distributions between the control group and the experimental group reached statistical significance in the subcategories of History and Physical Exam (H&P) (p=0.02; refer to Table 2) and Procedural Skills (p=0.01; refer to Table 2). However, statistical significance was not reached in the other subcategories of Patient Presentation (p=0.10), Knowledge Base (p=0.49), Patient Management (p=0.08), or Effort/Reliability (p=0.07).

The survey inquiring about the volume of the assigned readings that were actually completed by the student and the student's opinion regarding the clinical utility of the readings was returned by 26 of the 83 subjects in the experimental group (31%). Seven of the 26 respondents (27%) read between 81% and 100% of the assigned readings, six (23%) read between 61% and 80%, eight (31%) read between 41% and 60%, three (12%) read between 21% and 40%, and two (8%) read between none and 20%. All of the respondents stated that

Table 2. Group Grade Comparisons

	'02-'04 Control (Pre-Intervention)	'04-'07 Experimental (Post-Intervention)	p-value
Overall Grades			
Fail	0	0	
Marginal	0	0	
Pass	22 (27%)	15 (18%)	
High Pass	43 (52%)	46 (55%)	
Honors	18 (22%)	22 (27%)	0.40
Pass + High Pass			0.47
High Pass + Honors			0.19
Grades for History and Physical Exam Component			
Fail	0	0	
Marginal	0	0	
Pass	17 (24%)	9 (11%)	
High Pass	48 (67%)	54 (66%)	
Honors	7 (10%)	19 (23%)	0.02
Pass vs. High Pass			0.29
Pass vs. Honors			0.02
High Pass vs. Honors			0.19
Pass + High Pass vs. Honors			0.03
High Pass + Honors vs. Pass			0.04
Grades for Procedural Skills Component			
Fail	0	0	
Marginal	0	0	
Pass	19 (26%)	9 (11%)	
High Pass	43 (60%)	50 (61%)	
Honors	10 (14%)	23 (28%)	0.01
Pass vs. High Pass			0.13
Pass vs. Honors			0.01
High Pass vs. Honors			0.33
Pass + High Pass vs. Honors			0.03
High Pass + Honors vs. Pass			0.01

the assigned readings they completed were helpful in guiding the evaluation and management of patients that they were caring for while they worked clinically in the ED.

DISCUSSION

In a systematic review by Oxman, et al.,[14] it appears that passive distribution of information is an ineffective means of impacting behavioral changes. However, active information distribution and utilization is moderately effective in changing health professional behavior and health outcome. More recently, Costa, van Rensburg, and Rushton[15] found that interactive teaching styles are preferred by students and that knowledge retention is better for teaching orthopedic topics when compared to the traditional didactic lecture format. Our results support those of Oxman and Costa in that no difference was observed between those students with and without assigned topic-specific reading in an elective EM clerkship. Although the reading material was contained in a book small enough to be easily carried in the pocket of a lab coat and referred to during clinical shifts, not all the students used it in this manner. While the passive reading material presented clinical information to the readers, it did not include any interactive activities in which the readers could use the information in the readings for hypothetical problem-solving activities. It is possible that a difference in group performance might have been observed if the assigned readings also included problem-solving activities.

These data do demonstrate that those students participating in the EMIG and those students who later that same academic year matched in an EM residency do outperform their peers in terms of clinical performance as judged using a behavioral evaluation tool. This observation is likely a function of heightened attention to the subject matter and increased relevance to the student contemplating the specialty of EM as a career. Certainly, adult learners retain information better if they are attentive to the material, and the material is relevant to the individual learners. Despite the experimental group having more EMIG members and students later matching to an EM residency, a difference in clinical performance between the control and experimental groups was still not demonstrated in this study (Table 2).

The data also support that the experimental group who were supplied the text performed better in the subcategories of H&P and Procedural Skills (Table 2). The text specifically discusses an EM- based approach to both of these tasks that likely varies from the experience of the students on prior required rotations. The importance of brevity and efficiency in taking an initial H&P without sacrificing completeness is stressed in the text. This may be markedly different than the detailed H&P endorsed by other medical specialties, such as Internal Medicine and Pediatrics, to which the medical student would likely have had significantly more exposure up to this stage of their training when they would have been participating in an EM rotation. Additionally, the text has a section dealing with emergency procedures that students may be allowed to perform. Perhaps students having reviewed

this section were better prepared for performing a given emergency procedure when offered the opportunity.

LIMITATIONS

One limitation of this study is that the student evaluators varied according to the specific shift being worked and the academic year in which the student participated in the EM clerkship. The attending physician complement was constant during the period of time the control group participated in the clerkship (2002-2004 academic years). However, during the clerkship participation time of the experimental group (2004-2007 academic years), four student evaluators (attending physicians) were added and three student evaluators were lost due to turnover of employment positions. Consequently, the investigators could not ensure an equal distribution of shifts of students working with a specific evaluator (attending physician). In addition, there is no way of accurately accounting for all student absences. However, each individual student was allowed only a single shift absence during the clerkship. Otherwise, the clerkship was not considered complete, and the student had to schedule "replacement shifts" to complete the clerkship and receive a grade, a condition that was met by all the students during the study period.

Another study limitation is that the clinical evaluation tool's reliability and validity is unproven. Because of this, we cannot be certain that the data obtained through the evaluation form is reliable and valid. However, the evaluation form used in this study is similar to other institutional evaluation forms used to derive student grades for other clerkships, suggesting the form has face validity.

An accurate assessment of the volume of the assigned readings actually completed by all the subjects in the experimental group cannot be made without having had an investigator witness the reading for each study subject. The only available means of estimating this quantity is by self-report through the returned surveys, and only 26/83 (31%) of those forms were returned for inclusion in the study results. It may be more likely that those individuals returning the survey were also the individuals who were more likely to have completed the assigned readings. Consequently, it is possible that the 57 study subjects not returning the survey form (69%) might not have read any of the assigned readings for the clerkship.

A final study limitation is that because this study did not employ a randomized design there could be differences between the groups for which the model will not account. The performance evaluation could be relative to the year of the clerkship, so that even if students perform better in a given academic year, there might not be a difference in grade distribution. The textbook assignment and year of the clerkship are confounded so a significant difference could represent a year difference instead of an assigned reading difference.

CONCLUSIONS

The addition of uniform, topic-specific reading assignments to an elective EM senior medical student clerkship curriculum does not improve the overall clinical performance of those students as measured using a clinical behavioral evaluation tool. It does appear that EMIG members and those students who later match to an EM residency do perform at a higher level clinically during an EM clerkship when compared to their peers. These results and conclusions may not be generalized to EM senior medical student clerkships at other institutions with a dissimilar clinical experience or evaluation method.

Address for Correspondence: Lance Hoffman MD, 981150 Nebraska Medical Center, Omaha, NE 68198-1150. Email: LHoffman@UNMC.edu.

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Inter-Rater Reliability of Historical Data Collected by Non-Medical Research Assistants and Physicians in Patients with Acute Abdominal Pain

Angela M. Mills, MD
Anthony J. Dean, MD
Frances S. Shofer, PhD
Judd E. Hollander, MD
Christine M. McCusker, RN
Michael K. Keutmann, BA
Esther H. Chen, MD

University of Pennsylvania, Department of Emergency Medicine

Supervising Section Editor: Craig L. Anderson, MPH, PhD
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Objectives: In many academic emergency departments (ED), physicians are asked to record clinical data for research that may be time consuming and distracting from patient care. We hypothesized that non-medical research assistants (RAs) could obtain historical information from patients with acute abdominal pain as accurately as physicians.

Methods: Prospective comparative study conducted in an academic ED of 29 RAs to 32 resident physicians (RPs) to assess inter-rater reliability in obtaining historical information in abdominal pain patients. Historical features were independently recorded on standardized data forms by a RA and RP blinded to each others' answers. Discrepancies were resolved by a third person (RA) who asked the patient to state the correct answer on a third questionnaire, constituting the "criterion standard." Inter-rater reliability was assessed using kappa statistics (κ) and percent crude agreement (CrA).

Results: Sixty-five patients were enrolled (mean age 43). Of 43 historical variables assessed, the median agreement was moderate (κ 0.59 [Interquartile range 0.37-0.69]; CrA 85.9%) and varied across data categories: initial pain location (κ 0.61 [0.59-0.73]; CrA 87.7%), current pain location (κ 0.60 [0.47-0.67]; CrA 82.8%), past medical history (κ 0.60 [0.48-0.74]; CrA 93.8%), associated symptoms (κ 0.38 [0.37-0.74]; CrA 87.7%), and aggravating/alleviating factors (κ 0.09 [-0.01-0.21]; CrA 61.5%). When there was disagreement between the RP and the RA, the RA more often agreed with the criterion standard (64% [55-71%]) than the RP (36% [29-45%]).

Conclusion: Non-medical research assistants who focus on clinical research are often more accurate than physicians, who may be distracted by patient care responsibilities, at obtaining historical information from ED patients with abdominal pain.
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INTRODUCTION

A busy emergency department (ED) is a challenging site for collecting data for prospective clinical trials. Frequently, treating physicians are asked to enroll eligible patients and complete structured data forms, a time-consuming process that can interfere with clinical responsibilities. Research assistants (RAs) without formal medical training [e.g., undergraduate and post-baccalaureate students] have been used to assist

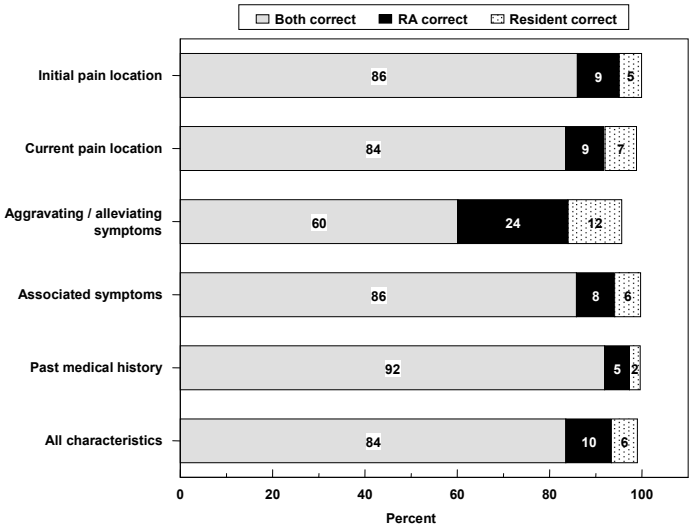

Figure 1. Accuracy of historical features by research assistants and physicians

in this process by identifying eligible patients, obtaining consent, documenting demographic information on standard data forms, and assisting with other data collection and management.[1-3]

Historical and physical examination features remain the basis for decision making about work-up and treatment of patients with acute abdominal pain; therefore, they are usually considered to be essential variables in research on this topic. Several studies have suggested that historical information obtained by medical providers may have significant inter-observer variability. In one such study, information recorded on standardized data sheets in a cohort of stroke patients revealed significant discrepancies in historical elements taken by six neurologists.[4] In a study of chest pain patients, the historical features documented by nurse practitioners were less typical of angina pectoris compared to those documented by physicians after interviewing the same patients.[5] These studies highlight the importance of assessing the reliability of the data- collection instrument as an integral part of the research project.

No study to date has examined the reliability of the non-medical RAs in obtaining historical information for research. We designed and piloted a survey instrument containing standard, simple historical questions about abdominal pain. We hypothesized that non-medical RAs can reliably use this questionnaire and be at least as accurate as resident physicians (RPs) in obtaining historical information from patients with acute abdominal pain.

METHODS

Study Design

We conducted a prospective comparative study to evaluate the reliability of the historical features obtained from ED patients with abdominal pain using a standard questionnaire administered by RAs compared to RPs. Our Institutional Committee on Research involving Human Subjects at the University of Pennsylvania approved the study. Informed consent was obtained from all subjects.

Study Setting and Population

This study was conducted at an urban university hospital ED with a annual census of approximately 55,000 visits. Adult patients with acute abdominal pain were enrolled from April 6 to 22, 2007. A survey instrument with questions about historical features was completed independently for each patient by a RA and a RP. RAs are undergraduate and post-baccalaureate students enrolled in the Academic Associate Program,[3, 6] a structured class at the University of Pennsylvania for which course credit is given. Students are responsible for attending research-related classes and working shifts in the ED during which they identify and enroll eligible patients for research projects, and in the current study, obtain historical information about patients with acute abdominal pain.

Study Protocol and Measurements

From 7 AM-midnight, seven days per week, the RAs identified and enrolled patients 18 years of age or older who presented with non-traumatic abdominal pain of less than 72 hours duration. Patients were excluded if they were pregnant, or if within the previous seven days they had sustained abdominal trauma or had an abdominal surgical procedure. A standardized questionnaire was completed independently by the RA and RP caring for the patient within 20 minutes of each other. The time of assessment was recorded on the data forms. Discrepancies between the two forms were resolved by a third person (RA) who was coached to specifically ask the patient: "we did not have a clear understanding of your answer to this question … [question repeated]," thus allowing patients to use either of their previous responses. This form was used as the "criterion standard." Formal training sessions were provided to the RAs teaching them open-ended and neutral questioning techniques most likely to avoid influencing respondents.

Data Analysis

Descriptive data are presented as means $\pm$ standard deviation, frequencies, and percentages. Cohen's kappa (κ) statistic and percent crude agreement (CrA), both with 95% confidence intervals (95% CIs), were used to measure inter-rater reliability. As described elsewhere, κ values range between 0 (chance agreement) and 1.00 (complete agreement); $\kappa<0.2$ represents poor agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 good agreement, and 0.81-1.00 excellent agreement.[7] To summarize specific types of questions (e.g., past medical history) we present the median

Table 1. Kappa statistics and crude agreement for abdominal pain characteristics

Characteristics	Kappa	95% CI		Crude agreement	95% CI	
Initial pain location						
Pain start RUQ*	0.73	0.54	0.92	89.2%	79.1%	95.6%
Pain start LUQ*	0.61	0.40	0.82	83.1%	71.7%	91.2%
Pain start RLQ*	0.60	0.41	0.79	80.0%	69.1%	89.2%
Pain start LLQ*	0.57	0.37	0.77	78.5%	66.5%	87.7%
Pain start epigastrium	0.77	0.57	0.96	92.3%	83.0%	97.5%
Pain start both lower quadrants	0.79	0.64	0.95	90.8%	81.0%	96.5%
Pain start diffuse	0.66	0.39	0.94	92.3%	83.0%	97.5%
Pain start right flank	0.23	-0.04	0.50	80.0%	69.1%	89.2%
Pain start left flank	0.59	0.34	0.85	87.7%	77.2%	94.5%
Median and IQR*	**0.61 (0.59-0.73)**			**87.7% (80.0-90.8%)**		
Current pain location						
Pain now RUQ	0.673	0.482	0.864	85.9%	75.0%	93.4%
Pain now LUQ	0.602	0.401	0.802	81.3%	69.5%	69.5%
Pain now RLQ	0.594	0.398	0.790	79.7%	67.8%	88.7%
Pain now LLQ	0.466	0.248	0.683	73.4%	60.9%	83.7%
Pain now epigastrium	0.656	0.442	0.870	87.5%	76.9%	94.5%
Pain now both lower quadrants	0.692	0.508	0.877	85.9%	75.0%	93.4%
Pain now diffuse	0.744	0.508	0.979	93.8%	84.8%	98.3%
Pain now right flank	0.455	0.184	0.726	82.8%	71.3%	91.1%
Pain now left flank	0.301	0.009	0.592	81.3%	69.5%	69.5%
Median and IQR	**0.60 (0.47-0.67)**			**61.5% (53.1-67.0%)**		
Aggravating/alleviating symptoms						
Pain ever gone	0.237	-0.010	0.480	68.3%	55.3%	79.4%
Eating aggravating	0.130	-0.050	0.310	50.8%	38.1%	63.4%
Urinating aggravating	0.040	-0.160	0.240	76.9%	64.8%	86.5%
Coughing aggravating	0.310	0.090	0.520	63.1%	50.2%	74.7%
Antacid alleviating	-0.050	-0.270	0.160	41.5%	29.4%	54.4%
Eating alleviating	-0.020	-0.200	0.160	60.0%	47.1%	72.0%
Median and IQR	**0.09(-0.01-0.21)**			**61.5% (53.1-67.0%)**		
Associated symptoms						
Vomiting	0.740	0.570	0.900	87.7%	77.2%	94.5%
Diarrhea	0.780	0.600	0.960	92.3%	83.0%	97.5%
Dysuria	NC*			96.9%	89.3%	99.6%
Pass gas	0.160	-0.090	0.400	60.0%	47.1%	72.0%
Fever	0.380	0.150	0.610	73.8%	61.5%	84.0%
Vaginal discharge	NC*			96.0%	86.3%	99.5%
Vaginal bleeding	0.370	-0.190	0.930	94.0%	83.5%	98.8%
Median and IQR	**0.38 (0.37-0.74)**			**87.7% (73.8-93.2%)**		

Table 1. Kappa statistics and crude agreement for abdominal pain characteristics

Characteristics	Kappa	95% CI		Crude agreement	95% CI	
Past Medical History						
HX* Abdominal surgery	0.690	0.520	0.870	84.6%	73.5%	92.4%
HX Gallstones	0.580	0.260	0.900	92.3%	83.0%	97.5%
HX Liver Disease	0.500	0.130	0.880	92.3%	83.0%	97.5%
HX Pancreatitis	1.000	1.000	1.000	100.0%	94.5%	100.0%
HX Inflammatory bowel disease	1.000	1.000	1.000	100.0%	94.5%	100.0%
HX Irritable bowel syndrome	0.420	0.020	0.820	92.3%	83.0%	97.5%
HX Diverticulitis	0.550	0.090	1.000	95.4%	87.1%	99.0%
HX GERD*	0.210	0.000	0.420	72.3%	59.8%	82.7%
HX Kidney stones	0.610	0.390	0.830	86.2%	75.3%	93.5%
HX Cancer	0.870	0.700	1.000	96.9%	89.3%	99.6%
HX Diabetes	0.700	0.390	1.000	95.4%	87.1%	99.0%
HX CAD*	0.380	-0.180	0.930	95.4%	87.1%	99.0%
Median and IQR		**0.60 (0.48-0.74)**		**93.8% (85.9-95.8%)**		
Overall Median		**0.59 (0.37-0.69)**		**85.9% (77.7-92.3%)**		

RUQ, right upper quadrant; *LUQ,* left upper quadrant; *RLQ,* right lower quadrant; *LLQ,* left lower quadrant; *IQR,* interquartile range; *NC,* not calculable; *HX,* history; *GERD,* gastroesophageal reflux disease; *CAD,* coronary artery disease.

kappa values with interquartile ranges (IQRs). Data were analyzed using SAS statistical software (Version 9.1, SAS Institute, Cary, NC) and StatXact (Version 6.1, Cytel Software Corporation, Cambridge, MA).

RESULTS

Sixty-five patients with acute abdominal pain were surveyed by 29 RAs and 32 RPs. The median age of the abdominal pain patients was 43 years; 77% were female and 54% black. There were 49 variables, of which 43 were dichotomized responses. The remaining six historical variables were related to times (e.g. when was the last time you vomited), which proved highly variable and not easily dichotomized. These were excluded. Therefore, there were 2754 comparisons (some variables had fewer comparisons and some were restricted by gender), of which there were 458 discrepancies between RP and RA (17%).

Inter-rater reliability measures for all historical variables are listed in Table 1. Overall, the median agreement was moderate (κ 0.59 [IQR 0.37-0.69]; CrA 85.9%) but varied across data categories: initial pain location (κ 0.61 [IQR 0.59-0.73]; CrA 87.7%), current pain location (κ 0.60 [IQR 0.47-0.67]; CrA 82.8%), past medical history (κ 0.60 [IQR 0.48-0.74]; CrA 93.8%), associated symptoms (κ 0.38 [IQR 0.37-0.74]; CrA 87.7%), and aggravating/alleviating factors (κ 0.09 [IQR -0.01-0.21]; CrA 61.5%).

Overall, crude agreement for both groups was above 80% in all but one of the five general categories (Figure 1). Of the 458 discordant results between the RP and RA, criterion standard was available for 429 (94%). Of these disagreements, the RA more often agreed with the criterion standard (N=274, 64% [55%-71%] compared with the RP (N=155, 36% [29-45%]. (See Table 2.)

DISCUSSION

This study explores the inter-rater reliability of historical features obtained by RAs and RPs using a standard questionnaire in the evaluation of abdominal pain. We found an overall moderate agreement between RAs and RPs for 43 historical variables. There was good agreement for initial pain location and moderate agreement for current pain location and past medical history. For associated symptoms, there was fair agreement using the kappa statistic with a crude agreement of 88%. The poorest agreement was found for aggravating and alleviating factors in which information obtained by both groups of investigators was correct only 62% of the time. The mathematical properties of the κ statistic determine that low rates of discrepancy in infrequent clinical findings will result in lower κ scores than the same rate in common ones. This may have resulted in the wide range of alleviating and aggravating factors, any one of which is encountered relatively infrequently, appearing to result in lower κ scores.

Our results are consistent with prior studies of inter-rater reliability of physicians obtaining historical features,

Table 2. Accuracy amongst discordant pairs compared to criterion standard

Characteristics	Number discordant pairs	%RA correct	%RP correct
Initial pain location			
Pain start RUQ*	7	71.4%	28.6%
Pain start LUQ*	11	63.6%	36.4%
Pain start RLQ*	12	50.0%	50.0%
Pain start LLQ*	14	57.1%	42.9%
Pain start epigastrium	5	100.0%	0.0%
Pain start both lower quadrants	6	50.0%	50.0%
Pain start diffuse	5	60.0%	40.0%
Pain start right flank	13	76.9%	23.1%
Pain start left flank	8	75.0%	25.0%
Median and IQR*		**63.6% (57.1-75.0%)**	**36.4% (25.0-42.9%)**
Current pain location			
Pain now RUQ	8	37.5%	62.5%
Pain now LUQ	11	45.5%	54.5%
Pain now RLQ	13	53.8%	46.2%
Pain now LLQ	16	56.3%	43.8%
Pain now epigastrium	7	42.9%	57.1%
Pain now both lower quadrants	8	75.0%	25.0%
Pain now diffuse	3	66.7%	33.3%
Pain now right flank	10	60.0%	40.0%
Pain now left flank	12	66.7%	33.3%
Median and IQR		**56.3% (45.5-66.7%)**	**43.8% (33.3-54.5%)**
Aggravating/alleviating symptoms			
Pain ever gone	19	63.2%	36.8%
Eating aggravating	27	74.1%	25.9%
Urinating aggravating	14	64.3%	35.7%
Coughing aggravating	21	71.4%	28.6%
Antacid alleviating	36	63.9%	36.1%
Eating alleviating	21	66.7%	33.3%
Median and IQR		**65.6% (64.0-70.2%)**	**34.5% (29.8-36.0%)**
Associated symptoms			
Vomiting	7	71.4%	28.6%
Diarrhea	5	60.0%	40.0%
Dysuria	2	100.0%	0.0%
Pass gas	26	65.4%	34.6%
Fever	17	41.2%	58.8%
Vaginal discharge	2	50.0%	50.0%
Vaginal bleeding	3	66.7%	33.3%
Median and IQR		**65.4% (55.0-69.0%)**	**34.6% (31.0-45.0%)**

Table 2. Accuracy amongst discordant pairs compared to criterion standard

Characteristics	Number discordant pairs	%RA correct	%RP correct
Past Medical History			
HX* Abdominal surgery	9	55.6%	44.4%
HX Gallstones	5	60.0%	40.0%
HX Liver Disease	5	100.0%	0.0%
HX Pancreatitis	0	no discordant pairs	no discordant pairs
HX Inflammatory bowel disease	0	no discordant pairs	no discordant pairs
HX Irritable bowel syndrome	4	100.0%	0.0%
HX Diverticulitis	3	0.0%	100.0%
HX GERD*	17	64.7%	35.3%
HX Kidney stones	9	77.8%	22.2%
HX Cancer	2	50.0%	50.0%
HX Diabetes	3	100.0%	0.0%
HX CAD*	3	100.0%	0.0%
Median and IQR		**62.4% (54.2-83.3%)**	**37.6% (16.7-45.8%)**
Overall Median		**63.9% (54.7-71.4%)**	**36.1% (28.6-45.3%)**

RUQ, right upper quadrant; *LUQ,* left upper quadrant; *RLQ,* right lower quadrant; *LLQ,* left lower quadrant; *IQR,* interquartile range; *NC,* not calculable; *HX,* history; *GERD,* gastroesophageal reflux disease; *CAD,* coronary artery disease.

showing fair to excellent agreement (κ range 0.27-0.89) in hospitalized chest pain patients,[8] fair to good agreement (κ range 0.37-0.69) in suspected stroke patients,[9] and good agreement (κ range 0.58-0.71) in patients with suspected osteoarthritis.[10] The current study also supports the findings of reports in which non-physician army medical practitioners demonstrated good overall agreement compared to physicians in the assessment of upper respiratory infection.[11, 12] Specific to abdominal pain, our results were also consistent with those of a recent study comparing pediatric emergency physicians with surgeons in the evaluation of appendicitis in children showing fair to excellent agreement (κ range 0.33-0.82) for historical questions.[13]

Accurate data collection is an essential component of high quality clinical research. Prospectively collected data is generally considered to be of higher quality than data collected retrospectively or through chart abstraction. In many prospective studies conducted in the ED, the treating physician is asked to record subjects' clinical data. This process may be cumbersome and time consuming. It may also be distracting or interfere with the physicians' other responsibilities or create a fundamental conflict between the physician's role as care provider and as researcher. To date, this is the first study to compare the ability of RAs with no formal medical training to RPs in obtaining historical information for research purposes. If, as the current study suggests, non-medical research assistants can obtain historical information about ED patients' acute abdominal pain that is as accurate or more accurate than that obtained by the treating physician, the burden of data collection may be lifted from the treating physician, allowing it to be obtained and recorded in a less hurried and more meticulous manner. This may result in higher quality medical research on this topic in the ED setting.

LIMITATIONS

As this study was conducted in a single institution with an established Academic Associate Program, our results may not be generalizable to other practice settings. Under-enrollment of patients evaluated in the overnight hours, the most acutely ill patients, and patients who did not consent to participate in the study may have caused some selection bias. The authors do not know of any "gold standard" available to be certain that patient responses to historical items are accurate. As such, this study design was our best attempt to study accuracy and inter-rater reliability in obtaining historical data for patients with abdominal pain. It is possible that patients may have been prompted into providing answers that were consistent with one of their prior responses when being interviewed by the third person for the "criterion standard" form. It is also possible that the third-person interviewer might have had a tendency to "coach" respondents to resolve discrepancies in a way that supported the data obtained by the first RA. Neither RAs nor RPs were blinded to the purpose of the study, which may have biased our results.

CONCLUSION

Non-medical research assistants focused on clinical research are often more accurate than physicians, who may be distracted by patient care responsibilities, at obtaining data for clinical research. They can reliably use a standardized data collection sheet to obtain historical information from patients who present to the ED with acute abdominal pain.

Address for Correspondence: Angela M. Mills, MD. Department of Emergency Medicine, Ground Floor, Ravdin Building, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia, PA 19104-4283. Email: millsa@uphs.upenn.edu.

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Incidence of Serious Bacterial Infections in Ex-premature Infants with a Postconceptional Age Less Than 48 Weeks Presenting to a Pediatric Emergency Department

Nobuaki Inoue, MD*
Tommy Y. Kim, MD*
Anne Marie Birkbeck-Garcia, MD†
Andrew Givner, MD‡
T. Kent Denmark, MD*

* Loma Linda University Medical Center and Children's Hospital, Department of Emergency Medicine, Division of Pediatric Emergency Medicine
† Kaiser Permanente Southern California, Department of Pediatrics
‡ Desert Regional Medical Center, Department of Emergency Medicine

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Objectives: Premature infants are at higher risk of developing serious bacterial infections (SBI). However, the incidence of SBI in ex-premature infants presenting to the emergency department (ED) remains undetermined. The objective of this study is to examine the incidence of SBI in ex-premature infants with a postconceptional age of less than 48 weeks presenting to a pediatric ED.

Methods: A retrospective medical record review was conducted on 141 ex-premature infants with a postconceptional age of less than 48 weeks who had a full or partial septic work up completed in a pediatric ED between January 1, 1998 and March 31, 2005.

Results: The overall median gestational age at birth was 35 weeks (IQR 33-36 week) and the overall median postconceptional age at ED presentation was 40 weeks (IQR 37-42 weeks). Thirteen (9.2%) infants were found to have a SBI. Five subjects had pneumonia, four with bacteremia, two with pyelonephritis, and two with a concomitant infection of meningitis/pneumonia and bacteremia/pyelonephritis.

Conclusion: The results of this study reveal that the incidence of SBI in ex-premature infants with a postconceptional age of less than 48 weeks is similar to in-term infants (9.2%) and is consistent with previously published incidence rates in-term infants (10%).
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INTRODUCTION

Premature infants are considered to be at higher risk of developing serious bacterial infections (SBIs). A younger gestational age at birth is associated with higher incidence of SBIs;[1-4] however, there is no literature showing the incidence of SBIs in discharged premature infants presenting to the emergency department (ED) at a postconceptional age of less than 48 weeks. Practice among ED practitioners varies due to the lack of evidence regarding SBIs in ex-premature infants whose postconceptional age is still less than 48 weeks, especially if their chronological age is more than two months. The objective of this study is to examine the incidence of SBIs in ex-premature infants presenting to a pediatric ED up to a postconceptional age of 48 weeks.

METHODS

Data Collection

A retrospective medical record review was conducted on ex-premature infants who presented to a university-based children's hospital pediatric ED between January 1, 1998 and March 31, 2005. A data collection sheet was completed by the primary study investigator (NI). Study subjects were identified from ED medical records with an ICD-9 code for prematurity. Data extracted from the records included the patient's gestational age at birth, age during the ED visit, gender, race, reason for ED visit, confounding variables such as underlying medical conditions, results of urine, blood, cerebrospinal fluid (CSF) cultures, chest x-ray results, and follow up for any return visit within one month for a SBI.

Patients

Inclusion criteria included premature infants delivered at less than a gestational age of 37 weeks, who returned to the pediatric ED with a postconceptional age less than 48 weeks at the time of presentation, and had a partial or full septic work up performed by the attending physician on duty. Full septic work up was defined as conducting all of these studies: blood, urine, and CSF cultures as well as chest radiograph; and partial septic work up was defined as conducting any of these studies. Exclusion criteria included those that were not born at our institution, missing/incomplete records, or those that did not have a full or partial septic work up completed in the ED.

A SBI was considered positive with any positive finding on urine, blood, CSF cultures or chest radiograph. Urine cultures were considered positive if a catheterized urine specimen grew greater than 10,000 colony forming units per milliliter of a single organism. Blood cultures were considered positive if a true pathogen was recovered or if skin flora was recovered through a central line. CSF cultures were considered positive if a true pathogen was recovered from the spinal fluid or if skin flora was isolated in the presence of a ventriculoperitoneal shunt. Chest radiograph readings were final interpretations read by a pediatric radiologist, and clinical correlation with the clinical history was used to determine the positive findings on the chest radiograph. Per ED policy during the study period, all patients discharged from the ED with cultures drawn are followed up by a clerical nurse and are often asked to return to the ED for positive culture results. Medical records were reviewed for return visits to the ED or hospitalization within one month of the initial ED visit to ensure that no patient was readmitted for a SBI after the initial ED visit.

Statistical Analysis

Data were analyzed to generate descriptive statistics using Statistical Package for the Social Sciences version 10. (SPSS Inc., Chicago, Illinois) Given that our data are not normally distributed, we present our results as medians with interquartile (IQR) ranges. Chi-square and Mann-Whitney test were used to evaluate the differences between groups. This study was approved by the local institutional review board.

RESULTS

There were 190 medical records identified as premature infants seen in the ED during the study period requiring a work up for a possible SBI. Forty nine subjects were excluded due to non-infectious ED visits (17), greater than 48 weeks postconceptional age at time of ED visit (31), and incomplete medical record (1). The remaining 141 subjects (64 females) were included into the analysis. (Figure 1)

The overall median gestational age at birth was 35 weeks (IQR 33-36 week) with no significant difference between the SBI and non-SBI group (p=0.60). The overall median postconceptional age at ED presentation was 40 weeks (IQR 37-42 weeks) with no significant difference between the SBI and non-SBI group (p=0.57). Gender and race were not found to be significant predictors of a SBI (p = 0.17 and p = 0.58, respectively). The common presenting symptoms that prompted a work up included apnea (29), fever (26), respiratory distress (24), irritability (6), and lethargy (4). Forty infants (28.4%) had a full septic work up completed in the ED.

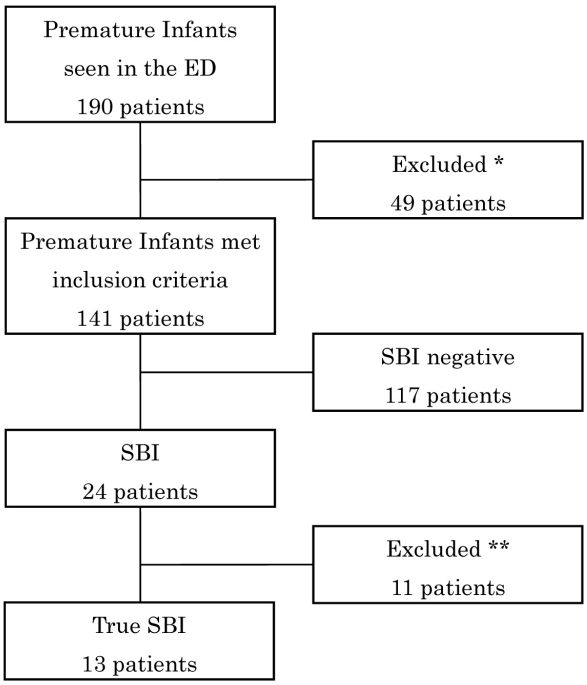

Figure 1. Flow diagram for patient inclusion
** Non-infectious ED visit (17), greater than 48 weeks postconceptional age at time of ED visit (31), and incomplete medical record (1)*
*** Urine with mixed flora (3), urine with <10,000 colony forming units per milliliter of a single organism (2), blood with contaminant (5), and CSF with contaminant (1)*

Twenty-four subjects were found to have positive culture results or radiographic findings suggestive of a SBI. Eleven subjects were excluded due to urine with mixed flora (3), urine with <10,000 colony forming units per milliliter of a single organism (2), blood with contaminant (5), CSF with contaminant (1) (Figure 1). The remaining 13 (9.2%) infants were found to have a SBI and admitted. Five subjects were diagnosed as pneumonia (38.4%), four had bacteremia (30.8%), two had pyelonephritis (15.4%), and one each for meningitis/pneumonia and bacteremia/ pyelonephritis (7.7%) (Table 1).

The only confounding factor found to be clinically significant was a patient with a vertriculoperitoneal shunt who had a positive CSF culture and a positive chest radiograph four weeks after shunt placement (subject 11). Of the infants discharged home from the ED after septic work up, no patient was found to have a SBI within one month of discharge.

Table 1. Ex-premature infants with SBIs

Case	Birth age (wks)	Actual age (wks)	Signs/ Symptoms	Positive results
1	30	7	apnea	**Urine:** *Klebsiella pneumonia*
2	31	4	apnea	**CXR:** LLL infiltrate
3	32	8	lethargy	**CXR:** Consolidation on left entire lung
4	32	11	respiratory distress	**CXR:** RLL pneumonia
5	33	3	apnea	**CXR:** LLL infiltrate
6	35	1	lethargy	**Urine:** *Enterobacter cloacae*
7	35	3	fever	**Blood:** *Streptococcus viridans*
8	35	6	respiratory distress	**CXR:** RUL infiltrate
9	35	11	fever	**CXR:** RML infiltrate **CSF:** *Streptococcus viridans* and *Neiserria sp*
10	36	1	blood stools	**Blood:** *Streptococcus viridans*
11	36	2	fever	**Urine:** Group B *Streptococcus* **Blood:** Group B *Streptococcus*
12	36	3	apnea	**Blood:** *Klebsiella*
13	36	10	cellulitis	**Blood:** Group A *Streptococcus* and *Staphylococcus aureus*

CXR, Chest X-ray*; LLL,* left lower lobe*; RLL,* right lower lobe*; RUL,* right upper lobe*; RML,* right middle lobe*; CSF,* cerebral spinal fluid.

DISCUSSION

Prematurity is a common risk factor for SBIs in infants.[1-4] The premature infant has a less developed immune system than the in-term infant as more maternal immunoglobulin G (IgG) is transferred to the fetus through the placenta later in the pregnancy.[5] Serum level of IgG is lower among preterm infants,[6] and a lower level of serum IgG is also a risk factor for SBIs among the premature infants.[7] There is also a higher incidence of neutropenia observed in premature infants[8, 9] and this is associated with higher mortality due to infection in these infants.[9]

Approximately 12 to 28% (n = 250 - 372) of neonates who present to the pediatric ED with fever have SBIs,[10-12] and up to 10% (n = 1298) of febrile young infants up to three months of age with low risk criteria have SBIs.[13, 14] There is no report identified to date showing the incidence of SBIs among ex-premature infants who present to the ED. The incidence of SBI found in this study was similar to the previous studies.

No statistical difference was found between the groups with SBIs and without SBIs in the median gestational birth age and the median postconceptional age at ED presentation. Confounding factors, such as indwelling devices, immunocompromised conditions, or any other underlying medical conditions were also assessed and revealed that none of subjects developed SBIs except one patient with a vertriculoperitoneal shunt. Further investigation is necessary to conclude their association with developing a SBI.

There are several limitations to this study. Above all, this is a retrospective study. Study subjects may have been missed due to miscoding. Conducting a full septic work up was determined by the attending physician on-duty. Although no infant returned to the ED or inpatient unit for a SBI within one month of discharge from the ED, they may have presented to another facility. However, all these concerns of "missing cases" would increase our incidence. Secondly, this study only evaluated 141 subjects, a relatively small sample size. We did not conduct a sample-size calculation because of the retrospective nature of this descriptive study.

Current guidelines suggest that febrile infants less than one month of age have a high risk of SBI and recommend conducting a full septic work up and hospitalization.[15, 16] Well-appearing febrile infants with low risk criteria between 28 to 90 days old can be treated outpatient with full or partial work up. However, being "full-term" is one criterion for "low risk." Therefore, all febrile ex-premature infants in this age range should have a full septic work up completed along with hospitalization based on these guidelines.[15] Clinical dilemma exists when considering chronological age vs postconceptional age. Based on our results, the postconceptional age for most of the subjects with SBI was less than 44 weeks, except one (subject 13). Further investigations are required to resolve this dilemma. Our results show that the incidence of SBI in ex-premature infants <48 weeks post-conceptual age is similar to that of in-term infants as reported in prior studies.

Address for Correspondence: Nobuaki Inoue, MD. 11234 Anderson Street, Suite A 108, Loma Linda, California 92354. Email: ninoue@llu.edu.

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Purpura Fulminans: A Cutaneous Marker of Disseminated Intravascular Coagulation

Sudip Kumar Ghosh, MD, DNB, D.DERMAT* * R.G. Kar Medical College, Kolkata, India, Department of Dermatology, Venereology, and Leprosy
Debabrata Bandyopadhyay, MD*
Abhijit Dutta, MD† † R.G. Kar Medical College, Kolkata, India, Department of Pediatric Medicine

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A previously healthy 14-year-old girl presented to the emergency department with high fever, cough, shortness of breath and right lobar pneumonia on chest radiograph. She had extensive purpura with hemorrhagic bullae on her left leg. The patient was very ill-appearing with hypotension, tachycardia, tachypnea, and oliguria. There was no other bleeding. Hemogram showed leukocytosis (13000/cmm) with 35% bands, platelets 76,000/ml and sedimentation rate of 98 mm. The prothrombin time and partial thromboplastin time were prolonged and the fibrin degradation products were grossly elevated. Blood culture grew group-A streptococci. A diagnosis of purpura fulminans from septic shock was made. She was resuscitated and given parenteral antibiotics and platelets. The patient recovered within two weeks and later had skin grafting.

Purpura fulminans is an infrequent, often fatal, acute cutaneous reaction resulting from infective or non-infective conditions.[1] When it arises during sepsis, in-hospital mortality is 42%.[2] Antecedent infections are most commonly group-A streptococcus, staphylococcus, peumococcus, vibrio, and meningococcus, and less commonly varicella.[3] Neonates with protein C and protein S deficiencies are at higher risk for purpura fulminans. Patients with systemic lupus erythematosis may have antiphospholipid antibody syndrome.[1] The disease may occur without preceding illness.[1]

Purpura fulminans from sepsis requires surgical debridement, skin grafting and even amputation.[4] Normal saline resuscitation restores volume and promotes urine output >0.5ml/kg/hour.[5] Although there is no proven benefit, treatment of severe disseminated intravascular coagulation with purpura fulminans with heparin may be warranted.[5,6] Most clinicians prefer to provide platelet replacement if platelet counts drop below 20,000/mL.[5,6] Administration of protein C concentrate early in the course of the disease may reduce both morbidity and mortality.[3] There is some evidence that recombinant tissue plasminogen activator infusion may result in improved organ perfusion and cardiac performance.[7]

Address for Correspondence: Dr. Sudip Kumar Ghosh Vill + P.O –Rajballavpur(Via-Maslandpur) Dist –24 parganas(N) ,West Bengal, PIN –743289, India e-mail: dr_skghosh@yahoo.co.in.

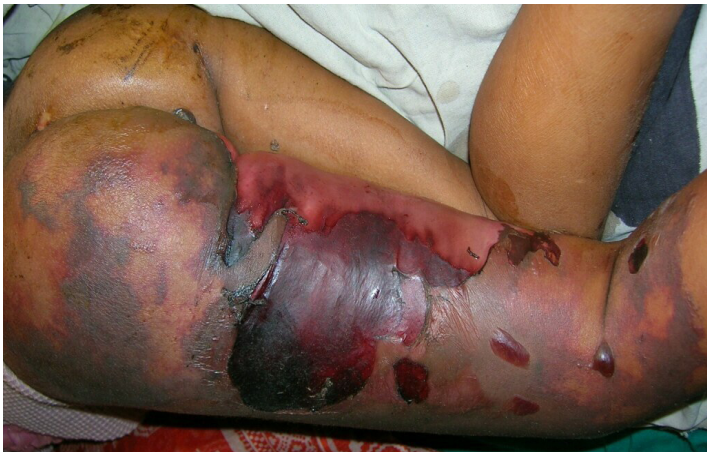

Figure. Extensive areas of purpura, ecchymosis and skin necrosis with hemorrhagic blebs and disrupted bullae, involving the left lower extremity.

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A Statistical Analysis of Santa Barbara Ambulance Response in 2006: Performance Under Load

Joshua C. Chang, MS University of California, Los Angeles, Department of Statistics
Frederic P. Schoenberg, ScB, PhD

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Ambulance response times in Santa Barbara County for 2006 are analyzed using point process techniques, including kernel intensity estimates and K-functions. Clusters of calls result in significantly higher response times, and this effect is quantified. In particular, calls preceded by other calls within 20 km and within the previous hour are significantly more likely to result in violations. This effect appears to be especially pronounced within semi-rural neighborhoods.
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INTRODUCTION

The importance of rapid ambulance response to emergency medical crises has been well-documented. Indeed, after early access, early cardiopulmonary resuscitation (CPR), and early defibrillation, early access to advanced care is the fourth and final link of the Cardiac Chain of Survival,[1] according to the American Heart Association .While a study in Ontario, Canada concluded that to improve survival rates after cardiac arrest, ambulance response times must be reduced and the frequency of bystander-initiated CPR increased,[2] a subsequent study found that system wide implementation of full advanced life support programs had a negligible impact on mortality among victims of major trauma.[3] A study performed in King County, Washington determined the survival rate to decrease by 2.1% per minute without intervention by advanced cardiac life support (ACLS).[4] When urban response time was correlated with myocardial infarction survival rate in a Southwestern metropolitan county with a population of 620,000 a response time of under five minutes was found to have a beneficial impact on survival.[5] Similarly, studies have shown that response time and transport time are correlated with survival rates for abdominal gunshot wound victims, and that the overall total emergency medical services (EMS) pre-hospital time interval was significantly lower for trauma survivors than for non-survivors.[6,7]

While any decrease in ambulance response time is likely to be beneficial, several studies have taken the approach of spatial-temporal modeling of response times to highlight particular areas where heightened efforts toward improved response may be especially desirable. For instance, a study in Houston, Texas used a queueing model to show that increased dispersion of ambulances in areas away from those of high demand improves the tail of the response time distribution.[8] Similarly, a computer-based model developed for Los Angeles County was able to reliably predict response time and search for an optimum pattern of ambulance deployment to minimize mean response time as well as response time excesses.[9]

The focus of this paper is the retrospective analysis of the spatial-temporal pattern of response times in Santa Barbara County, California in 2006 with particular attention to the impact of the number of spatial-temporally proximate emergency calls on response times. Our goal is to investigate the dependence of ambulance response time on system load, to identify particular areas where improvements might have the most effect. For a fixed region with a finite number of ambulances, one may anticipate that response times may increase during times when a substantial portion of the ambulances are unavailable due to previous emergencies.

METHODS

Data

Santa Barbara County consists of three geographic service areas. Each area is further divided into zones dependent upon population density. The fire department provides basic life support (BLS) first response within the two-tiered response system. ALS response and transport is contracted out to various ambulance companies. Santa Barbara has adapted ambulance response-time regulations dependent upon

population density (Table 1). The county operates on a base hospital system with each geographically defined base hospital providing all field medical direction. All approved hospitals in the county are designated base hospitals.

Response-time regulations effective January 2005 provided standards for the timeliness of an ambulance response given its response code and the population density of the area to which it is responding. From these regulations it was determined whether each dispatch event was in compliance with the standard, or whether it was a *violation*, i.e. an exceedance of local response-time standards.

County ambulance dispatch data for 2006 were provided by Santa Barbara's EMS agency for the UCLA Statistics Department's EMS study group, and this study was approved by the agency's director. As measures of ambulance response performance, both response time and response-time regulation compliance were used, with ambulance response times defined as the time elapsed between ambulance dispatch and ambulance on scene arrival. Events for which ambulance response time could not be determined due to missing data were excluded. Events where the location could not be determined are excluded from analysis as well. Since the focus of this study is on emergency calls, analysis of Code 3 dispatched calls (ambulance response with lights and sirens)[10] was emphasized, but other calls were considered as well since they are drawn from the same resource pool.

Table 1. Conditions for compliance (non-violation status), depending on response code and population density, according to Santa Barbara County ambulance response time regulations effective January 2005.

Response code	Population Density	First Responder	Ambulance Arrival
Code 3	Urban	< 8 minutes	< 10 minutes
Code 3	Semi-rural	< 15 minutes	< 17 minutes
Code 3	Rural	< 30 minutes	< 33 minutes

Data Analysis

Our analysis uses existing tools for analyzing spatial data. The spatial call distribution was estimated non-parametrically using kernel intensity estimation,[11,12,13] which involves smoothing the data and interpolating values between observations by averaging nearby values, weighting them by distance. Logistic regression[14] was used to investigate the relationship between the number of calls closely preceding any given incident and the percentage of violations. One aim of the present study is to look for evidence of spatial clustering of violation incidents, and in particular for clustering of violation incidents that had a positive number of preceding calls, and the inhomogeneous K-function[15,16] was used for these purposes.

Methodological Details

The R Language and Environment for Statistical Computing[17] was used to perform data management, Fisher's exact test, multiple comparisons, and spatial analyses. Variables recorded include the incident time, geographical address, incident type, response code, response district, response district type, ambulance dispatch time, ambulance on scene time, hospital arrival time, and incident clear time. The addresses were geo-coded by the EMS study group into longitude and latitude coordinates and subsequently transformed into more natural units of kilometers using the Universal Transverse Mercator coordinate system.

As a measure of system load at the time of each call, we define the statistic ß for each call, as follows: If $\{(t_i, \mathbf{x}_i); i = 1, ..., 21{,}944\}$ represents the collection of times (t_i) and locations ($\mathbf{x}_i$) of recorded calls, let $ß_i(\Delta_t, \Delta_x) = \sum_{j<i} \mathbf{1}\{t_i - t_j \le \Delta_t\}\ \mathbf{1}\{d(\mathbf{x}_i, \mathbf{x}_j) \le \Delta_x\}$, where **1** denotes the indicator function, and $d(\mathbf{x}_i, \mathbf{x}_j)$ denotes the spatial distance between locations $\mathbf{x}_i$ and $\mathbf{x}_j$. Thus $ß_i(\Delta_t, \Delta_x)$ represents the number of calls prior to call *i* that were within Δ_t hours and within Δ_x km of call *i*; such calls are subsequently referred to as *predecessors* of call *i*.

After many choices of the parameters Δ_t and Δ_x were inspected, particular attention was focused on the case where Δ_t = 1 hour and Δ_x = 20km, which appears to have the highest correlation with response time. The parameter Δ_x may be interpreted as an approximation of the average area of an ambulance dispatch region, while a possible interpretation of Δ_t may be the mean time required for an ambulance to return to service after it has been dispatched to a previous call.

To see how variation in the number ß of predecessors is associated with response time, the incidents were first blocked for response code and district type. Within each block, the relationship between ß and response time was smoothed using simple moving average (MA) filtering.[18]

If *M* represents the total number of ambulances available for service in a particular area, and *k* represents the number of ambulances that are actively responding to incidents, then *M-k* is the number of ambulances in service that are available to respond to new calls. One would expect response time to depend less heavily on *k* in regions where *M* is larger. Similarly, in such regions, one would anticipate a one-unit increase in ß to be associated with a smaller increase in mean response times for such regions.

A one-sided Fisher's exact test was used to determine whether the proportion of violations was significantly greater for incidents where ß>0, compared with incidents where ß=0. The relationship between the number of predecessors and the probability of a violation was summarized using logistic regression.[14]

The spatial call distribution was estimated non-parametrically using kernel intensity estimation, with an edge-corrected, isotropic Gaussian kernel.[11] Due to geo-coding

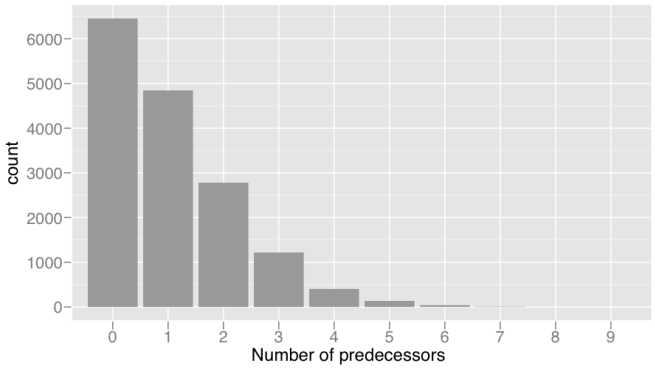

Figure 1. Histogram of the number of predecessors (ß) within 20 kilometers and within the previous hour of recorded calls.

precision inaccuracies, 24 call incidents lay outside of Santa Barbara County boundaries; for the kernel intensity estimate, these points were excluded.

The inhomogeneous K-function[15] was used to measure spatial clustering of violation incidents and of violation incidents that had a positive number of predecessors. The inhomogeneous K-function may be used as a measure of the degree of clustering or inhibition in points above and beyond what one would expect from a baseline model.[16] Here, we used the kernel estimate of the call rate at each location, scaled by the proportion of calls in violation, as a baseline model. Since many of the points in the data set lie near the county borders, the choice of edge correction technique may have a substantial impact on the estimated inhomogeneous K-function, so standard edge-correction methods were used.[11,12]

To identify areas where ß shows more of an effect on the proportion of violations, the fraction of calls that were violations among calls with predecessors was compared with the same fraction among calls without predecessors, for each spatial-temporal sub-region. This difference was computed for all calls within a bandwidth λ around each incident, provided there were at least 10 incidents within a distance of λ. As with other smoothing procedures, the bandwidth λ should be chosen to be sufficiently small so that local detail is detectable, but large enough so that main features are not obscured by local fluctuations.[11] Contours were drawn around regions where the difference in proportion of violations was 5% or greater for Code 3 calls. These areas reflect regions that might benefit the most from increased ambulance units or from optimizing the deployment pattern of existing ambulances.

An exponential distribution was fitted to the distribution of incident inter-arrival times, which are defined simply as the elapsed time between each incident and the event preceding it. The exponential distribution for inter-arrival times is consistent with a time-homogeneous Poisson process for call arrivals. As an alternative to the time-homogeneous Poisson process, we considered an inhomogeneous Poisson process with the temporal rate given by a kernel density estimate of the call times.

All multiple hypothesis testing was performed controlling family-wise error rate at $\alpha = 0.05$ using Holm's stepwise p-value correction.[18]

RESULTS

Of the 21,944 recorded emergency ambulance dispatch events in Santa Barbara County in 2006, 15,883 (72.4%) were Code 3 responses. Of these, 14,199 (89.4%) ambulances were to urban zoned areas, 1,382(8.7%) to semi-rural zoned regions, and 302(1.9%) to rural regions. Overall, 97.4% of Code 3 ambulance responses had response times within legislated limits.

Figure 1 shows the distribution of the number ß of predecessors, within the previous hour and within a radius of twenty km, for all Code 2 and Code 3 events in 2006. The rapid decrease in frequency of calls with number of predecessors is readily evident in Figure 1. The majority (68.5%) of events have fewer than two predecessors, and less than 2% of calls have more than four predecessors.

For calls where ß=0, i.e. calls without predecessors within one hour and within 20 km, the proportion of response time violations was 2.96%, whereas for calls with ß>0, the proportion of violations was 4.56%. The increase in probability of violation associated with having predecessors is highly significant (Fisher's exact test; $p = 7.2 \times 10^{-10}$). As ß increases, both the response time and the probability of a response time violation were seen to increase. The fit of a logistic regression model to the relationship between violation and ß implies that on average, for each additional predecessor, the log odds ratio $\log\{p \div (1-p)\}$ of the probability of violation increased by 19.1% ($p = 6.3 \times 10^{-11}$). The increase in response time associated with increasing ß is seen in Figure 2, which shows the response time as a function of number of predecessors, smoothed using a moving average (MA) filter. The positive association between ß and response time across different response codes and population densities is evident in Figure 2. However, the difference in probability of violation associated with changing ß is seen to vary across response codes and district types. The increase in proportion of violations is most pronounced in semi-rural calls.

Overall, the inter-arrival times between calls follow approximately an exponential distribution with a rate of 2.51 calls per hour. The rate of call arrivals seems to vary, however, according to the time of day, the highest frequency of calls were at mid-day. Indeed, the frequency of calls between 9 am and 6 pm is approximately three times higher than that between 2 am and 6 am. Not surprisingly, the proportion of calls where ß>0 varies according to the time of day as well. A multiple-comparison one-sided Fisher's exact test shows that for the hours of 9am-10am, 12pm-1pm, 5pm-6pm, 8pm-9pm, and 10pm-11pm, there is a statistically significantly

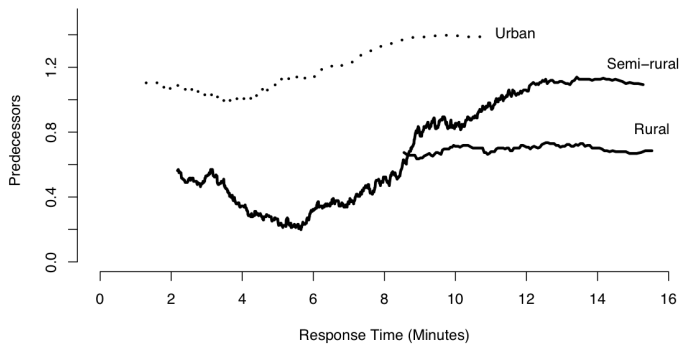

Figure 2. Number of predecessors (ß) versus response time for Code 3 responses, for different area types. Results for ß and response time are averaged within pixels, and filtered using a moving average (MA) filter.

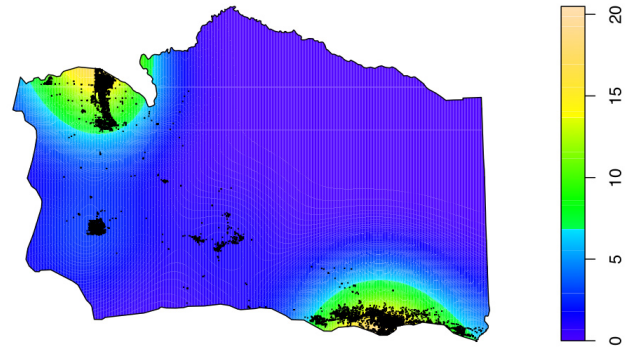

Figure 3. Kernel density estimate of the number of calls per squared kilometer during 2006. An isotropic Gaussian kernel was used. The points overlaid are the call locations.

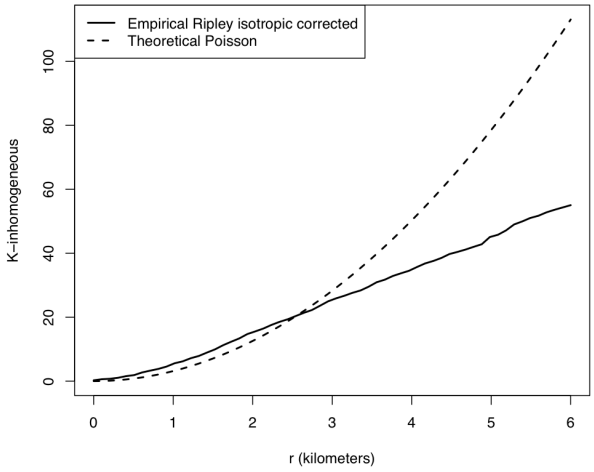

Figure 4. Inhomogeneous K-function for calls which were violations and which had predecessors.

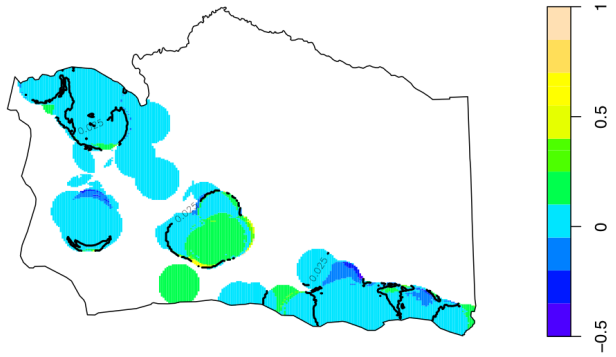

Figure 5. Smoothed plot of the proportion of Code 3 calls with ß > 0 which were violations minus the proportion of Code 3 calls with ß = 0 which were violations, for all areas with at least 10 calls within λ = 4km.

higher *proportion* of calls that have predecessors. The difference in proportion of calls that were violations for ß=0 and ß>0 varies according to the hour of day as well with the highest proportion between 6am-7am and between 5pm-6pm, perhaps due to traffic incidence. We then categorized the calls according to whether ß=0 by hour. We found that between 6am and 8am, 5pm-6pm, 8pm-9pm, and 11pm-11:59 pm, the proportion of calls with ß > 0 that are violations is much higher than that for calls with ß = 0. By contrast, during other hours the proportions are similar, and between 4am and 5am, the proportion of calls that are violations is actually higher for calls *without* predecessors than for calls with predecessors, perhaps due to lack of available personnel.

The spatial distribution of ambulance response events consists of several areas of high concentration, surrounded by vast areas of very low concentration, within the 9,814 km^2 that comprise Santa Barbara County. Figure 3 shows a kernel intensity estimate of the spatial call rates. One sees that the vast majority of calls are clustered within the main urban parts of Santa Barbara County, especially in the cities of Santa Barbara, Carpinteria and Goleta (in the southeast), with one cluster in Santa Maria (in the northwest), and another in Lompoc (toward the southwest).

Using the inhomogeneous K-function, one can assess the extent to which the observed points exhibit significant clustering beyond what one would expect from an inhomogeneous Poisson process. The inhomogeneous K-function, for calls which were in violation and which had a positive number of predecessors, is shown in Figure 4.

It is clear from Figure 4 that there are areas where violations are more likely to coincide with predecessors than expected under the null hypothesis that the violations occur according to an inhomogeneous Poisson process. Hence, the relationship between system load and occurrence of response time violations is not only inhomogeneous in time, but in space as well. Essentially, the inhomogeneous K-function in Figure 4 suggests that violations are more clustered at a scale of 0-3 km than one would expect if they were randomly

sampled from the distribution of all calls.

Figure 5 highlights the regions in Santa Barbara County where the difference between the proportion of violations for ß=0 and ß>0 ambulance responses exceeds 5%, within a distance λ of 4km. The regions within these contours all have a statistically significantly greater proportion of violations for calls where ß>0 than calls where ß=0. Hence, Figure 5 suggests that these highlighted locations, especially areas in central Santa Barbara County, such as Solvang and Santa Ynez, may represent areas where ambulance response time appears to be significantly more sensitive to system load than elsewhere.

DISCUSSION

Our statistical analysis of Santa Barbara County ambulance response in 2006 indicates a significant effect of load on violation frequency. For calls which were preceded by at least one other call within the previous hour and within 20 km, the proportion that are violations is 4.56% compared with 2.96% for calls without such predecessors. The effect of preceding calls seems to be especially pronounced during busy morning and evening commuting hours, whereas during the very early morning (2-5 am), the effect is slightly reversed. The impact of system load is also seen in the fact that the violations themselves are significantly clustered, even after accounting for clustering due to population inhomogeneity. Indeed, at a scale of 0-3 km, it appears that violations are significantly more clustered than one would expect if these calls were a random sampling from all calls. The effect of load on the frequency of response-time exceedances appears to be especially pronounced within semi-rural neighborhoods in central Santa Barbara County, such as Solvang and Santa Ynez.

This study does not attempt to address specific causes for underperformance during system load. Further investigation is necessary to determine what methods may be used to improve response in underperforming areas and to determine how best to implement those improvements. In addition, we did not explore variables that may be confounded with system load and response, such as inclement weather or dangerous traffic conditions. Santa Barbara County is a somewhat unique blend of urban and rural neighborhoods, with few locations of extremely high population density and also few locations that are extremely far from any urban neighborhood. Extension of the present analysis to larger domains and to domains other than Santa Barbara County are important directions for future work.

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Address for Correspondence: Frederic Paik Schoenberg, ScB, PhD. Associate Professor, UCLA Dept. of Statistics, 8142 Math-Science Building, Los Angeles, CA 90095 USA. Email: frederic@stat.ucla.edu.

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A Descriptive Analysis of 1251 Solid Organ Transplant Visits to the Emergency Department

Sarah Unterman, MD
Michael Zimmerman, MD
Carissa Tyo, MD
Ethan Sterk, DO
Lisa Gehm, MD
Marcia Edison, PhD
Enrico Benedetti, MD
Elizabeth Orsay, MD

University of Illinois at Chicago

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Background: As solid organ transplants become more common, recipients present more frequently to the emergency department (ED) for care.

Methods: We performed a retrospective medical record review of ED visits of all patients who received an organ transplant at our medical center from 2000-2004, and included all visits following the patients' transplant surgery through December 2005 or until failed graft, lost to follow up, or death. Clinically relevant demographic variables, confounding and outcome variables were recorded. Kidney, liver and combined kidney with other organ transplant recipients were included.

Results: Five hundred ninety-three patients received kidney (395), liver (161), or combined renal (37) organ transplants during the study period, resulting in 1,251 ED visits. This represents 3.15 ED visits/patient followed over a mean of 30.8 months. Abdominal pain/gastrointestinal (GI) symptoms (31.3%) and infectious complaints (16.7%) were the most common presentations. The most common ED discharge diagnoses were fever/infection (36%), GI/Genitourinary (GU) pathology (20.4%) and dehydration (15%). Renal transplant recipients were diagnosed with infectious processes most often, despite time elapsed from transplant. Liver transplant patients had diagnoses of fever/infection most often in their first 30 days post transplant. Thereafter they were more likely to develop GI/GU pathology. After the first year of transplantation, cardiopulmonary and musculoskeletal pathology become more common in all transplant organ groups. Of the 1,251 ED visits, 762 (60.9%) resulted in hospitalization. Chief complaints of abdominal pain/GI symptoms, infectious complaints, cardiovascular and neurologic symptoms, and abnormal laboratory studies were significantly likely to result in hospitalization.

Conclusions: This study demonstrates a significant utilization of the ED by transplant recipients, presenting with a wide variety of symptoms and diagnoses, and with a high hospitalization rate. As the transplant-recipient population grows, these complex patients continue to present diagnostic and treatment challenges to primary care and emergency physicians.
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INTRODUCTION

Since the first successful kidney transplant from a healthy live donor to his identical twin over half a century ago, transplant surgery has emerged as a well established

treatment for end-stage organ disease.[1,2] At the end of 2004, over 150,000 people were living with a functioning transplant, up from over 91,000 in 1998, with one-year graft and patient survival rates at or above 80- 90%.[2,3] One-year patient survival rates are somewhat higher for kidney than for liver transplant recipients (96% vs. 87%).[3]

As the transplant recipient population grows and lives longer, emergency physicians (EP) are increasingly faced with caring for these complex patients with acute and chronic medical and surgical conditions arising from their transplant surgeries, underlying medical conditions, immunosuppressive therapies and comorbidities. Surprisingly little research has been published in the general medical or emergency medicine literature. Review articles are available on specific topics in transplant recipients, including infectious disease treatment principles in transplantation,[4] complications that cause liver transplant recipients to visit the emergency department (ED),[5] the long-term medical complications for pediatric patients with renal transplants,[6] the care of renal transplant recipients in the ED [7] and disease progression, comorbid conditions and patient mortality in renal transplant recipients.[8] A few original research articles on the evaluation and care of the transplant patient in the ED provide some information on the infectious and medical complications of renal, liver and heart/lung transplant recipients.[9,10,11,12] We describe our ED's experience with transplant recipients, focusing on frequency and timing of presentation post-transplant, presenting complaints and diagnoses and comparison of liver and kidney transplants.

METHODS

Study Design

We performed a retrospective medical record review of ED visits of all patients who received an organ transplant at our medical center from 2000-2004 using standardized chart review methods.[13] We included all ED visits following the patients' transplant surgery through December 2005.

Setting

The study was conducted at an urban, university-based tertiary care medical center with over 50,000 ED patients per year. The transplant surgery program is well established. Transplants performed here include kidney, liver, combined kidney and liver, and a small number of pancreas, small bowel, heart and lung. The majority of transplant recipients continue their primary healthcare with our institution following their transplants.

Selection of participants

We obtained the patient roster from the Department of Transplant Surgery for all surgeries done from 2000-2004, without exclusions. Solid organ transplants (kidney, liver and combined kidney and liver transplants) were selected for analysis. Appropriate Institutional Review Board approval was obtained.

Methods of Measurement and Data Collection and Processing

Since 1995 this institution has used an electronic medical record (EMR) (Cerner Corporation, Kansas City, MO) that maintains all laboratory, imaging, gastrointestinal, cardiac and urologic procedures, pathology reports, hospitalizations, and both ED and outpatient visits. ED visit documentation consisted of triage, nursing and resident handwritten notes scanned into the database, with the vast majority of ED attending notes entered directly. The few handwritten attending notes were also scanned into the EMR. Registered ED visits without a physician note were considered to be "Left without being seen" (LWBS). ED visits were included for analysis for patients with functioning grafts and excluded for renal transplant recipients with graft failure and on dialysis.

As described in reference 13, the data were collected by trained abstractors (ED physicians) blinded to study hypothesis, using a standardized abstraction form and input data directly into a database (Microsoft Office Access 2003). Each author abstracted one year of transplant patients, with the senior author (EO) assessing chart review and data extraction samples from each year for completeness and consistency. Interobserver reliability was not tested. Data elements included demographics (date and patient age at the time of transplant, gender, race/ethnicity); organ(s) transplanted; source of organ (cadaver, living related or living non-related); pathology leading to organ failure; and co-morbidities. In addition, we recorded the following outcome measures: date of ED visit; number of days post transplant; total number of ED visits; chief complaint; treatments rendered in the ED; ED final diagnosis; disposition and outcome (living, graft failure, death, lost to follow up or care transferred to primary care physician).

Chief complaints were grouped into the following categories: abdominal pain/gastrointestinal symptoms (includes vomiting, diarrhea, gastrointestinal bleed); fever/infection (includes soft tissue infections and abscesses); central nervous system symptoms (dizziness, weakness, headache, focal neurologic deficits); cardiopulmonary symptoms (shortness of breath, peripheral edema, chest pain or hypertension); urinary symptoms (dysuria, decreased urine output or hematuria);and "other" complaints (including clinic referral, musculoskeletal, injury and laboratory abnormalities). One chief complaint was assigned per visit. If more than one was listed, abstractors ascertained the most prominent complaint as listed in the triage note, with oversight by the senior author.

ED final diagnoses were grouped as infection (fever, wound infections, abscesses, urinary tract infections, pneumonia, presumed bacteremia); GI/genitourinary (GU) pathology (noninfectious, including elevated renal/liver function tests, suspected biliary anastomosis stenosis or leakage, hematuria, GI bleed, nausea, vomiting, diarrhea);

dehydration; cardiopulmonary pathology (chest pain, hypertension, acute decompensated heart failure, asthma, thromboembolic disorders); musculoskeletal pathology (injury, strain, fracture); electrolyte abnormality; r/o acute/chronic rejection or graft failure; diabetes complications (steroid induced or primary disease); recurrence of primary disease (hypertension, diabetes, hepatitis); neurologic pathology [transient ischemic attach (TIA); cerebrovascular accident (CVA), headache]; hematologic pathology (anemia, thromboycytopenia, neutropenia, sickle cell complications); and other (e.g., dental pain, psychiatric complaints and medication refills). Multiple ED diagnoses were recorded. ED final diagnoses were then analyzed by time elapsed from transplant into the following categories: <30 days, 30 days - one year and > one year post transplant, based on established transplant literature.[7]

Data were analyzed utilizing Statistical Package for Social Sciences version 15.0 (SPSS Incorporated, Chicago, IL) after extraction from the Microsoft Access database. Statistical methods used in the analysis included cross tabulations, Chi-square analysis and analysis of variance.

RESULTS

From January 2000 through December 2004, 593 patients received kidney, liver or combined kidney and liver transplants. Of these, 13 patients died during their initial hospitalization or at <30 days post operation and 12 were lost to follow up or had their care transferred to an outside facility at <30 days post operation, leaving 568 patients for analysis. Demographic characteristics were: 312 male (54.9%), mean age 44.7 years (SD=15.6), 50 patients (8.8%) under 18; and 47 (8.3%) over 65 years of age. Race/ethnicity characteristics were: 216 (38%) African American, 188 (33.1%) Hispanic, 129 (22.7%) non-Hispanic white, 18 (3.2%) Asian, and 16 (2.8%) with no or "other" ethnicity reported. This was the first transplant for 483 (85%) patients. Forty-one patients (7.2%) died, 50 patients (8.8%) were lost to follow up or had their care transferred to outside facilities/healthcare provider after 30 days post transplant, and 52 patients (9.2%) developed graft failure at some time during the five-year time period of data collection. Patients were followed for a mean of 938 days (30.8 months, SD=557 days).

The majority of patients underwent renal transplant alone or in conjunction with pancreas or liver. The most common organ source was cadaveric (Table 1).

There were 1,251 ED visits by 400 (70.4%) of the transplant recipients. The majority were made by renal patients (66.2%), followed by liver (24.5%) and combined renal (9.3%) transplant recipients, reflecting the organs transplanted distribution in this sample. The mean number of ED visits per patient was 3.15 (SD=3.02) with no statistically significant differences based on organ transplanted or organ source. An ED record was not found for 51 registered ED visits (4.1%) and were considered LWBS (and therefore excluded from analysis) This rate is similar to the 3% rate of LWBS for the general ED population during this period. The distribution of ED visits in relation to time from transplant is shown in Table 2.

Table 1. Organs transplanted and organ source

Organs Transplanted	**Frequency**
Kidney	378 (66.5%)
Liver	153 (26.9%)
Combined renal: kidney + pancreas or kidney + liver	37 (6.5%)
Organ Source	
Cadaver	316 (55.6%)
Living Related	210 (37%)
Living Non-Related	42 (7.4%)

Table 2. Time from Transplant to ED visit

Time from Transplant to ED Visit	**Frequency**
< 30 days	141 (11.3%)
30 days - 1 year	490 (39.2%)
>1 year - 5 years	620 (49.6%)
Total	1251 (100%)

Overwhelmingly, across all transplant types, the most common presenting complaints were abdominal pain and GI complaints (nausea, vomiting, diarrhea and/or GI bleed, 31.3%) and infectious problems (fever, wound infections, abscesses, 16.7%) (Figure 1). Other common presenting symptoms were cardiovascular symptoms (shortness of breath, edema, chest pain, hypertension, 10.9%); neurologic symptoms (dizziness, weakness, neurologic deficits, 10.1%); lab abnormality (7%); urinary symptoms (5.8%); and "other," which included clinic referral, musculoskeletal pain or injury, psychiatric symptoms, dental pain or other symptoms not fitting into the above categories (16.6%). No presenting complaint was listed for 21 visits (1.7%).

Of the 1,679 ED final diagnoses listed (more than one diagnosis per visit was possible), the most common were fever/infection (36%), GI/GU pathology (20.4%) and dehydration (15%). Diagnoses listed as "other" included a wide variety including psych disorders, dental complaints, medication refills, sent from clinic and others (Figure 2).

There were 81 ED visits with diagnosis of rule out rejection or graft failure. Those patients presented with chief complaints including: abdominal pain and GI complaints (53.1%), fever/infection (14.8%), shortness of breath with or

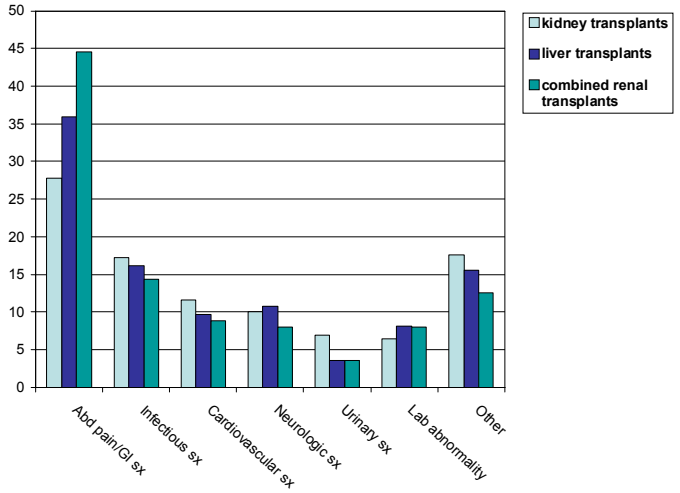

Figure 1. Presenting Complaints for 1251 emergency department visits. Abdominal pain/gastrointestinal (GI) symptoms (sx): nausea, vomiting, diarrhea and/or GI bleed. Infectious sx: fever, wound infections, abscesses, presumed bacteremia. Cardiovascular sx: shortness of breath, edema, chest pain, hypertension. Neurologic sx: dizziness, weakness, neurologic deficits. Urinary sx: dysuria, hematuria, urgency, frequency.

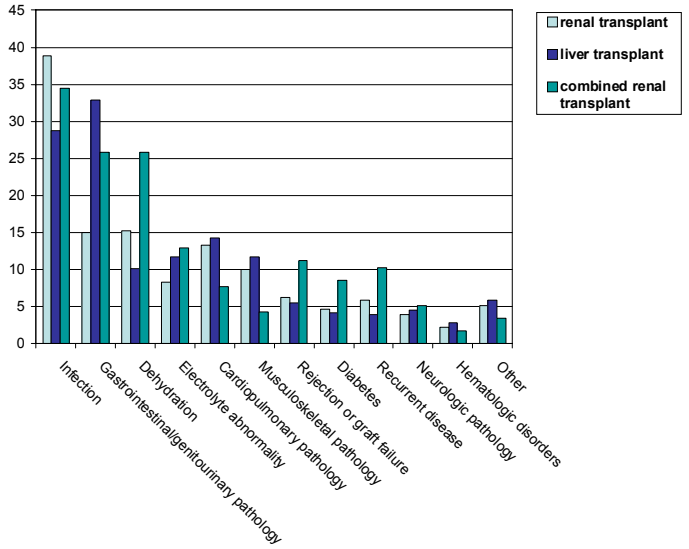

Figure 2. Emergency department discharge diagnoses

without edema (13.6%), dizziness with or without weakness (6.2%), lab abnormality (6.2%), and other complaints (6.2%). These visits occurred significantly more often among kidney transplant patients (51) than among liver transplant patients (17) ($p<0.016$) and significantly more often among patients whose organ source was a cadaver (49) versus a living related donor (20) ($p<0.006$).

Infectious processes and noninfectious GI/GU pathology were the most common diagnoses in all transplant patients. Infectious diagnoses rates remained fairly constant and prevalent over time, while GI/GU pathology, dehydration and electrolyte abnormalities rates decreased after the first year of transplantation. Conversely, cardiopulmonary diagnoses (including hypertension) and injuries or musculoskeletal pathology rates increased with time elapsed from transplantation (Figure 3).

A total of 1,506 ED treatments were recorded. The most common were IV hydration (513, 34.1%); antimicrobial agents (antibiotics, antivirals and antifungals, 301, 20%); and other pharmaceutical treatments (antihypertensives, antipyretics, pain medications, hypoglycemic agents, antirejection agents and anticoagulation medications, 478, 31.3%). Critical care, including intubation, cardiac resuscitation or resuscitation for clinical shock, was rendered in 43 cases (2.9%).

Of the 1,251 ED visits, 762 (60.9%) resulted in hospitalization. This compares with an overall approximate 17% hospitalization rate for all ED patients during this time period. The chief complaints most likely to result in hospitalization from the ED were abdominal pain/GI symptoms (72.1% hospitalized), cardiovascular complaints (71.2%), fever/infection (70.6%), neurologic symptoms (65.4%), and abnormal labs (61.2%). All were statistically significant compared to all other chief complaints ($p<0.05$). Conversely, patients presenting with urinary symptoms or other complaints were unlikely to be hospitalized (33.8% and 33.3% not hospitalized, respectively, $p< 0.05$).

Renal Transplants

Three hundred seventy-eight patients underwent renal transplantation alone. The underlying pathologies leading to their organ failure were diabetes with or without hypertension (286, 75.6%); acquired renal disorders (glomerulonephritis, sclerosis, systemic lupus erythematosis, drug or contrast induced nephropathy; sickle cell anemia, 67, 17.7%); and congenital or structural anomalies (51, 13.5%). Some patients had more than one underlying pathology listed. The most common source of donated organs were living-related (47.6%), followed by cadaver (43.4%) and living non-related (9.0%).

Two hundred sixty five patients (70.1%) generated 828 ED visits, of which 464 (56%) resulted in hospitalization, a significantly lower rate than the hospitalization rate for the overall group ($p<0.03$). The most common chief complaints were abdominal pain and GI complaints (231, 27.9%) and infectious complaints/fever (143, 17.3%) (Figure 1). The ED discharge diagnoses paralleled these presenting complaints, with the most common being fever/infection (38.8%), dehydration (15.3%) and noninfectious GI/GU pathology (15%) (Figure 2). When analyzed by time elapsed since transplant, infectious processes remained the most

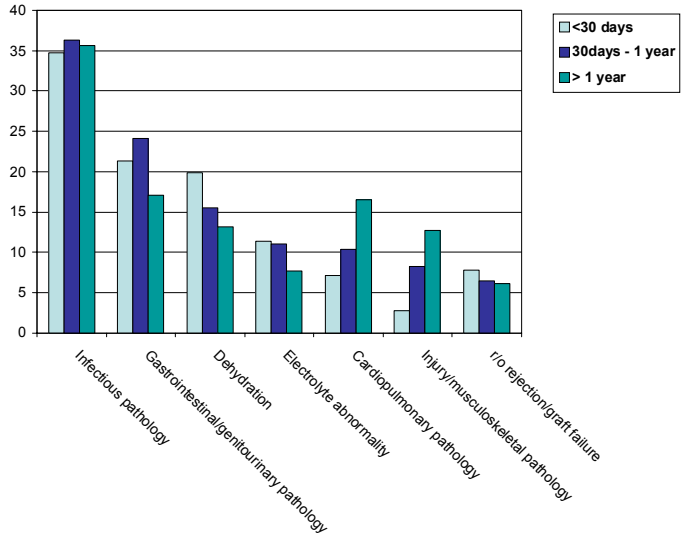

Figure 3. Emergency department discharge diagnoses: time elapsed from transplant

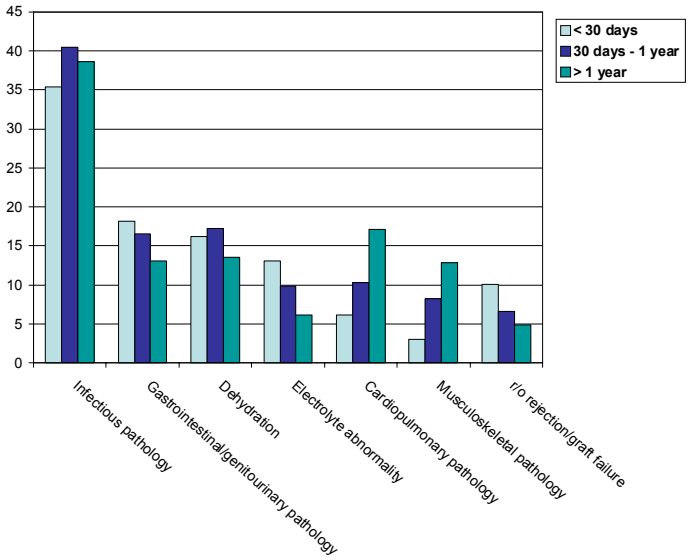

Figure 4. Emergency department diagnoses of 828 renal transplant patient visits: time elapsed since transplant

common diagnosis and remained high over time. However, GI/GU pathology, dehydration, electrolyte abnormalities and r/o rejection/graft failure all decreased over time, while cardiopulmonary pathology and musculoskeletal pathology increased (Figure 4).

Thirty-seven patients had a renal transplant in combination with either liver or pancreas. Thirty-two (86.5%) of those patients generated 116 ED visits, of which 89 (76.7%) resulted in hospitalization, a significantly higher rate than the overall group ($p< 0.001$). These patients were notable in that their most prevalent chief complaints were GI complaints or abdominal pain (Figure 1). Their ED final diagnoses were similar to other renal transplant recipients, with infectious processes most common. However, they suffered more from dehydration, r/o rejection or graft failure, diabetes and recurrence of their underlying diseases than the other transplant recipients (Figure 2).

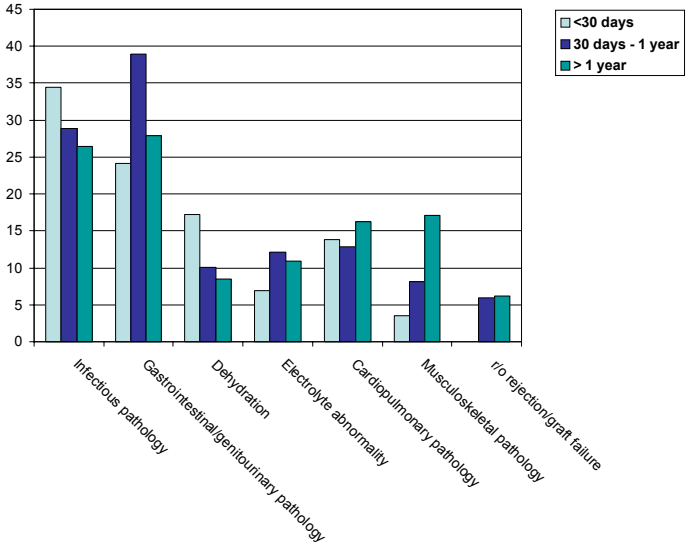

Figure 5. Emergency department diagnoses of 307 liver transplant patient visits by time elapsed since transplantation

Liver Transplants

One hundred fifty-three patients underwent liver transplantation alone, due to underlying pathologies of: hepatitis A, B or C (90, 58.8%); alcohol abuse (52, 34%); liver carcinoma (28, 18.3%); or congenital/structural abnormalities (10, 6.5%). (More than one underlying pathology may be present). Source of the donated organ was quite different from that of the renal patients, with 77.6 % cadaveric, 17.1% living related and 5.3% living non-related. One hundred three patients (67.3%) had at least one ED visit, with a total of 307. Two hundred nine (68.1%) ED visits resulted in hospitalization, significantly higher than the entire sample ($p<0.02$). The most common presenting complaint was abdominal pain or GI symptoms (111, 36.2%) (Figure1) and remained the most common for all elapsed time frames from transplant. Infectious processes were the most common ED diagnosis in the first 30 days following liver transplantation, then declined thereafter. After 30 days post-transplant, noninfectious GI/GU pathology diagnoses were prevalent, peaking during the 30 day – one-year time frame. Similar to the other transplant recipients, cardiopulmonary pathology and musculoskeletal pathology increased as time elapsed from transplant (Figure 5).

DISCUSSION

This large retrospective study demonstrates significant

utilization of the ED by transplant recipients, with a wide variety of presenting symptoms and ED diagnoses and a high hospitalization rate. Our data show that transplant patients are most commonly admitted for infectious processes, GI/GU pathology and dehydration, resulting in high rates of antimicrobial use, intravenous hydration and other pharmaceutical treatments. As time elapsed from their transplants, the infectious pathology remained high, the GI/GU pathology, dehydration and electrolyte abnormalities decreased, and the cardiopulmonary and musculoskeletal pathology increased. This is the largest study to date of the ED visit profile of solid organ transplant recipients.

In our hospital's EMR, the vast majority of ED attending notes are directly entered, with the remaining few scanned in. Clear, concise ED documentation that is easy to access and read made this review feasible. Despite a paucity of published material, two studies, one of liver and one of kidney transplant patients, allow some comparisons. Data for our liver transplant recipients are surprisingly similar to a descriptive study reporting on 143 patients with 290 ED visits.[10]

They found most common presenting complaints of abdominal (39%), febrile (17%), respiratory (13%) and neurologic (11%) symptoms. This compares to our reported presenting complaints of abdominal pain/GI/GU symptoms (36.2%), febrile/infectious (16.3%), neurologic (10.8%) and cardiopulmonary symptoms (9.8%). They reported similar patterns of ED final diagnoses, with abdominal (27%), infectious (24%), and metabolic (11%) disorders most frequent, compared to our reported discharge diagnoses of noninfectious GI/GU pathology (32.9%), infectious pathology (28.4%) and cardiopulmonary disorders (14.3%). The authors reported a hospitalization rate for their liver transplant patients of 69%, similar to our 68.1% rate. They reported an ED visit rate of 2.0 visits/patient over a mean follow-up time of nine months compared with our 2.0 visits/patient over a mean follow-up time of 30.8 months.

A study of 78 renal transplant recipients presenting to an ED in Turkey[12] reported a wide variety of presenting signs and symptoms, with fever most common (26.9%), similar to our findings. That study reported a 57.7% hospitalization rate, similar to our 56%.[12]

High rates of hospitalizations are inherent in the complexity and risk of serious disease among transplant recipients. A wrong diagnosis or under treatment could have grave consequences for the graft or patient. Their signs and symptoms may be atypical or subtle with significant pathology. Consequently, admission is both prudent and common. Transplant recipients present to the ED with complex problems, both related and unrelated to their transplant. In addition to the post-operative complications, they continue with the morbidities that led to their organ failure, such as hypertension, diabetes, and hepatitis. One author writes in a review of kidney transplant survival, "Despite the introduction of various potent immunosuppressive agents, there has been little or no impact on the prevalence as well as progression of recurrent disease."[15] This is supported by the increasing prevalence of cardiopulmonary pathology with time demonstrated in our data.

Transplant patients are placed on life-long immunosuppressant regimens and are subject to a myriad of acute, recurrent and opportunistic infections.[4,7,11,17,18] Furthermore, the medications themselves can cause serious side effects, such as renal tubular damage, neurotoxicity and neutropenia.[17,18] Neurologic complications include infection, encephalopathy, seizure, stroke and peripheral neuropathy.[19] There are also a variety of long term complications, including steroid-induced diabetes, hypertension, hypercholesterolemia, diarrhea and peptic ulcer disease.[20,21,22,23] As patients survive longer, they are subject to increased rates of malignancy as a result of their immunocompromised states, including non-Hodgkin's lymphoma, squamous cell cancers of the skin, cervical cancer and hepatobiliary cancer.[24] Our data demonstrate increased prevalence of injury and musculoskeletal disorders as the time from transplant elapses, possibly due to the effects of long term steroid and immunosuppressive therapy. It is the combination of subtle presentations, prevalence of underlying pathologies and co-morbidities, adverse drug reactions and complications from the immunosuppressant therapies and the potential for serious morbidity inherent in the transplant recipient that makes these patients so challenging. EPs must be aware of these factors to provide the highest level of care.

LIMITATIONS

This study has several limitations. This is a single center, retrospective review, with a primarily minority patient population; 71.1% of the patients in this sample were either African American or Hispanic, and less than one quarter was non-Hispanic white. Racial disparities in renal transplant outcomes have been identified, with African Americans having a shorter graft half-life than other ethnicities.[14,15,16] Additionally, post-transplant new-onset diabetes is increased among ethnic minorities, further increasing morbidity and utilization of healthcare resources.[16] Ideally, a multi-center study with a large sample would provide more comprehensive data.

Not all ED visits by these transplant recipients were captured in this study, as we report only those to our institution. Patients may have been seen in other EDs during the study period, as some may live far from this institution. If transported by ambulance, the emergency medical system takes patients to the closest ED only. Almost 9% of our patient sample was lost to follow-up some time during the study period. Some patients were intentionally transferred to the care of their referring physicians, while others required

nursing home or long term care, and still others moved out of the region.

Address for Correspondence: Elizabeth M. Orsay, MD. Associate Professor, Department of Emergency Medicine, University of Illinois at Chicago, 1740 W. Taylor, M/C 722, Chicago, IL 60612. Email: Lorsay@uic.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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Polycystic Kidney Disease with Renal Failure Presenting as Incarcerated Inguinal Hernia in the ED

Eric F. Silman, MD* * University of California, San Francisco
Bharath Chakravarthy, MD† † Loma Linda University
Federico Vaca, MD, MPH‡ ‡ University of California, Irvine School of Medicine
Mark I. Langdorf, MD, MHPE‡

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Autosomal dominant polycystic kidney disease may present to the emergency department (ED) with vomiting, abdominal pain or hernias, renal insufficiency or failure, or bleeding from cerebral aneurysms. A 37-year-old man presented to the ED with signs and symptoms of incarcerated inguinal hernia. Laboratory studies showed renal failure with anion gap acidosis, and bedside ultrasound showed multicystic kidneys. Computed tomography confirmed the diagnosis. Emergency physicians should be aware of this common connective tissue defect and its serious associated conditions. [*West*JEM. 2009;10:55-57]

INTRODUCTION

Autosomal dominant polycystic kidney disease (ADPKD) is relatively common, estimated to occur in one in 1000 live births.[1] A defect in epithelial cell function, its multiorgan structural manifestations cause complications including hepatic cysts, cerebral arterial aneurysms, and abdominal wall hernias, any of which are life-threatening and require prompt diagnosis and treatment in the emergency department (ED).

CASE REPORT

A 37-year-old Hispanic male presented with progressive pain in his abdomen and inguinal area for four days. The pain began suddenly and was located in the right upper quadrant, right inguinal and scrotal area. The patient had anorexia, nausea and vomiting the prior day with chills, fevers to 105°F and sweats. He had normal bowel movements without hematochezia or melena. He also reported a three-year history of inguinal hernia that was previously asymptomatic. Review of systems was significant for three episodes of gross hematuria in the previous three days without urgency, frequency, or changes in urinary output. All other review of systems was negative. The patient denied any medication use or allergies. There was no significant prior illness, surgery, or family medical history. He had not seen a doctor since childhood.

The patient's initial vital signs were a temperature of 36.8°C, a heart rate of 94 beats per minute, a blood pressure of 137/86 mmHg, respirations at 18 breaths per minute and oxygen saturation of 99% on room air. Relevant physical findings included a soft and diffusely tender abdomen, with rebound tenderness and pain on gurney movement suggesting peritoneal irritation. There was an exquisitely tender 25 x 30 cm right inguinal hernia extending into the scrotum with bowel sounds and visible peristalsis, without overlying skin changes or crepitus (Figure 1A). There were no other masses appreciated on physical exam and the remainder of the physical examination, including rectal and genitourinary, was unremarkable.

Pertinent initial laboratory results included: a leukocytosis of 18,300 cells/mm^3 with 84% neutrophils and no bands, a mild anemia with hemoglobin of 11.1 g/dl and a normal platelet count. Chemistry results yielded potassium of 3.3 mEq/dl, bicarbonate of 8 mEq/dl, anion gap of 20, blood urea nitrogen (BUN) of 178 mg/dl and creatinine of 19.9 mg/dl. Lipase was greater than 400 U/l with normal hepatic function panel. Urinalysis showed positive leukocyte esterase and negative nitrite, 20 mg% protein, large hemoglobin, 300 red blood cells and 23 white blood cells per high-power field. A surgical consultation was obtained to evaluate for strangulated inguinal hernia. Initial therapy included intravenous piperacillin/tazobactam in the ED.

Arterial blood gas revealed pH 7.10, pCO2 16 mmHg and bicarbonate 4.9 mEq/L with a base deficit of 23. Serum lactate level was normal, suggesting the anion-gap acidosis was more

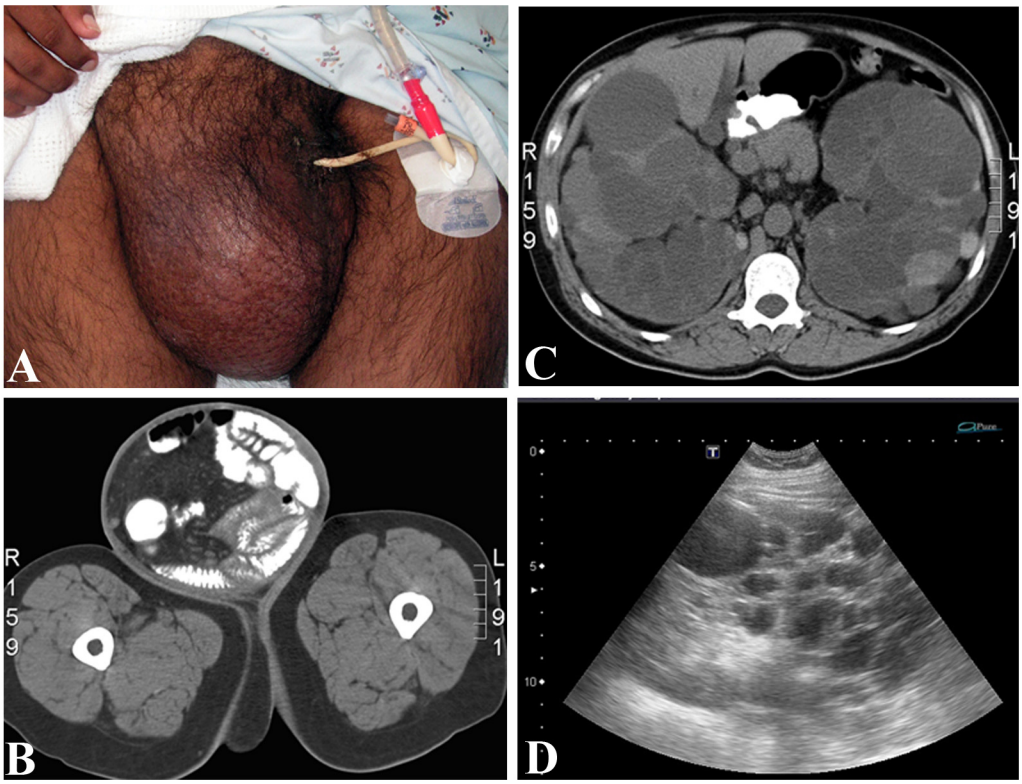

Figure 1. *A*, Gross appearance of inguinal hernia. *B*, computed tomography showing large inguinal hernia containing small bowel and cecum with intraluminal contrast. *C*, appearance of bilaterally-enlarged kidneys with innumerable cysts. *D*, emergency department ultrasound image of the right upper quadrant showing multiple cystic structures.

likely due to uremia than bowel infarction. A Foley catheter returned 50 ml amber-colored urine.

Abdominal CT showed intraluminal contrast in the hernia sac (Figure 1B), diffuse small bowel edema with a transition point at the entrance to the hernia sac, multiple liver cysts and bilaterally enlarged kidneys with innumerable cysts filling most of the abdominal cavity (Figure 1C), as well as a 7 mm stone in the left renal pelvis. The pancreas was incompletely seen due to lack of intravenous contrast, which was withheld due to renal failure. A bedside ultrasound performed in the ED showed multiple cystic structures in both upper quadrants and flanks (Figure 1D).

A dialysis catheter was placed in the ED and the patient was emergently dialyzed. He was admitted to intensive care for acute renal failure, incarcerated inguinal hernia with a partial small bowel obstruction, dehydration and an acute exacerbation of polycystic kidney disease. The patient was awake, alert, and in only moderate distress throughout his ED course, suggesting an element of tolerance to chronically elevated BUN and creatinine levels. Regarding family history, he reported that his father had a renal transplant for unknown reasons.

The following day the patient's electrolytes and pH nearly normalized. His BUN/creatinine, white blood cell count and lipase trended down in the following days. Blood and urine cultures were negative. Urology was consulted and elected to delay nephrectomy to determine if one kidney could be salvaged. General surgery planned a hernia repair after the nephrectomy. The partial small bowel obstruction resolved with bowel rest. A screening MRI of the brain the following day revealed no bleeding or cerebral aneurysms.

DISCUSSION

The diagnosis of ADPKD may become evident to the emergency physician (EP) in four ways. First, routine testing for complaints of vomiting or abdominal pain may reveal renal failure. Second, abdominal wall or inguinal hernias associated with renal insufficiency or hematuria may suggest the diagnosis. Third, with increasing use of ED ultrasound, multicystic kidneys may be seen during a search for the cause of abdominal pain. Finally, non-contrast CT, while investigating abdominal or flank pain, or clinical bowel obstruction, may offer the unifying diagnosis. In our patient, surgery for incarcerated hernia with bowel obstruction was delayed by the condition which caused the hernia, namely renal failure from ADPKD.

ADPKD affects approximately one in 1000 people.[2] Cysts arise from the nephrons and collecting tubules.[2] The most

common presentation is a palpable mass, hypertension (after their third decade of life), abdominal pain, and hematuria.[1, 2] Hypertension often predates renal failure. Up to 73% of patients will have hepatic cysts, 9% have pancreatic cysts, and 5% have splenic cysts.[2-6] Family history often includes renal disease and/or transplantation, as in our patient, and abdominal CT scan shows bilaterally-enlarged kidneys with multiple cysts. It is the fourth leading cause of end-stage renal disease in adults,[7] and about 10-12% of patients receiving maintenance hemodialysis have ADPKD.[2-6]

The genetic basis for ADPKD has been traced to mutations in two genes. Type I is caused by a defect in the PKD1 gene (85-90% of cases), while Type II is related to a defect in the PKD2 gene.[8]

Diagnostic criteria center on the presence and quantity of cysts, age, and familial risk. Patients typically present with enlarged kidneys with multiple cysts bilaterally and a positive family history consistent with autosomal dominant inheritance. For age 15-29, at least two cysts (uni- or bilateral) are sufficient for diagnosis. At age 30-59, as the prevalence of simple cysts increases, at least two cysts in each kidney are required for diagnosis, and beyond age 60, four cysts on each side. [9]

The common endpoint in half of ADPKD patients is renal insufficiency.[6] Concomitant cardiovascular pathology includes aortic root dilatation, aortic regurgitation, bicuspid aortic valves, coarctation of the aorta, mitral regurgitation, and abdominal aortic aneurysm.[10, 11] Aneurysms of cerebral arteries have been found in up to 50% of patients.[10-12] Abdominal wall hernias are up to five times more common in ADPKD patients with prevalence up to 45%.[14] The prevalence of abdominal wall hernia is even higher in those on chronic ambulatory peritoneal dialysis.[14] The most common type of hernias are inguinal followed by incisional and paraumbilical.[13,14] The increased prevalence is thought to be due to a combination of increased intraabdominal pressure from enlarged kidneys and weak abdominal musculature due to the connective tissue pathology.[12] We could find no data on the prevalence of incarceration or strangulation compared to the general population.

In addition to renal failure, this particular patient had laboratory and imaging evidence for pyelonephritis and nephrolithiasis, two other common complications of ADPKD.[13] Despite a significantly elevated serum lipase, pancreatitis was not diagnosed. The level was thought to be due to a combination of decreased renal excretion as well as intraperitoneal irritation. Pancreatic cysts can be present with ADPKD, but our patient had none.[15]

ADPKD has an array of associated symptoms and complications. Many of these are potentially life-threatening and may bring a patient to the ED. It is important for the EP to be familiar with these and not to be distracted from the true etiology.

Address for Correspondence: Mark I. Langdorf, MD, MHPE. Department of Emergency Medicine, University of California, Irvine School of Medicine, 101 The City Dr., Rte 128-01, Orange, CA 92868. Email: milangdo@uci.edu.

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Bottoms Up: Methamphetamine Toxicity from an Unusual Route

Malkeet Gupta, MD, MS* * University of California, Los Angeles, Department of Emergency Medicine
Scott Bailey, MD† † St. Francis Hospital, Evanston, Illinois
Luis M. Lovato, MD‡ ‡ Olive View-University of California, Los Angeles Medical Center, Sylmar, California

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Methamphetamine (MA) use is becoming commonplace, and emergency physicians (EPs) are seeing patients with abuse-associated complications. Previous reports have described inhalational and intravenous routes. We present the second case of rectal MA abuse in the literature. Trans-rectal use is important for EPs to consider because ongoing absorption of massive quantities may be averted upon detection. Additionally, trans-rectal abuse risks anorectal trauma and vascular necrosis with colonic perforation.
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INTRODUCTION

Methamphetamine (MA) and chemically related compounds have become preeminent drugs of abuse. Internationally, MA use ranks second only to cannabis as the most commonly abused drug with 35 million users worldwide.[1] In Canada reports have documented increasing popularity in addition to concomitant morbidity.[2-4] A recent national survey estimates the lifetime incidence of any use to be 6% for all Canadians.[5] MA use in the United States (U.S.) is similarly common. The 2005 U.S. National Survey on Drug Use and Health reported 10.4 million (4.3%) Americans aged 12 or older had tried MA, while 1.3 million reported MA use in the last year and 512,000 in the past month.[6] The MA problem is socially costly due to violence associated with its use, economic non-productivity of abusers, and the harm to individuals near labs from highly toxic by-products of manufacture.[7] Emergency physicians (EPs) witness directly the tremendous impact on medical, trauma, and psychiatric care systems. One report estimates that 2.3% of emergency department (ED) visits are related to MA use.[8,9] According to another recent assessment, abusers of MA, compared to abusers of cocaine, are more likely to require admission to a psychiatric unit and to have longer stays.[10]

MA toxicity can occur via a variety of exposure routes. The most frequently cited forms are intranasal, oral, intravenous (IV), or inhaled.[6] We present a case report of a patient who developed toxicity following a unique method of exposure.

CASE REPORT

A 30-year-old man was brought to the ED by paramedics from outside a gas station bathroom. Police had been called because the patient had been in the bathroom for an hour, and they had to forcibly open the door to release him. The patient admitted to taking a "large" amount of MA in addition to six beers. The patient reported racing thoughts and feeling anxious but denied chest pain, shortness of breath, nausea, vomiting, or suicidal ideation. The patient denied having any medical problems or medications.

The patient was awake and conversant, but also agitated and restless. His vital signs were pulse 145 beats per minute, blood pressure 145/ 77 mmHg, oral temperature 37.2°Celsius, respiratory rate at 22 breaths per minute, pulse oximetry 97% on room air and a normal blood glucose. His physical exam revealed 4mm mydriasis without nystagmus and minimal reaction to light. He had positive bowel sounds and was not diaphoretic. The rest of his lung, heart, and extremity exam was unremarkable. An ECG demonstrated a sinus tachycardia, with no ischemic changes and normal intervals. Initial laboratory tests included electrolytes, complete blood count, liver function tests, and cardiac markers, with the following abnormal results: creatinine 1.3 mg/dL, creatinine kinase 1779 IU/L and troponin I of 0.11 ng/mL. A urine and serum toxicology screening was positive only for MA and alcohol.

The patient became more manageable over a period of four hours and asked to use the restroom. Appearing improved, remorseful, and ambulatory, his request was

granted. He then disappeared for an hour and was later found in another part of the hospital in a decompensated state with tachycardia, agitation and altered mental status. The patient was restrained, sedated and admitted to the hospital. Tachycardia and agitation persisted despite over three liters of IV normal saline and almost 50 mg of IV lorazepam over the next 12 hours. Finally, the patient had a bowel movement productive of a tampon. In the morning, the patient's mental status had resolved. Upon further questioning, the patient admitted to inserting a MA-soaked tampon trans-rectally. The tampon was not tested for MA. He subsequently signed out against medical advice rather abruptly and further information regarding his past MA use could not be obtained.

DISCUSSION

To our knowledge, we present the first report of a case of MA toxicity after intentional rectal administration with a tampon. Awareness of this novel usage is important for EPs as prolonged exposure to MA can potentially be avoided by specific questioning and careful physical exam.

Routes of MA administration are varied, with prior reports of exposure via nasal insufflation, IV administration, ingestion of liquid formulations, and a single case report of intravaginal exposure.[11] Our report of MA toxicity demonstrates a novel delivery method – intentional rectal administration with a tampon. The rectal bioavailability of MA is not well-defined, but enteric absorption via the oral route is good with relatively low protein binding (<20%). The volume of distribution is approximately 4L/kg.[12] Similar to the oral route, absorption of MA across rectal mucosa may provide significant quantities of MA to be delivered rapidly into the systemic circulation via the anorectal-venous circulation. Though the literature lacks data regarding relative speed of onset via different routes, a popular website dedicated to MA subculture reports the following times for various routes: oral (20-30 minutes); intra-nasal (3-5 minutes); smoking (7-10 seconds); trans-rectal (3-5 minutes); and IV (15-30 seconds).[13]

Complications of intestinal absorption to MA have been reported primarily in the context of both body packers and stuffers. Body packers, often referred to as "mules," swallow packets (such as condoms) containing large quantities of drugs as a transport method with the expectation of subsequently defecating the packets intact. Body stuffers, on the other hand, swallow drugs to avoid capture while in possession of drugs. The former group experiences toxicity when transport vehicles fail and inadvertently release drugs into the gastrointestinal tract. The latter group absorbs drugs as a result of haphazard packaging and rapid consumption of the drug. The occurrence of ischemic bowel after systemically administered cocaine or ergotamine use, secondary to mesenteric vasoconstriction, is well documented. There have also been at least four case reports of ischemic bowel after MA use.[14] The application of methamphetamine directly to rectal mucosa likely has local vasoconstrictive effects, making rectal ischemia and necrosis a potential complication.

A recognized problem with rectal administration is leakage of the mixture after dosing; this is discussed on websites dedicated to the MA use subculture.[15] Presumably, the tampon used by this patient was intended to prevent such leakage. Our patient seemed to experience delayed and possibly recurrent toxicity from this route of administration, possibly due to a delayed-release effect of using a tampon.

Cantrell et al.[16] have recently reported a similar case of a woman who suffered toxicity following transrectal MA use. However, their patient experienced a more acute onset and resolution of symptoms consistent with direct instillation of liquid solution. Additional information and case reports of these types of exposures may help clarify whether the time-course and complications of anorectal exposure to MA are distinct from other routes of exposure.

CONCLUSION

Use of MA will likely increase, requiring EPs to manage multiple patients with sympatho-mimetic toxidromes, some of them severe. Epidemiologic data suggest that MA use will not wane like PCP and LSD. The users of this drug are inventive, and almost no method or route of administration goes untested. As this case highlights, the EP should specifically question patients about the route of administration, and perhaps include a rectal exam for patients suspected of MA toxicity, or at least those with recurrent or prolonged intoxication.

Address for Correspondence: Malkeet Gupta, MD, MS. Dept of Emergency Medicine, 924 Westwood Blvd, Suite 300, Los Angeles, CA 90024-1777. Email malkeetgupta@yahoo.com.

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Tension Pyothorax Causing Cardiac Arrest

Terence L. Ahern, BA* * Keck School of Medicine of the University of Southern California
Gregg A. Miller, MD† † Harbor-UCLA, Department of Emergency Medicine

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A 28-year-old woman was seen by an emergency physician for flu-like symptoms and discharged home with a presumptive viral syndrome. A week later, she was readmitted to the emergency department by ambulance in severe respiratory distress. She presented with a blood pressure of 78/42 mm Hg, heart rate at 120 beats per minute, respirations at 50 per minute, a temperature of 103.3 degrees Fahrenheit, and pulse oximetry at 50% on room air. Breath sounds were decreased on the right, and a portable chest radiograph showed a collapsed right lung and congested right pleural cavity with a massive mediastinal shift to the left side (Figure 1). The patient's airway was secured by endotracheal intubation due to severe hypoxia and the radiograph findings of a large effusion. Minutes after intubation, the patient deteriorated to cardiac arrest. The combination of IV fluids, chest compressions, and two rounds of atropine and epinephrine elicited no hemodynamic response. Concomitant emergency needle thoracostomy was performed on the right and then the left chest with a 14-gauge cannula, but the patient did not respond. Considering the possibility of a tension pyothorax, the decision was made to perform a tube thoracostomy on the right chest. Immediately upon dissection through the pleura, purulent fluid began draining under pressure and the patient instantly experienced the return of spontaneous circulation. A total of 1500-2000 ml of purulent exudate was drained, and her condition continued to stabilize until transfer to the ICU. She was later diagnosed as HIV positive.

Tension pyothorax is rare and may occur as a complication of pneumonia or lung abscess.[1] Although the accumulation of gas is the most common cause of an expanding interpleural space, the presence of other substances (hydrothorax, hemothorax, chylothorax, and pyothorax) under pressure may be sufficient to cause hemodynamic and respiratory compromise. Tension pyothorax occurs when a large volume of purulent fluid evokes an inflammatory and fibrotic response that entraps the lung and shifts the mediastinal organs including the heart, lungs, and trachea. Increased intrathoracic pressure can reduce venous return with secondarily decreased cardiac output, and mediastinal deviation can compress the contralateral lung, leading to an emergent situation.[2] The typical clinical presentation of pyothorax includes fever, tachycardia, cough, dyspnea, and chest pain. Emergency treatment entails the drainage of fluid through a chest tube.[3] Risk factors for pyothorax include age (more likely in children and the elderly), male sex, chronic obstructive pulmonary disease, diabetes, alcoholism, pneumonia requiring hospitalization, and an immune-compromised host.[1,2] In this case, the patient was HIV positive. Pyothorax is a more frequent complication of respiratory tract infections in patients with HIV and its incidence may approach 5.4%.[4] Additionally, HIV patients often have more complex cases that require surgery with lung resection, multiple antibiotics, and longer periods of chest tube drainage.[4] Given the serious progression and evolving nature of this case, it seems reasonable to consider tension pyothorax as a cause of emergent cardio-respiratory arrest.

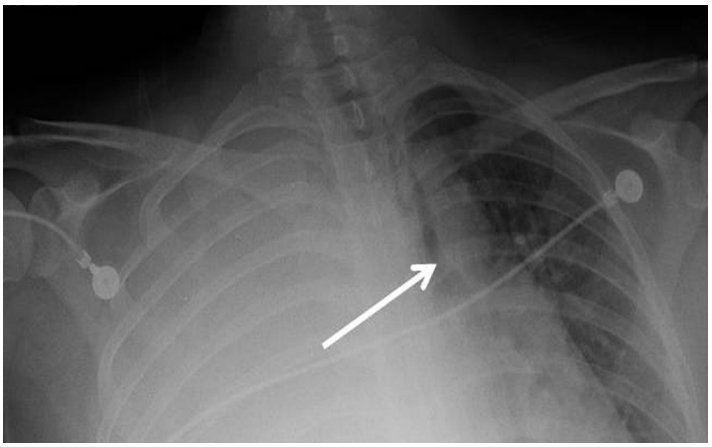

Figure 1. Portable chest radiograph reveals a right pyothorax with a mediastinum that is drastically shifted to the left.

Address for Correspondence: Terence L. Ahern, BA. Department of Emergency Medicine, LAC + USC Medical Center, 1200 State Street, Room 1011 Los Angeles, CA 90032. Email: tahern@usc.edu.

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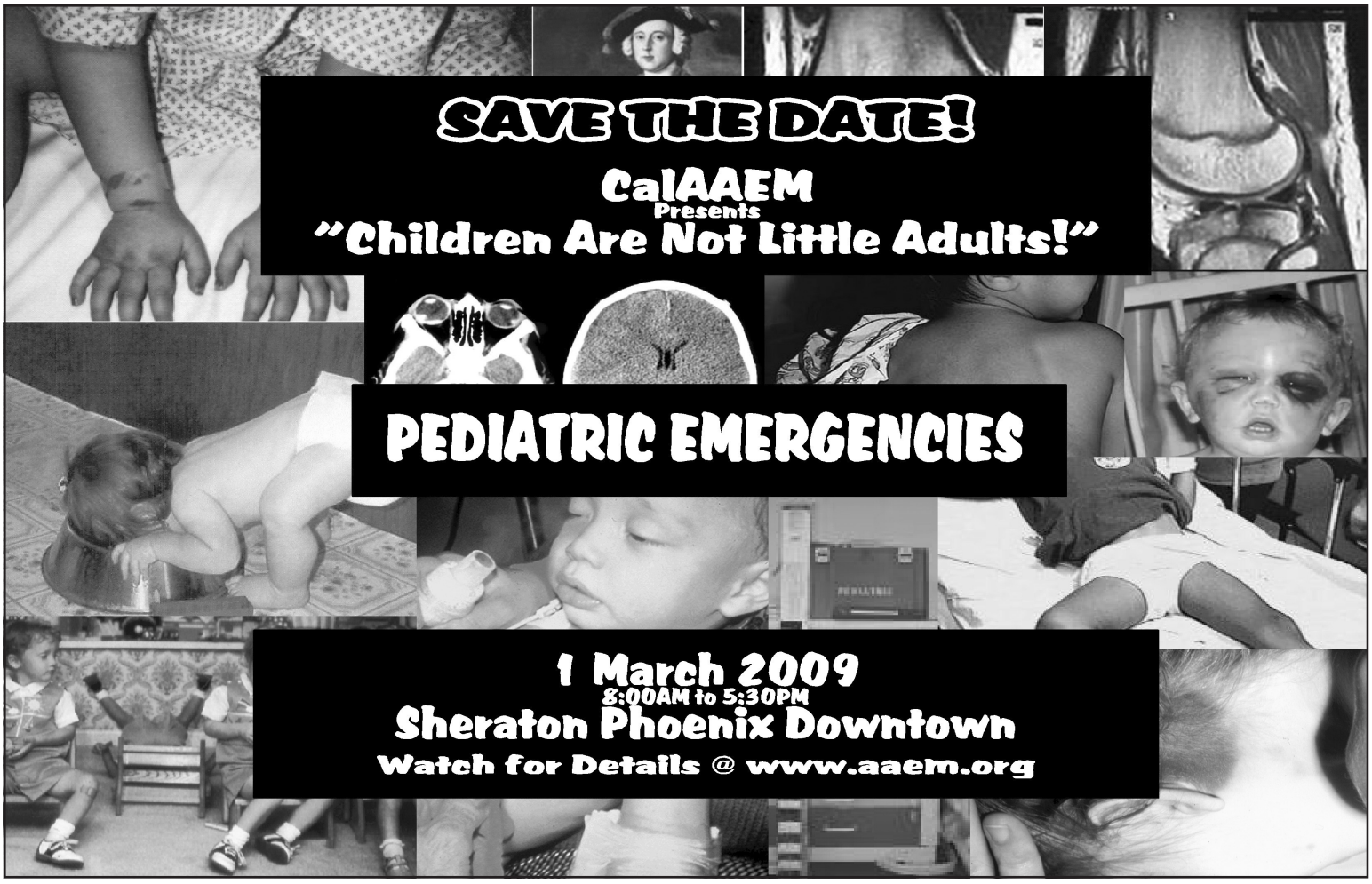

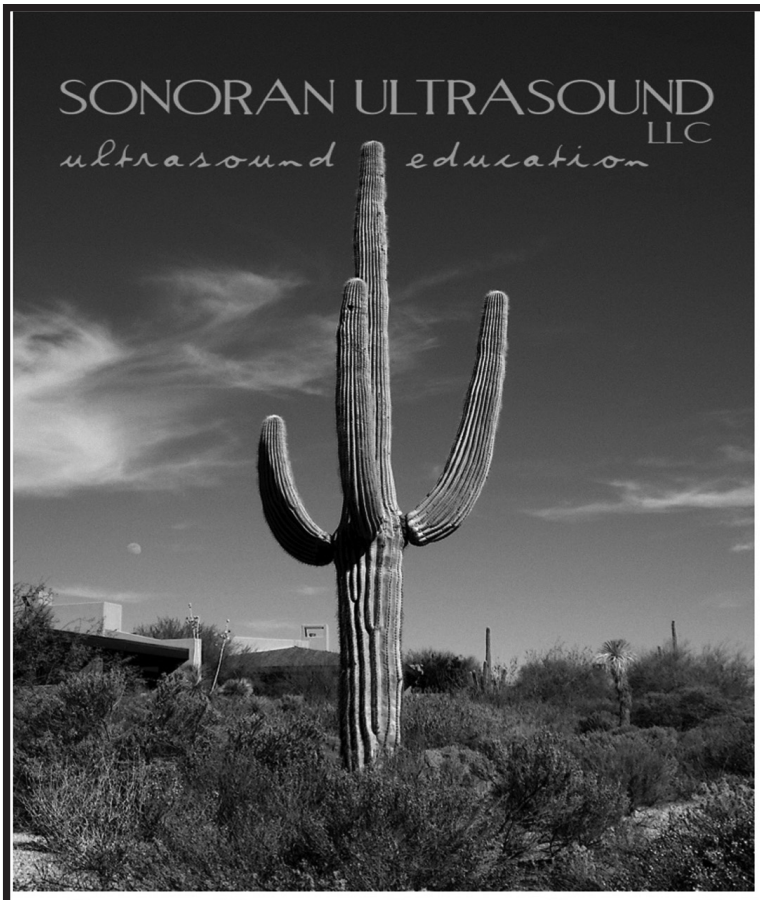

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Sonoran Ultrasound, LLC is comprised of nationally recognized emergency physician experts in ultrasound. All instructors are fellowship trained and have Registered Diagnostic Medical Sonographer (RDMS) Credential.

Category I AMA CME. 1-Day courses qualify for 6.5 units while 2-Day courses qualify for 13 units.

IMPLEMENTATION

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