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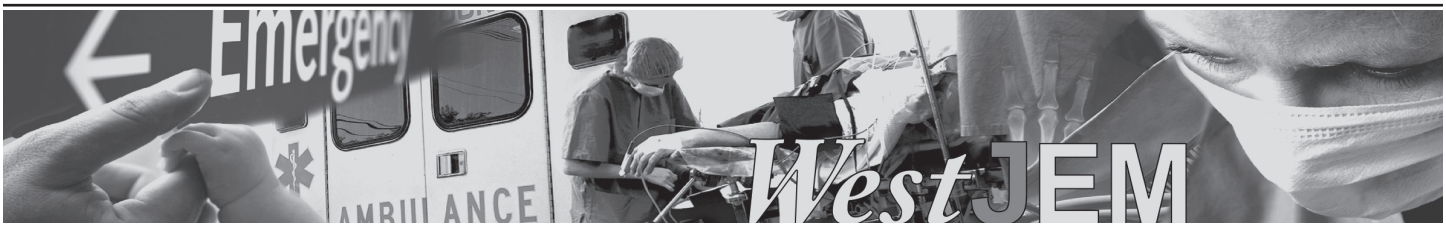

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Challenging the Pathophysiologic Connection between Subdural Hematoma, Retinal Hemorrhage and Shaken Baby Syndrome

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Child abuse experts use diagnostic findings of subdural hematoma and retinal hemorrhages as near-pathognomonic findings to diagnose shaken baby syndrome. This article reviews the origin of this link and casts serious doubt on the specificity of the pathophysiologic connection. The forces required to cause brain injury were derived from an experiment of high velocity impacts on monkeys, that generated forces far above those which might occur with a shaking mechanism. These forces, if present, would invariably cause neck trauma, which is conspicuously absent in most babies allegedly injured by shaking. Subdural hematoma may also be the result of common birth trauma, complicated by prenatal vitamin D deficiency, which also contributes to the appearance of long bone fractures commonly associated with child abuse. Retinal hemorrhage is a non-specific finding that occurs with many causes of increased intracranial pressure, including infection and hypoxic brain injury. The evidence challenging these connections should prompt emergency physicians and others who care for children to consider a broad differential diagnosis before settling on occult shaking as the de-facto cause. While childhood non-accidental trauma is certainly a serious problem, the wide exposure of this information may have the potential to exonerate some innocent care-givers who have been convicted, or may be accused, of child abuse. [West J Emerg Med. 2011;12(2):144-158.]

INTRODUCTION

For many years the relationship between retinal hemorrhage (RH) and the shaken baby syndrome (SBS) has been accepted as fact and widely used to diagnose children as victims of child abuse. (Please see Table 1 for a list of abbreviations used in this manuscript)

The scientific literature, both old and new, has cultivated the belief that RH is uniquely linked and virtually pathognomonic of shaking and nonaccidental trauma. The child abuse community, including most pediatricians and ophthalmologists, assume that the presence of RH proves that a child was shaken abusively. Donohoe[1] graded the quality of the child abuse literature from 1966 to 1998 and found significant weaknesses, concluding that there was inadequate scientific evidence to come to "a firm conclusion on most matters pertaining to SBS." He called appropriately for controlled, prospective trials into SBS and opined: "Without published and replicated studies of that type the commonly held opinion that the finding of subdural hematoma and RH in an infant was strong evidence of SBS was unsustainable, at least from the medical literature."

The established assumption has been that shaking directly and independently damages capillaries in the eye and tears bridging veins in the brain, causing hemorrhage.[2] In the absence of overt brain damage, RH and subdural hematoma (SDH) have emerged as sufficient criteria necessary to diagnose SBS. Furthermore, either one at times has been used independently to make the diagnosis and initiate criminal proceedings. However, both SDH and RH can result from a number of other traumatic or medical conditions. This paper will challenge the rationale behind the exclusive link between RH, SDH and child abuse, and whether vessels in the cranial vault and eye are damaged by a shaking mechanism.

The History of Shaken Baby Syndrome

SBS was first theorized by Guthkelch and later Caffey who published in the 1970s. They proposed the concept of "Whiplash Shaken Infant Syndrome" in two published

Table 1. Common abbreviations used in article.

ABT	abusive head trauma
ALTE	apparent life threatening event
BV	bridging veins
CCD	cerebrocranial disproportion
CSDH	chronic subdural hematoma
CSF	cerebrospinal fluid
CT	computed tomography
DIC	disseminated intravascular coagulation
EDH	epidural hematoma
HIE	hypoxic ischemic encephalopathy
ICP	intracranial pressure
ICT	intracranial trauma
IDH	intradural hemorrhage
ILM	internal limiting membrane
IOP	intraocular pressure
LOC	level of consciousness
MRI	magnetic resonance imaging
NHTSA	Nathional Highway Traffic Safety Administration
PSDH	perinatal subdural hematoma
RH	retinal hemorrhage
SAH	subarachnoid hemorrhage
SBS	shaken baby syndrome
SDH	subdural hematoma
VDD	vitamin D deficiency

articles,[2,3] which extrapolated from an experiment on monkeys by A.K. Ommaya[4], a neurosurgeon. Ommaya[4], in 1968, looked at the substantial head and neck injuries in rhesus monkeys subjected to whiplash in simulated 40 mph rear end motor vehicle "collisions" using a mechanical piston.

Caffey[2] and Guthkelch[3], without further independent investigation, theorized that human shaking could cause intracranial injury similar to Ommaya's monkeys. To explain the RHs that were often present with SDH, Caffey[2] advanced that RH would result from human shaking by damaging retinal capillaries.

This theory explained the findings of RH and SDH in patients with, in their view, inadequate mechanisms to account for "severe head injury." They therefore proposed another explanation: that clandestine shaking could produce the combination of SDH and RH. Their theory did not consider the significant literature (discussed below) that had established that intracranial hemorrhage and increased intracranial pressures (ICP), without impact or shaking, are well-documented causes of RH. The new construct was published and subsequently advanced in large-scale conferences aimed at law enforcement, social services and physicians. Those who accepted this theory came to believe that violent human shaking and high speed impacts would produce similar physical findings.

Ommaya's Study: Physics of Shaking in the Brain and Eye

On this basis it is instructive to examine Ommaya's study, which became the biomechanical basis of "shaken whiplash," and later "shaken baby" syndrome. Using rhesus monkeys, he attempted to quantify the "rotational acceleration" (i.e. whiplash) that was necessary to cause loss of consciousness. Whiplash is defined as a rotational force, with the head rotating around a point in the lower cervical spine in an arc.[4] Rotational force is calculated from the speed of rotation measured in degrees per unit of time (rotational velocity), and the distance from the point of rotation (lower neck) to the center of gravity of the rotating object (the head). In Ommaya's study, after a single, forceful impact, he documented loss of consciousness, recovery and autopsy findings (Figure 1).

Ommaya's monkeys were strapped to a chair on a sled with unrestricted head movements. Impacts to the back of the chair produced significant accelerations, which can be measured in Gs. One G is the acceleration (change of velocity) due to gravity of an object falling in our atmosphere when air resistance is negligible. It is a constant at 32.2 ft/sec^2, a number that connotes an exponential change in speed. In physics this is "acceleration." Linear (straight line) acceleration can be measured in Gs or in ft/sec^2, and rotational accelerations (movement around a center point in an arc) can also be measured in Gs or in radians/sec^2, where a radian is equal to about 57 degrees of arc (about 1/6th of a full circle). Acceleration is the rate of change in velocity of any object under a variety of circumstances, including falls, impacts and

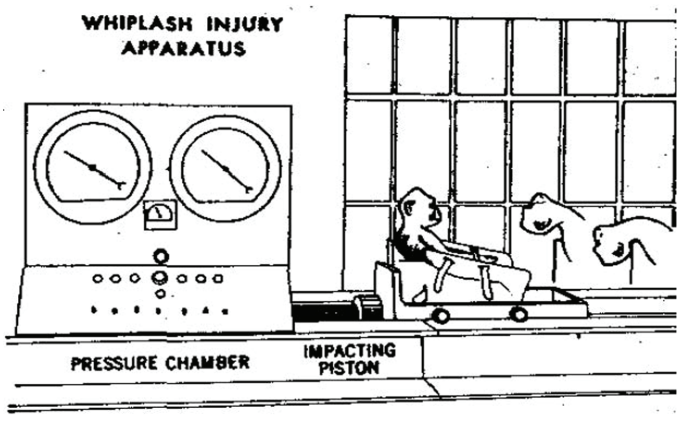

Figure 1. Ommaya's whiplash study apparatus. *Foot note:* Reproduced with permission Ommaya et al, JAMA 1968;204(4)[4] Copyright Auspices of the Board of Trustees, 1968.

shaking. When velocity is increasing, we measure "acceleration," and when decreasing, "negative acceleration," which is often referred to by the more common term "deceleration." The time it takes to change from one velocity to another is the deceleration time.

Ommaya subjected the monkeys to a very forceful whiplash: 40,000 radians/sec^2 of rotational acceleration to the head. In these monkeys, with the distance from the base of the neck to the center of gravity of the head estimated at 6 inches, it was the equivalent of about 600 Gs or 600 times the acceleration due to gravity. Based on National Highway Traffic Safety Administration (NHTSA) data, known injury thresholds to the brain are in the 80-100 Gs range.[5] Above 100 Gs, injury to the brain can be expected. Below 50 Gs no injury occurs. [6]

After impact, Ommaya looked at autopsy findings of the 19 subjects that lost consciousness with the whiplash. Fifteen (79%) had significant gross SDH, and eight of the 19 (42%) had gross evidence of severe neck injury with visible hemorrhage to the brainstem surface. In addition, Ommaya[7,8] separately studied soft tissue and histologic damage, and neurologic dysfunction, which were widespread and considerable in the brain stem.

With current technology, these neck findings following whiplash injury would be evident as soft tissue swelling from hematoma or edema on magnetic resonance image (MRI) and computed tomography (CT) of the neck. The consistent association of SDH and RH with neck damage that Ommaya found is important because shaking forces reach the head via the neck, the weak link between torso and head movement. In recent years, as MRI has become routine in child abuse evaluation, neck pathology has not been found in virtually all cases of alleged SBS.[8,9] In Bandak's[10] study of projected neck damage from abusive shaking he stated, "We have determined that an infant head subjected to the levels of rotational velocity and acceleration called for in the SBS literature, would experience forces on the infant neck far exceeding the limits for structural failure of the cervical spine. Furthermore, shaking cervical spine injury can occur at much lower levels of head velocity and acceleration than those reported for the SBS."

Technologically advanced biomechanical testing with sophisticated instrumented mannequins have failed to demonstrate that abusive shaking of an infant can generate comparable G forces to Ommaya's impacts, or from common household falls over three feet, as calculated below. Testing has shown humans can generate only about 10-15 Gs of acceleration of the brain with the most forceful shaking, a fraction of Ommaya's 600 Gs, and well below the NHTSA's acknowledged threshold for injury. [11,12] The strength of the infant neck increases in a linear manner, with the newborn most vulnerable to abusive shaking. Bandak[10] showed that neck failure, across a spectrum of ages for infants, will occur before brain injury. Barnes[13] more recently used his MRI experience at Stanford to further document the lack of neck findings with alleged shaking and reaffirmed the expectation of neck pathology with a substantial shaking mechanism, including soft tissue injury, ligament damage, fractures and in the extreme, decapitation.[14,15]

Children may be shaken to minor degrees in the course of child care and during well-meaning attempts at resuscitation. Caregivers use various bouncing behaviors to console and entertain children (swinging, rocking, lifting, throwing), and minor resuscitative "shakes" are taught in cardiopulmonary resuscitation classes as "checks for responsiveness." These reports of shaking, in the author's experience, are often regarded by police and child abuse specialists as "confessions of shaking."[16] However, they involve simple translational (side to side) motion and using biomechanical analysis, have been shown to produce low single-digit G accelerations.[17] The level of force is equivalent to that during child's play and normal handling. In a 2001 report by the National Association of Medical Examiners Ad Hoc Committee on SBS, these forces were acknowledged to be "quite benign", yet these admissions are used by prosecutors and child abuse professionals as confessions of abusive shaking, even when the force generated is known to be minimal. [17]

Thus, based on analysis of the force required to cause intracranial injury and the impact of shaking on the neck, without some findings of neck injury on imaging, intracranial pathology resulting from human shaking of a previously healthy child should be seriously called into question.

Other studies looking at accelerations and the alleged relationship between acceleration and RH have similarly shown that high accelerations do not cause RH. Funk[18] looked at 26,000 instrumented football helmet collisions measured during games, with about 2000 collisions generating >85 Gs (or >6000rad/sec^2) of force each. While serious injury occurs in football, this study measured force with routine contact. In this study, the four most severe of the 26,000 collisions resulted in mild traumatic brain injury (concussion). No other injuries, including SDH or RH, occurred to any other players. In this study the threshold for a 10% chance of injury to occur was established at 165 Gs. Animal experimentation generating extreme accelerations to the eye without impact at around 1000 Gs has also failed to produce any RH.[19,20] These accelerations are 70-100 times greater than those that can be generated by humans through a shaking mechanism.

Case reports of witnessed or videotaped shaking of a previously healthy child with demonstrated RH or SDH upon immediate evaluation are conspicuously absent from a thorough search of the forensic and medical literature. Conversely, shaking episodes have been recorded, but have not been associated with SBS injury markers (see link with "References" below to download and view "shaking without injury videos).

If human shaking is not responsible for cases of RH, then what are the mechanisms associated with it? It seems clear

that RH does not occur in pure high G situations. What will be explored first is the long-known relationship of increased intracranial pressure (ICP) to RH. Other possible mimics to alleged abuse and their particular findings will be discussed.

Impact trauma may be the common etiology of increased ICP, SDH and other neuropathologic findings. This connection requires comparison of forces in impact vs. shaking to determine if the data further undermines the link with SBS.

Calculation of Force with Impact and Clinical Considerations

The intensity of force related to shaking or impact is related to (1) change in velocity, (2) the deceleration time and (3) the mass of the object in motion. Force declines rapidly as deceleration time increases by even fractions of a second. A pole vaulter who drops 20 feet and lands in a deep foam pit with a one-second (1000 milliseconds) deceleration time, which is long in physics terms, is not injured. Conversely, extremely rapid changes in velocity on the order of 7.5 milliseconds, from either rapid accelerations like Ommaya's rear end impact experiments or rapid decelerations like a fall to a hard surface, both produce much higher G forces. For example, when a four-pound head hits a concrete floor from three feet high, it would be moving at 13.9 feet/second and would stop in about 7.5 milliseconds (a standard time for a moving skull hitting a hard surface to reach zero velocity). This almost-instantaneous change produces a peak deceleration of 130 Gs. To calculate force at impact the mass of the object must be considered and assuming a four-pound head (about average for a 15-20 pound baby), the peak force at impact is about 265 pounds. To underscore the nonlinear increase of Gs at impact with small changes in velocity, when the same four- pound head hits concrete from just 18 inches higher (4 feet 6 inches), it is traveling at 17 feet/second and generates 170 Gs and 360 pounds of force*. If there is rotation at the time of impact (rotating and falling), velocity attributed to gravity and rotational velocity is cumulative and "resultant" forces increase as well. The most conservative force calculations assume a single part like the head, dropping straight down with no rotation.

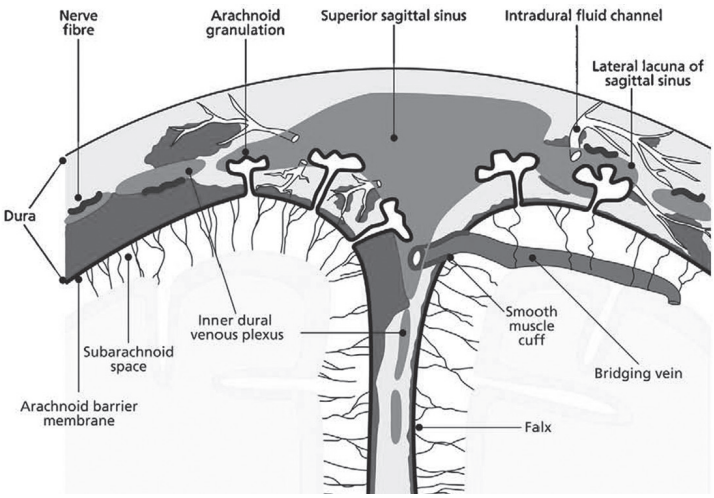

Figure 2a. Dural anatomy. Reproduced with permission Squire and Mack, Forensic Science International, 2009; Copyright Elsevier, 2009.

While biomechanical analysis supports the mechanistic link between falls and high impact, clinically, short falls have been documented to cause serious injury. Greenes et al.[21] in 1997 reported that among children with falls of less than three feet brought to an ED approximately 18% had severe intracranial trauma (ICT) or skull fracture. Another of Greenes'[22] studies in 1998 found 19% of children with significant head injury, primarily skull fractures, were "occult," without neurologic symptoms or evidence of external trauma.

On this basis, the consideration of intentional impact must be carefully evaluated to diagnose abuse, as it is clear that short falls in household situations are sufficient to cause not only ICT, but even death.[23]

Bridging Veins and the Relationship to Subdural Hematoma in Healthy Children

Integral to the SBS hypothesis has been the concept that movement of the brain during shaking shears off the large veins between the brain and the dura, causing SDH. These large veins, the bridging veins (BV), are substantial and move blood from the brain to the dural sinuses. (Figures 2a and 2b) There are about 10 to 20 BVs between the brain and the dura.[24]

Autopsy photos show that BVs are large, appear to stretch substantially and even with severe cerebrocranial disproportion (CCD, extra space around the brain), restriction of movement remains substantial[25] (Figure 3).

Furthermore, if torn BVs were the cause of SDH

*The chain of physics calculations used is this: Impact velocity, V, resulting from free fall from a given height, h, is: V = SQRT(2*g*h) where g is the force of gravity (32.2 ft/sec^2) and h is the height. dV is change in velocity. Average acceleration at impact (a), occurring over a time (dt) with the change in velcoity dV, is a = (dV/dt) OR, average acceleration (a), occurring over a stopping distance, d, can be calculated: a = V^2/(2*d). For a 3-foot fall (h = 3 feet), V = 13.9 ft/sec. If we pick a reasonable impact duration of 7.5 msec, then: a = (13.9 / 0.0075) = 1,853 ft/sec^2 or 58g and for a velocity of 17 feet/sec then a = (17 / 0.0075) = 2,666 ft/sec^2 or 70g. The alternative approach is to pick a reasonable stopping distance of 0.5 inches (0.042 ft) then: a = 13.9^2 / (2*0.042) = 2300 ft/sec^2 or 71g at 3 feet and 106g at 4.5 feet. If we split the difference between the two approaches, that is roughly 65g average acceleration at 3 feet and 90g at 4.5 feet. If we assume a triangular force pulse at impact (standard concept), then the peak values (peak force) are double the average or about 130g peak linear acceleration from 3 feet and 180g at 4.5 feet. The IARV (injury assessment reference value) for the CRABI 6 month ATD (anthropomorphic test device; a type of biofidelic dummy used by the NHTSA) is 50g. To calculate force at impact the mass of the object must be considered. Assuming at head is 4 lbs yields an average force at impact of 265 lbs at 3 ft and about 360 lbs at 4.5 ft. (Calculations validated by John D. Lloyd, PhD, CPE).

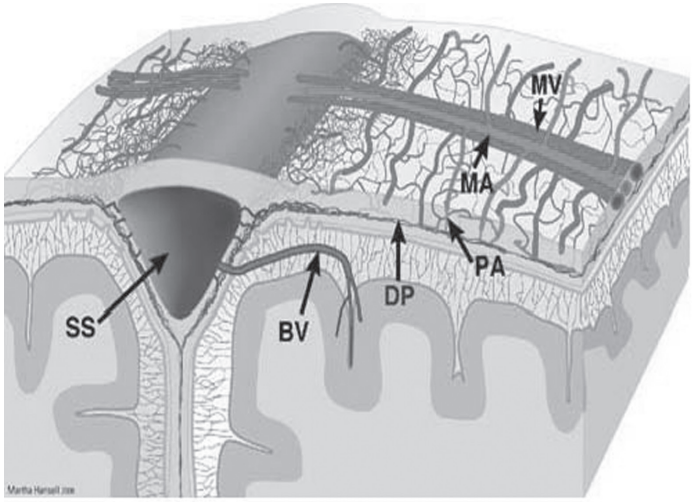

Figure 2b. Three dimensional view of the dural anatomy. The meningeal arteries (MA) and veins (MV) are superficially located, while the dural venous plexus (DP) is located within the inner portion of the dura (intradural). The dural plexus is particularly dense parasagittally, where it connects to the sagittal sinus independently of the cortical BV. From Mack, et. al. 2009. *BV,* bridging vein; *MA*, meningeal artery; *MV*, meningeal vein; *PA*, penetrating arteriole extending to inner dural plexus; *DP* dural plexus; *SS*, superior sagittal sinus. Reproduced with permission Mack et al, Pediatr Radiol. 2009; 39:200-10[28] Copyright Springer, 2009.

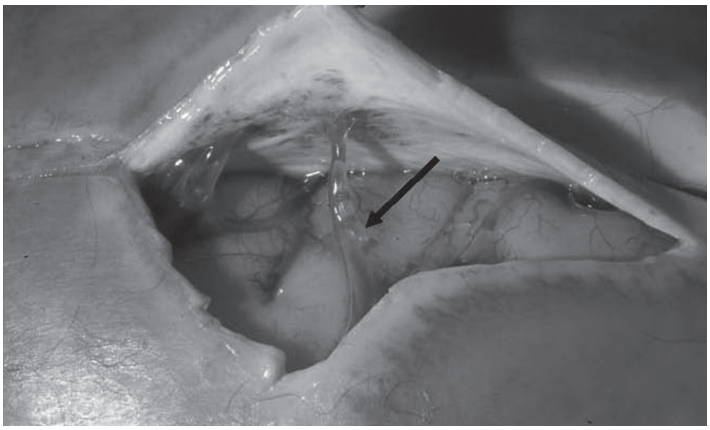

Figure 3. A bridging vein (arrow) at autopsy connecting the dura (reflected) and the brain surface.

formation there would be large collections of blood in SBS cases at autopsy or on CT in all SBS cases. This picture is virtually never seen in alleged SBS.[26] Instead we see smaller collections of blood in the subdural space from only intradural hemorrhage (IDH) from "thin film" to about 1 cm thick. Furthermore, larger bleeds, when found, are relatively contained due to lower capillary pressures, as compared to BVs with higher pressures that increase the mass of extravasated blood. The result would be massive SDH as demonstrated in Figure 4.

BVs can be torn in severe head trauma when depressed skull fractures intrude into the brain space or with extreme CCD. The CCD occurs with severe atrophy in the elderly or in infants with previous birth-related SDH. In either case, a large

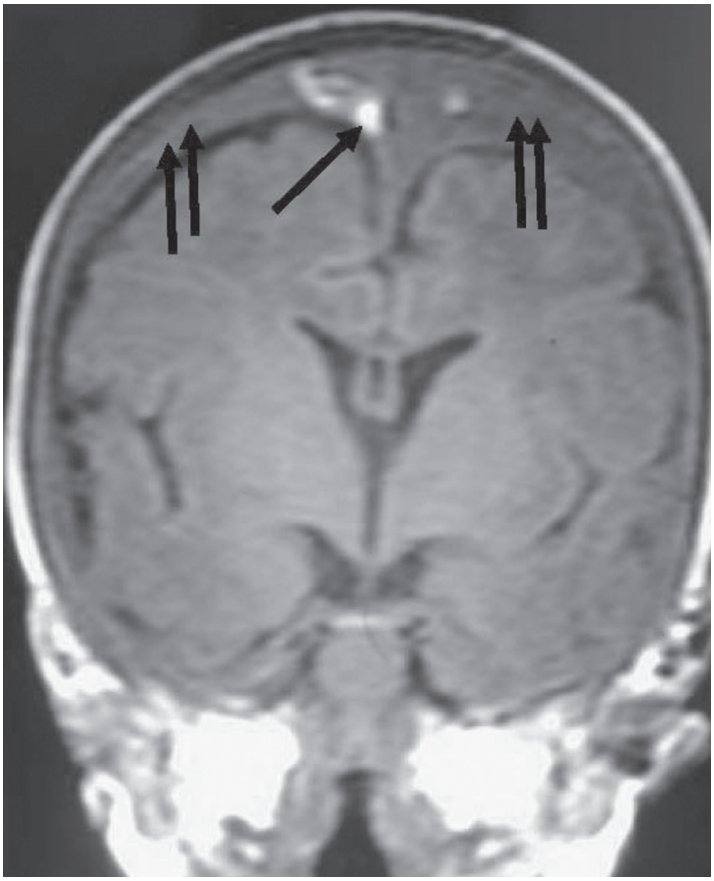

Figure 4. Magnetic resonance imaging of an infant showing massive bleeding from a torn bridging vein with active bleed near the superior sagital sinus (white area is acute blood leaking out, single arrow) and large subdural hematoma filling the subdural space (double arrows).

subarachnoid space between the brain and skull can stretch BV to their tensile limit with even minor movement. If the limits are exceeded and the veins fail, the end result is massive SDH. Therefore, tearing of BVs is an unlikely a cause of SDH in previously healthy infant, but may play some role in the rebleed of an infant with severe CCD from previous SDH, chronic subdural hematoma (CSDH) and significant hygroma.

These situations, however, are distinctly different from the neurologic state of a healthy child allegedly being shaken or the victim of impact trauma. Calculations of flow capacity through a single BV has been studied in elderly adults with micro-ultrasound Doppler techniques, showing that each vein carries on average about 5 cc/min of blood.[27] Thus, when BVs tear, the result is substantial hemorrhage in a very short time with a grave consequences (Figure 4).

The Pathophysiology of Subdural Hematoma

If tearing of BVs in healthy children via shaking is not plausible and intrusive brain injury has not occurred, then what different mechanisms and etiologies can produce SDH in healthy children?

We know that impact trauma can cause SDH; hence, a

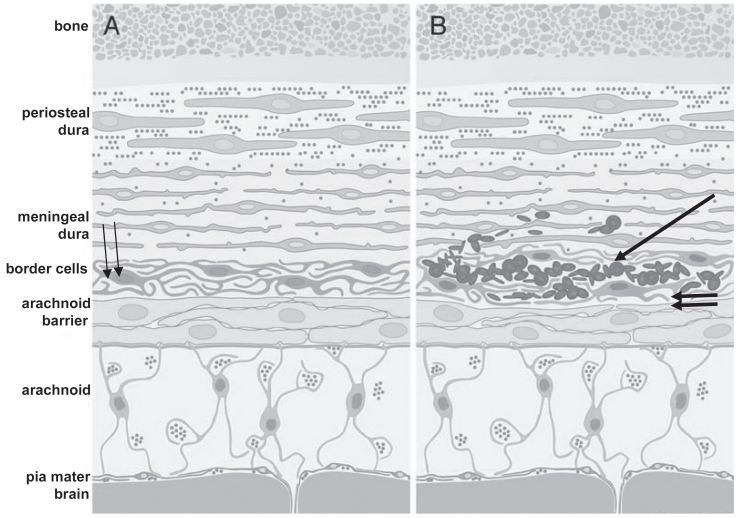

Figure 5a. Dural anatomy and early intradural collection of blood. Figure 5a, panel A. Normal, before hemorrhage. Border cell layer (double arrows) is composed of loosely adherent cells, capillaries, no extracellular collagen, and enlarged extracellular spaces. Figure 5a, panel B. Intradural hemorrhage (single arrow) is seen as a precursor of subdural hemtoma (SDH). SDH is the collection of blood overflowing the intradural space as it grows in size. The blood leaking from the dural capillaries will overflow through the porous border layer (double arrows in 5a, panel B) to a newly created subdural space that forms between the border cells and the arachnoid barrier. The SDH forms due to the dissecting capability of the leaking blood from the intradural plexus to cleave the border cells of the dura from the arachnoid (Figure 5c Panel A and B. In panel B the SDH form between the white arrows). Reproduced with permission Mack et al, Pediatr Radiol. 2009; 39:200-10[28] Copyright Springer, 2009.

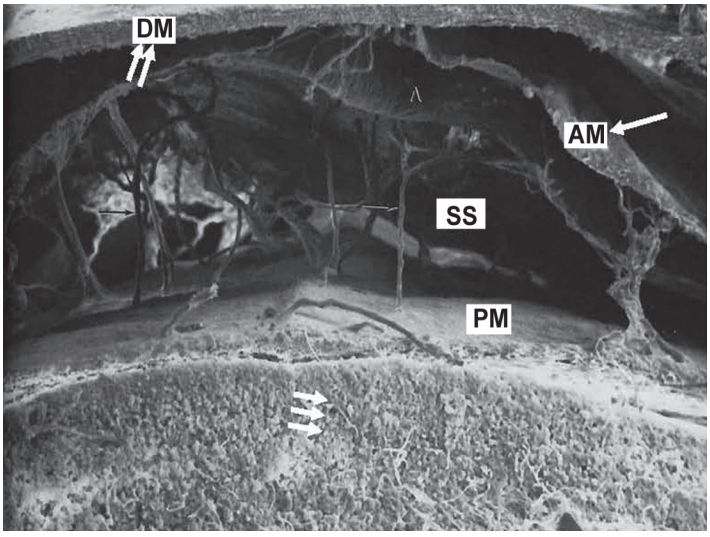

Figure 5b. Photo showing the relationship of the arachnoid (AM, single arrow) easily separating from the dura mater (DM, double arrow) and its relation to the subarachnoid space (SS) and the pia mater (PM). This postmortem photo does not have subdural hematoma (SDH). The PM is closely attached to the brain (triple arrows). Hygroma forms in the SS. Chronic SDH compresses the subarachnoid space and remain closely adherent to the dural border cell layers, which supplies it with blood.

closer examination of the intricate layers covering the brain may reveal that SDH can occur without the tearing of BVs. It is now clear that that SDH begins as IDH and is caused by physical or physiologic damage to the dural capillary plexus.[28] IDH can occur in response to a variety of primary insults. However, if a child has a preexisiting SDH of any etiology, and chronic SDH has developed, shaking or even normal handling can result in spontaneous rebleeding of the previous SDH (subacute or chronic SDH). Vinchon et al[29] in 2010 found 10% of all SDH cases over a three year period at his institution (16 children total) had spontaneous rebleeds without evidence of abuse. Again the distinction between the previously healthy child and the previously damaged child must be made.

These traumatic etiologies in any child, however, are not the only etiology of dural bleeding. Cohen and Scheimberg[30] in 2008, demonstrated that "SDH and cerebral hypoxia are common associations of IDH and that SDH (often seen as a thin film of hemorrhage) almost always occur in association with diffuse falcine IDH. Diffuse IDH with SDH are more frequently associated with severe or moderate hypoxic ischemic encephalopathy (HIE), while mild or early HIE is more common with focal IDH without SDH." Their findings in cases clearly not involving abuse of any type, often occurred in the context of documented increased ICP, acidosis, coagulopathies and/or sepsis, among other medical neuropathologies. Destruction of brain tissue in meningitis and encephalitis and disseminated intravascular coagulation (DIC) are among other things that commonly result in SDH, subarachnoid hemorrhage (SAH), intraparenchymal hemorrhage and intraventricular hemorrhage.[31]

In all cases of SDH in a previously healthy child, IDH occurs first since the capillaries of the dural venous plexus are the source of blood in SDH (Figure 2b). When copious, the hemorrhage overflows the intradural space to fill the "potential" subdural space between the easily cleavable and porous dural border cell layer and the arachnoid. The SDH forms in this newly created "subdural" space (Figures 5a, 5b and 5c).

Pediatric child abuse specialists have acknowledged that a large number of children fall each day and have posited that only a small number of short falls, perhaps "one in 1 million," produce serious or at times fatal injuries.[32] With a large pediatric population, we can assume that serious falls will occur every day. As we know, most parents will seek medical attention for their children after only the more frightening accidental fall. We also know that about one in six of these frightening falls result in serious injury.[21,22] On this basis, it is illogical to reflexively assume a different, sinister act has occurred in patients who are found to have SDH after an accidental fall. Rather, we should recognize that a very small

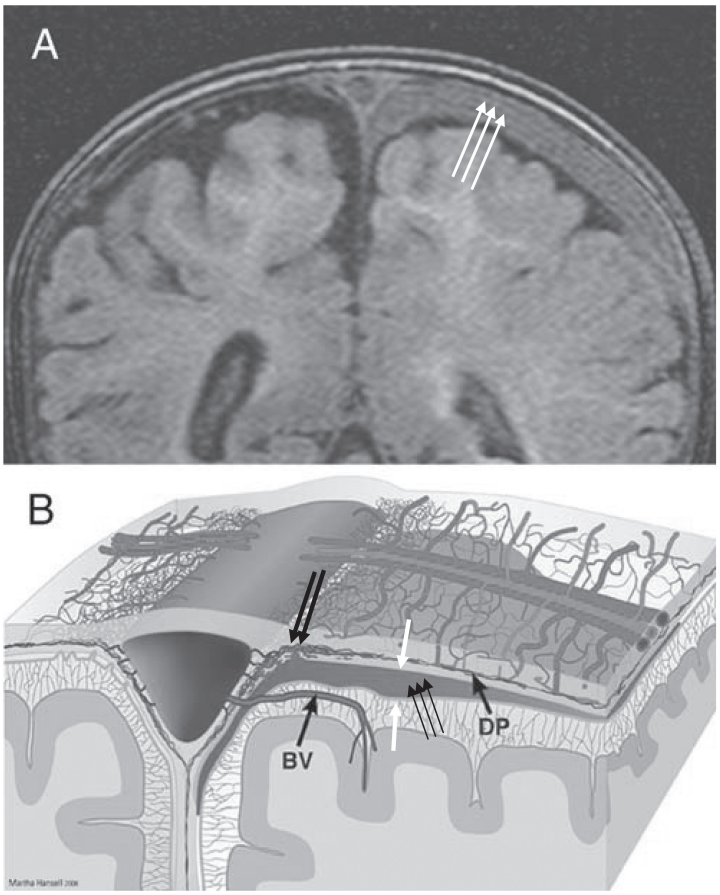

Fig. 5c. Left subdural compartment hemorrhage.
Figure 5c panel A. T1-W coronal magnetic resonance image shows left subdural compartment hemorrhage (triple arrows). Figure 5c, panel B. Graphic representation of hemorrhage originating from the intradural plexus (DP) and its relation to intact bridging vein (BV). Blood overflows the intradural space at a damaged area (double arrows on B) and cleaves the dural border cell layer from the arachnoid (between the white arrows; border cells on top and arachnoid on bottom), filling the space with blood forming the conventional subdural hematoma (triple arrows). Reproduced with permission Mack et al, Pediatr Radiol. 2009; 39:200-10[28] Copyright Springer, 2009.

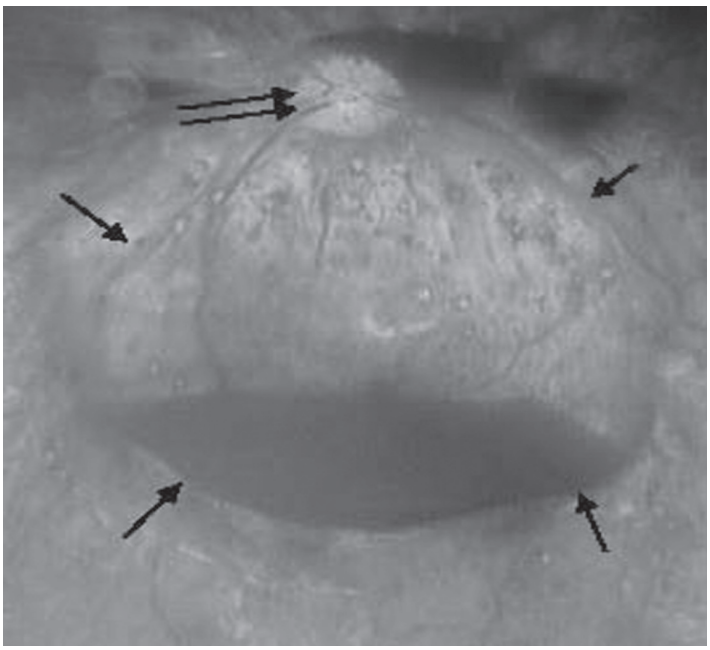

Figure 6a. Schisis cavity on the macula, also referred to a boat shaped retinal hemorrhage or macular schisis, of a child lying right side down with free blood in the cavity creating a red blood cell/serum interface. The edges of the schisis cavities (single arrows) form ridges that are called retinal folds. Optic disc at double arrows.

subset of all accidental falls can and do result in serious brain injury. With a large denominator of accidental falls, the serious brain injuries can and do result from innocent, accidental mechanisms, and each of these cases most likely prompts a medical encounter.

The nature of the serious fall, as compared to the large number of non-serious falls, is that the baby must land just so, with a vulnerable part (i.e. skull) taking the brunt of the impact at a sufficient speed, against a sufficiently hard surface to generate the requisite forces. Most importantly, with head impacts, every time these criteria are reached, serious injury results: SDH, skull fractures, epidural hematoma (EDH), RH, cerebral edema and other injuries are expected. Yet Caffey[23] and his cohorts presumed from the inception of the SBS theory that short falls could not produce adequate force to cause serious injury. This was incorrect.[23] Now with both new and old research,[33] some child abuse specialists will for the first time admit that short falls can cause serious injury, including SDH, and have recently acknowledged that RH and other retinal damage can occur with short falls as well.[34-37]

Relation of Increased Intracranial Pressure to Retinal Hemorrhage

There is a long and well-documented relationship of RH to increased ICP unrelated to abuse. The non-abuse causes of increased ICP leading to RH can be due to infection, hypoxic-ischemic encephalopathy (HIE), post-event cerebral edema from any traumatic or metabolic calamity and in some cases an idiopathic etiology.

The first of many studies to show that RH is associated with increased ICP of any etiology was published in 1900 by Dr. Albert Terson[38], a French ophthalmologist. Terson's syndrome, as it came to be known, showed that increased ICP after hemorrhagic stroke produced RHs. Medele[39] in 1988 revalidated Terson's original study. More recent studies have done the same.[40]

Walsh[41] in 1951 demonstrated the relationship of increase ICP with optic nerve sheath hemorrhage and RH. The optic nerve sheath is the dura surrounding the optic nerve, and the mechanism that produces optic nerve sheath hemorrhage, IDH and RH, is the same. Muller[41] in 1974 confirmed that increased ICP caused optic nerve sheath hemorrhage. Aoki[43] in 1986 found that 100% of children, not shaken, with SDH from

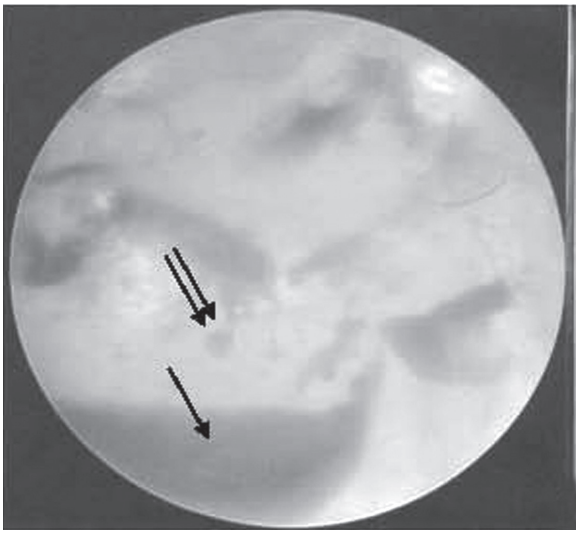

Figure 6b. Vitreous hemorrhage (single arrow) and a typical retinal hemorrhage (double arrows) on indirect opthalmoscopy unrelated to abuse.

Figure 6c. Fundus OS, demonstrating moderate vitreous hemorrhage now diffusely dispersed in the vitreous creating a cloudy appearance, obscuring retinal detail.

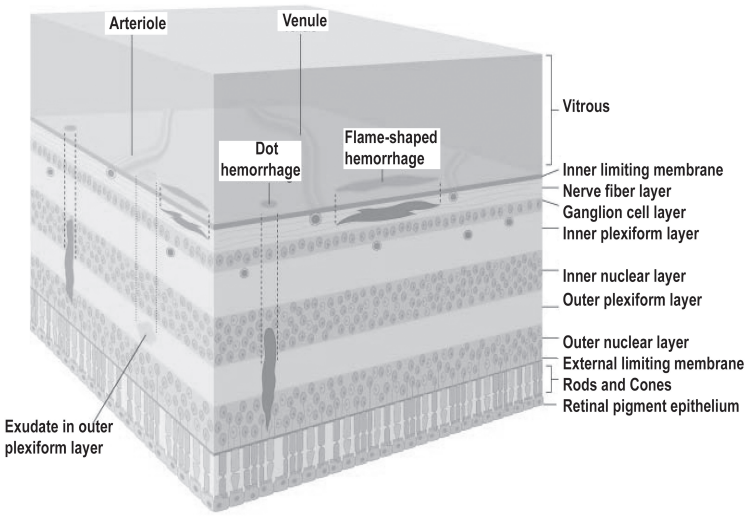

Figure 6d. Retinal microanatomy. Schisis cavities are in same layer as the flame shaped hemorrhages (under the ILM) but larger and centrally located (Figure 6a). Other types of retinal hemorrhage described in abuse cases are shown as well. With more widespread capillary damage, vitreous hemorrhage occurs (Figure 6b).

impact trauma, had RH. Lashutka[44] in 2004 plotted a 1:1 correlation between increased ICP and increased intraocular pressure. Tayal[46] in 2007 found that optic nerve diameter, measured by ultrasound, nearly doubled in size when increased ICP was present after impact trauma that resulted in increased ICP. Increasing intraocular pressure (IOP) decreases flow through the eye by increasing intracapillary pressure, decreasing both ingress and egress of blood from the eye, contributing to the metabolic compromises, capillary wall damage and leakage of blood, and RH.

Other etiologies of RH include transient increases in ICP with extreme coughing and valsalva, which can occur with choking episodes.[47-48] High altitude cerebral edema, another form of protracted hypoxemia, also produces RH.[49] RH from the compressive forces of labor alone raising ICP in the head, occurs in 45% of all births.[50]

It is clear that RH occurs from many causes and that shaking, if capable of causing RH, is quite nonspecific.

Pathophysiology of Retinal Hemorrhages, Schisis Cavities and Vitreous Hemorrhage

A closer examination of RH itself supports the relationship of RH to brain pathology with increased ICP. RH could be regarded as the first finding in a continuum of ocular hemorrhages associated with brain pathology and increased ICP, not specifically from shaking, or even a traumatic mechanism.

As ICP increases, IOP also increases.[44,46] As IOP increases, intraocular capillary perfusion pressure decreases and oxygen delivery to the retina falls. This is similar to the well-accepted mechanism that a decrease in cerebral perfusion pressure occurs in the cranium as ICP rises. In the brain, this leads to metabolic catastrophe, HIE and brain death. Similarly, when capillary blood flow to the eye decreases, a relative or absolute hypoxemia occurs in the retinal capillary cell wall, damaging the capillary wall that then leaks, forming RH.[51] This is the same mechanism that creates IDH and SDH during harmful hypoxic-ischemic periods in the brain.

In the eye, as pressure and hypoxia increase, capillary wall failure is more likely and the number, size and distribution of RH increase. Early in the process, RH is manifest as a few, small, central (macular) hemorrhages located in a single layer. But as more capillaries fail, especially in the denser and metabolically demanding areas of the retina, more hemorrhage occurs and blood can coalesce into larger hemorrhages in both the retina and the vitreous.

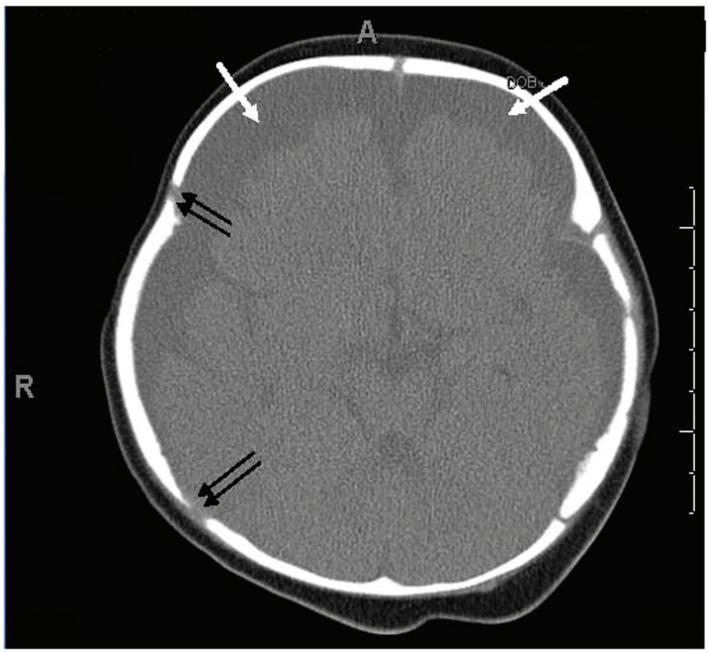

Figure 7. Female, four months old, on admit after apparent life threatening event (ALTE). Note extra space around brain at single arrows: bilateral subdural hygromas filled with cerebral spinal fluid (CSF). This fluid is generally described as "hypodense"or "attenuated" on computed tomography. This darker grey is consistent with density of CSF or a mixture of xanthochromic CSF and older blood. Slightly splayed sutures are noted in several locations (double arrows).

When this occurs, RHs are distributed more widely to the periphery of the eye to the ora serrata, and occur in different layers of the retina. As challenges to the diagnostic reliability of a few central RHs arose after central RH alone appeared in documented non-SBS cases, the criteria to diagnose shaking were changed so that only the more severe forms of intraocular hemorrhage were to be considered diagnostic of nonaccidental injury. Studies by Gilliland[52] and Emerson[53] document the invalidity of using any pattern as more or less diagnostic of abuse. Emerson found among 118 suspected abuse cases, all forms of eye pathology were present in significant numbers and in different combinations: RH in 44%, folds with schisis cavities in 23% and bilateral in 50% of those cases. Peripapillary scleral hemorrhage was present in 38% of cases, and SDH was present in the distal optic nerve in 46% of cases. Hemosiderin was present in 27% of cases. The variety of findings in abuse did not fit any particular pattern and were distributed almost equally among blunt head injury and blunt injury to the body (52% vs. 40%). Gilliland[52] added that "various ocular findings including retinal hemorrhages have been proposed in the literature to unequivocally distinguish non-accidental injuries. Retinal hemorrhages are frequently associated with nonaccidental injuries but other causes must be excluded." Lantz[35] found from autopsy work on 425 eyes of the recently deceased that 17% exhibited RHs associated with a variety of diseases and conditions. It becomes clear that using quantity, location or pattern of RH to diagnose abuse is invalid when extensive RH, often in multiple layers and at times with frank vitreous hemorrhage, is predictably seen in a variety of conditions of extreme ICP, protracted hypoxemia or other conditions.[35]

Beyond RH, any combination of decreasing perfusion pressure and increasing venous outflow obstruction, both proportional to increased ICP, will result in significant hypoperfusion and hypoxia, damaging more capillaries. The sequence starts in the macula area, dense with capillaries, which leaks first and blood can accumulate under the internal limiting membrane (ILM) the most anterior layer of the retina (Figure 6d). It is here that individual hemorrhages, if sufficient in number, can coalesce to form a pool of blood called a schisis cavity. When these disc-shaped collections of blood pool on the inner surface of the ILM, the blood mass tents the membrane, creating what appear to be retinal folds seen at the edge of the cavity as raised edges (Figure 6a).

In the most extreme hypoxic states or with DIC, blood overflows these schisis cavities and other areas of dense RH, leading to frank vitreous hemorrhage (Figure 6b) along with more widespread RH to extending to the periphery of the retina. When Blood diffuses into the vitreous and is widely distributed, a cloudy appearance results that can obscure the retinal landmarks (Figure 6c).

The American Academy of Ophthalmology has endorsed and taught the current corps of ophthalmologists that RH, schisis, retinal folds and vitreous hemorrhage are identified with intentional abuse when in fact these findings are more likely the consequence of metabolic catastrophe within the eye itself and unrelated to shaking forces as discussed above.

Perinatal Subdural Hematoma and its Relation to Shaken Baby Syndrome

The finding of SDH in a neonate, by itself, may not have occurred due to abuse or other types of postpartum trauma. A 2008 study by Rooks[54] using MRI to screen "normal" newborns, showed that almost half of newborns have SDH at birth, the result of forces applied to the head during labor. This perinatal SDH (PSDH) was present in 46% of the apparently "normal deliveries." Extreme molding, cephalohematoma and overriding sutures, common findings after "normal" deliveries, are testament to the forces involved. Protracted labor, pelvic dystocia, the use of oxytocin, prematurity, macrosomy, forceps or vacuum extraction delivery, and vitamin D deficiency (discussed below) are significant risk factors for excess compression of the skull, deformation and dural damage and SDH. With any of these circumstances, PSDH can occur. PSDH, if complicated, in turn can lead to hydrocephalus, subdural hygroma, increased ICP and RH.

When the forces of labor compress the neonatal skull, or protracted hypoxemia occurs for any reason, dural capillaries are damaged and leak as discussed above, forming the PSDH. Newborns must rely on this dural capillary plexus to absorb

cerebral spinal fluid (CSF) passing through the porous dural border layer until the arachnoid granulations, which facilitate CSF reabsorption, fully develop around six months of age (Figure 2a). When CSF absorption is blocked by extravasated red blood cells from the PSDH before the arachnoid granulations develop, CSF accumulates between the pia (closely adhered to the brain) and the arachnoid, which remains associated with the dural border cells and the dura. The space that forms is a hygroma. As pressure increases, the hygroma expands and continuous forces are exerted on the unfused skull, resulting in splayed sutures lines and hydrocephalus (Figure 7). Hydrocephalus is the primary clinically measurable complication of PSDH and evolves over weeks to months. It is driven by increased ICP and if the increased ICP is sufficient, RH will develop as discussed above. If the situation does not resolve or stabilize, increased pressure persists and other neuropathic events may occur.

Although more than 99% of neonates with PSDH recover without complications, Rooks described 1/101 (1%) of her subjects who developed these two common complications of PSDH: hygroma and hydrocephalus. The actual complication rate may be as low as .05%, but with about four million births per year in the United States (U.S.) these numbers would still yield 2,000 cases of unresolved PSDH cases with complications. While infrequent, most of these situations lead to a neuropathic event before six months of age that triggers a medical encounter. When the event is frightening, it is considered an apparent life-threatening event (ALTE). The ALTE typically involves apnea, color changes, either erythema, cyanosis, pallor or plethora; changes in muscle tone, usually limpness, but seizures also can occur. Many ALTEs involve choking, gagging and vomiting. At the encounter, any old or new intracranial blood seen on head imaging may generate a working diagnosis of abuse, and initiates a forensic investigation.

Note that in the U.S., healthcare providers are considered "mandatory reporters," obligated by law to report suspicion of child abuse. Hence, while these findings may be due to rare but described complications of birth trauma, they would invariably result in a report to the local Child Protective Services and/or police agency.

PSDH is generally regarded as asymptomatic at birth, but some neonates have subtle findings that can appear in pediatric outpatient records, if sought. These symptoms and signs may be dismissed as normal postnatal behaviors, such as minor feeding problems, unexpected crying over the first few days after birth, positional problems when breast feeding or a preference to being held upright (to reduce ICP). These findings are virtually never linked to PSDH nor is a specific etiology dependably sought. Newborn ultrasound, done frequently to screen for intracranial bleeding, especially intraventricular hemorrhage, appears incapable of identifying virtually any of the 46% of children born with PSDH and should not be relied on to rule out perinatal intracranial bleeding.[54, 55] When such findings are more severe or sufficient to be noted in the record, screening MRI is indicated but virtually never done. Early identification of problematic PSDH with MRI, however, should be regarded as important to investigate subtle behavioral abnormalities to prevent later accusations of abuse if complications arise.

Accelerated head circumference growth, while often missed or ignored, is a relatively reliable clinical indicator of possible complications of PSDH and is readily accessible in most pediatric outpatient records. Early identification of CSDH as a complication of PSDH can lead to appropriate follow-up, more careful handling of such children until the condition resolves and the early detection of potential problems.

Late Complication of Perinatal Subdural Hematoma: Chronic Subdural Hematoma Rebleeds and Apparent Life Threatening Events

If PSDH persists, progresses, or is complicated, neuropathic events occur, including ALTE, usually between six weeks and six months of age.[56] This corresponds to the average age bracket in which SBS is diagnosed, 10-13 weeks.[57] These ALTE children become the object of intense scrutiny, and child abuse investigations are triggered with any intracranial blood, RH or other bone and soft tissue findings. When SDH and RH, in any form is noted, SBS and intentional abuse is likely to be diagnosed early and other possible etiologies and favorable social factors (no prior violence, long documented records of loving childcare, good character), less seriously considered and frequently disregarded.

When PSDH does not completely resolve, CSDH develops. CSDH is a retracted acute clot infiltrated with fibroblasts and fibrin that achieves structural integrity in the subdural space. (Figures 8a and 8b). This structure can result in "neomembranes" and intradural hemosiderin deposits in or on the inner surface of the dura that can be seen on MRI and at autopsy as free hemosiderin or hemosiderin-laden macrophages. A neomembrane is the result of proliferation and excessive thickening of the normal layer of dural border cells where chronic SDH form and attach.[58]

CSDH is a common finding on a first CT of a child presenting with ALTE, who may also have acute or subacute SDH.[59] While CSDH may exist without apparent brain damage, it is a bioactive mixture of clotting and declotting factors competing to stabilize and be reabsorbed simultaneously. It is physically fragile and prone to rebleeds with low levels or no apparent force. Rebleeding can occur with a minor trauma (including resuscitative shakes or consoling behaviors), during lumbar puncture or intravenous starts with physical restraint, or crying (Figure 8a), or with normal handling. It is possible that rebleeding of CSDH may be a basis for connecting nonabusive shaking to SDH when mixed collections of old and new blood are seen on imaging and some minor movement event has been reported.

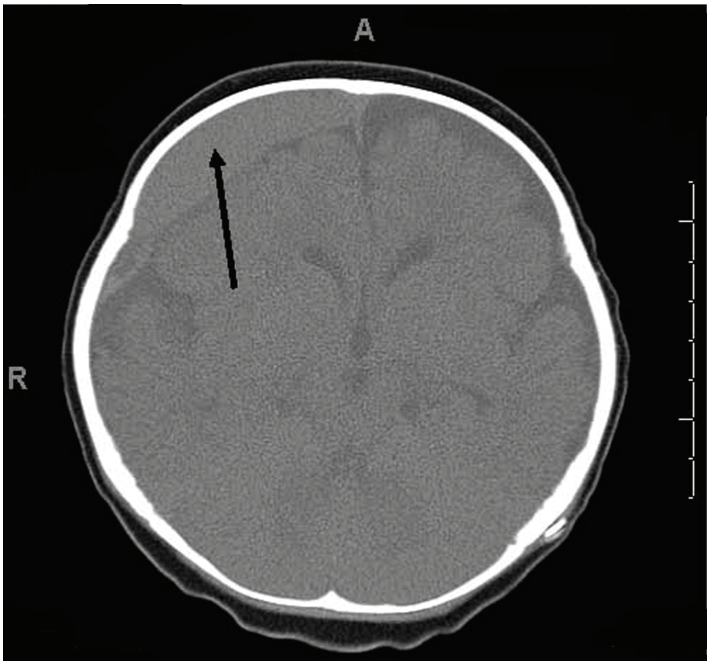

Figure 8a. Same four month old female in figure 7; Second computed tomography after admit. New acute subdural hematoma in right frontal area (arrow) that occurred in the hospital after an lumbar puncture without anesthesia.

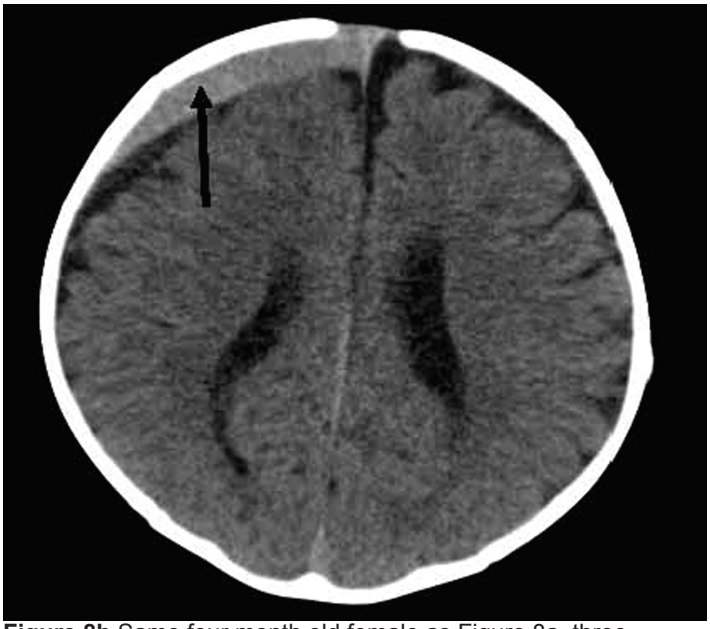

Figure 8b Same four month old female as Figure 8a, three months later with acute subdural now a chronic subdural (arrow) attached to inner layer of dura (dural border cell layer), compressing the hygroma space and right ventricle.

It takes about three weeks for CSDH to appear on CT or MRI, and thereafter the appearance is stable.[59] CSDH older than three weeks all appear the same and therefore birth-related bleeding can be present as stable CSDH for some time after birth, generally a number of months to about one year. When imaging demonstrates hematomas of different ages in the same image, there may be no identifiable clinical events to correlate with either a primary or recurrent bleeding. Each episode of rebleeding can elevate already increased ICP, new RH and ALTE may occur, generally before the age of six months.

With premature infants, neurologic events can occur soon after birth, since neuropathic events including apnea spells, dysphagia, and regurgitation, among other neurologic abnormalities, are more frequent with an immature neurologic system. These children with occult birth-related neurologic damage remain quite susceptible to later ALTEs that are frequently not linked to birth-related problems. In spite of very short intervals between the birth problems and the subsequent ALTE, an abuse event may be suspected.

When these infants present after an ALTE, they may have seizures, decreased muscle tone (limpness), vomiting, failure to thrive, hydrocephalus, altered level of consciousness (LOC), color changes from hypoxic episodes, conventional or dysphagic choking, abnormal breathing patterns, and apnea.[60] Pediatric records going back to birth may reveal hydrocephalus, irritability, fussiness, and other subtle post-natal problems without explanation, both episodic and recurrent. Examination of perinatal records may be key to identifying subtle signs of PSDH and CSDH, as this may explain the etiology of RH and SDH more plausibly than unwitnessed abusive shaking.

Physical findings of CSDH can include unstable and abnormal vital signs, respiratory instability, including apnea, dysphagia, regurgitation, bulging fontanelle, altered LOC, or seizure activity (focal, generalized or petit mal). RH may be seen immediately by the primary provider, but frequently eye examination is not done until one to two days after presentation. In the interim, ICP may be elevated from a variety of causes and may result in new RH within hours of a precipitous increase in ICP and IOP. RH is expected to be present within 12-36 hours after onset of an event that gradually increases ICP, but if DIC occurs after HIE, sepsis or injury, RH can occur sooner.

With any of these symptoms or physical findings, abuse should be uniformly considered; hence, CT of the head and neck, skeletal surveys and ophthalmology consults are done routinely. Head imaging can show hygroma, hydrocephalus, acute or chronic SDH, or intraventricular or intraparenchymal bleeding. Skeletal survey may reveal metabolic bone disease or prior injury. Eye exam may reveal RH if ICP has been elevated for as little as several hours, if the insult is sufficiently severe. Lab testing can reveal metabolic bone disease, genetic abnormalities, or coagulopathy.

Associated Findings in Suspected Child Abuse Cases

When an infant is found to have RH or SDH, pediatricians routinely perform a skeletal survey to search for corroborative findings of suspected child abuse. However, vitamin D

deficiency (VDD) and its bony manifestation, rickets, can lead to deformation of the weakened skull during birth resulting in PSDH, and contribute to bony findings that seemingly confirm the child abuse etiology. VDD and rickets are both widely under-recognized and widespread. In one of the first of a number of studies screening for VDD, 85% of pregnant women in Pittsburgh, screened during labor, were VDD and these deficient levels, as well as any total body calcium deficiency will be passed to the neonate at birth more or less in equal measures.[61,62]

Skeletal survey frequently reveals various dysplastic bone abnormalities of the extremities and ribs related to VDD rickets. The bony dysmorphic areas seen in rickets may be diagnosed as abusive fractures without consideration of vitamin deficiency. Pathologic fractures may occur as well, as the bones are both soft and weak and generally osteopenic when tested.[63]

In long bones, the most common rickets-related findings are referred to as classic metaphyseal lesions (CML) and are characterized by child abuse specialists as abusive injuries. These "corner" or "bucket handle" fractures in most alleged abuse cases are painless, have normal range of motion, and no soft tissue injury, making intentional application of force unlikely. The radiographic findings are transient (Figure 9) but may nevertheless be interpreted as abusive, without clinical correlation, vitamin D testing, meaningful differential diagnosis or corroborative history of violence.[64]

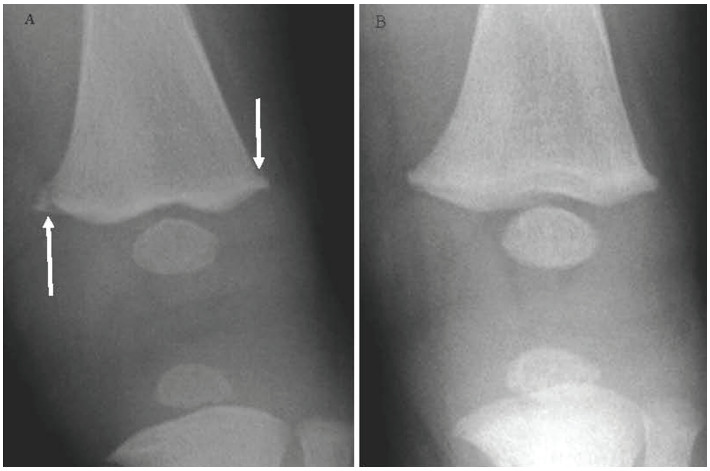

Figure 9. A. The "corner fractures" or classic metaphyseal lesion of L femur seen in vitamin D deficient babies that represents dysplastic growth. In this case the leg was nontender with normal painless range of motion. B. Sixteen days later the findings are resolved without callus formation after vitamin D supplementation.

Confusion Between Central Nervous System Infection and Shaken Baby Syndrome

Fever, irritability, meningeal signs, elevated white counts and tense fontanelles suggest central nervous system infection. However, SBS may nevertheless be misdiagnosed for the following reasons. Antibiotics may be given early and empirically, resulting in negative blood cultures. Antivirals are being given empirically as well. Diagnostic lumbar puncture is frequently omitted due to concerns for increased ICP related to SDH. CSF cultures, if done, may be falsely negative after empiric antibiotics, and viral cultures are rarely done on blood and not uniformly on CSF. The self-limited nature of viral meningitis and its low mortality, identified as a cause of ALTE in 1-3% of all ALTE cases, may contribute to missing this diagnosis.[56] Chadwick[65] estimates that some 30,000 cases of viral meningitis occur in the U.S. per year. While treating "meningitis" prior to laboratory confirmation is certainly a sound clinical strategy, this has substantial legal consequences. Absent or negative cultures due to common early treatment, increases the number of infectious disease cases that go undiagnosed. Absent laboratory evidence of infection, the abuse diagnosis is supported by default. While the presence of RH is an indication for neurologic and ophthalmologic consultation and admission, the presence of RH alone should not be regarded as diagnostic of abuse. Ophthalmologic exam, when increased ICP is present, predictably reveals RH. Absent an obvious medical problem or witnessed accident, the caregiver's explanation of either a prodromal illness or an accidental injury may be dismissed. The treating physicians relying on the belief that SDH and RH equate to abuse are likely to dismiss other possible etiologies, and meaningful differential diagnosis may cease. The abuse diagnosis is advanced as an increasing certainty in both the medical records and in legal proceedings.

Medical Legal Concerns

Concerns about diagnostic accuracy of SBS are now present and have been recognized by some U.S. courts and the Canadian government.[66-67] The Goudge commission, set up in Canada in 2008, investigated SBS and afterwards called for a review and reevaluation of all previous SBS convictions in Canada. The Innocence Project has done a careful and detailed legal and medical analysis further delineating the controversy.[68]

In response to criticism of the mechanism of SBS, new names have been applied through the years. What began as "shaken whiplash" evolved to SBS. In the 1980s, when biomechanical challenges to the sufficiency of pure human shaking to cause brain injury emerged,[6] the concept morphed to encompass "shaken impact." Now with more evidence disputing the link between shaking and RH, a small group of influential child abuse specialists have advanced the label: "abusive head trauma" (AHT). In April 2009 in a media campaign, SBS was officially rebranded by the American Academy of Pediatrics as AHT, a term crafted to connote an etiology and a legal conclusion and to, in the organization's words, "provide more clarity in the courtroom."[69-70] While this term's validity as a medical diagnosis deserves further scrutiny, it does appear to acknowledge that the shaking mechanism is no longer thought sufficient to account for the resultant pathology.

CONCLUSION

According to the evidence presented here, the "prognostic" relationship between shaking and RH is seriously called into question. It appears that SBS does not stand up to an evidenced-based analysis. It appears that RH should not be used as a diagnostic sign of child abuse. It appears that the weight of evidence, both old and new, suggests that increased ICP is a valid, common and predictable cause of RH and that human shaking, by itself, in a healthy child, is insufficient to cause this. Furthermore, children with perinatal SDH, or pre-existing SDH of any cause, are prone to rebleed, resulting in episodes of increased ICP, new RH and more symptoms, which may occur with minimal force applied to the head or with normal handling.

While we must always be mindful of child abuse, which is certainly real and pervasive, we must exercise appropriate restraint to avoid a form of iatrogenic abuse. When children are removed inappropriately from their families, sometimes permanently, based on a specious connection between physical findings and mechanism, there is certainly harm. A detailed history, longitudinal evaluation of the family, true differential diagnosis, and in-depth analysis of all factors discussed here must be done in each case. To do any less is a disservice to our children and their families.

Link to All References

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Link to Videos of Two Separate Episodes of "Shaking without Injury"

https://www.yousendit.com/download/bFlHWmd0UnEwZ214dnc9PQ

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Management of Pediatric Skin Abscesses in Pediatric, General Academic and Community Emergency Departments

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Objectives: To compare the evaluation and management of pediatric cutaneous abscess patients at three different emergency department (ED) settings.

Method: We conducted a retrospective cohort study at two academic pediatric hospital EDs, a general academic ED and a community ED in 2007, with random sampling of 100 patients at the three academic EDs and inclusion of 92 patients from the community ED. Eligible patients were ≤18 years who had a cutaneous abscess. We recorded demographics, predisposing conditions, physical exam findings, incision and drainage procedures, therapeutics and final disposition. Laboratory data were reviewed for culture results and antimicrobial sensitivities. For subjects managed as outpatients from the ED, we determined where patients were instructed to follow up and, using electronic medical records, ascertained the proportion of patients who returned to the ED for further management.

Result: Of 392 subjects, 59% were female and the median age was 7.7 years. Children at academic sites had larger abscesses compared to community patients, (3.5 versus 2.5 cm, p=0.02). Abscess incision and drainage occurred in 225 (57%) children, with the lowest rate at the academic pediatric hospital EDs (51%) despite the relatively larger abscess size. Procedural sedation and the collection of wound cultures were more frequent at the academic pediatric hospital and the general academic EDs. Methicillin-resistant *Staphylococcus aureus* (MRSA) prevalence did not differ among sites; however, practitioners at the academic pediatric hospital EDs (92%) and the general academic ED (86%) were more likely to initiate empiric MRSA antibiotic therapy than the community site (71%), (p<0.0001). At discharge, children who received care at the community ED were more likely to be given a prescription for a narcotic (23%) and told to return to the ED for ongoing wound care (65%). Of all sites, the community ED also had the highest percentage of follow-up visits (37%).

Conclusion: Abscess management varied among the three settings, with more conservative antibiotic selection and greater implementation of procedural sedation at academic centers and higher prescription rates for narcotics, self-referrals for ongoing care and patient follow-up visits at the community ED. [West J Emerg Med. 2011;12(2):159-167.]

INTRODUCTION

Concurrent with the emergence of Methicillin-resistant *Staphylococcus aureus* (MRSA) as a community pathogen, the incidence of skin and soft tissue infections has rapidly increased over the past decade.[1-3] Since many skin and soft tissue infections, in particular skin abscesses, require urgent evaluation for potential surgical management and antibiotic therapy, emergency departments (EDs) receive a large number of visits for these infections, with children comprising a significant proportion of patients.[4-9] Since ED care for pediatric patients is often provided in varied settings, ranging from the community setting to academic pediatric EDs, the management of pediatric skin abscesses has the potential to vary greatly based on the site of emergency care.[10-12]

While evidence-based consensus guidelines can result in improved patient care, few currently exist for the management of cutaneous abscesses.[13] This is further complicated by differences in routine care of adult and pediatric cutaneous abscesses, such as wound packing following incision and drainage, which has come into question in pediatric abscesses, and the use of routine wound cultures for bacterial surveillance.[14-16] In addition, oligoanalgesia may complicate ED abscess care, particularly in the pediatric population.[17,18] A common approach to abscess drainage includes local anesthesia; however, its use is questionable owing to the lower pH within the abscess cavity, which may reduce the effectiveness of lidocaine.[14,19] As a result, local anesthesia, systemic analgesics and procedural sedation are variably used in different practice settings, although these differences have not been previously described.[18]

Given the potential for highly variable clinical management, we initiated this investigation to examine practice patterns for skin abscess across three different emergency care settings: two academic children's hospital EDs, a general academic ED and a community ED. We sought to compare these differences for three important aspects of care for skin abscesses: (1) procedural and antimicrobial therapies, (2) rates of wound culture and MRSA prevalence and (3) provision of analgesia.

METHODS

Study Design

This was a retrospective cohort study of children who presented to the ED for evaluation of a skin abscess.

Study Setting and Population

Eligible subjects included children ≤18 years, diagnosed with a cutaneous abscess in one of four participating EDs between January 1 and December 31, 2007. Our goal was to focus on children with routine skin abscesses. To this end, we excluded children who presented with an isolated pilonidal or genital abscess, as these infections frequently involve consultation and management by a subspecialist. We also excluded patients with isolated paronychial infections since management is relatively standard, involving a minor drainage procedure and also because the causative organisms are typically oral rather than skin flora. The study was approved by each participating site's institutional review board.

Of the four participating study centers, The Children's Hospital of Philadelphia and St. Christopher's Hospital for Children are dedicated academic, tertiary care pediatric hospitals with an approximate annual ED census of 82,000 and 58,000 respectively. Cooper University Hospital is an academic center that provides care to both adults and children. This center has a nested pediatric ED located within the main (general academic) ED, where approximately 12,500 children are evaluated annually by fellowship-trained pediatric emergency physicians (EP) from 9 AM to 1 AM, and general EPs for the remaining eight hours. Our Lady of Lourdes Hospital, the fourth center, is a community ED, receiving 9,000 pediatric visits per year. Children are cared for by board-certified EPs and nurse practitioners, none of whom are subspecialty trained pediatric healthcare providers.

We acquired study data using computerized billing and data entry systems and identified potential subjects at each participating center using International Classification of Diseases, Ninth Revision codes consistent with skin infections (680.0–686.9). We reviewed medical records to identify patients who presented with a cutaneous abscess. A random selection of 100 patients from each of the three academic centers and 92 abscess patients from the community ED comprised the study cohort. We achieved the random selection of children from the academic centers using a random number generator (http://www.random.org).

Study Protocol

Data Abstraction Incorporated recommended protocols for chart review research, including case selection protocols, abstractor training and monitoring, and the use of standardized data abstraction forms.[20] To ensure data quality, each site underwent a training period where 10 patient medical records were abstracted by both the originating site and the primary site. We compared these data forms and discussed and resolved any discrepancies (<1% of all data) before actual data collection was initiated. Each site had a primary data abstractor who was blinded to the goals of this investigation. Demographics, predisposing conditions,[1, 21] physical exam findings, incision and drainage procedures, therapeutics (e.g. antibiotics, warm compresses), and final disposition were recorded. Laboratory data were reviewed for culture results and antimicrobial sensitivities. For subjects managed as outpatients from the ED, we determined where patients were instructed to follow up (pediatrician versus ED) and, using electronic medical records, ascertained the proportion of patients who returned to the ED for further management.

Statistical Analysis

Normally distributed data are presented using summary

statistics with means ± standard deviation. Non-parametric data are presented as medians with interquartile ranges (IQR). We compared patient characteristics and patient management at three ED settings, academic pediatric EDs, a general academic ED and a community ED. For comparisons of categorical variables, we used Fisher's exact and χ^2 tests, where appropriate. We performed comparisons between the three settings using one-way analysis of variance for parametric data and the Kruskal-Wallis test for non-parametric data. Comparisons between two settings (i.e. the three academic sites versus the community site) were made using Student's t-test for continuous variables. Significance was set at $p \leq 0.05$. We analyzed data using SPSS version 15.0 (SPSS, Inc., Chicago, Il).

RESULTS

Patient Characteristics

A total of 392 patients were included in this cohort; data were available for all 392 (100%) eligible subjects. The study population consisted of 230 (59%) girls, 186 (47%) black and 90 (23%) Hispanic children. The median age was 7.7 years (IQR: 2 to 15 years), with a bimodal distribution: 103 (26%) children between one and two years and 68 (17%) children 16-17 years. Age differed among sites, with a younger patient population presenting to the children's hospital EDs (median age 4.8 years; IQR: 1.7 to 13.8 years), older children at the community site (median age 8.4 years; IQR: 2.7 to 16.1 years), and the oldest group at the general academic ED (median age 12.4 years; IQR: 3.4 to 16.6 years), p= 0.007. We present other patient characteristics, including co-morbidities, prior and family history of skin infections, in Table 1.

Compared to the community ED, children who presented to centers with dedicated pediatric EPs (the two academic pediatric hospital EDs and the general academic ED) had larger mean abscess size (3.5 ±2.4 cm versus 2.5 ±1.7cm; p=0.02). Over half of subjects, 216 (55%), underwent incision and drainage of their abscess in the ED. Nine additional children, all of whom presented to the academic pediatric hospital EDs, underwent incision and drainage in the operating room. Median age of these patients was 1.4 years (Range: 5 months to 10.5 years). Mean abscess size was smallest in patients who did not undergo incision and drainage (2.8 ±2 cm), larger in those who underwent ED-based procedures (3.5 ±2.4 cm) and largest in those who went to the operating room (5.4 ±3.5cm) (p=0.01). (Table 2).

Culture Rates and Antimicrobial Sensitivities

Wound cultures were more commonly obtained at the children's hospital and general academic EDs. MRSA was the most common organism isolated at all three study sites,

Table 1. Patient characteristics for academic pediatric, general academic pediatric and community emergency department (ED).

Characteristic	Academic Pediatric Hospital ED (n=200)	General Academic Pediatric ED (n=100)	Community ED (n=92)	All Patients (n=392)
Female, n, %	114, 57%	61, 61%	55, 60%	230, 59%
Predisposing conditions				
History of prior abscess	55, 28%	34, 34%	16, 17%	105, 27%
In contact with prior abscess patient	39, 20%	26, 26%	7, 8%	72, 18%
Attend daycare (children <5 years)	17 of 101, 17%	4 of 30, 13%	4 of 35, 11%	25 of 166, 15%
Hospitalized in past 30 days	13, 7%	3, 3%	4, 4%	20, 5%
Most common abscess sites				
Lower extremity	50, 25%	42, 42%	29, 32%	121, 31%
Buttock	51, 26%	21, 21%	22, 24%	94, 24%
Abdomen	16, 8%	17, 17%	11, 12%	44, 11%
Face	23, 12%	6, 6%	9, 10%	38, 10%
Upper extremity	22, 11%	8, 8%	7, 8%	37, 9%
Axilla	13, 7%	9, 9%	4, 4%	26, 7%
Groin	14, 7%	5, 5%	5, 5%	24, 6%
Multiple abscesses at presentation	59, 30%	31, 31%	7, 8%	97, 25%
Surrounding cellulitis*	168, 84%	21, 21%	16, 17%	205, 52%
Presence of fever (≥38° Celsius)†	41, 21%	11, 11%	13, 14%	65, 17%
Hospitalized	48 , 24%	0	10, 11%	58, 15%

* If noted in the medical record that there was an area of cellulitis surrounding the abscess
† Temperature measured rectally in children <5 years and orally if ≥5 years.

ranging between 61-76%. MRSA prevalence did not significantly differ among EDs, nor did the rates of Methicillin-sensitive *Staphylococcus aureus* (MSSA) [Table 2]. Of the non-MRSA/MSSA organisms, the most common isolates were coagulase negative *Staphylococcus aureus* (n=6); *Proteus mirabilis* (n=5), group A beta hemolytic streptococcus (n=3), and *Pseudomonas aeruginosa* (n=3).

Antimicrobial sensitivities were obtained for the 138 MRSA isolates. In all three practice settings, there was 100% susceptibility to trimethoprim-sulfamethoxazole and 97-100% susceptibility to vancomycin. Linezolid susceptibility, tested only at the academic pediatric hospital EDs and at the community ED, was 100%. Cindamycin sensitivity was variable: 96% for the academic pediatric hospital EDs, 98% for the general academic ED and 80% for the community ED.

Outpatient Instructions

At discharge, outpatient antibiotics were routinely prescribed at all sites, with practitioners at the academic pediatric hospital EDs prescribing empiric coverage for MRSA in the highest proportion of patients (Table 3). Instructions or prescriptions for eradication therapy were only provided at the academic pediatric hospital and the general academic EDs and included mupirocin ointment

Table 2. Medical management and culture results at three pediatric care settings.

Medical management	Academic Pediatric Hospital ED (n=200)	General Academic Pediatric ED (n=100)	Community ED (n=92)	P-value*
Underwent incision and drainage in ED, n, %	92, 46%	74, 74%	50, 54%	< 0.0001
Infiltrated anesthetic (lidocaine)	23 of 92, 25%	22 of 74, 30%	34 of 50, 68%	< 0.0001
Topical anesthetic cream	53 of 92, 58%	53 of 74, 72%	0	< 0.0001
Procedural sedation used	26 of 92, 28%	24 of 74, 32%	6 of 50, 12%	0.04
Packing placed in abscess cavity	16 of 92, 17%	39 of 74, 53%	25 of 50, 50%	< 0.0001
Wound culture obtained†	126 of 156, 81%	70 of 89, 79%	18 of 63, 29%	< 0.0001
Organisms obtained at culture				
MRSA	74 of 126, 59%	53 of 70, 76%	11 of 18, 61%	0.06
MSSA	28 of 126, 22%	17 of 70, 24%	5 of 18, 28%	0.85
Other organism(s)	24 of 126, 19%	0	2 of 18, 11%	0.0005

*χ^2 used to compare patient management and organism characteristics at the three settings.
†Wound culture percentages reflect only those patients who had a spontaneously draining abscess or underwent incision and drainage of their abscess, including in the operating room.
ED, emergency department; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *MSSA,* methicillin-sensitive *Staphylococcus aureus*

Table 3. Discharge instructions and follow up at three pediatric care settings.

Medical management	Academic Pediatric Hospital ED (n=152)	General Academic Pediatric ED (n=100)	Community ED (n=82)	P-value
Adjuvant antibiotics given at discharge, n, %	148, 97%	89, 89%	76, 93%	0.05
Empiric coverage for MRSA*	140, 92%	86, 86%	58, 71%	<0.0001
Trimethoprim-sulfamethoxazole	34 of 140, 24%	63 of 86, 73%	57 of 58, 98%	<0.0001
Clindamycin	106 of 140, 76%	23 of 86, 27%	1 of 58, 2%	<0.0001
Eradication therapy recommended†	14, 9%	23, 23%	0	<0.0001
Advised to return to ED for follow-up	8, 5%	34, 34%	53, 65%	<0.0001
Patients who returned to the ED for follow up wound care/packing change	20, 13%	35, 35%	30, 37%	<0.0001

*Empiric antibiotic coverage for MRSA included oral trimethoprim/sulfamethoxazole or clindamycin. Antibiotics used that did not have MRSA coverage included: Cephalexin (n=13), Augmentin (n=6), Amoxicillin (n=5), Doxycycline, (n=2), Tetracycline (n=2), and Ciprofloxacin (n=1)
†Eradication therapy using mupirocin ointment, hibiclens/chlorhexidine washes or bleach baths
ED, emergency department; *MRSA*, methicillin-resistant *Staphylococcus aureus*

(n=35) and chlorhexidine baths (n=20) [Table 3]. Follow-up recommendations also varied by site: academic pediatric hospital EDs were the most likely to refer patients back to their primary care providers. In contrast, the community ED instructed the majority of patients to return to the ED for follow up (Table 3). The highest follow-up rates were at the general academic and the community EDs. Of children who returned for follow up, nine at the two academic pediatric hospital EDs, three at the general academic ED and five at the community ED, had an unchanged or worsening presentation. Based on electronic admission data and subsequent review of individual medical records, 10 patients originally discharged from the ED were admitted to the hospital within 30 days of their initial visit for worsening of their original abscess. One child was admitted to one of the children's hospitals, six were admitted to the general academic hospital and three were admitted to the community hospital.

Procedural Sedation and Analgesia

Assessment and treatment of pain differed among study sites. Although the community ED was the least likely to provide procedural sedation for abscess incision and drainage or use a topical anesthetic for pain control, practitioners at the community ED were the most likely to use infiltrated anesthesia prior to incision and drainage and to provide patients with oral pain medication. For the procedural sedation procedures conducted at the three academic centers (academic pediatric hospital and general academic EDs), a narcotic (fentanyl or morphine) was only used in two (2%) [academic pediatric hospital EDs] and 10 (14%) [general academic ED] patients. Ketamine was used in 31 (19%), midazolam in 35 (21%), and propofol in eight (5%) of the three academic center patients. Provision of and instructions for the use of analgesics at discharge also differed between the three settings, with the general academic and the community EDs most frequently providing analgesic instructions and prescriptions (Table 4).

Age as a Factor Influencing Outcomes

Given the relatively younger patient population served by the academic pediatric hospital EDs, we were concerned that this patient subset may have influenced our results. To address this potential confounder, we excluded children two years and under and conducted selected analyses on the older subjects. These findings are presented in Table 5.

DISCUSSION

In this study we describe the current presentation, bacteriology, sedation and analgesia practices and therapeutic strategies for pediatric cutaneous abscesses in three different ED settings. Prior studies of other conditions have demonstrated differences in patient characteristics and specific aspects of medical management between pediatric and general EDs; however, ours is the first to examine practice differences for pediatric abscesses among varying sites of emergency care.[22,23]

Medical management of patients differed among the academic pediatric hospital, the general academic and the community EDs. Abscess incision and drainage rates were higher in our four sites (55%) than previously described, with the highest rate in the general academic ED.[11] Use of packing was nearly 2.5 times higher in the general academic and in the community EDs when compared to the academic pediatric hospital EDs. This difference may be due to provider preference, and neither method is considered superior to the

Table 4. Pain assessment and treatment at three pediatric care settings.

Characteristic	Academic Pediatric Hospital ED (n=200)	General Academic Pediatric ED (n=100)	Community ED (n=92)	P-Value
Pain assessed at triage, n, %	134, 67%	87, 87%	67, 73%	0.001
Mean pain score*	2.1 ±3.4	3.8 ±4.1	4.8 ± 3.5	0.003
Pain relievers given during ED visit				
Acetaminophen	13, 7%	4, 4%	6, 7%	0.66
Ibuprofen	14, 7%	13, 13%	22, 24%	<0.0001
Oral narcotic	16, 8%	14, 14%	20, 22%	0.004
Topical anesthetic†	57 of 92, 62%	54 of 74, 73%	0	<0.0001
Infiltrated anesthetic (lidocaine)‡	23 of 92, 25%	22 of 74, 30%	34 of 50, 68%	<0.0001
Discharged with any pain medication	38 of 152, 25%	64, 64%	35 of 82, 43%	<0.0001
Discharged with a narcotic pain medication	7 of 152, 5%	9, 9%	19 of 82, 23%	<0.0001

*Triage pain scale of 1-10 completed for 63 academic pediatric hospital ED patients, 12 general academic ED patients and 28 community ED patients. The remaining scores were either using the Wong Baker Faces scale or a descriptive assessment.
†Topical anesthetic use is only reported for patients who underwent an incision and drainage procedure.
‡Infiltrated anesthetic was only used in incision and drainage patients.
ED, emergency department

other. Packing is theorized to prevent the wound margins from closing and forming a potential dead space, and periodic removal of packing is considered to provide gentle debridement of necrotic tissue.[14] These theoretical benefits, however, have never been scientifically demonstrated, and a recent investigation demonstrated no significant difference in the need for a second intervention in adults who underwent packing of their abscess (17%) compared to those who did not (20%).[15] An alternative reason for reduced packing rates at dedicated children's hospitals is that abscess patients are routinely referred back to their pediatricians for ongoing care. Most pediatricians are not familiar or comfortable with the management of a packed wound, and, upon encountering one, may refer the patient back to the ED for ongoing wound management.

We also demonstrated differences in wound culture rates for pediatric skin abscesses. The academic pediatric hospital EDs and the general academic ED almost routinely obtained wound cultures, whereas the community ED obtained them only one third of the time. The community ED practice is discordant with recommendations from the Center for Disease Control, which encourages clinicians to collect specimens for culture and antimicrobial susceptibility testing from all patients with purulent skin lesions.[24] Recently, however, the use of routine culturing has been questioned, with some EPs suggesting that unless the patient appears systemically ill or is immunocompromised, simple incision and drainage without routine antimicrobial susceptibility testing or therapy should suffice.[15,16] Two additional concerns regarding all-inclusive routine culturing, are whether it is appropriate to conduct such testing when the results will minimally (or not at all) alter patient management, and, whether it is appropriate for the individual patient to bear the cost of a test for perceived public health benefit.[25]

Although overall MRSA prevalence was higher in our cohort than previously described, MRSA prevalence in the community ED most closely approximated rates reported in the literature.[10,11,26] The routine use of antibiotics was somewhat unexpected, since only about half of the patients in our sample had a surrounding cellulitis documented in their medical record, an indication for antimicrobial therapy in the setting of a draining cutaneous abscess.[16] There are several reasons why practitioners at the academic pediatric hospital and the general academic EDs were more likely to initiate empiric therapy for MRSA than the practitioners at the community ED. Given the tertiary care centers at which they practice, pediatric specialists are more likely to encounter children at higher risk for complications due to immunosuppression or comorbid factors. Alternatively, the high rates of MRSA prevalence may have influenced adjuvant outpatient therapy. Lastly, pediatric EM healthcare providers may be more likely to encounter life-threatening infections

Table 5. Medical management, culture results and pain control in children >2 years at three pediatric care settings.

Medical management	Academic Pediatric Hospital ED (n=200)	General Academic Pediatric ED (n=100)	Community ED (n=92)	P-value*
Underwent incision and drainage in ED, n, %	61, 46%	62, 72%	45, 59%	0.001
Infiltrated anesthetic (lidocaine)	19 of 61, 31%	20 of 62, 32%	30 of 45, 67%	0.0002
Topical anesthetic cream	37of 61, 61%	43 of 62, 69%	0	< 0.0001
Procedural sedation used	18 of 61, 30%	21 of 62, 34%	5 of 45, 11%	0.03
Packing placed in abscess cavity	13 of 61, 21%	33 of 62, 53%	22 of 45, 49%	< 0.0001
Wound culture obtained†	74 of 95, 78%	61 of 74 , 82%	12 of 56, 21%	< 0.0001
Organisms obtained at culture				
MRSA	38 of 74, 51%	42 of 61, 69%	7 of 12, 58%	0.12
MSSA	18 of 74, 24%	14 of 61, 23%	4 of 12, 33%	0.75
Other organism(s)	18 of 74, 24%	0	1 of 12, 8%	0.0001
Adjuvant antibiotics given at discharge	111 of 113, 98%	76 of 86, 88%	64 of 70, 91%	0.02
Empiric coverage for MRSA	103 of 113, 91%	73 of 86, 85%	49 of 70, 70%	0.0008
Pain assessed at triage	134, 67%	87, 87%	67, 73%	0.001
Discharged with any pain medication	28 of 113, 25%	56 of 86, 65%	30 of 70, 43%	<0.0001
Discharged with a narcotic pain medication	7 of 113, 6%	9 of 86, 11%	16 of 70, 23%	<0.0001

*χ^2 used to compare patient management and organism characteristics at the three settings.
†Wound culture percentages reflect only those patients who had a spontaneously draining abscess or underwent incision and drainage of their abscess, including in the operating room
ED, emergency department; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *MSSA*, methicillin-sensitive *Staphylococcus aureus*

due to community associated-MRSA (CA-MRSA), due to referrals and transfers of such children to their highly specialized practice settings. This may also have lowered their thresholds for administering antibiotics for uncomplicated skin abscesses.[27-29]

Nevertheless, the high rate of empiric antimicrobial therapy at all three practice settings is not consistent with the standard of care for uncomplicated abscess management, which remains incision and drainage.[16] With the emergence of MRSA, this practice was re-examined in an adult population, where over 90% of patients experienced a clinical cure after undergoing incision and drainage and receiving a placebo.[30] Similar observations are documented in children who were discharged after their incision and drainage without antibiotics or on agents ineffective against MRSA.[12,31,32] The results of a recent randomized controlled trial in children provides additional evidence that antimicrobial therapy is not required for the resolution of uncomplicated abscesses after incision and drainage.[33] At three months, there was no difference between placebo and antibiotic treatment with respect to new abscess formation.[33] At this time, it is unknown if CA-MRSA-associated life-threatening infections and fatalities are related to prior or current cutaneous abscesses.[34] Until this is demonstrated, the routine use of antimicrobial agents for uncomplicated, draining cutaneous abscesses remains questionable.[16]

We noted differences in the use of procedural sedation and analgesia among the sites of care as well. Topical anesthetics and procedural sedation for abscess drainage were more routinely employed in the academic pediatric hospital and the general academic EDs, whereas lidocaine infiltration was more common at the community site. These differences may be due to several factors. The mean abscess size in the community sample was approximately one centimeter smaller as compared to mean abscess size at the other sites. A smaller abscess may have lent itself to more effective local anesthesia. In contrast, procedural sedation may have been deemed necessary for the larger abscesses which were encountered at the other three sites. At discharge, the provision of analgesics (or instructions for the parent to provide the child with an analgesic medication) was also the lowest at the academic pediatric EDs. In contrast, the community ED had the highest rates of oral narcotic medication use during the ED visit and also at discharge. Our findings demonstrate that the need for acute pain control appears to be recognized across practice settings, yet improvements in pain assessment and outpatient pain management are still needed. These therapeutic oversights suggest that oligoanalgesia in the pediatric abscess population remains an issue at academic pediatric hospital, general academic and community EDs.

LIMITATIONS

Because we identified study subjects using billing data from each site, it is possible that potential subjects were missed, owing to errors in coding. Additionally, all data were obtained via medical record review, thus subjecting the study to information bias from missing data elements. The academic pediatric hospital EDs provided care to children who were younger than those who presented to the general academic and the community EDs, which may have had some influence on practitioners' evaluation and management of pediatric abscess patients. We respectfully counter that age was not a primary factor in practice patterns, since the differences we noted in the use of procedural sedation and topical anesthetics for drainage procedures, abscess packing, antibiotic administration and selection, the assessment of pain at triage, and recommendations for follow up and for outpatient pain control remained even after limiting the analyses to children over two years of age.

We were also unable to differentiate if MRSA abscesses were from community or hospital-associated strains. Our intention was to be inclusive of routinely evaluated cutaneous abscesses, not to focus on MRSA specifically. Cultures were not obtained in all cases of cutaneous abscesses, so our report of MRSA prevalence rates may not be accurate, although wound cultures were among the practices we wished to assess.

While not a primary objective of this investigation, we did attempt to assess outcomes. These efforts were limited, due to the retrospective nature of this investigation. To maximize our ability to identify adverse outcomes, such as revisits to the ED and hospitalization, we conducted electronic ED visits, admissions and medical record reviews. Given that the four sites were all within a circumscribed geographic area, we are confident that the majority of patients who may have worsened during the 30-day window would have presented to one of the four sites and, therefore, would have been captured by our review. Pain scores were not consistently documented and only available for older children. Thus, the mean pain scores we reported may not accurately represent the level of pain in children at each site. Lastly, there were only four sites that participated in one metropolitan area, with only one general academic pediatric ED and one community ED, limiting the generalizability of our results.

CONCLUSION

The results of our study demonstrate that the management of pediatric skin abscesses vary greatly by site of care. Community ED practitioners are more likely to use local anesthesia and wound packing but less likely to routinely obtain wound cultures. Academic pediatric hospital and general academic EDs, often staffed with pediatric emergency trained physicians, were more likely to use procedural sedation during ED management and send cultures after drainage procedures. Discharge practices also differed between sites. Practitioners at academic pediatric hospital EDs were more likely to refer patients back to their pediatrician, whereas at the community ED, and less so for the general academic ED, patients were instructed to return for ongoing

care. Outpatient pain management was highest at the general academic ED and practitioners at the community ED were the most likely to prescribe a narcotic pain reliever. Our findings highlight the differences in abscess management across emergency care settings, and reflect the lack of consensus regarding therapy for pediatric skin abscess. Dissemination of current research findings and subsequent standardization of care across settings could result in consistent and improved care for pediatric abscesses. As best evidence practices continue to develop, translation of this knowledge should be targeted at academic children's hospital, general academic, and community EDs.

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Test Characteristics of Urinalysis to Predict Urologic Injury in Children

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Objective: To use receiver operator characteristic curve methodology to determine the test characteristics of microscopic hematuria for identifying urologic injuries in children who underwent computed tomography (CT) of the abdomen and pelvis as part of a trauma evaluation.

Methods: We performed a retrospective medical record review of all children from 0 to 12 years of age who presented to our pediatric emergency department within a Level 1 trauma center, had an abdominal and pelvic CT and a microscopic urinalysis as part of an initial evaluation for trauma. Urologic injury was defined as any injury to the kidneys, ureters or bladder. We defined hematuria from the microscopic urinalysis and reported by the clinical laboratory as the exact number of red blood cells per high power field (RBC/hpf).

Results: Of the 502 children in the study group, 17 (3%; 95% CI [2%-5.4%]) had evidence of urologic injury on the abdominal or pelvic CT. Microscopic urinalysis for those children with urologic injury ranged from 0 to15,544 RBC/hpf. The remaining 485 children without urologic injury had a range of hematuria from 0 to 20,596 RBC/hpf. A receiver operating characteristic curve was generated and the area under the curve is 0.796 (95% CI [0.666-0.925]).

Conclusion: If the abdominal and pelvic CT is used as the criterion standard for identifying urologic trauma, the microscopic urinalysis has moderate discriminatory power to predict urologic injury. [West J Emerg Med. 2011;12(2):168-172.]

INTRODUCTION

There is considerable debate regarding the role of a microscopic urinalysis in the evaluation of a traumatized child. Historically, a microscopic urinalysis has been used to risk stratify traumatized children with respect to urologic injuries.[1-3] Traumatized children who had more than a threshold number of red blood cells per high-powered field (RBC/hpf) on microscopic urinalysis or gross hematuria were deemed at higher risk for urologic injury and subsequently underwent radiologic imaging. Prior to the 1990s, an intravenous pyelogram was the imaging modality of choice. Currently, computed tomography (CT) is preferred.[4,5]

A number of researchers have attempted to identify this threshold number of red blood cells. Some researchers have suggested threshold values ranging from 5, 20, 50, 100 RBC/hpf and gross hematuria.[3,5-13] Other researchers have suggested that any degree of microscopic hematuria places a traumatized child at increased risk for urologic injury.[14,15] At the other end of the spectrum, some authors have suggested that microscopic hematuria does not reliably predict urologic injury.[2,4,16-19]

Our objective was to use receiver operator characteristic (ROC) curve methodology to determine the test characteristics of microscopic hematuria for identifying urologic injuries in traumatized children who underwent CT scanning of the abdomen and pelvis as part of a trauma evaluation in the emergency department (ED).

METHODS

We performed a retrospective medical record review of all children from 0 to 12 years of age who presented to our pediatric ED within a Level 1 trauma center from January 2000 to December 2004. Children were included if they had a pelvic CT and a microscopic urinalysis performed as a part of a trauma evaluation. Children were excluded if the CT was performed for an indication other than trauma, if the CT was performed in the hospital after the initial trauma evaluation in the ED, microscopic urinalysis was not performed, or if the medical record was incomplete. A board-certified/eligible radiologist provided the reading of the CT proximate to the time of the index visit. We included children transferred for a trauma evaluation from an outside facilities if they met all inclusion criteria.

A trained researcher extracted the age of the patient, CT report and microscopic urinalysis results from the medical record, using a standardized data collection form. Urologic injury was defined as any injury to the kidneys, ureters or bladder. Injuries to any intra-abdominal or pelvic structures that do not directly function to produce urine were not considered urologic injury in our study. Congenital urogenital anomalies identified on CT were not considered urologic injuries. The urine samples were processed using the iQ-Elite automated urinalysis system (IRIS International Inc., Chatsworth, California) and reported by the clinical laboratory as the exact number of red blood cells per high power field.

We calculated descriptive statistics, generated a ROC curve, and calculated the area under the curve to assess the ability of a microscopic urinalysis to discriminate urologic injury. Statistical analyses were performed using Stata 9.1 (Statacorp, College Station, Texas). Our local institutional review committee approved this study.

RESULTS

We identified 3,680 children who met inclusion criteria. We excluded 2,890 children for CT not performed in the ED as part of the initial trauma evaluation. We excluded an additional 288 children without a microscopic urinalysis. All medical records were available for review. The study group

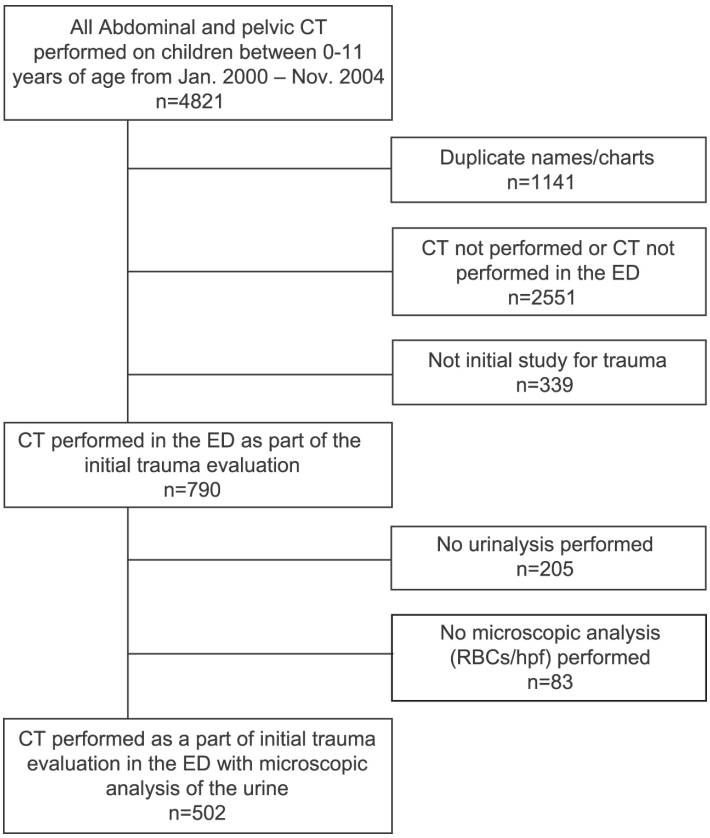

Figure 1. Patient Flow Diagram
CT, computed tomography; *ED,* emergency department; *RBC/hpf*, red blood cells per high power field

Table 1: Urologic injuries with corresponding ages and urinalysis results (n=17)

Patient age	Urinalysis (RBC/hpf)	Description of urologic injury
1 year 2 months	0	Renal contusion with perinephric fluid
1 year 2 months	7212	Acute vascular insult of kidney
2 years 5 months	75	Renal laceration
2 years 9 months	996	Renal laceration
3 years 10 months	3	Renal contusion
4 years 8 months	270	Bladder rupture
4 years 11 months	46	Renal hypoperfusion
6 years 5 months	2	Vascular avulsion of kidney
7 years 3 months	46	Devascularization injury
7 years 6 months	15,544	Renal contusion and laceration
7 years 7 months	15	Renal contusion
7 years 8 months	879	Bladder contusion
8 years	132	Renal contusion
10 years	0	Renal laceration
10 years 1 month	70	Decreased renal perfusion
10 years 1 months	83	Renal laceration
10 years 9 months	1	Acute renal vascular injury

RBC/hpf; red blood cells per high power field

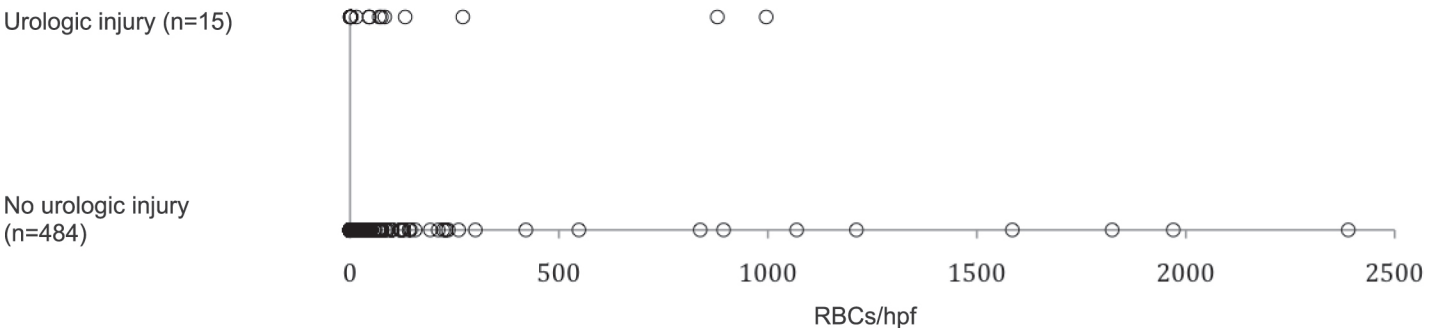

Figure 2. Distribution of urinalysis results (red blood cells per high power field [RBC/hpf]) in those children with and without urologic injury (n=499)*
*Three extreme urinalysis results were excluded from this graph: 20,596 RBC/hpf from the non-urologic injury group, 7212 and 15,544 RBCs/hpf from the urologic injury group.

consisted of 502 children (Figure 1) with a median age of 5.8 years (range: 21 days to 10.9 years). Of the 502 children, 17 children (3%; 95% CI [2%-5.4%]) had evidence of urologic injury on the abdominal or pelvic CT scan with an age range of 14 months to 10.9 years. The urologic injuries included renal contusions, bladder contusion, kidney lacerations, bladder rupture, perinephric hematomas/hemorrhage, and vascular insults described as renal hypoperfusion, infarct, or vascular disruption (Table 1). The results of the microscopic urinalysis for those children with evidence of urologic injury ranged from 0 to 15,544 RBC/hpf. The remaining 485 children without urologic injury had a range of hematuria from 0 to 20,596 RBC/hpf (Figure 2). A 10-year-old with no urologic or intra-abdominal trauma noted on the abdominal/pelvic CT had the highest degree of hematuria (20,596 RBC/hpf).

We calculated the test characteristics for the microscopic urinalysis to discriminate children with urologic injury identified on CT (Table 2). A ROC curve was generated with an area under the curve of 0.796 (95% CI [0.666-0.925]) (Figure 3).

In a sub-analysis, 59% (10/17; 95% CI [32.9-81.6]) children with urologic injury noted on abdominal/pelvic CT had concomitant non-urologic intra-abdominal injury. The amount of hematuria for these children ranged from 0 to 15,544 RBC/hpf. The identified non-urologic intra-abdominal injuries included intraperitoneal or pelvic free fluid, pelvic fractures, solid organ lacerations and/or solid organ hematomas. Of the 56 children with intra-abdominal injury and hematuria (defined as >5 RBC/hpf for this analysis), 86% (48/56; 95% CI [73.8-93.6]) had no evidence of urologic injury on the CT scan.

Non-traumatic abnormalities of the urogenital system were identified in 14/502 children (2.8%; 95% CI [1.5-4.6]). Only one of these children had an acute injury related to the trauma (pelvic fracture) and the urinalysis had 260 RBC/hpf. The amount of hematuria for the children without evidence of trauma ranged from 0 to 51 RBC/hpf. The urogenital

Table 2. Test characteristics of various thresholds of hematuria for predicting urologic injury on abdominal and pelvic computed tomography.

RBC/hpf	Sensitivity (%)	Specificity (%)	LR +	LR -
0	100	0	1.00	-
5	70.6	73.6	2.67	0.40
10	70.6	81.2	3.76	0.36
20	64.7	86.8	4.90	0.41
40	64.7	90.3	6.68	0.39
50	52.9	91.8	6.42	0.51
70	52.9	93	7.55	0.51
100	35.3	94.4	6.34	0.69
7000	11.8	99.8	57.06	0.88

RBC/hpf; red blood cells per high power field

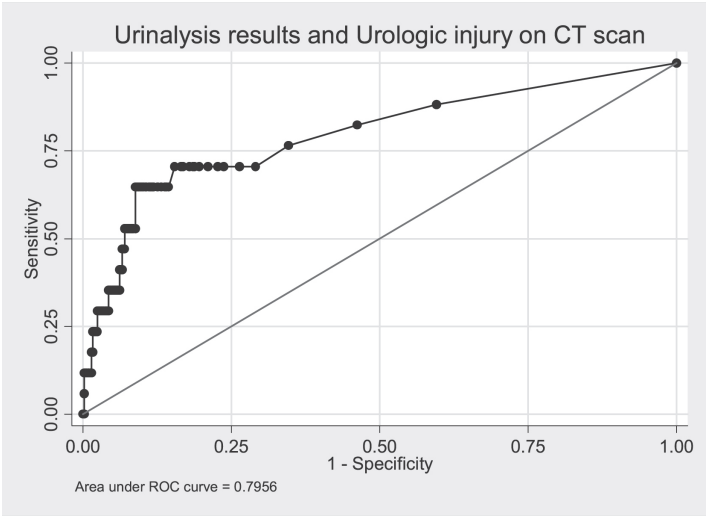

Figure 3. Receiver Operating Characteristic (ROC) curve shows an area of 0.7956 for the urinalysis results and urologic injury on abdominal and pelvic computed tomography (CT).

abnormalities identified included undescended testes, ureteropelvic junction obstruction, renal cysts, ureteral stones, congenital absence of a kidney and a duplicated renal system.

DISCUSSION

If the abdominal and pelvic CT is used as the criterion standard for identifying urologic injury in a traumatized child, the microscopic urinalysis has moderate discriminatory power to predict urologic injury.[20, 21] Urologic injuries were identified in children with and without hematuria. Similarly, hematuria was encountered with and without urologic injury. In addition, non-urologic abdominal injury was present in children with and without hematuria.

The area under the ROC curve provides a more robust description of the capabilities of a test beyond a single measure of sensitivity and specificity. The usefulness of the urinalysis in predicting urologic injury is called into question when the test has moderate discriminatory power and the confidence interval for the area under the curve is wide. Statistically, the urinalysis ranges from being a fair to good predictor of urologic injury with a point estimate of moderate predictive ability. Of the children with blunt abdominal trauma who were evaluated at our Level 1 pediatric trauma center, urologic injury was infrequently encountered. This low prevalence of urologic injury decreases the odds that disease is present prior to obtaining any testing and must be taken into consideration when interpreting the likelihood ratios.

Recognizing that patterns of injury vary by age, we divided our study population into age groups. There were no urologic injuries in children less than one year, five injuries in the 1-3 age group, seven injuries in the 3-7 age group, and five injuries in the >8-year old group. With the infrequency of urologic injury distributed over the age groups, we were unable to perform a meaningful analysis of the predictive ability of the urinalysis by age. A large multi-center study may provide a larger number of urologic injuries to perform this analysis in the future.

Many authors have suggested various thresholds of hematuria that would prompt further radiographic evaluation in a traumatized child.[1,3,5,6,7,8,9,10,11,12,13] Our study methodology does not allow us to make recommendations on when a clinician should perform an abdominal and pelvic CT in the context of blunt abdominal trauma, but using the urinalysis as the sole indicator of injury may be misleading. Hematuria (defined as > 5 rbc/hpf for this discussion) was more frequently encountered in those children with non-urologic abdominal injury rather than urologic injury. Prior literature suggests that hematuria used in conjunction with other signs of urologic injury, such as the physical examination or clinical appearance, may be a better predictor of urologic and intra-abdominal injury than the presence of hematuria alone.[2,6,7,9,10,19] A linear regression model may be helpful in identifying those risk factors that better predict urologic injury in a traumatized child.

Of the 17 urologic injuries identified, nearly half were renal/bladder contusions and could be considered non-emergent and require no intervention. Previously published reports found that trauma patients with asymptomatic microscopic hematuria who were clinically diagnosed with renal contusion and did not receive radiographic imaging had a good prognosis and no complications at follow up.[3-5,16,22] It is possible that the abdominal and pelvic CT is too sensitive in identifying clinically insignificant urologic findings in a traumatized child. As the CT technology improves, it is possible that the urinalysis will become less helpful in predicting clinically significant urologic injury.

We identified a small percentage of children with urogenital abnormalities found incidentally, and these findings were not associated with the trauma. These findings are in conjunction with previous reports that the abdominal/pelvic CT in the pediatric trauma patient identifies renal and urologic abnormalities not associated with the trauma itself.[17,23]

LIMITATIONS

The limitation of the retrospective methodology is that the treating physician is using his discretion in ordering the urinalysis and abdominal/pelvic CT. It is possible that subjects with urologic trauma were not included in this analysis because the urinalysis and/or CT were not performed. Furthermore, we limited our evaluation to initial trauma evaluations performed in the ED. It is possible that some children were later diagnosed with urologic trauma and/or hematuria after admission to the hospital or discharge from the ED.

The ideal methodology to meet our study objective would be performing an abdominal/pelvic CT and urinalysis on all children who presented with blunt abdominal trauma. This methodology raises ethical concerns of potentially exposing children to unnecessary radiation. Performing a multi-center retrospective review may increase the amount of urologic injury that is encountered, but it is doubtful that the urinalysis would become a better predictor of urologic injury even with a larger study population.

The CT readings were provided proximate to the time of the index visit and it is conceivable that different radiologists have variations in their readings. Rather than staging the degree of injury, our objective was to use the urinalysis to predict any acute urologic injury. Therefore, we felt small differences in radiologist' readings would have minimal effect on the results.

Our study does not have a mechanism for capturing cases of hematuria due to menses, prior history of renal disease, or benign hematuria present in healthy children. We attempted to minimize cases of menses by excluding pubescent teenagers. Asymptomatic microscopic hematuria in the healthy pediatric population is uncommon and the frequency is approximately 22 out of 1,000 girls and nine out of 1,000 boys for children ages 6-12 years during two separate screening examinations.[24]

Gross hematuria has a frequency of 1.3/1000 visits in the pediatric outpatient setting.[25]

The method of urine collection for the urinalysis may be important as pediatric patients or severely traumatized patients often require catheterization. It can be argued that catheterization may account for some cases of hematuria in our study. The literature that has evaluated hematuria produced by catheterization alone involves only healthy adult subjects, but the procedure of catheterization in these studies produced less than four RBCs/hpf [26,27].

CONCLUSION

If the abdominal and pelvic CT is the criterion standard for identifying urologic trauma, than the microscopic urinalysis has moderate discriminatory power to predict urologic injury.

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Transphyseal Fracture of the Distal Humerus in a Neonate

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An 18-hour-old neonate was found to have absent movement of the left arm and a mildly edematous elbow following precipitous delivery with observed traction applied to the left arm. Radiographs (Figure 1) showed abnormal elbow alignment without osseous fracture and a moderate joint effusion. Magnetic resonance imaging (MRI) [Figure 2] revealed a transverse fracture through the distal left humeral physis with posterior displacement of the distal cartilaginous epiphysis. An orthopedic surgeon placed the patient in a long arm splint with the arm at 90° of flexion and pronation to align the transphyseal fracture. One week later the splint was removed. The fingers and hand appeared to move normally, but left shoulder movement was persistently decreased, thought secondary to a brachial plexus stretch injury.

Traumatic separation of the neonatal distal humeral epiphysis is a rare injury, usually due to birth trauma or occasionally child abuse.[1] Clinical findings include elbow swelling, muffled crepitus and pseudo paralysis of the extremity.[1] Evaluation with plain radiography may be challenging and give the spurious appearance of dislocation until the capitellar ossification center had developed, usually around three to nine months of age.[2] MRI may be achieved without sedation in neonates. It is accurate and will provide definitive diagnosis with good visualization of the cartilage, bone and soft tissue in multiple planes.[2] Treatment involves casting, usually with closed reduction if the injury is detected early.[1]

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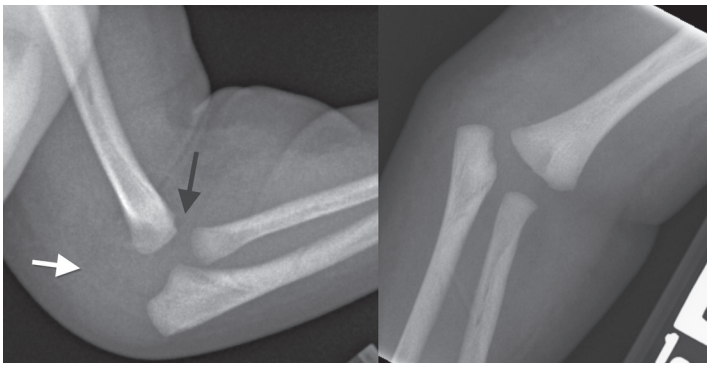

Figure 1. Anterior/posterior and lateral images of elbow demonstrate abnormal alignment with the black arrow pointing out the site of distal humeral physes and the white arrow pointing out the location of the posteriorly displaced cartilaginous humeral epiphysis.

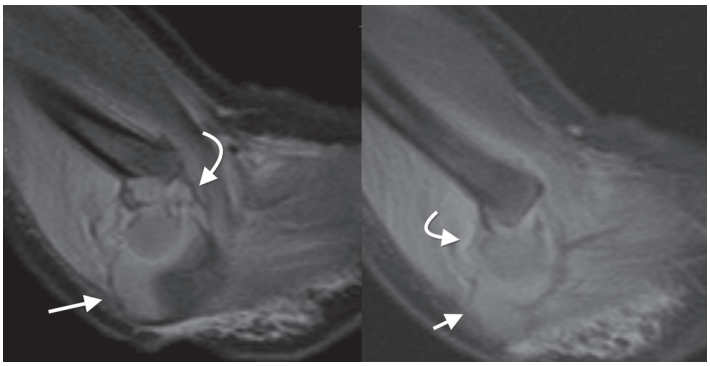

Figure 2. Magnetic resonance imaging demonstrates fracture through the humeral physes with posterior displacement of the cartilaginous epiphysis (curved arrow) but intact articulation with radius and ulna (arrow).

Online Health Information Impacts Patients' Decisions to Seek Emergency Department Care

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Objective: To investigate the impact of online health information (OHI) and patients' decisions to seek emergency department (ED) care.

Methods: We conducted a survey of a convenience sample of 489 ambulatory patients at an academic ED between February and September 2006. The primary measure was the prevalence of Internet use, and the secondary outcome was the impact of OHI on patients' decision to seek ED care.

Results: The study group comprised 175 (38%) males. Mean age was 33 years old; 222 (45.4%) patients were white, 189 (38.7%) patients were African American, and 33 (6.7%) were Hispanic. 92.6% had Internet access, and 94.5% used email; 58.7% reported that OHI was easy to locate, while 49.7% felt that it was also easy to understand. Of the subjects who had Internet access, 15.1% (1.6, 95% CI 1.3-2.0) stated that they had changed their decision to seek care in the ED.

Conclusion: This study suggests that Internet access in an urban adult ED population may mirror reported Internet use among American adults. Many ED patients report that they are able to access and understand online health information, as well as use it to make decisions about seeking emergency care. [West J Emerg Med. 2011; 12(2):174-177.]

INTRODUCTION

The Internet can be an effective way to distribute information. For instance, it has provided access to online health information (OHI) that had previously been limited to university libraries and expensive medical textbooks. This access has improved health consumers' knowledge and enhanced their participation in their own health.[1, 2]

Many sources of OHI target patients, physicians or researchers.[3-5] There are no current uniform mechanisms to ensure that the OHI is true, accurate, unbiased, or even understandable by a layperson although some sites (e.g., WebMD or MayoClinic.com) do enjoy a level of perceived credibility. Providers often use subscription-based sites, such as MDConsult.com and Uptodate.com, because they are easy to navigate and provide peer-reviewed and evidence-based resources. Patients tend to use free sites and more general health information distilled for laypersons. This division of medical information for providers and patients, in conjunction with the lack of any regulatory oversight, leads to concerns about the quality of OHI. Fortunately, many organizations and medical specialty associations are working on criteria to enhance this quality.[6, 9-12]

Today's patient is often well-informed regarding his symptoms upon arrival at the emergency department (ED) and the diagnoses those symptoms might suggest. Recent studies show that 70% of American adults use the Internet as a source of information on various topics, which can range from sending emails to exploring their hobbies to taking online classes.[11] Among those United States residents who use the Internet, 80% have searched for OHI.[12] However, in one study, 90% of survey respondents stated that their use of the Internet and email for healthcare did not affect their number of contacts within the healthcare system.[13] Many medical emergencies do not allow patients to go online and search for information regarding their illnesses; however, there are a significant number of patients reporting to the ED with

sub-acute or chronic illnesses. Although there is literature regarding general patient access to and use of the Internet in finding OHI, we examine these issues specifically in the ED. Our goals were (1) to learn about access to OHI, specifically by ED patients, and (2) to study the impact that OHI has on patients' decisions to seek emergency care.

METHODS

Under the approval of the Institutional Review Board, we conducted a survey at an urban academic ED in Washington, D.C. between February 2006 and September 2006. This ED treats 57,000 visitors per year. A convenience sample of 489 English-speaking ambulatory patients between 18 and 99 years of age, all of whom sought care from the ED, were enrolled in the study. All critically ill patients (Emergency Severity Index Level 1 and 2) and those arriving by ambulance were excluded. Research assistants (RA) periodically collected 489 surveys from 8AM to midnight. RAs were tasked with collecting data for multiple studies and therefore made best efforts to recruit patients during the period. A limited number of RAs from May to August limited recruitment. The survey required approximately 10 minutes to complete and included questions regarding demographics (e.g., education, citizenship, employment, race, etc.) and access to and use of the Internet. Participants were questioned about their access to email, their Internet connection and usual access location, and their frequency of Internet use. They were asked to rate the ease of accessing the Internet, how frequently they used it to find OHI, and whether they considered such information easy to find and understand. They were specifically asked whether they used OHI in their decision to seek attention from the ED, and whether OHI had ever made them change this decision ("Do you use the health information you find on the Internet to determine whether you should come to the Emergency Department," "Have you changed your decision to come to the hospital based on information that you got from the Internet"?). Participants were also asked about the number of times they had spoken to their physicians about OHI, their level of satisfaction regarding the OHI, and whether they preferred an email follow-up about their medical situation. Responses to the Internet-usage measures were made using numerical values in open-ended response formats (filling in a blank with a number representing the frequency of acts). Numerical response formats reduce arbitrary anchor biases that can occur with lower- and upper-bound numerical rating scales.[14] We asked participants how many times they had engaged in various Internet activities in the past three months, and they responded with a numeric value.

Table 1. Demographic characteristics of Internet users (N= 489)

	%
Age, years	
15-29	47.9
30-44	28.6
45-59	14.7
60-74	3.9
Mean(SD)	33.3(12.8)
Gender	38.0
Male	38.0
Female	62.0
Education	
Lower than Bachelor's degree	46.3
Bachelor's degree and beyond	53.7
Race	
White	45.4
Black	38.7
Hispanic	6.7
Access to Internet	
Yes	92.6
No	7.4
Access to E-mail	
Yes	94.5
No	5.5

SD, standard deviation

RESULTS

The primary data analyses were univariate descriptions and tabulations of patient responses. Data forms were completed for a convenience sample of 489 patients visiting the ED during the enrollment period. Results showed a range in frequency of Internet use among the surveyed patients. The study group comprised 175 (38%) males. The mean age was 33 ± 12 years; 222 (45.4%) patients were white, 189 (38.7%) were African American, and 33 (6.7%) were Hispanic. The gender and age distributions were not significantly different than the 2006 annual ED patient population. Table 1 describes the demographic characteristics of this group.

The survey asked five main questions about Internet and email usage in finding OHI. Ninety-two percent of the respondents stated that they have access to the Internet, while 94.5% reportedly have access to E-mail. Based on our survey data, 37% of patients with Internet access use it to find OHI; 58.7% of the respondents reported that the OHI they reviewed was easy to locate, and 49.7% felt that it was also easy to understand. Table 2 describes the frequency of Internet use in finding OHI.

Of those subjects who have access to the Internet, 15.1% stated that they had changed their decision to seek care in the ED due to OHI. The survey also showed that 31% of respondents would be interested in receiving email follow-ups regarding their ED visits.

Table 2. Frequency of Internet use for health-related information (HRI) [N= 489]

	%
Look on the Internet to find HRI	
Yes	37.2
No	30.3
Neutral*	32.5
Find HRI easy to locate	
Yes	58.7
No	10.2
Neutral	31.1
Find HRI easy to understand	
Yes	49.7
No	17.9
Neutral	32.4
Used HRI to determine whether to come to ED	
Yes	22.9
No	41.9
Neutral	35.2
HRI changed decision to come to ED	
Yes	17
No	83
Interested in E-mail follow-up	
Yes	31
No	69

*Neutral: No impact on their decision or behavior

ED, emergency department

LIMITATIONS

Findings should be interpreted with caution in light of the study's methodological limitations. We surveyed a very small convenience sample of ED patients without rigorous enrollment criteria. All of the data in this study were collected using self-report instruments during certain hours of the day and are therefore limited by all of the constraints and potential biases common to self-reporting.[15] Failure to enroll all eligible patients makes the study susceptible to selection bias, as we were only able to survey the patients who actually came to the ED. It is unclear how many patients with unknown conditions used OHI to decide either to avoid the ED or to postpone their visit. Our study was not capable of addressing the issues of variability in a patients' health knowledge base, or any search criteria performance that may impact patients' discovery and interpretation of OHI.

DISCUSSION

The Internet has become a powerful resource for medical providers. A recent Pew study suggests that patients are increasingly using OHI each year to care for themselves and others.[12] They are becoming more adept in finding OHI and medical resources, as well as in using that information when consulting with their medical provider. However, the quality and context of OHI can play a major role in its applicability. Providers are challenged to help a better-informed health consumer understand OHI, which can be complex or sometimes erroneous.

In this study, ED patients report that they do not have difficulty either in accessing OHI or in understanding that information. In our experience, however, patient interactions often reveal that they do have difficulty understanding OHI. OHI often causes patients unnecessary anxiety regarding symptoms or demand for unnecessary diagnostic tests. The discrepancy in patients' understanding of OHI and the medical providers' perception of their understanding should be further explored. There may be opportunities to develop tools that can assist patients and providers in ensuring that accurate information is exchanged.

Interestingly, a large percentage of surveyed patients reported interest in using email to communicate with a medical provider (Table 2). Ease of Internet access and willingness to use email may have implications for ED satisfaction surveys, quality assurance and follow-up communications. Our study did not address patients' perceptions of security and privacy issues that may occur through electronic communications.

Finally, in our study population, 15.1% of respondents changed their decision to seek emergency care based on OHI. Other studies suggest that OHI does impacts decisions to seek medical attention, but do not specifically look at the impact on emergency care in which a medical evaluation may be more time sensitive. Large numbers of people may base potential life-or-death decisions on OHI, which varies in quality and may be taken out of context.

CONCLUSION

This study suggests that Internet access in an urban adult ED population may mirror reported Internet use among American adults. Many ED patients report that they are able to access and understand online health information, as well use it make decisions about seeking emergency care. We believe that healthcare providers and medical organizations should contribute to ensuring clear, concise, and easily accessible OHI.

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Rural-Urban Disparities in Emergency Department Intimate Partner Violence Resources

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Objective: Little is known about availability of resources for managing intimate partner violence (IPV) at rural hospitals. We assessed differences in availability of resources for IPV screening and management between rural and urban emergency departments (EDs) in Oregon.

Methods: We conducted a standardized telephone interview of Oregon ED directors and nurse managers on six IPV-related resources: official screening policies, standardized screening tools, public displays regarding IPV, on-site advocacy, intervention checklists and regular clinician education. We used chi-square analysis to test differences in reported resource availability between urban and rural EDs.

Results: Of 57 Oregon EDs, 55 (96%) completed the survey. A smaller proportion of rural EDs, compared to urban EDs, reported official screening policies (74% vs. 100%, p=0.01), standardized screening instruments (21% vs. 55%, p=0.01), clinician education (38% vs. 70%, p=0.02) or on-site violence advocacy (44% vs. 95%, p<0.001). Twenty-seven percent of rural EDs had none or one of the studied resources, 50% had two or three, and 24% had four or more (vs. 0%, 35%, and 65% in urban EDs, p=0.003). Small, remote rural hospitals had fewer resources than larger, less remote rural hospitals or urban hospitals.

Conclusion: Rural EDs have fewer resources for addressing IPV. Further work is needed to identify specific barriers to obtaining resources for IPV management that can be used in all hospital settings. [West J Emerg Med. 2011;12(2):178-183.]

INTRODUCTION

Intimate partner violence (IPV) includes any pattern of assaultive and coercive behaviors, including physical injury, psychological abuse, sexual assault, social isolation, stalking, deprivation, intimidation or threats perpetrated by someone who was or is in an intimate relationship with the victim.[1] It occurs in an estimated two million United States (U.S.) women each year and 26% of U.S. women over their lifetime.[2,3] However, partner violence is even more common among individuals visiting the emergency department (ED) for care; estimates range from past-year prevalence of 12 to 19% and lifetime prevalence of 44 to 54%.[4-8]

The prevalence of IPV in rural settings appears to be similar to that in non-rural settings.[9-12] However, in rural areas, geographic and economic barriers to seeking healthcare are often greater and alternatives for follow up and referrals may be limited.[13,14] Therefore, the ED visit may be particularly important as an opportunity to identify and comprehensively address IPV. The objective of this study was to assess differences in IPV resource availability between urban and rural EDs.

METHODS

Study Design

We conducted the study among ED directors and managers at all of Oregon's 57 hospitals, using a standardized telephone survey. We targeted ED physician directors and ED nurse managers, reasoning that these individuals would be responsible for and knowledgeable of the protocols and services in use in the ED. We merged survey data with hospital-level variables from the Office for Oregon Health Policy and Research and the Oregon Office of Rural Health. The Institutional Review Board of the study institution approved this protocol.

Study Setting and Population

Oregon has an estimated population of 3.8 million people. Fifteen rural areas in Oregon are defined as geographic areas 10 or more miles from the centroid of a population center of 40,000 or more, while frontier counties are those with less than six people per square mile.[16] Approximately 26% of the Oregon population lives in rural or frontier counties and 54% in mixed urban and rural counties; the rest (20%) live in one of six urban areas. Of Oregon's 57 acute care hospitals, 35 are classified as rural.[16]

An additional framework for understanding the needs and resources of the acute care hospitals is provided by Oregon's Medicaid program, which reimburses hospitals according to one of three categories, based on hospital capacity (inpatient bed size) and remoteness (distance from nearest acute inpatient care facility).[17] Type A rural hospitals are small, with 50 beds or fewer, and are located greater than 30 miles from the closest acute care facility. Type B rural hospitals also have 50 beds or fewer but are located 30 miles or less from the closest acute inpatient care facility. Diagnostic Related Group (DRG) hospitals, which receive a fixed payment for each patient based on the DRG to which the patient is assigned, are larger-capacity hospitals typically located in urban areas; only three DRG hospitals are classified as rural.

Measurements

To measure availability of IPV resources, we adapted survey questions from the "Delphi Instrument for Hospital-Based Domestic Violence Programs" developed by the Agency for Healthcare Research and Quality (AHRQ).[18] To optimize participation, we limited our survey to six questions addressing policies and procedures relevant to the ED setting (Figure 1). The survey was pilot tested among ED staff unaffiliated with the study and revised based on their feedback prior to administration elsewhere.

The survey was administered by telephone to ED directors and nurse managers over a one-month period from September to October 2008. A single individual was interviewed at each site. Respondents were asked to answer "Yes" or "No" to the availability of each of the resources. The full survey included three additional questions about ED resources for the management of child abuse; these results were reported separately.[19] The survey took approximately five minutes to complete.

Figure 1. Survey of emergency department (ED) administrators.*

1. Is there an official policy in place that requires mandatory screening of all women for domestic violence in the ED?
2. Does the hospital or ED provide regular, ongoing training on domestic violence for nurses and/or doctors working in the ED?
3. Are there posters and/or brochures on domestic violence on public display in your ED?
4. Does the ED use a standardized instrument, with at least three questions, to screen patients for domestic violence?
5. Is there a standard intervention checklist for staff to use/refer to when domestic violence victims are identified?
6. Are on-site victim advocacy services (for example, by a social worker, counselor, or trained nurse) for domestic violence provided in the ED?†

*"Domestic violence," instead of "intimate partner violence," was used for the survey, assuming that this term would be most familiar to hospitals and their staff.
†On-call advocates were not considered "on site."

We obtained hospital-level variables, including urban/rural designation, annual ED census, bed size, trauma capabilities and a nurse staffing score, from the Office for Oregon Health Policy and Research.[20,21] The nurse staffing score represents the number of nursing full time equivalents (FTE) for every 100 hospital admissions and was included to reflect available hospital human resources. The distribution of these characteristics between urban and rural locations is shown in Table 1.

Statistical Analysis

We used frequencies and proportions to characterize the reported availability of IPV resources among the surveyed EDs. Differences in the proportion of rural and urban EDs reporting individual resources were evaluated using univariate (Pearson's chi-square) analysis. We examined the advocacy variable both as a dichotomous variable (present or not present) and as a categorical variable (not present, part-time, or full-time). We also examined differences between rural and urban EDs with respect to total number of IPV resources (0-1, 2-3, ≥4) using chi-square analysis.

To see if resource availability was related not just to rural / urban designation but also to factors such as hospital capacity and remoteness, we repeated analyses using the Medicaid reimbursement categories (DRG hospitals versus Type A and Type B hospitals). Finally, to address whether resource availability was related to higher ED volume – with presumably higher numbers of IPV cases – among rural hospitals, we compared resources reported and between larger (>10,000 vists/year) and smaller (<10,000/year) ED census.

Table 1. Characteristics of rural versus urban Oregon hospitals.[a]

	Rural	Urban	p-value
Total N (%)[b]	34 (63%)	20 (37%)	N/A
Survey respondents[c]			0.44
Nurse managers	27 (79%)	14 (70%)	
Physician directors	7 (21%)	6 (30%)	
Average 2008 emergency department Census (median)	10,978 (10,151)	34,586 (30,844)	<0.001
Mean inpatient bed count (median)[d]	39 (35)	205 (134)	<0.001
Mean nursing full time equivalents per 100 patient admissions (median)[d]	1.16 (1.15)	1.85 (1.75)	<0.001
Medicaid reimbursement type[e]			N/A
Rural Type A	12 (35%)	N/A	
Rural Type B	19 (56%)	N/A	
Diagnostic related group	3 (9%)	20 (100%)	

a) According to the Oregon Office of Rural Health, except as noted.
b) Represents row percentage.
c) Based on survey results.
d) This variable was not available for one urban hospital that participated in the survey; results reflect 54 hospitals
e) Represents column percentage.

We defined statistical significance as a probability of a type I error of less than 5% (2-tailed). Analyses were conducted using Stata, version 10.1 (StataCorp LP, College Station, TX).

RESULTS

Fifty-five of 57 EDs (96%) participated in the survey, with 13 physician directors and 42 nurse managers responding. The director and nurse manager of one hospital could not be reached, and one ED declined participation. Table 1 compares characteristics of rural and urban hospitals. Thirty-four (63%) of the participating hospitals are classified as rural.

Figure 2 shows reported resource availability by practice setting. In univariate analysis, a smaller proportion of rural hospitals reported official IPV screening policies (p=0.01), standardized screening instruments (p=0.01), regular clinician training (p=0.02), and on-site IPV advocates (<0.001). Urban EDs more often reported availability of full-time on-site advocates than rural EDs (38% vs 6%, p<0.001). Use of public displays regarding IPV and standardized intervention checklists was greater in urban settings, although these differences were not statistically significant.

The total number of available IPV services differed significantly between urban and rural EDs (Figure 3) as well. Twenty-seven percent of rural services reported none of the six resources examined, while all urban hospitals reported two or more IPV resources and 65% had four or more (p=0.003).

Results based on reimbursement category are shown in Table 2. For every resource except use of public displays, a smaller proportion of Type A hospitals reported resource availability than Type B hospitals, and a smaller proportion of

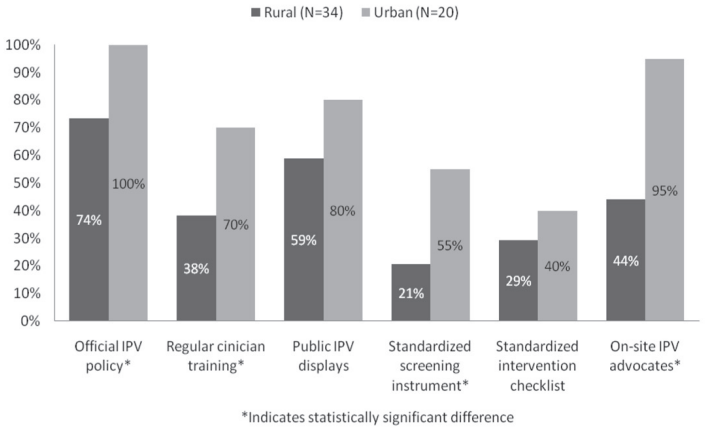

Figure 2. Availability of individual intimate partner violence (IPV) resources in rural vs. urban emergency departments (N=55).

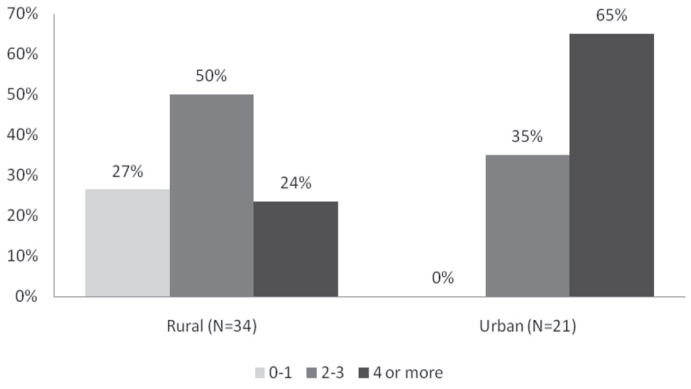

Figure 3. Total number of intimate partner violence (IPV) services in rural vs. urban emergency departments (N=55).

Table 2. Reported resources by Oregon Medicaid hospital reimbursement category.[a]

	Type A[b]	Type B[c]	DRG[d]	p-value
Total N (%)[e]	12 (22%)	19 (35%)	24 (24%)	N/A
Intimate partner violence (IPV) policy (%)	7 (58%)	15 (79%)	24 (100%)	0.005
Regular clinician training (%)	2 (17%)	9 (47%)	16 (67%)	0.018
Public IPV displays (%)	6 (50%)	14 (74%)	16 (70%)	0.396
Screening instrument (%)	0 (0%)	5 (26%)	13 (54%)	0.004
Intervention checklist (%)	0 (0%)	8 (42%)	10 (42%)	0.024
On-site advocates, any (%)	4 (33%)	9 (47%)	22(96%)	0.001
On-site advocates, how often				0.002
None (%)	8 (67%)	10 (53%)	2 (8%)	
Part-time (%)	3 (25%)	8 (42%)	14 (61%)	
Full-time (%)	1 (8%)	1 (5%)	8 (35%)	
Total reported IPV resources				<0.001
0-1	6 (50%)	3 (15%)	0 (0%)	
2-3	6 (50%)	9 (47%)	7 (30%)	
≥4	0 (0)	7 (37%)	17(70%)	

a) According to the Office for Oregon Health Policy and Research.
b) As defined by Oregon's Medicaid program, Type A rural hospitals are small, with 50 beds or fewer, and located greater than 30 miles from the closest acute care facility.
c) Type B rural hospitals have 50 beds or fewer and are located 30 miles or less from the closest acute inpatient care facility.
d) Diagnostic Related Group (DRG) hospitals are larger-capacity hospitals typically located in urban areas.
e) % represents row percentage; for the rest of the table, % represents column percentage.

Type B hospitals reported resource availability than DRG hospitals. Fifty percent of Type A hospitals reported none of the examined resources, while all DRG hospitals reported at least two resources and 70% had four or more (p= <0.001).

In the comparison of hospitals by annual ED census, the only resource with a statistically significant difference was a written IPV policy, which was reported more frequently among hospitals with an annual ED census less than 10,000.

DISCUSSION

We describe differences in the reported availability of IPV resources between urban and rural EDs. Overall, rural EDs seem to have fewer resources to address partner violence, with less reported availability of all six types of studied IPV resources and fewer total number of IPV resources. Comparison of reported resource availability based on hospital reimbursement categories suggests that resource limitations were exacerbated by factors such as small size and remoteness. However, we did not find a correlation between ED volume and number of resources reported. It seems unlikely, therefore that need (i.e., number of IPV cases encountered) is what dictates availability of services.

In 1992, the Joint Commission (formerly known as the Joint Commission on the Accreditation of Healthcare Organizations, or JCAHO) defined basic standards for hospital policies and procedures to increase the identification of IPV within EDs and hospital-based ambulatory care centers.[22] Updated in 2004, the standards include maintenance of specific criteria for identifying victims of IPV, identification of victims upon entry into the healthcare system (e.g., at ED triage), education of staff about the management of IPV, and appropriate assessment and referrals by staff. These recommendations are uniform for all hospitals and do not acknowledge potential resource differences between rural and urban hospitals, or hospitals of varying sizes.

There are a number of potential solutions to resource limitation in rural areas. Resources such as IPV management guidelines or patient educational posters and pamphlets are relatively inexpensive to develop and use, particularly with the increasing availability of free or low-cost materials from non-profit domestic violence groups and medical societies.[23,24] Existing leadership and continual medical education activities may be modified to include material on IPV and to emphasize skills that will allow individuals to train others within their institution. Statewide or county-wide collaborations may allow rural institutions to benefit from a variety of educational, research and community initiatives related to the management of IPV. [25] State and national hotlines are available 24/7 for counseling patients experiencing IPV. Telemedicine is providing intriguing new possibilities for counseling victims of IPV in rural locations.[26]

LIMITATIONS

Resource availability was determined by the responses of surveyed ED staff. The studied resources may have been mistakenly reported as present when absent or reported as absent when actually present. Further, a resource may be technically present but not provided to patients meaningfully;

Table 3. Reported resources among rural hospitals, by emergency department (ED) annual census.[a]

	Smaller Hospitals (≤10,000 ED visits/year)	Larger Hospitals (>10,000 ED visits/year)	p-value
Total N (%)[b]	17 (50%)	17 (50%)	N/A
Intimate partner violence (IPV) policy (%)[c]	16 (94%)	9 (53%)	0.007[d]
Regular clinician training (%)	7 (41%)	6 (35%)	0.72
Public IPV displays (%)	8 (47%)	12 (71%)	0.16
Screening instrument (%)	4 (24%)	3 (18%)	0.67
Intervention checklist (%)	7 (41%)	3 (18%)	0.13
On-site advocates, any (%)	8 (47%)	7 (41%)	0.73
On-site advocates, how often			0.94
None (%)	9 (53%)	10 (59%)	
Part-time (%)	7 (41%)	6 (35%)	
Full-time (%)	1 (6%)	1 (6%)	
Total reported IPV resources			0.14
0-1	2 (12%)	7 (41%)	
2-3	10 (59%)	6 (35%)	
≥4	5 (29%)	4 (24%)	

a) According to the Office of Oregon Health Policy and Research
b) Represents row percentage
c) Represents column percentage
d) Statistically significant, but note that smaller hospitals have greater reported resource availability than larger hospitals in this category

for example, a written policy may exist but would have little effect on patient care if it was rarely referred to or if there was no quality assurance process to make sure it was adhered to rigorously. On the other hand, it may be that an ED does not have a formal policy in place yet in practice still delivers a service well. Our study was not able to measure actual ED practices.

Our findings may also be limited by recall bias. ED representatives may have been more likely to report having resources when unsure, particularly if they were aware that specific IPV resources are mandated for hospitals by the Joint Commission. Further, as a non-anonymous survey, respondents may not have felt free to answer honestly. However, there is no reason over-reporting or under-reporting of resources should have occurred differentially between rural and urban sites, so this bias, if present, would not explain our findings.

Because our study was limited to the state of Oregon, the findings may not be generalizable to the entire U.S. Oregon does not require reporting of IPV unless a weapon was used to inflict an injury. States without reporting requirements may have different resource utilization than those with these requirements. The hospitals surveyed did represent a broad range of practice settings, with varying bed and staff sizes and trauma capabilities, so are likely to be relevant to a broad range of practice types.

CONCLUSION

Rural EDs in our study reported limited resources for IPV management compared to urban EDs. Further research is needed to identify specific barriers to obtaining IPV resources. At the same time, further cost-effective means of improving the initial assessment and care of IPV victims in the ED should be identified and developed.

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Applying Lean: Implementation of a Rapid Triage and Treatment System

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Objective: Emergency department **(**ED) crowding creates issues with patient satisfaction, long wait times and leaving the ED without being seen by a doctor (LWBS). Our objective was to evaluate how applying Lean principles to develop a Rapid Triage and Treatment (RTT) system affected ED metrics in our community hospital.

Methods: Using Lean principles, we made ED process improvements that led to the RTT system. Using this system, patients undergo a rapid triage with low-acuity patients seen and treated by a physician in the triage area. No changes in staffing, physical space or hospital resources occurred during the study period. We then performed a retrospective, observational study comparing hospital electronic medical record data six months before and six months after implementation of the RTT system.

Results: ED census was 30,981 in the six months prior to RTT and 33,926 after. Ambulance arrivals, ED patient acuity and hospital admission rates were unchanged throughout the study periods. Mean ED length of stay was longer in the period before RTT (4.2 hours, 95% confidence interval [CI] = 4.2-4.3; standard deviation [SD] = 3.9) than after (3.6 hours, 95% CI = 3.6-3.7; SD = 3.7). Mean ED arrival to physician start time was 62.2 minutes (95% CI = 61.5-63.0; SD = 58.9) prior to RTT and 41.9 minutes (95% CI = 41.5-42.4; SD = 30.9) after. The LWBS rate for the six months prior to RTT was 4.5% (95% CI = 3.1-5.5) and 1.5% (95% CI = 0.6-1.8) after RTT initiation.

Conclusion: Our experience shows that changes in ED processes using Lean thinking and available resources can improve efficiency. In this community hospital ED, use of an RTT system decreased patient wait times and LWBS rates. [West J Emerg Med. 2011;12(2):184-191.]

INTRODUCTION

Emergency department (ED) crowding is a major concern that affects both patients and providers. EDs today provide a safety net for patients without medical insurance and are used by patients who need evening and weekend service. In 2003 there were almost 114 million visits to EDs, up almost 26% from 1993. During this same period, 425 EDs closed nationwide.[1] The Institute of Medicine's Committee on the Future of Emergency care in the United States Health System recommended that improving hospital efficiency and patient flow become a top priority for the nation's hospitals and EDs.[1]

Lean is a set of business operating principles developed by Japanese auto manufacturers.[2,3,4] These principles may be applied to any business system and have been successfully used for healthcare and in emergency medicine in the past.[5-10] Lean principles seek to increase efficiency, decrease waste, and promote flow through the system. The goals of this paper were to evaluate and discuss the application of Lean principles to our ED processes. In particular we were interested in how the redesign of ED systems to develop a Rapid Triage and Treatment (RTT) system, using existing resources, affected certain important ED metrics (left without being seen [LWBS] rates, waiting times, ED length of stay [LOS]).

METHODS

Study Design, Settings, and Participants

We performed a retrospective, observational study before and after implementation of a rapid triage and treatment

(RTT) system within our ED. The Kaiser Foundation Research Institute Investigational Review Board approved this study.

ED Setting

Our ED, located approximately ten miles from downtown Sacramento, California, sees approximately 67,000 patients annually. We were not a trauma center at the time of this study. Our ED saw a nearly 100% increase in volume between 1999 and 2001 due to several factors. There was tremendous community growth in the South Sacramento/Elk Grove area. Elk Grove, (just south of our facility) was the fastest growing city in the nation among cities with population >100,000.[11] Kaiser Permanente health plan membership in this area has steadily grown to a current level of over 50% penetration in the insured market. Our ED also treats approximately 20% non-health plan patients.

Kaiser Permanente South Sacramento Medical Center has 118 licensed hospital beds. Depending on time of day, two to five physicians staff 38 ED beds. During peak census hours, hallway gurneys provide up to nine additional beds. Residents of all levels from the University of California Davis Emergency Medicine Residency Program rotate through our department. All resident cases are supervised by attending emergency physicians. Resident presence varies, with zero to three residents in the department at any time. Attending physician staffing does not change based on resident presence.

ED Process Prior to RTT System

Prior to initiation of the RTT system, our patient flow process was similar to that of many EDs. Upon arrival, an ED technician "greeter" met patients and determined whether there was need for immediate placement into the patient care area. Non-critical patients then experienced multiple delays before evaluation by a physician. First, a nurse performed an extensive "medical screening examination" (MSE). This MSE consisted of 18 questions, including chief complaint, brief history, vital signs, allergies, medications, domestic violence regulatory question and focused physical examination. The nurse then sent the patient to be registered by a hospital registration clerk. After this triage process, which took an average 12-18 minutes, patients returned to the waiting room. When an ED bed became available, the patient was placed in an exam room and evaluated by a second nurse. Following this evaluation, the patient was assigned to and seen by a staff physician. Our physician staffing consisted of two to five physicians depending on time of day. Nursing staffing consisted of 14-18 nurses and four to six ED technicians, also depending on time of day. No changes in physician, nursing or technician staffing were made during the study period.

Prior to the study period we employed different strategies to deal with lower acuity patients, including a "fast track" (urgent care). This system of care entailed an extensive patient triage, then redirection of lower acuity cases to the "fast-track" area. These patients waited in a separate waiting room before being seen by the "fast-track" emergency physician. This inefficient system created repetitive queues and extra steps. In the worst-case scenario, a patient was mis-triaged from the ED to "fast-track" then returned to the main ED after evaluation by the fast-track physician. Mis-triage caused delays for patients and wasted work for ED staff. Additionally, our hospital administration had regulatory concerns related to triaging of patients out of the ED to a lower level of care.

Process Improvements and Implementation of RTT System

We focused on staff and physician involvement in these process changes. A critical aspect of the Toyota production system, the pioneers of Lean application, is the involvement of those providing value-added steps at every level of process design and modification.[2,7] This "bottom up" management philosophy is critical for the successful implementation of process improvements and elimination of waste.[2,3] Months prior to any system changes, we initiated weekly "process improvement" meetings to draw nurses, ED technicians, physicians, and department leadership into this process. Staff input was introduced, discussed, and process changes planned.

We then applied the five Lean steps (system evaluation, identification of value/waste, elimination of waste, creation of improved flow and constant adaptation to changes) to improve LWBS numbers in our ED.[1] First, we directly observed the flow of patients through the system and developed a value stream map.[1,5,6] Value stream mapping is technique to analyze the flow of materials and information required to bring a product or service to a consumer. In the ED, a value stream map is simply a diagram showing the progression of patients through the system as services are provided (Figures 1 and

Core Lean Principles:	Examples:
Evaluation of systems	Direct visualization, value-stream mapping
Identification of waste	Identifying non-value added steps
Elimination of waste	Elimination of extensive triage steps
Improvement of flow	Standardized triage work-flows, rapid triage and treatment area
Constant adaptation / improvement	Throughput committee, Kaizen

Figure 1. Lean principles.

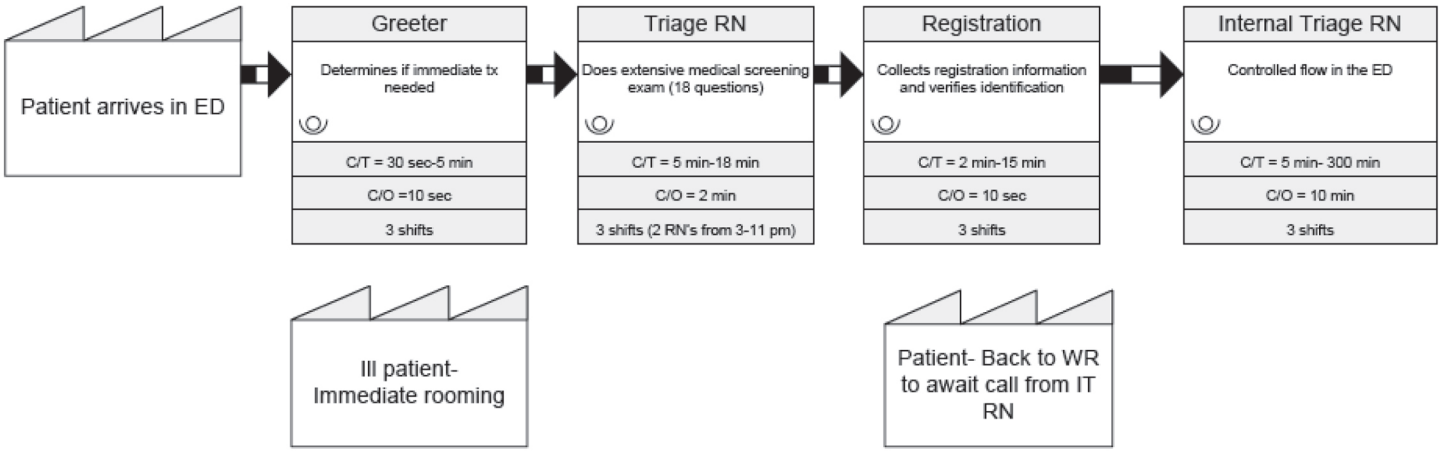

Figure 2. Value-stream map of the triage process prior to Lean process changes.
C/T, cycle time; *C/O*, changeover time; *WR,* waiting room; *IT*, information technology

2). From these observations, we identified steps that did not add value for the patient. Value in a Lean system is any operation or process step that contributes directly to providing the service or product the patient/customer desires. Waste is defined as any work, time or supplies that add no value in the eyes of the customer (or patient).[3] We then streamlined our triage and admitting processes to remove waste. An "RTT" physician was placed in an area immediately adjacent to the triage nurses (formerly triage bays), which decreased unnecessary movement and allowed that physician to immediately address triage questions, thus decreasing mis-triages. We also partnered the RTT physician with one nurse to increase efficiency through improved communication and teamwork. Following these process improvements, we have maintained a system of constant re-evaluation to identify problems and make further modifications as needed. Most of this work of re-evaluation is done at weekly process meetings involving ED technicians, nurses and physicians.

ED Process after RTT System

Following initiation of the RTT system, the flow process has been significantly altered for patients presenting to the ED. The re-arranged triage area places a triage nurse and registration clerk close by, so that the initial triage and registration processes may be performed simultaneously. Upon arrival patients undergo a "quick registration," including name and medical record number entry into the computer system, armband placement and consent signature. Full registration processes are then completed after patients have been seen by a physician. Concurrently a nurse obtains vital signs, collects the chief complaint, records allergies, and assigns Emergency Severity Index (ESI) triage category. A regulatory domestic violence question is also asked at this point. The performance goal for this team is under two minutes. The ESI triage criteria is a 5-level triage system designed to rapidly sort patients not only by acuity, but by likely need for ED resources.[12,13]

Higher acuity patients (ESI 1, 2, or 3) are immediately placed into examination rooms in the main patient care area and assigned to a physician. Lower acuity patients (ESI level 4 or 5) are placed into the RTT area, which consists of several hallway chairs and three small examination/procedure rooms (formerly triage bays). This area is immediately adjacent to the triage team in the triage area. The RTT physician treats and releases patients placed in the RTT area, apart from the main patient care area. Resource allocation in the RTT area is at the discretion of the RTT physician; usually two rooms are used for examinations and the third for minor procedures (i.e.: small lacerations, casting, foreign body removal, etc.). Under the RTT system, lower acuity patients may also be evaluated and treated while seated in ED hallway chairs. RTT patients who are uncomfortable with being treated from a chair have the option of waiting for an open bed in the main patient care area. This option is prominently posted on signs within the RTT area. In the event that the RTT area is full, lower acuity patients (ESI level 4, 5) may be placed in the waiting room until space becomes available. The theoretical effect of this system is to maintain space in the main patient care area for rapid rooming of higher acuity patients (ESI 1,2,3), while lower acuity patients (ESI 4,5) are triaged and treated as efficiently as possible from the RTT area.

During the study period, the RTT area was open from 8 AM to 2 PM. Staffing consisted of one physician and one nurse. An ED technician may also be assigned to the area depending on availability and time of day. The RTT physician and nurse are encouraged to communicate and work closely as a team, and the triage nurses are encouraged to communicate freely with the RTT physician to resolve any triage questions or issues as they arise. Simple imaging tests may be ordered by the triage nurse prior to RTT placement in anticipation of patient needs.

Methods of Measurement, Data Collection and Analysis

All study data was extracted from the Kaiser Permanente Healthconnect system, which is the electronic medical record

Table 1. Emergency department (ED) data before and after initiation of the rapid triage and treatment (RTT) system.

	Period pre-RTT:	Period post-RTT:	Statistical testing:
ED census	30,981	33,926	NA
ESI level 1,2,3 (% / 95% CI)	17,478 (56.4 / 55.9-57.0)	18,994 (56.0 / 55.4-56.5)	$\chi^2 = 0.272$
ESI level 4&5 (% / 95% CI)	13,032 (42.1 / 41.5-42.6)	14,648 (43.2 / 42.7-43.7)	$\chi^2 = 0.004$
Ambulance arrivals (% / 95% CI)	3967 (12.8 / 12.3-13.3)	4199 (12.4 / 12.0-12.8)	$\chi^2 = 0.101$
Hospital admissions (% / 95% CI)	3986 (12.9 / 12.7-13.1)	3938 (11.6 / 11.2-12.0)	$\chi^2 = <0.001$
Mean monthly boarder hours (SD / 95% CI)	349.2 (130.6 / 212.3-486.3)	312.6 (85.7 / 222.7-402.6)	p = 0.578
Mean ED LOS (hours) (SD / 95% CI)	4.2 (3.9 / 4.2-4.3)	3.6 (3.7 / 3.6-3.7)	p = <0.001
Mean arrival to room time (min) (SD / 95% CI)	46.7 (58.9 / 45.9-47.4)	25.4 (30.9 / 25.0, 25.6)	p = <0.001
Mean arrival to MD start time (min) (SD / 95% CI)	62.2 (60.3 / 61.5-63.0)	41.9 (37.7 / 41.5-42.4)	p = <0.001
LWBS (% / 95% CI)	1407 (4.5 / 3.1-5.5)	512 (1.5 / 0.6-1.8)	$\chi^2 = <0.001$

ESI, emergency severity index; *LOS,* length of stay; *LWBS*, left without being seen; *SD*, standard deviation; *CI,* confidence interval

(EMR) order entry, and patient-tracking system used at our hospital. Treating nurses and physicians document all patient activity prospectively into the system at the time of the patient's ED visit. Data was analyzed for six months prior to RTT initiation and six months following RTT. A one-month start-up phase was excluded from data analysis as we considered this a transitional period during which staff and physicians were learning new ED processes.

We report ambulance arrival rates, hospital admission rates, LWBS rates, ESI triage levels, LOS times, arrival to emergency physician start times and arrival to room times using simple descriptive statistics. We provide 95% confidence intervals where appropriate and made comparison of proportions using Chi-squared test for ambulance arrival rates, hospital admission rates, LWBS rates and ESI triage levels. We used student's T-test for comparison of mean LOS times, arrival to emergency physician start times and arrival to room times. We performed all data analysis using SAS statistical software (version 9.1.3, released 2004).

RESULTS

We implemented the RTT system February 1, 2007. We evaluated the six-month period prior to implementation (August 2006 – January 2007) and the six-month period following implementation (March 2007 – August 2007). We excluded data from the first month of RTT (February 2007).

The ED census was 30,981 in the six months prior to RTT and 33,926 in the study period after RTT. The mean monthly census was slightly lower in the period before RTT (5163.5; 95% confidence interval [CI] = 4954.7- 5372.3; standard deviation [SD] = 261.0) when compared to that after RTT (5654.3; 95% CI = 5504.8-5803.8; SD = 186.8). Lower acuity patients (ESI levels 4 & 5) comprised a similar proportion of patients during both time periods (42.1% vs. 43.2). The percentage of patients arriving by ambulance was also similar in the period prior to RTT (12.8%, 95% CI = 12.3-13.3) and after RTT (12.4%, 95% CI = 12.0-12.8). Hospital admission rate was 12.9% (95% CI = 12.7-13.1) prior to RTT and 11.6% (95% CI = 11.2-12.0) after RTT. (Table #1)

Despite an increasing ED census, we found that the LWBS rates decreased between study periods. The mean LWBS rate for the six months prior to RTT was 4.5% (95% CI = 3.1-5.5) and 1.5% (95% CI = 0.6-1.8) after RTT initiation. In the month directly preceding the implementation of the RTT process, the LWBS rate had risen as high as 7.7%, but in the first month following RTT had decreased to 3.0% (Figure 1 and Table 1).

The mean ED length of stay was longer in the period before RTT (4.2 hours, 95% CI = 4.2-4.3, SD = 3.9) than after RTT (3.6 hours, 95% CI = 3.6-3.7; SD = 3.7). The mean ED arrival time to physician start time was 62.2 minutes (95% CI = 61.5-63.0; SD = 60.3) in the period prior to initiation of RTT and 41.9 minutes (95% CI = 41.5-42.4; SD = 37.7) after RTT. Arrival time to room time was 46.7 minutes (95% CI 45.9-47.4; SD = 58.9) prior to RTT vs. 25.4 minutes after RTT (95% CI = 25.1-25.7; 30.9) [Table 1]. Tables 2 and 3 show

Table 2. Mean arrival to room times by emergency severity index (ESI) triage category in minutes.

ESI Triage Level:	Pre-RTT:	Post-RTT:	P-Value:	Difference in means:	95% CI:
1	17.1	4.1	0.220	13.0	-7.8 - 33.8
2	19.6	11.2	< 0.001	8.5	6.7 - 10.3
3	41.2	25.0	< 0.001	16.4	15.6 - 17.2
4	64.3	41.6	< 0.001	22.6	21.4 - 23.9
5	55.3	34.8	< 0.001	20.5	14.7 - 26.4

RTT, rapid triage and treatment; *CI,* confidence interval

Table 3. Mean arrival to emergency physician start times in minutes.

ESI Triage Level:	Pre-RTT:	Post-RTT:	P-Value:	Difference in means:	95% CI:
1	24.34	21.82	0.585	2.52	-6.55 - 11.6
2	33.86	27.01	< 0.001	6.85	5.11 - 8.58
3	57.68	41.64	< 0.001	16.04	15.13 - 16.95
4	79.36	56.68	< 0.001	23.25	21.92 - 24.56
5	68.13	47.38	< 0.001	20.75	14.3 - 27.2

RTT, rapid triage and treatment; *CI,* confidence interval

the mean arrival times to room time and physician start time broken down by ESI triage category.

LIMITATIONS

The primary limitations of this study are those associated with retrospectively collected data. However, the use of the computerized EMR in our facility leads to fairly standardized and reliable data collection similar to that of prospective studies. Recall bias is not an issue as the data points of interest were recorded during the course of the patient's ED visit.

Ideally we would have studied longer pre- and post-intervention intervals in order to adjust for any seasonal variation in ED patient patterns. However, this was difficult as we also needed to pick a study period that didn't include any significant changes in department staffing, processes, or external factors that may have confounded our results. We therefore chose to evaluate six-month periods before and after the RTT intervention. We felt that this time period adequately represented the different seasons but, to our knowledge, did not include any confounding changes.

Unfortunately, for this study we did not collect data regarding patient satisfaction, ED return visits, insurance co-pay collection, physician relative value unit (RVU) productivity or physician satisfaction. It is unclear how use of the RTT system affected patient satisfaction, ED return rates, RVU productivity, and/or collection of co-pays in the ED. Similarly, how the RTT system may have affected physician job satisfaction is unknown.

We found a slight decrease in hospital admission rates in the post-intervention period when compared to the pre-intervention period. The reason for this difference is not clear. A decrease in admission rates might represent a decrease in patient acuities presenting to the ED between periods; however, this is not reflected in the rates of ambulance arrivals or ESI triage categories. It is also possible that institution of the RTT system somehow decreased hospital admission rates. It is unclear why this would occur.

In this paper we describe a process change at one hospital ED. It is important to note that our results may be unique to this single physician group within a single hospital system. We, however, feel that our ED is similar to many other departments in the United States and our findings will be of interest to other EDs.

DISCUSSION

This study demonstrates that by decreasing inefficiencies associated with our triage process and creating a more efficient system for treating lower acuity patients in our ED, we were able to significantly decrease waiting times and LWBS rates. These process improvements were made without changes in existing ED resources. Prior to implementation of the RTT system, LWBS rates were steadily climbing reaching a high of 7.7% in the month just prior to RTT. The mean LWBS rate in the pre-RTT period was 4.5% and in the post-RTT period was 1.5%. This improvement in LWBS occurred despite a slight increase in ED census and similar numbers reflecting ED acuity (ESI acuity, ambulance arrivals) [Table 1].

There was, however, a significant decrease in hospital admission rates between the pre- and post- RTT periods

(12.9%; 95% CI 12.7-13.1 vs. 11.6%; 95% CI 11.2-12.0). It is not clear whether this change represents a difference in baseline characteristics of the two study groups or is a result of implementation of the RTT system. Determination of whether the RTT actually caused a decrease in hospital admission rates would require more study.

We feel that the decreases in patient waiting times (ED presentation to room time and ED presentation to emergency physician start times) that we observed were the primary factors leading to improvement in LWBS rates. It has been shown previously that ED LWBS rates (and patient satisfaction) are directly associated with patient waiting times to see a physician.[14-18] The largest decreases we observed occurred in lower acuity patients (ESI triage category four and five). However, waiting times for category two and three patients also appeared to improve (Tables 2 and 3).

Because ED crowding and rising census are widespread problems, several strategies have been attempted to improve ED patient waiting times in the face of increasing census numbers:

EDs can Increase Department Resources to Meet Census Needs

Unfortunately this option requires a substantial financial commitment as multiple resources must be increased simultaneously (i.e.: nurses, physicians, clinical space, radiology, and lab). Partial resource enhancement tends to simply move the resource "bottleneck" to another area of the ED. Flexible resource expansion (at times of high volumes) would be ideal, but is frequently impractical. Generalized resource expansion ensures periods of low resource utilization at a substantial cost.

Departments can Seek to Decrease ED Volumes

Referral of low acuity patients to outside clinics has been attempted [19,20] but with multiple drawbacks. Use of a "triage out" system does require dedication of some ED resources for MSE and clinic transport. Unfortunately, these activities do not add value for the patient and, in the end, are completely wasted steps. Also, mis-triage to a lower level of care is a potentially harmful error both from the standpoint of patient care and potential regulatory violation of the Emergency Medical Treatment and Active Labor Act.

EDs can Seek to Decrease the Acuity of Patients they See

In one previous study, increasing numbers of "trauma & resuscitation" patients were directly associated with LWBS rates.[14] These high acuity resuscitation patients divert scarce ED resources and slow department throughput. Additionally, in the era of nursing ratios, a single critical patient can close three ED beds. While we cannot control the patients who present to our departments, ambulance diversion might be used as a method to control ED patient acuity. Unfortunately, ambulance diversion has adverse effects on the emergency medical services system and is a frequently applied measure of ED quality.

Departments can Seek to Rearrange Resources to Optimize Efficiency and Decrease ED Wait Times

Several studies have demonstrated that better use of existing ED resources can lead to improved metrics.[14,21-23] In our department we sought to apply Lean principles to our ED processes to develop efficiency, thus improving patient wait times and LWBS numbers. Lean is a business concept that has previously been applied to ED systems to improve patient care processes.[6,7,8,9,10] Because the ED is comprised of multiple different work flows making up the patient care experience it is both an ideal and difficult setting for creation of Lean process changes. The application of Lean principles requires: evaluation of systems, identification of waste, elimination of

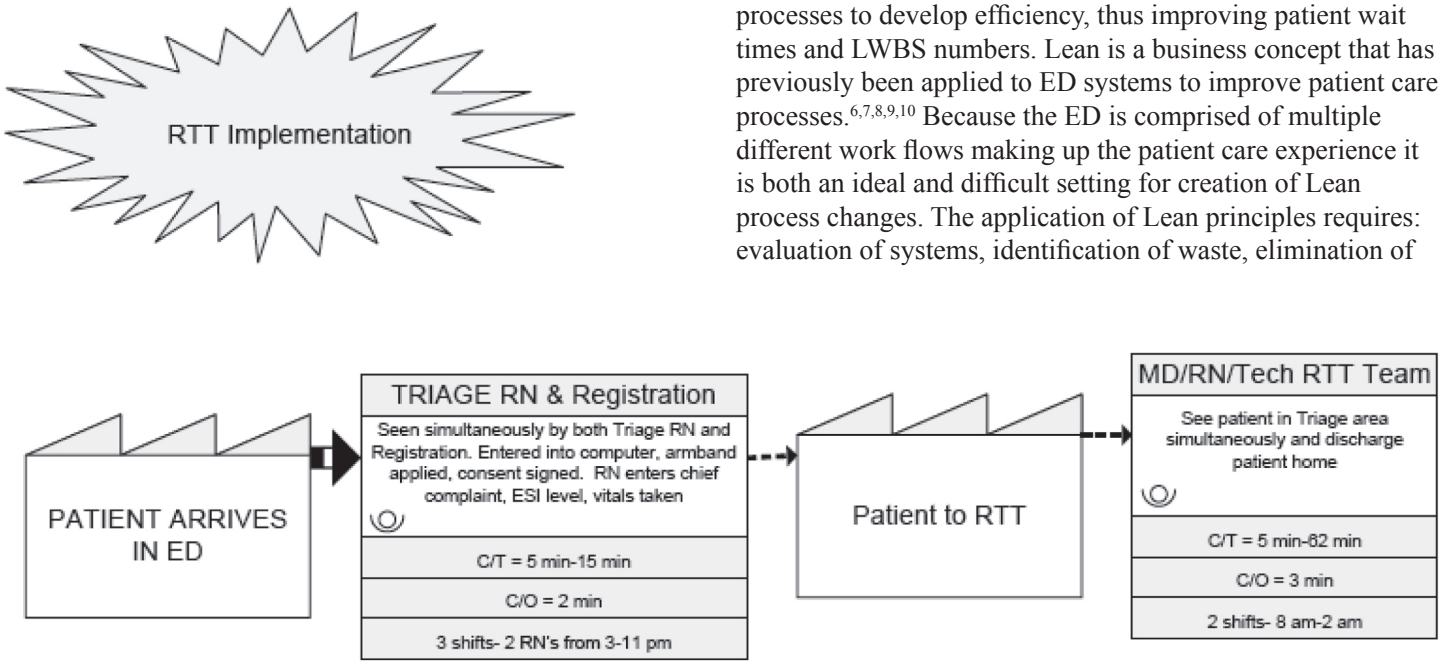

Figure 3. Value-stream map of the triage process after Lean process changes.
RTT, rapid triage and treatment, *ED,* emergency department; *C/T*, cycle time; *C/O*, changeover time.

waste, improvement of flow, and constant adaptation to change (Figure 1). The core concept of Lean is that the only important steps in any process are those that add value for the customer (or patient in this case). Value is any operation or process step that contributes directly to providing service to the patient. Waste is any activity that doesn't add value.

The initial step in implementing any Lean system is actually watching the processes and mapping workflows, rather than describing them from memory. For the process improvement described in this paper, we made a value-stream map of the entire ED experience for low acuity patients prior to any discussion of improvements (Figure 2). The use of front-line workers to develop process improvements is another key Lean principle. In our department we formed a "throughput committee" comprised of all levels of ED workers. All staff members were coached in the Lean principle of "continuous process improvement" and were invited to give input on the process throughout the timeline. This "bottom up" approach tends to yield the best ideas for process improvements and better implementation of those improvements.

Members of the throughput committee then dissected each portion of the value- stream map and classified activities as "value-added" or "non-value added." In our process, we first identified that certain triage questions could be considered non-value added and eliminated them. We further evaluated the value-stream map and developed a shortened workflow for lower acuity patients to improve throughput times (Figure 3). We also used 5-S principles to standardize equipment in the triage and RTT areas.[24] In our experience, the most difficult Lean process adaptation is standardization of workflows. It is critical that all members of the healthcare team identify task sequence, and then perform them in a standard way and time. This required a cultural shift and constant vigilance by members of the committee for the first month of the implementation and beyond. It also requires that staff have an open mind and be able to adapt to changes. As stated above, investment by front-line staff members in the flow improvement process is crucial to its eventual success.

Fostering a culture of continuous process improvement among ED staff ensures that gains aren't lost and allows for rapid adaptation to future changes. We have accomplished this in our department by continuing our multidisciplinary throughput committee, which focuses on ED processes and application of Lean to solve problems.

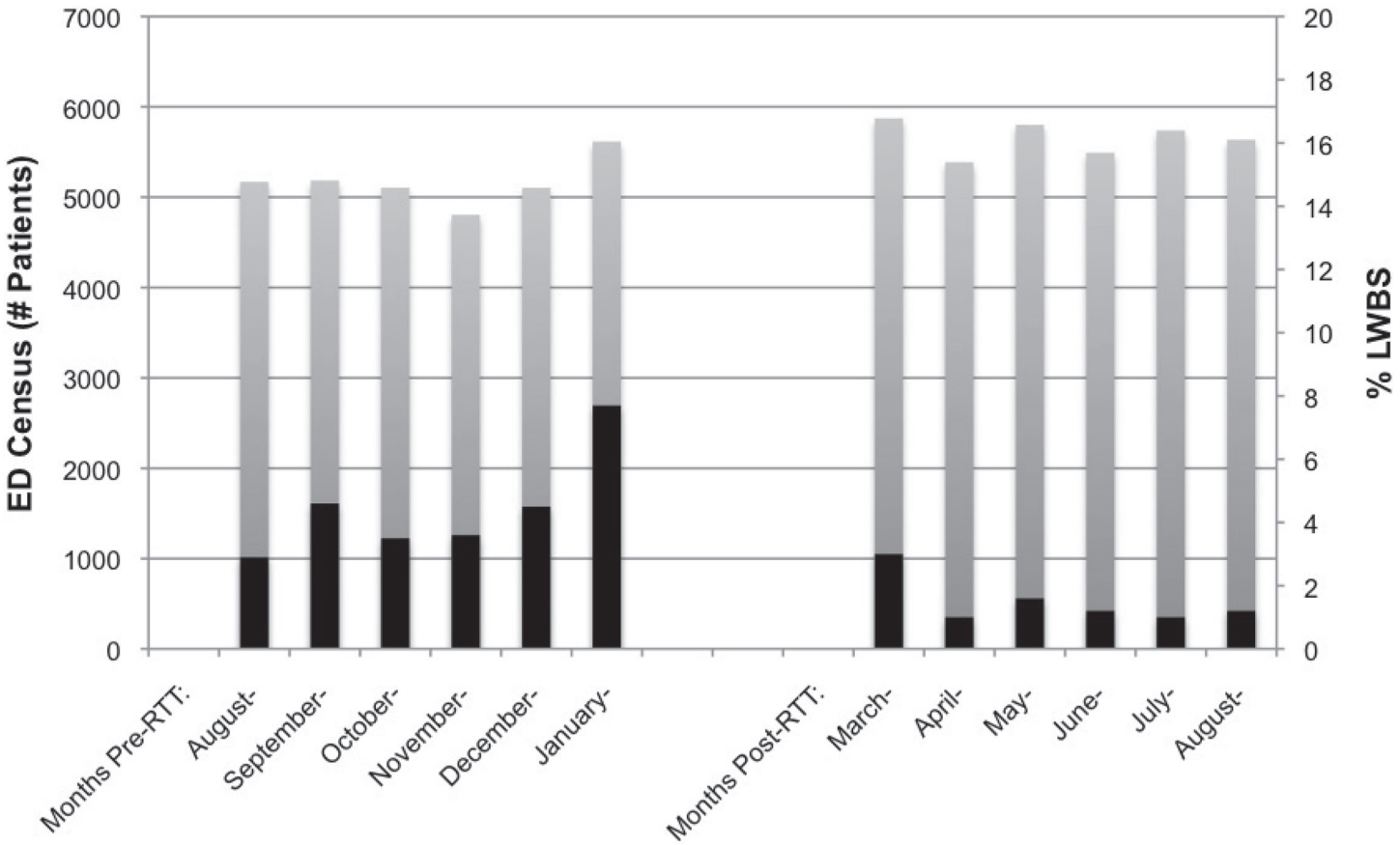

Figure 4. Emergency department (ED) census and left without being seen (LWBS) rates. Gray bars denote monthly ED census (left axis) and black bars denote LWBS rates (right axis).

CONCLUSION

In our ED we found that redesign of ED processes, using Lean principles and existing department resources, improved important metrics. By implementing an RTT system we were able to decrease patient wait times and LWBS rates. These changes occurred despite a moderate increase in ED census during the study period.

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Financial Impact of Emergency Department Crowding

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Objective: The economic benefits of reducing emergency department (ED) crowding are potentially substantial as they may decrease hospital length of stay. Hospital administrators and public officials may therefore be motivated to implement crowding protocols. We sought to identify a potential cost of ED crowding by evaluating the contribution of excess ED length of stay (LOS) to overall hospital length of stay.

Methods: We performed a retrospective review of administrative data of adult patients from two urban hospitals (one county and one university) in Brooklyn, New York from 2006-2007. Data was provided by each facility. Extrapolating from prior research (Krochmal and Riley, 2005), we determined the increase in total hospital LOS due to extended ED lengths of stay, and applied cost and charge analyses for the two separate facilities.

Results: We determined that 6,205 (5.0%) admitted adult patients from the county facility and 3,017 (3.4%) patients from the university facility were held in the ED greater than one day over a one-year period. From prior research, it has been estimated that each of these patient's total hospital length of stay was increased on average by 11.7% (0.61 days at the county facility, and 0.71 days at the university facility). The increased charges over one year at the county facility due to the extended ED LOS was therefore approximately $9.8 million, while the increased costs at the university facility were approximately $3.9 million.

Conclusion: Based on extrapolations from Krochmal and Riley applied to two New York urban hospitals, the county hospital could potentially save $9.8 million in charges and the university hospital $3.9 million in costs per year if they eliminate ED boarding of adult admitted patients by improving movement to the inpatient setting. [West J Emerg Med. 2011;12(2):192-197.]

INTRODUCTION

Emergency department (ED) crowding continues to be a major problem for our healthcare system. In 2006 the Institute of Medicine (IOM) reported that one area warranting special attention at Academic Medical Centers (AMCs) was "the need to address AMC emergency department crowding and its adverse effect on quality of care and patient safety."[1]

While the IOM focuses on improving patient care, other studies look at financial impact and specifically how decreasing crowding will produce an increase in hospital revenue and a decrease in expenditures.[2-6] Krochmal and Riley[3] outline how hospital lengths of stay (LOS) are extended for patients with an extended ED LOS and predicts the financial impact of these implications. These authors calculated that an increased ED LOS increases hospital costs by $6.8 million over three years.[3] Therefore, decreasing ED crowding by decreasing the ED LOS per patient has a significant potential to decrease costs.

Using Krochmal and Riley's[3] findings, we sought to project charge and cost savings for two New York City

hospitals if ED crowding were reduced by decreasing ED LOS for admitted patients.

METHODS

This is a retrospective review of administrative data from two separate urban hospitals in Brooklyn, New York. During the study period, neither hospital had an ED crowding protocol in place. The relationship between clinical throughput data and patient charge/cost data was drawn using previously published estimates regarding the impact of ED LOS on hospital LOS. We extrapolated data from Krochmal and Riley,[3] who evaluated the association of an ED LOS greater than one day with the total hospital LOS. We then calculated potential costs and charges accrued by increasing hospital LOS due to increased ED LOS .

The first hospital is a county institution with 627 inpatient beds and an annual ED census of 125,000 patients. The other hospital is university-based with 406 inpatient beds and an annual ED census of 88,000 patients. Neither hospital had a formal ED holding or observation unit. A holding unit is a predetermined, staffed location in the ED to hold admitted patients until an inpatient location is ready. An observation unit is a predetermined, staffed location in the ED where a person is observed for a predetermined amount of time before discharge from the hospital. Data collected from each institution included annual ED census, ED admissions per month, average number of ED admissions per day, average ED output times per month, average hospital LOS, and cost or charge per medical/surgical bed per day. We collected ED data for the county hospital from the Misys-Computerized Patient Record/Computerized Physician Order Entry (CPR/CPOE) system software (Misys Healthcare Systems, Raleigh, NC, USA) from July 2006 to March 2007. We obtained ED data for the university hospital from October 2006 to October from that institution's Performance Improvement (PI) committee. The PI committee collected its data using NaviCare software (Hill-Rom Services, Inc. Batesville, IN, USA). The average hospital LOS and cost/charge data were collected by respective hospital officials.

In order to assess the financial impact of ED crowding on an institution and its costs/charges, we examined clinical throughput and fiscal variables at these two hospitals. We calculated the ED LOS for patients admitted to the hospital from when a patient entered the ED (signing in at triage) until the patient physically exited the ED. The ED LOS includes the output time for each admitted patient. The output time is a measure of the length of time an admitted patient (inpatient) is physically located in the ED while waiting for an inpatient bed. The hospital (inpatient) LOS is defined from when the admission order is placed by the ED physician until the time of discharge. Therefore, ED LOS is a subset of the hospital LOS, and includes the ED output time, as in Krochmal and Riley's[3] study. We used these variables to calculate an extended ED LOS of admitted patients.

Krochmal and Riley[3] defined an extended ED LOS of an admitted patient as one that remained in the ED at midnight. This calculation was used because inpatient days at the institution that Krochmal and Riley[3] studied are counted by the midnight census regardless of patient location (ED or inpatient bed). Total inpatient LOS included the time the patient spent boarding in the ED after being admitted.

We obtained fiscal variables from each hospital's respective ED administrator. Unfortunately, each hospital quantifies the expense of an inpatient bed differently. The county hospital in our study reports the expense of an adult inpatient bed by charges per day, while university hospital reports this by the cost of this occupied bed for one day. We used only the cost/charges of adult medical/surgical floor beds and not intensive care unit (ICU) beds, despite the fact that some patients were admitted to the ICU. We did not use the cost/charges of pediatric inpatient beds as pediatric admissions were excluded.

We subsequently used previously published calculations to determine cost/charge endpoints.[3] The number of patients who stayed in the ED greater than one day, as per the Krochmal and Riley[3] definition, was found to have an average increase in hospital LOS of 11.7%. We calculated the number of patients who stayed in the ED greater than one day at each hospital based on their output time. This was calculated by collecting the average output time and multiplying by the average number of admissions per hour during the same time frame to obtain the quantity of admitted patients located in the ED at midnight each day.

The number of admitted patients located in the ED at midnight represents the number of patients who had an extended ED LOS. We multiplied this figure by 365 to represent the total number of patients admitted to the hospital in one year who had an extended ED LOS and were therefore predicted to have an extended hospital LOS.

Krochmal and Riley[3] concluded that there was a 11.7% increase in hospital LOS due to an ED LOS greater than one day.[3] We obtained the average inpatient LOS at each hospital from each institution's administrators and calculated the average increase in hospital stay for a patient who had an extended ED LOS based on Krochmal and Riley's[3] conclusions. Therefore, we calculated the extended hospital LOS due to an extended ED LOS by adding 11.7% of the average hospital LOS to the average hospital LOS.

The total number of patients admitted to the hospital in one year who were predicted to have an extended hospital LOS was multiplied by the average hospital stay at each site. We also multiplied the total number of patients admitted to the hospital in one year who were predicted to have an extended hospital LOS by the predicted extended hospital LOS based on the Krochmal and Riley[3] conclusions. The difference between these two figures resulted in the total increase of unnecessary hospital inpatient days due to an extended ED LOS.

Table 1. Impact data due to increased length of stay (LOS) at emergency department (ED) greater than one day.

Variable	Site 1	Site 2
Hospital type	County	Academic/university
Annual ED census	125,000	88,000
Average ED admissions per hour	1.49	1.26
Average ED output times (hours)	11.4	6.6
Average number patients with ED LOS > one day per day*	17	8.3
Annualized number patients with ED LOS > one day	6205	3017
Average hospital LOS (days)	5.2	6.06
Estimated additional hospital LOS days for patients with ED LOS > one day	0.61	0.71
Adjusted hospital LOS based for patients with ED LOS > one day	5.81	6.77
Cost/charge per hospital LOS perday	$2,590	$1,800
Estimated average increased cost/charge per patient	$1,580	$1,278
Estimated increase annual cost/charges	$9,803,280	$3,855,726

**The estimated increase in average number of patients with an ED LOS > one day per day and the estimated additional hospital LOS days for patients with an ED LOS > one day were based on previously published data.[5]*

Lastly, the total number of increased hospital inpatient days – due to an extended ED LOS over a one-year period – was multiplied by either the cost of a medical/surgical bed per day at the university-based institution or the charge for a medical/surgical bed per day at the county hospital.

RESULTS

The county hospital had an average adult patient output time of 11.4 hours for 2007 along with an average of 1.49 admissions per hour. An average of 17 adult admitted patients were present in the ED at midnight daily for a total of 6,205 adult admitted patients for the year 2007. The average hospital LOS was 5.2 days and is calculated to be 5.81 days for those with an extended ED LOS. Since the average charge for a medical/surgical floor bed per day is $2,590, it is calculated that the hospital was charging an extra $1,580 per patient who had an extended stay in the ED. Therefore, an average 11.7% increase in hospital LOS for the 6,205 adult patients with an increased ED LOS would amount to $9,803,280 in excess charges for 2007 (Table 1).

The university hospital had an average adult patient output time of 6.6 hours for the time period studied along with an average of 1.26 admissions per hour. It is calculated that an average of 8.3 adult admitted patients would be present in the ED at midnight daily or a total of 3,017 patients per year. The average hospital LOS was 6.06 days and is calculated to be 6.77 days due to an extended ED LOS. Since the average cost for a medical/surgical floor bed per day is $1,800, it is calculated that it cost the hospital an extra $1,278 per patient who had an extended ED LOS. Therefore, an average 11.7% increase hospital LOS for the 3,017 adult patients with an increased ED LOS would amount to $3,855,726 in excess costs for the university hospital in 2007 (Table 1).

DISCUSSION

This study suggests that hospitals could avoid significant patient charges/costs by reducing ED LOS. According to our model, the county hospital could have saved $9.8 million in charges and the university hospital could have saved $3.85 million in costs over one year if ED boarding were eliminated. Furthermore, payers are less likely to pay fees following extended inpatient stays, which means that much of these charges and costs may not be recouped.

While ED crowding and its morbidity and mortality is well documented, the cost of ED crowding has yet to be elucidated. The documentation of increased morbidity and mortality has not stimulated the implementation of ED crowding solutions, but the financial drain to hospitals due to ED crowding may provide this stimulus. Many factors that contribute to ED crowding, including ambulance diversion and patients leaving without being seen, are suspected to be fiscally detrimental to a hospital. While all of these factors need to be explored, this study is the second, after the Krochmal and Riley study,[3] that examines the effect of ED

crowding on the expense of increased hospital length of stay.

While the Krochmal and Riley[3] study estimates direct costs to the hospital due to increased ED LOS, other studies have found potential loss of revenue due to ED crowding. Bayley et al.[4] sought to determine the additional cost of an extended ED LOS for chest pain patients awaiting non-ICU monitored beds, a relevant point because more than six million patients present to the ED with chest pain each year.[7] This study found that 91% of admitted patients waited more than three hours for an inpatient bed, which amounts to a potential revenue loss of $204 per patient.

Falvo et al.[5] also found a significant loss of potential hospital revenue and ED functional treatment capacity due to increased length of ED stays of admitted patients. This study concluded that "transferring admitted patients from the ED to an inpatient unit within 120 minutes would have increased the functional treatment capacity of the ED by 10,397 hours" over one year. Furthermore, by reducing admission process delays during their 12- month study, "the hospital could potentially have accommodated another 3,175 patient encounters in its existing treatment spaces." Lastly, the authors concluded that in 12 months $3,960,264 in net revenue for the hospital could have been generated by providing emergency services to new patients in ED beds used to board inpatients. The findings of both Falvo et al.[5] and Bayley et al.[4] are relevant to the two New York City hospitals presented in our study because the average output times for these NY hospitals (11.4 and 6.6 hours respectively) are longer than the benchmark output times used in the aforementioned studies (three hours and 120 minutes).

Significant revenue can also be lost due to ED ambulance diversion, a result of ED crowding and decreased patient flow. In a Canadian study by Schull et al.[8] ED crowding was directly linked to ambulance diversion. Authors found that the length of ambulance diversion increased with the number of admitted patients boarded in the ED (6.2 minutes per patient) and also increased with ED patient boarding time (11.3 minutes per hour). It has also been demonstrated that ambulance diversion can affect hospital revenue. Falvo et al.[6] found that during a 12-month period, a 450-bed nonprofit community teaching hospital with 62,588 patient visits to the ED "may have lost $3,881,506 dollars in net revenue as a result of ambulance diversions and patient elopements." Authors concluded that "significant revenue may be foregone as a result of throughput delays that prevent the ED from utilizing its existing bed capacity for additional patient visits."

A proposed solution to ED crowding is a Full Capacity Protocol (FCP). An FCP is a plan that uses additional hospital resources and atypical bed space to decompress overcrowded EDs. The State University of New York at Stony Brook has had an FCP in place since 2001.[9] Its protocol calls for admitted patients who are boarding in the emergency room, when the ED is at full capacity, to be boarded in the acute care beds located in the hallways of the inpatient floor, – up to a maximum of two additional patients per inpatient unit. A boarding patient is defined as a patient who has been admitted to the hospital from the ED, who is no longer an active patient in the ED, and who is waiting to occupy a cleaned, unoccupied room. The theory behind this protocol is that ED crowding is a hospital problem and not just an ED problem, and that the entire hospital should participate in a solution.

Since 2001, only a few hospitals have adopted an FCP due to multiple administrative roadblocks– all despite an FCP's potential to decrease costs, augment revenue, and increase patient satisfaction and safety. Among the most strident opponents have been nursing associations and hospital administrations.

The California Nurses Association openly opposed California State Assembly bills AB2207 in 2008 and AB911 in 2009, which require hospitals to regularly assess the condition of the ED based on a national score and develop an FCP. AB2207 would have allowed boarded ED patients to be moved to hallways of inpatient units in the most severe and dangerous instances of ED crowding. Nursing associations objected to these protocols – and continue to do so – claiming that if these protocols were to be implemented, inpatient nurses would have too many patients to care for and might be required to provide that care in hallways.

Hospital administrations, on the other hand, oppose FCPs for largely unknown reasons. The California Hospital Association also openly opposed AB2207 and currently opposes AB911. It is speculated that hospital administrators believe that boarding patients in ED hallways is a better financial option than reserving inpatient rooms for those patients admitted through the ED. However, since an economic analysis of FCPs has not been completed, the magnitude of the financial impact of an FCP is unknown. It is additionally speculated that boarding patients in the ED is logistically easier for the hospital administration than making other arrangements for these patients. Again, there is no research or evidence to support this theory.

In addition to opposition from nursing associations and hospital administrations, FCPs have been slow to gain widespread adoption because, aside from one abstract, there have been no published prospective studies that assess the benefits of implementing an FCP. Published out of a hospital in Vancouver, Canada, the abstract prospectively studied the effects of implementing an Overcapacity Care Protocol (as it is called in Canada).[2] The abstract outlined two benefits to implementing the Overcapacity Care Protocol: a decrease in the average ED LOS for all admitted patients by five hours, and an increase in ambulance arrivals. In addition, during the period of the study the ED volume increased and the average LOS decreased by approximately 24 hours for all admitted patients. These are significant results and suggest that implementing a hospital-based ED crowding protocol can be beneficial by decreasing ED crowding, decreasing hospital costs, and decreasing ambulance diversion.

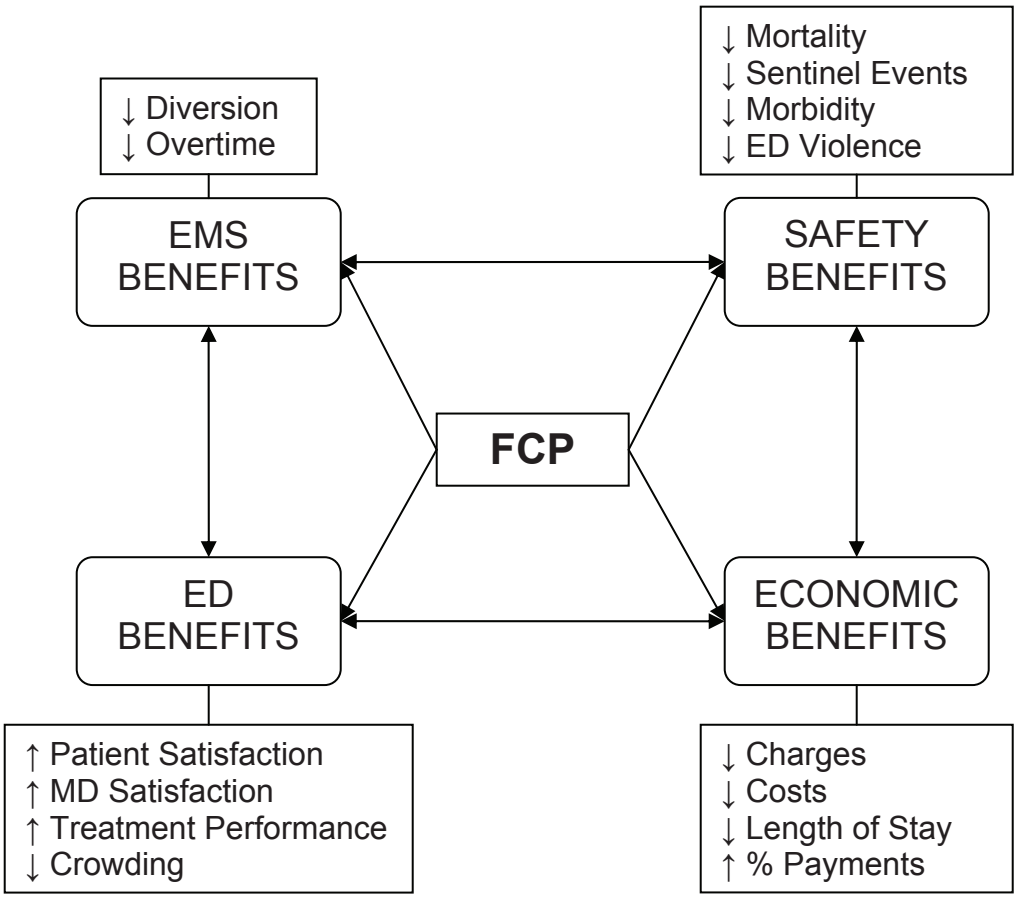

Figure 1. Full capacity protocol (FCP) benefits.
FCP, full capacity protocol, *EMS*, emergency medical services, *ED*, emergency department, MD, medical physician

An FCP can provide various economic, patient safety, ED and emergency medical services (EMS) benefits. Patient safety benefits are well documented, include decreased mortality, decreased morbidity, decreased sentinel events, and decreased ED violence.[10-11] The ED significantly benefits from FCPs by improving the working environment and increasing physician satisfaction, increasing patient satisfaction, and improving treatment performance.[11-12] As described above, FCPs can affect EMS by decreasing ambulance diversions, and therefore decreasing EMS overtime (Figure 1). Since patient safety and patient satisfaction have not been enough to convince many hospital administrations to adopt hospital-based ED crowding protocols, perhaps potential cost savings and potential revenue earned will persuade the appropriate officials. While prospective studies of implementing hospital-based ED crowding protocols are crucial, there is currently a lack of any published prospective or retrospective studies.

LIMITATIONS

The calculations for the county hospital charges and university hospital costs cannot be compared. The county hospital provided average charges per medical/surgical bed, while the university hospital provided average costs per medical/surgical bed. It should be noted that charges are often misleading, and inflated compared to what the actual cost is to a hospital. Furthermore, these figures are conservative estimates because ICU bed costs and charges are not calculated. The average charge for an ICU bed at the county hospital is $4,060 per day and $2,760 per day at the university hospital. Lastly, the above calculations do not take into account that third-party payers are more likely to reimburse charges for patients with shorter stays in the hospital.

CONCLUSION

A strong argument can be made that the ED is the safety net for the American healthcare system.[13] Despite this argument, EDs around the country do not receive enough support from either the government or the hospitals in which they reside in order to function adequately. America's "Emergency Department Crisis" is well documented, as there has been a decrease in the number of EDs and an increase in the number of visits to our national EDs over the past two decades.[14] Contrary to popular belief, ED crowding should not be attributed to the uninsured population.[15] Rather, it is a

consequence of both increased visits and inefficient patient flow within the hospital. Decreasing ED crowding has the potential to save hospitals money and create more revenue streams for them. The estimates provided by studying the above two New York City hospitals consider just one factor of ED crowding: increased ED length of stay. This one factor has the potential to save each of these hospitals millions of dollars without considering the savings or revenue of other factors, such as decreasing ambulance diversion and improving ED bed use. Both the government and hospital administrations can and should aid in decreasing ED crowding. If viewed as a healthcare system and hospital problem – and not just an ED problem – decreasing ED crowding has the potential to significantly help our patients, increase hospital revenue, and decrease healthcare costs.

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Impact of an Expeditor on Emergency Department Patient Throughput

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Objective: Our hypothesis was that an individual whose primary role was to assist with patient throughput would decrease emergency department (ED) length of stay (LOS), elopements and ambulance diversion. The objective of this study was to measure how the use of an expeditor affected these throughput metrics.

Methods: This pre- and post-intervention study analyzed ED patients ≥ 21-years-old between June 2008 and June 2009, at a level one trauma center in an academic medical center with an annual ED census of 40,000 patients. We created the expeditor position as our study intervention in December 2008, by modifying the job responsibilities of an existing paramedic position. An expeditor was on duty from 1PM-1AM daily. The pre-intervention period was June to November 2008, and the post-intervention period was January to June 2009. We used multivariable to assess the impact of the expeditor on throughput metrics after adjusting for confounding variables.

Results: We included a total of 13,680 visits in the analysis. There was a significant decrease in LOS after expeditor implementation by 0.4 hours, despite an increased average daily census (109 vs. 121, p<0.001). The expeditor had no impact on elopements. The probability that the ED experienced complete ambulance diversion during a 24-hour period decreased from 55.2% to 16.0% (OR:0.17, 95%CI:0.05-0.67).

Conclusion: The use of an expeditor was associated with a decreased LOS and ambulance diversion. These findings suggest that EDs may be able to improve patient flow by using expeditors. This tool is under the control of the ED and does not require larger buy-in, resources, or overall hospital changes. [West J Emerg Med. 2011;12(2):198-203.]

INTRODUCTION

Contrary to the media portrayal of the emergency department (ED), patients commonly experience lulls in their treatment during the course of an ED visit. These are known as "non-value added steps" since they add little to the care that the patient receives.[1] For example, after a patient is triaged, the patient often waits to be brought back to a room. After the initial assessment, the patient may wait during the diagnostic testing and treatment phases. Finally, when the physician reviews the information and makes a disposition decision, the patient may wait to either be discharged or admitted. It is during these down times when the attention to patient care wanes and delays are experienced.

Anticipating these delays can result in a smoother, more efficient operations model. In a restaurant, the maître d' controls the flow of patrons. Their role is to ensure that guests who arrive are seated as quickly as possible, that their needs are met, and that the table is turned over rapidly and efficiently for the next customer. With this model in mind, our ED created a new position to be similarly mindful of patient flow. We refer to this role as an expeditor. The expeditor's primary responsibility was to ensure that patient care moved forward.

This role did not involve any additional personnel resources; instead, it expanded the role of existing ED paramedics. Prior to this study, paramedics helped in the ED with basic medication administration and starting intravenous (IV) injections. We felt that paramedics would be well suited for the role as an expeditor because their clinical training allows them to assist with the initiation of care when needed. We chose paramedics rather than the charge nurse so that the charge nurse could continue to focus on the overall flow of the ED. The expeditor communicated with and reassessed patients in the waiting room, roomed patients as directed by the charge nurse, and assisted with ambulance arrivals. While the patient was in a treatment room, the expeditor monitored how well their pain was being controlled and provided analgesics as directed by the nurse. Expeditors also placed IVs, drew labs, and ran point-of-care tests. The expeditor assisted with the discharge process by removing IVs and helping the patient get dressed. For admitted patients, the expeditor facilitated patient transport to inpatient units.

Given that this new role focused on the throughput of patients, the hypothesis of this study was that the presence of the expeditor would decrease ED length of stay (LOS), elopements, and ambulance diversion. LOS has been found in other studies to be a proxy for patient satisfaction, along with elopement or left without being seen (LWBS) rates. [2,3] These terms have been used interchangeably to define patients that have either left before being seen by a provider and/or before their treatment has been complete. For the purposes of this study, we define elopements as any patient who leaves before being seen by a provider or before the patient's treatment in the ED is complete. Patients who left against medical advice (AMA) were defined as patients who had a particular treatment plan recommended to them by the provider (such as hospital admission), but decided to not comply with this plan and be discharged from the ED.

METHODS

Study Design and Setting

This was a pre- and post- intervention cohort study designed to assess the impact of an expeditor on ED LOS, elopements and ambulance diversion. We chose these variables as objective measures of ED throughput based on the conceptual model of the input, throughput, and output of patients.[4]

In December 2008, we selected ED paramedics and trained them in their new role as expeditors. Prior to this, the charge nurse oversaw the flow of patients through the ED. Since the expeditor position was a modification of an existing one, it did not entail adding new personnel. ED staff members assumed the previous responsibilities of ED paramedics. Expeditors worked from 1PM-1AM daily from January to June 2009. We excluded December 2008, from our analysis because we were training expeditors during this time. The pre-intervention period was June 1 to November 30, 2008, and the post-intervention period was January 1 to June 30, 2009. The expeditor's responsibilities were explained during the training period. Expeditors were expected to communicate with patients in the waiting room after they were triaged and to reassess them every 45 minutes. Expeditors advised patients of anticipated wait times and explained why delays were occurring. In addition, expeditors roomed patients as directed by the charge nurse and prepared the patient for evaluation. Expeditors also assisted with ambulance arrivals. Additional tasks included administering medications, placing IVs, and suture or staple removal. Lastly, the expeditor monitored all patients waiting for an inpatient bed and proactively addressed any barriers delaying their transfer.

We conducted the study at an ED with an annual census of 40,000 patients in a Level one trauma center. The ED is part of an academic medical center in a city of approximately 500,000 people. The hospital has 534 inpatient beds. We included all ED patients 21-years-old and older in the analysis, which accounted for approximately 23% of the patient population during this period. Patients younger than 21-years-old were not included because they were seen in the separate pediatric ED, which has a distinct throughput process. Our facility's Institutional Review Board approved the study.

Methods of Measurement

We used retrospective data from our electronic health record (Epic; Verona, WI). All patient identifiers were removed prior to analysis. We analyzed two patient level outcome measures including the patient's LOS (in hours) and whether or not the patient eloped. The ED level outcome measure we used was whether or not ambulance diversion occurred that day. The primary independent variable was the intervention period, i.e., whether or not the expeditor was present that day. Expeditors were present daily during the study period. Potential confounders and predictors include both patient level and ED level daily variables. Patient level variables were used for patient level outcomes and included triage acuity (Emergency Severity Index 1-5), gender, age, time of arrival, type of insurance (private, public [Medicare, Medicaid], self-pay, and other), disposition (for LOS model only), and whether or not the patient was seen on a weekend or weekday. In addition, we provided scripting to some patients to notify them of the longest time a patient was currently waiting. This was included as a patient level variable. ED level daily variables represented crowding and overall volume. Both variables were used for patient and ED level outcomes. The variables included: average LOS for both discharged and admitted patients (only for elopement and diversion outcomes), total number of patients, percent of time the ED was on complete ambulance diversion (only for LOS and elopement outcomes), and the daily average of hours patients boarded in the ED while waiting for an inpatient bed. Since inpatient hospital occupancy was not available, we used daily boarding hours as a proxy to measure delays in getting

Table 1. Overall patient characteristics and emergency department level variables of pre-expeditor and expeditor periods.

	Pre-expeditor period	Expeditor period	p-value
Patient Characteristics	*N = 7,588*	*N = 6,029*	
Age (mean years, and standard deviation)	40.7 (15.0)	41.6 (16.0)	<0.001*
Gender (% male)	46.0	44.7	0.135
Insurance status			
Private insurance (%)	32.9	30.0	
Publicly insured (%)	30.1	31.9	0.003*
Self-pay (%)	34.0	34.8	
Other (%)	3.1	3.4	
Patient arrival time			
7AM-3PM (%)	41.8	36.5	<0.001*
3PM -11PM (%)	46.4	53.4	
11PM -7AM (%)	11.8	10.1	
Arrived on weekend (%)	28.0	27.1	0.246
Disposition			
Admitted (%)	13.5	13.7	0.140
Discharged (%)	80.0	80.6	
Elopements/against medical advice (%)	6.6	5.7	
Emergency Severity Index triage level			
1 or 2 (%)	5.9	4.9	
3 (%)	60.3	58.9	<0.001*
4 or 5 (%)	28.2	29.3	
Unknown (%)	5.5	6.9	
Average overall length of stay (hours, SD)	5.4 (5.5)	5.0 (5.1)	<0.001*
ED level variables	*N= 183*	*N = 182*	
Daily average boarding hours for admitted patients (hours, SD)	1.9 (1.1)	1.9 (1.1)	0.564
Daily volume of patients (mean, SD)	108.5 (10.9)	121.1 (13.7)	<0.001*
Daily ambulance diversion (% of days with at least one episode)	15.7	1.3	<0.001*

*statistically significant
SD, standard deviation

patients admitted. No specific criteria existed for complete ambulance diversion. The decision to use ambulance diversion was made by ED attendings and the charge nurse. For the elopement and ambulance diversion models, we analyzed the average LOS for discharged and admitted patients separately rather than together since the LOS for discharged patients was within the control of the ED. Another ED level variable was the percentage of patients who eloped each day. We calculated this for consideration in the diversion model. We included the variable of month in all models to adjust for temporal fluctuations.

Primary Data Analysis

We compared differences in patient characteristics and ED daily variables pre- vs. post-intervention using a two-sided t-test for continuous variables and a chi square test for categorical variables. The unit of analysis for LOS and elopement was visit. We used a generalized estimating equation's (GEE) linear regression to assess the impact of intervention for LOS. We used logistic regression to assess the impact of intervention for elopement. We applied the GEE approach to control for clustering within subjects who had more than one ED visit. For LOS, the outcome variable was log-transformed to satisfy the assumption of normality. Therefore, the exponentiated coefficients were interpreted as the ratio of LOS between the two levels in comparison. For example, the exponentiated coefficient for the expeditor represented the ratio of

$$\frac{\textbf{Mean LOS Before Expeditor}}{\textbf{Mean LOS After Expeditor}}$$

For continuous variable, it is the ratio of LOS for each unit increase of that variable. A ratio <1 indicated a decrease in LOS, and a ratio >1, indicated an increase of LOS. We reported this ratio in our results section. We also performed a sensitivity analysis to look at the impact of an expeditor on

LOS for admitted and discharged patients, separately. Since the results were similar, we only reported results on LOS for all patients. For ambulance diversion, we performed a logistic regression with the unit of analysis as day. For all models, we investigated associations between outcome and each independent variable in univariate analyses. Variables with a p-value of ≤ 0.20 were then considered in the multivariate model. A p-value of less than 0.05 was considered significant in the final model. We allowed important confounding variables to remain in the model even if $p > 0.05$. In addition, we assessed for linearity between outcome and continuous variables for each model. If linearity was not satisfied, the continuous variable was categorized and entered into the model as a categorical variable. We used Stata v10.0 (StataCorp, College Station, TX) for all data analysis.

RESULTS

We included a total of 10,030 patients accounting for 13,680 ED visits in the analysis. The mean age for all patients in the study was 40.9-years-old (± 15.0). A summary of patient characteristics and daily variables is available in Table 1.

The mean LOS (standard deviation) was 5.4 (±5.5) hours before the intervention and 5.0 (±5.1) hours after, despite an increased average daily census (Table 1). Based on the GEE linear regression for the logarithmically transformed LOS, the presence of an expeditor had a significant reduction in the LOS. The mean LOS after intervention was 0.93 times (95% CI 0.88-0.99) the mean LOS before intervention (p=0.014). Additional variables associated with a significant reduction in LOS included an ESI acuity of 3 compared to 2 or 1, an ESI of 4 or 5 compared to 2 or 1, patients discharged versus admitted, patients who eloped or left AMA versus admitted, and patients presenting over the weekend. Patients with a significant increase in their LOS included those with public insurance compared to private insurance, days when the ED was on complete ambulance diversion for greater than 25% of the time, and patients who were boarded in upper two quartiles of boarding hours (from 1.8-2.2 hours and > 2.2 hours, respectively) (Table 2).

There were 6.6% and 5.7% of patients who eloped during the pre- and post-expeditor period, respectively (Table 1). After adjusting for confounding variables, the presence of an expeditor had no association with elopements (OR 1.09, 95% CI 0.74-1.61) [Table 3]. Patients who were provided scripting, were older than 55 years, and seen on a weekend were less likely to elope. In contrast, patients between 42 and 55 years of age, publicly insured or self-pay, and presenting between 3 PM and 7 AM, were more likely to elope.

Before the expeditor intervention, the ED experienced ambulance diversion during a 24-hour period with a probability of 55.2%. After the intervention, the probability that the ED experienced ambulance diversion was 16.0%. The impact of the expeditor was significant after controlling for other variables (OR 0.17, 95% CI 0.05-0.67) (Table 4).

Table 2. Generalized estimating equations linear regression for length of stay.

Variable	Ratio (95% CI)	p-value
Expeditor present that day	0.93 (0.88-0.99)	0.014*
Scripting provided	1.01 (0.98-1.04)	0.610
Age	1.002 (1.001-1.002)	<0.001*
Insurance status		<0.001*
Private insurance	Referent	
Publicly insured	1.03 (1.00-1.06)	0.041*
Self-pay	1.02 (0.99-1.04)	0.221
Other	0.87 (0.81-0.92)	<0.001*
Patient Disposition		<0.001*
Admit	Referent	
Discharge	0.64 (0.62-0.66)	<0.001*
Elopement/against medical advice	0.44 (0.41-0.46)	<0.001*
Emergency Severity Index triage level		<0.001*
1 or 2	Referent	
3	0.80 (0.76-0.84)	<0.001*
4 or 5	0.46 (0.44-0.48)	<0.001*
Patient seen on weekend	0.96 (0.94-0.99)	0.003*
Daily ambulance diversion (% of days with at least one episode)		<0.001*
0%	Referent	
0-25%	1.03 (1.00-1.06)	0.047*
>25%	1.08 (1.04-1.13)	<0.001*
Daily average boarding hours (quartiles)		0.005*
<1.2 hours	Referent	
1.2-1.7 hours	1.00 (0.97-1.03)	0.973
1.8-2.2 hours	1.04 (1.01-1.07)	0.019*
>2.2 hours	1.05 (1.01-1.09)	0.005*
Total daily emergency department patients	1.002 (1.001-1.003)	<0.001*

*statistically significant

An increased LOS for discharged patients was also associated with ambulance diversion (OR 2.57, 95% CI 1.41-4.70 for each hour increase).

DISCUSSION

The use of an ED expeditor was associated with decreased LOS and ambulance diversion but not with patient elopements. The expeditor had a significant impact in reducing ambulance diversion over a 24-hour period. Conversely, boarding patients for greater than 2.2 hours and prolonging LOS for discharged patients both increased the odds of ambulance diversion. Since a decrease in the LOS was associated with the presence of the expeditor, it is possible that the expeditor's role in decreasing LOS transitively led to a decrease in ambulance diversion.

Table 3. Generalized estimating equations logistic regression for likelihood of patient elopement.

Variable	OR (95% CI)	p-value
Expeditor present that day	1.09 (0.74-1.61)	0.663
Scripting provided	0.76 (0.62-0.93)	0.007*
Age		<0.001*
< 30 years	Referent	
30-42 years	1.12 (0.92-1.37)	0.266
42-55 years	1.26 (1.03-1.55)	0.025*
>55 years	0.74 (0.58-0.93)	0.011*
Insurance status		<0.001*
Private insurance	Referent	
Publicly insured	1.45 (1.19-1.77)	<0.001*
Self-pay	1.88 (1.56-2.26)	<0.001*
Other	0.84 (0.51-1.38)	0.481
Patient arrival time		<0.001*
7AM -3 PM	Referent	
3PM -11PM	1.72 (1.46-2.03)	<0.001*
11PM -7AM	1.32 (1.02-1.71)	0.032*
Emergency Severity Index triage level		0.008*
1 or 2	Referent	
3	1.30 (0.91-1.86)	0.150
4 or 5	0.99 (0.68-1.45)	0.957
Patient seen on weekend	0.63 (0.52-0.77)	<0.001*
Daily ambulance diversion (% of days with at least one episode)		0.124
0%	Referent	
0-25%	1.20 (1.00-1.44)	0.047
>25%	1.18 (0.92-1.50)	0.188
Daily average boarding hours (quartiles)		<0.001*
<1.2 hours	Referent	
1.2-1.7 hours	1.16 (0.92-1.45)	0.212
1.8-2.2 hours	1.08 (0.86-1.35)	0.530
>2.2 hours	1.06 (0.84-1.35)	0.610
Total daily emergency department patients	1.01 (1.01-1.02)	<0.001*
Length of stay for discharged patients	1.38 (1.18-1.61)	<0.001*

*statistically significant

Table 4. Logistic regression for ambulance diversion.

Variable	OR (95% CI)	p-value
Expeditor present that day	0.17 (0.05-0.67)	0.011*
Daily average boarding hours (quartiles)		
<1.2 hours	Referent	
1.2-1.7 hours	1.08 (0.49-2.38)	0.852
1.8-2.2 hours	1.22 (0.55-2.69)	0.631
>2.2 hours	2.81 (1.20-6.54)	0.017*
Total daily emergency department patients	1.02 (0.99-1.05)	0.158
Percentage of patients who elope	1.06 (0.99-1.12)	0.074
Length of Stay for discharged patients	2.57 (1.41-4.70)	0.002*

*statistically significant periods.

Patients were more likely to elope if they were publicly insured or uninsured compared to those with private insurance. They were also more likely to elope if they were 42-55 years of age compared to those younger than 30-years-old. In addition, patients eloped more frequently during our busiest time of the day from 3PM-11PM. Our study focused on the variable of LOS for discharged patients, since this variable is within the control of the ED. Conversely, patients were less likely to elope during the weekends when fewer patients were seen. As demonstrated in a prior study, the use of scripting at triage had a positive impact on decreasing elopements.[5]

This was the first study to explore the novel role of an expeditor. A significant impact was demonstrated after taking an existing resource and focusing it on improving the flow of patients. No other studies could be found in the literature that used such a role. Future research should explore techniques from other industries, such as food service and amusement parks to understand how their best practices might apply to the healthcare setting.

Our data suggest that the expeditor had little impact on patients who remained in the waiting room. Prior studies have demonstrated that a physician at triage has decreased elopements and improved patient satisfaction.[6-10] It remains to be seen if an expeditor can have a similar impact. Instead, the expeditors' efforts could have remained more within the treatment area during the patient's care and when disposition was made. Also, the result of decreased ambulance diversion could have led to a relative increase in patients eloping, as more patients arriving by ambulance would displace patients coming by other means to the waiting room. This could have blunted any improvements seen in terms of a decrease in elopements. There are a number of ED level factors that have been shown to be associated with elopement rates, including ED volume, the number of boarding hours for admitted patients, the percent of patients arriving by ambulance, and LOS for discharged patients.[11]

LIMITATIONS

Several limitations were inherent to the study. First, there was no proof that the expeditors fulfilled the job description duties completely when they were assigned to a particular shift. This study did not account for variations of individual expeditors who may have been more or less effective in their role. In addition, there is concern that other improvement

initiatives, including the use of scripting at triage to provide wait time notification, may have been confounding variables despite controlling for this and other variables in the models. Throughout both the pre- and post-intervention periods, an ED full-capacity protocol was undergoing modification to address surges in patient volume. Since the protocol was applied inconsistently during this time, it is unclear what affect this may have had on outcomes. Given limitations in how the data could be collected, only daily variables could be used for the analysis when hourly variables might have been able to provide further detail. Also, since the study was conducted in one academic ED, the results may not apply to other EDs.

CONCLUSION

In summary, the creation of an expeditor in our ED was associated with decreased patient LOS and ambulance diversion, but not elopements. Further definition and standardization of the role may ensure that the expeditor is involved in the care of ED patients in the waiting room, which may drive down elopements.

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Predicting Patient Patterns in Veterans Administration Emergency Departments

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Veteran's Affairs (VA) hospitals represent a unique patient population within the healthcare system; for example, they have few female and pediatric patients, typically do not see many trauma cases and often do not accept ambulance runs. As such, veteran-specific studies are required to understand the particular needs and stumbling blocks of VA emergency department (ED) care. The purpose of this paper is to analyze the demographics of patients served at VA EDs and compare them to the national ED population at large. Our analysis reveals that the VA population exhibits a similar set of common chief complaints to the national ED population (and in similar proportions) and yet differs from the general population in many ways. For example, the VA treats an older, predominantly male population, and encounters a much lower incidence of trauma. Perhaps most significantly, the incidence of psychiatric disease at the VA is more than double that of the general population (10% vs. 4%) and accounts for a significant proportion of admissions (23%). Furthermore, the overall admission percentage at the VA hospital is nearly three times that of the ED population at large (36% versus 13%). This paper provides valuable insight into the make-up of a veteran's population and can guide staffing and resource allocation accordingly. [West J Emerg Med. 2011;12(2):204-207.]

INTRODUCTION

Over the past two decades, the role of the emergency department (ED) has evolved from its intended function of providing acute emergent care to become the "safety net" of the healthcare system, providing both urgent and non-urgent care to millions of patients who have no alternative.[1,2] From 1995 to 2005, annual ED visits in the United States increased by 20%, from 96.5 million to 115.3 million per year, and the number continues to rise. Despite the increased consumption of emergency services, EDs nationwide are struggling to keep their doors open. Saddled with heavy operating costs and growing rates of non-reimbursed care, the number of EDs has decreased by nearly 10% over the last five years. Moreover, the number of hospitals and hospital beds has also dropped, creating a dangerous bottleneck for sick patients waiting to be admitted to the hospital.[3, 4]

Veteran's Affairs (VA) hospitals represent a unique patient population within the healthcare system. They have few female and pediatric patients and VA EDs typically do not encounter many trauma cases or accept 911 ambulance runs. While numerous studies have evaluated patient characteristics and patient flow through the ED, limited information exists about the specific demographics of the veterans' ED.[5-9] The purpose of this paper is to analyze the patients served at a large VA ED and compare them to the ED population at large. Specifically, the paper will look at patient complaints and admissions, severity of illness, and the timing of visits of the VA population. The data will help VA hospitals and community practitioners caring for veterans to better anticipate the needs of a typical VA patient.

METHODS

A retrospective analysis was performed on all patients presenting to the ED of a large urban Level I Veteran's Administration medical center over a one-year period, from January 1, 2006, to December 31, 2006. The center is a 188-bed, Level I-B tertiary hospital that provides care to approximately 62,000 veterans in a major urban area. The ED

consists of 15 beds and is staffed by a combination of board-certified emergency physicians, internists, internal medicine residents and staff nurses. During the study, the majority of overnight shifts were staffed by internists and residents, a practice that has since changed. Twenty-four hour psychiatric services are available. The ED does not accept 911 ambulance calls and is not a trauma referral center.

In total, 13,464 patient encounters were identified via the hospital's electronic medical records system. Prior to analysis, all patient data were de-identified to include patient age, sex, visit day and date and time and length of ED stay. Visit severity was divided into five categories based on current procedural code (CPT): self-limited/minor, low, moderate, high and highest severity. For admitted patients, the type of admission (ward, ICU, etc) and primary admission diagnosis were included, as coded by International Classification of Disease Clinical Modification, ninth revision (ICD-9-CM). National data were derived from the 2006 National Hospital Ambulatory Medical Care Survey (NHAMC). For data not included in the national report, data were available from the public dataset at http://www.cdc.gov/nchs/ahcd/ahcd_questionnaires.htm. We tabulated and analyzed data for statistical significance using SAS-PC for Windows Version 8.0. The local institutional review board approved the research proposal.

RESULTS

From January 1, 2006, to December 31, 2006, there were 13,464 patient encounters in the Veterans Administration ED. Ninety-five percent of patients were men. The mean age was 60 years old, with a range from 21 to 101 years. January was the busiest month, accounting for 9.2% of patient visits, and Monday was the busiest day of the week, with 16% of visits. November and July were the least busy months (7.7% each), while Sunday was the quietest day of the week, with 12% of visits. In the national survey, January also proved to be the busiest month (9.1% of visits), while April was the quietest month (7.2%). Nationally, Monday was also the busiest day of the week (15.3%), while Thursday was the quietest day (13.9%).

The majority of patient visits to the VA ED occurred during the hours of 9AM-5PM, followed by the periods of 5 PM -1 AM and 1 AM to 9 AM, respectively. Overall, 4,847 patients, or 36%, were subsequently admitted. The highest gross number of admissions occurred during the hours of 9AM-5 PM (2,036); however, the highest *percentage* of admissions occurred from 5 PM - 1 AM (51%). Nationally, the highest number of visits took place from 5 PM – 1 AM, while the highest percentage of admissions came during the daytime hours (9 AM - 5 PM). Admission percentages for all time periods were significantly different ($p<0.01$) between the VA and the national population.

The majority of patients admitted to the VA hospital were admitted to general medical-surgical floors, followed by telemetry and intensive care. Twenty-three percent were admitted to the psychiatric unit. The average length of stay in the ED for admitted patients (from time of triage to admission to the inpatient ward) was three hours and six minutes. Length of stay in the national survey was three hours and 18 minutes; this difference was not statistically significant.

Table 1. Top 10 diagnoses at presentation and admission in the veteran's affairs emergency department.

	Presenting complaint	Primary admission diagnosis
1	Psychiatric (inc. substance abuse)	Psychiatric (inc. substance abuse)
2	Heart disease (excl. ischemia)	Heart disease (excl. ischemia)
3	Respiratory (URI, asthma, COPD)	Chest pain
4	Chest pain	Respiratory (URI, asthma, COPD)
5	Trauma	Abdominal pain
6	Cellulitis/abscess	Shortness of breath
7	Spinal disorders	Cellulitis/abscess
8	Abdominal pain	Musculoskeletal
9	Musculoskeletal	Trauma
10	Shortness of breath	Spinal disorders

URI, upper respiratory infection; *COPD,* chronic obstructive pulmonary disease

The most common presenting complaints at the VA were psychiatric in nature (including substance abuse), accounting for over 10% of all visits. This was followed by non-ischemic heart disease, respiratory complaints, chest pain and trauma. The most common diagnoses leading to *admission* were psychiatric, followed by non-ischemic heart disease. Chest pain, respiratory complaints and abdominal pain complete the top five diagnoses leading to admission. A list of the top 10 presenting and admitting diagnoses is provided in Table 1. The majority of visits were of a moderate severity (45%), followed by high and low severity. Problems categorized as "highest severity" accounted for only a small percentage of visits (2%). Table 2 provides a comparison of primary diagnosis, problem severity, admissions and length of stay in the VA and national ED populations.

DISCUSSION

The data in this survey provide information about the veteran population that may be used to better anticipate and guide staffing needs in VA EDs and communities where veterans reside. The overall admission rate for the VA ED was 36% -significantly higher than that of the ED population nationally (13%). This percentage is partially explained by the large proportion of psychiatric illness, which surpassed all other diagnoses, including cardiac disease, and led to nearly one-fourth of all admissions. Such a high incidence of

Table 2. Veteran's affairs (VA) population versus general emergency department (ED) population.

	VA	General ED	P-value
Admission Percentage			
% Admitted	36%	13%	**<0.01**
Presenting Diagnosis			
Psychiatric (inc. substance abuse)	10%	4%	**0.012**
Heart disease (excl. ischemia)	9%	1%	**0.002**
Respiratory (URI, asthma, COPD)	7%	7%	0.895
Chest pain	7%	4%	0.148
Trauma	3%	15%	**<0.01**
Cellulitis/abscess	3%	2%	0.534
Spinal disorders	2%	3%	0.643
Abdominal pain	2%	4%	0.264
Musculoskeletal	2%	6%	**<0.01**
Shortness of breath	2%	3%	0.6
*Severity*ϕ.			
Non-urgent (self-limited/minor)	17%	14%	0.989
Semi-urgent (low)	18%	21%	**<0.01**
Urgent (moderate)	45%	33%	**<0.01**
Emergent (high)	18%	10%	**<0.01**
Immediate (highest)	2%	6%	**<0.01**
Admission Level			
General medicine/surgery floor	43%	69%	
Telemetry	26%	<15%*	
Intensive care unit	8%	16%	
Psychiatry	23%	<15%*	
Length of Stay			
Mean ED time	3.1 hours	3.3 hours	0.05

ψ *Based on CDC National Hospital Ambulatory Medical Care Survey: 2006 Emergency Department Summary.*

ϕ. *In the NHAMC Survey, 17% were labeled as "unknown triage." To equalize data, this portion was removed.*

* *No specific ED data were provided for telemetry or psychiatry admissions. However, given that general medicine/surgery and intensive care unit admission comprise 85% of the total, telemetry and psychiatry admission together cannot make up more than 15% of admissions.*

URI, upper respiratory infection; *COPD,* chronic obstructive pulmonary disease

psychiatric patients has prompted this institution to have 24-hour mental health staff available. When these patients are removed from the data, the VA admission percentage drops to 30%. However, this is still more than double the rate of the national ED population, suggesting that the VA treats a sick patient population.

Beyond psychiatric disease, the top diagnoses in the VA appear in similar proportions to the general ED population, with a few notable exceptions. First, non-ischemic cardiac disease is seen in a significantly higher percentage at the VA. This may be attributable to the older age of the VA population. Second, the incidence of trauma was significantly lower at the VA – as this institution is not a trauma referral center, a lower percentage is not surprising. Finally, musculoskeletal complaints were also significantly lower at the VA. This may be associated with the scarcity of minor trauma in the older VA population.

LIMITATIONS

This study has a number of limitations. First, the study was retrospective in nature and relied heavily on subjective diagnostic coding for analysis. Government-funded VA hospitals place less emphasis on insurance providers and billing than non-government centers. Accordingly, the CPT coding may not be reliable.

The study was conducted at a single urban veteran's hospital, which may not be "typical." As such, the data may not be generalizable to the VA population as a whole. During the study, morning shifts (1 AM - 9 AM) were staffed almost exclusively by internists and an assortment of residents, while other hours of the day were staffed by a combination of internists, emergency physicians and residents. Data regarding specific staffing are not available, and the impact this has on admissions is unknown. Finally, though comparison data from the CDC NHAMC Survey was generally analogous to our data, certain information was not equivalent. For example, admission level (general, ICU, etc.) was not broken down into the same categories as our data and thus required some extrapolation.

CONCLUSION

This paper yields practical data that characterizes the VA ED patient population and aids practitioners in determining the unique needs of this demographic. There are limited data pertaining specifically to the VA population and this study will allow a re-evaluation of resource allocation within the VA ED to ensure satisfactory staffing and ancillary services are available. With ongoing wars in Iraq and Afghanistan, increasing numbers of women serving in the armed forces, and an aging veteran population, the VA ED remains a dynamic place. As such, this paper not only provides insight into current ED trends, but can act as a baseline for future research.

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Does Pelvic Exam in the Emergency Department Add Useful Information?

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Objective: Physicians are taught that the pelvic exam is a key part of the evaluation of a woman presenting with abdominal pain or vaginal bleeding. However, the exam is time consuming and invasive, and its use in the emergency department (ED) has not been prospectively evaluated. We evaluated how often the findings of the pelvic exam changed management in a cohort of consecutive female patients presenting with acute abdominal pain or vaginal bleeding.

Methods: We enrolled women who required a pelvic exam together with the providers caring for them in an academic ED from September 2004 to August 2005. We collected the results of the general history and physical exam. The provider was asked to predict the findings of the pelvic exam, and these were compared with the actual findings of the exam.

Results: One hundred eighty-three patients were prospectively entered into the study. When compared with predicted findings, the pelvic exam was as expected in 131 patients (72%). In a further 40 patients (22%), the findings of the pelvic exam were not as predicted, but resulted in no change in the clinical plan. In 12 cases (6%) the exam revealed a finding that was both unexpected and changed the clinical plan. Only one of these patients was admitted. Of the 24 patients who were admitted, four had a pelvic exam that revealed unexpected results, but only one of these cases caused the physician to change the care planned for the patient.

Conclusion: In 94% of women with acute abdominal pain or vaginal bleeding, the results of the pelvic exam were either predictable or had no effect on the clinical plan. This suggests that there may be a subset of women with abdominal pain or vaginal bleeding in whom a pelvic exam may safely be deferred. [West J Emerg Med. 2011;12(2):208-212.]

INTRODUCTION

From early in their training, physicians were taught that all women with lower abdominal pain or vaginal bleeding should have a pelvic exam as part of their evaluation. The exam is thought to add valuable information that will aid the physician in reaching the correct diagnosis, and most emergency medicine and general surgery texts describe the pelvic exam as a key part of the evaluation of a woman presenting to the emergency department (ED) with these symptoms. However, performing a pelvic exam in a busy ED is often challenging. It requires that the patient be placed in an examination room that offers privacy and that a chaperone be present for the duration of the exam. Furthermore, the reliability and accuracy of the exam itself has been questioned.[1,2] It can be uncomfortable as well as being emotionally and physically invasive and is a source of anxiety and embarrassment.[3-6] Given all this, we wondered how the pelvic exam actually changes the management of ED patients with abdominal pain or vaginal bleeding. Is there important information that can only be obtained through the performance of the pelvic examination, or would the ED management be largely unaffected by the findings of

the exam? To provide some preliminary answers to this we performed a pilot study to examine the influence of the pelvic exam on the management of women with acute abdominal pain or vaginal bleeding in the ED. We also decided to study the role of the pelvic exam in patients who were admitted, since this subgroup is generally more sick and the findings of the pelvic exam may play a greater role in determining their clinical pathway.

METHODS

We performed a prospective cohort study of a convenience sample of women in whom the attending physician determined that a pelvic examination was required because of a complaint of abdominal pain or vaginal bleeding. The pelvic exam was performed on patients needing a bimanual exam to assess for tenderness, as well as those requiring a visual examination to look for bleeding or discharge. The study was performed in a large urban academic ED that treats 60,000 patients each year. Trained research assistants enrolled consecutive patients for 16 hours a day over a one-year period, September 2004 through August 2005.

During the study period, research assistants approached consecutive female patients with abdominal pain or vaginal bleeding for whom the physician or provider felt that a pelvic exam was necessary. If the patient gave her written consent, the treating physician or provider was asked to consent to the study as a secondary subject. Once informed consent from both the patient and her ED physician or provider had been obtained, a two-part survey was completed by the patient and the physician or provider. The surveys were structured instruments with fixed options for answers. The patient survey gathered demographics and data about medical history and the primary complaint. The provider survey collected the reasons for performing the pelvic exam and predictions about what the exam would show based on the information already gathered from the patient's history and general physical exam. The provider then performed the pelvic exam in the usual way and was interviewed a second time by the research assistant. In this second interview, the provider was asked to report the actual findings of the pelvic exam and to record if the pelvic exam findings changed the patient's ED management – although the exact change in management was not recorded. Results of laboratory and radiographic tests were also collected and correlated with the predicted and actual findings of the pelvic exam. Researchers also recorded the results of other laboratory and radiological testing as well as the final discharge diagnosis.

The Institutional Review Board approved the study. We excluded the following patients from further analysis; a) patients who had been examined by a medical students (because of inexperience); b) patients with a suspected vaginal foreign body (direct visualization is required); c) patients who had the exam to obtain cultures (pelvic exam was required to obtain cultures), and d) patients in whom the exam was performed to look for products of conception (visualization is required).

Table 1. Patient demographics.

Number of patients	183
Mean age (range)	31 (18-81)
Pregnant patients (%)	57 (30%)
Admitted	24 (13%)

Table 2. Provider demographics.

Type of training	N	%
EM resident	117	62
Intern	25	13
Other/missing	9	5
GYN resident	9	5
IM resident	8	4
Physician assistant	8	4
Attending ED physician	6	3
Surgery resident	1	<1

EM, emergency medicine; *GYN,* gynecologist; *IM,* internal medicine; *ED,* emergency department

RESULTS

A total of 320 patients with a mean age of 31 agreed to participate in the study, of whom 26 were pregnant. We excluded 42 patients who had been examined by medical students, eight who had a suspected vaginal foreign body, 40 who had the exam to obtain cultures, and 43 who had the exam to look for products of conception. In these final 43 cases, the pelvic exam was performed before the results of a pregnancy test confirmed that the patient was pregnant. The provider determined the need to look for products of conception based on the patient's unconfirmed history of being pregnant. Data about the overall impression of the pelvic exam were incomplete in four cases, which were also excluded from the analysis. This resulted in 183 patients enrolled in the study, on whom the pelvic examination had been performed to obtain clinical information unobtainable from a routine history and abdominal exam (Table 1). The levels of experience of the providers are shown in Table 2; the majority of the providers performing the pelvic examination were emergency medicine residents (n=117, 63%).

The reasons for performing the pelvic exam are shown in Table 3, and providers were able to give more than one reason for doing the exam. The most common reasons were to assess for adnexal tenderness, (n=90, 48%), cervical motion tenderness (n=61, 33%), and to asses the cervical os (n=44, 25%). The findings most commonly predicted were a normal exam (n=66, 36% of all exams done), uterine bleeding (n=44,

Table 3. Reasons for performing the pelvic exam.

Reasons for performing the pelvic exam*	n	%
To assess for adnexal tenderness	91	48
To check for cervical motion tenderness	63	33
To assess the os	46	25
To assess for discharge	45	24
To assess for uterine tenderness	43	23
To check for uterine bleeding	8	4

*Physicians may have had more than one reason.

Table 4. Overall impression of the pelvic exam findings.

Impression	n	%
As expected	131	70
Unexpected finding No change in clinical plan	40	21
Unexpected finding Change in clinical plan	12	6
Missing/Not answered	4	2

Table 5. Unexpected findings on pelvic exam in 12 patients that changed the clinical plan.

Normal exam	7
Not specified	1
Adnexal tenderness	1
Intrauterine device needing removal	1
Less uterine bleeding than expected	1
Cervical motion tenderness	1

Table 6. Outcome of pelvic exam in admitted patients.

Patient #	Admitting Service	Admitting diagnosis	Pelvic exam impression
1	OB-GYN	Ectopic pregnancy	As expected
2	OB-GYN	Ectopic pregnancy	As expected
3	OB-GYN	Anemia	As expected
4	OB-GYN	Dysfunctional uterine bleeding	As expected
5	OB-GYN	Dysfunctional uterine bleeding	As expected
6	OB-GYN	Spontaneous abortion	As expected
7	OB-GYN	Vaginal bleeding	As expected
8	OB-GYN	Incomplete abortion	As expected
9	OB-GYN	Abdominal pain	As expected
10	OB-GYN	Uterine fibroid	As expected
11	OB-GYN	Uterine fibroid	As expected
12	Surgery	Appendicitis	As expected
13	Surgery	Appendicitis	As expected
14	Surgery	Appendicitis	As expected
15	Surgery	Appendicitis	As expected
16	Surgery	Appendicitis	Unexpected result (not recorded)
17	Surgery	Abdominal pain	As expected
18	Surgery	Abdominal pain	As expected
19	Surgery	Diverticulitis	Unexpected result (less tenderness)
20	Medicine	Anemia	Unexpected (normal exam)
21	Medicine	Back pain	As expected
22	Medicine	Diabetes	Unexpected result (no discharge)
23	Medicine	Urinary tract infection	As expected
24	Urology	Kidney stone	As expected

OB-GYN, obstetric-gynecologist

24%) and adnexal tenderness (n=44, 24%). The overall provider impression of the pelvic exam was that it was either as expected or was unexpected but resulted in no change in plan for 171 cases (94%) [Table 4]. In the remaining 12 cases (6%) the exam revealed a finding that was both unexpected and changed the clinical plan (Table 5).

The overall admission rate was 13% (n=24). Of the 24 patients admitted, 20 had a pelvic exam that was as predicted, three had an unexpected finding that resulted in no change in the clinical plan, and one had a finding that caused the physician to change the care planned for that patient, who was admitted with a diagnosis of anemia (Table 6).

DISCUSSION

The pelvic exam has long been required as an essential part of the physical exam for women with abdominal pain regardless of the presumed etiology. This is because it is thought to add important information, and thus should be performed despite its invasive nature. For example, in the chapter on the approach to acute abdominal pain in one standard emergency medicine textbook, authors suggest that "…it is wise to maintain a low threshold for performing a pelvic examination in the evaluation of abdominal pain, particularly in women of reproductive age, regardless of where in the abdomen the pain is localized."[7] A recent video teaching the technique of the pelvic exam states that "[a]ny patient with genital or pelvic symptoms should…undergo a gynecological exam".[8] Standard textbooks of surgery share this approach, which may be traced back to the early surgical texts.[9-11] J.W MacDonald's[12] *Clinical Textbook of Surgical Diagnosis and Treatment,* published in 1898, states that mistakes made in the diagnosis of appendicitis occur because "the surgeon has neglected the imperative duty of making a vaginal examination…diagnosis of appendicitis in a female

should never be entertained until pelvic inflammation, especially of the ovaries and tubes, has been excluded."

Although these authors emphasis the importance of the pelvic exam, our pilot study demonstrated that out of this sample of 183 ED patients, the findings from pelvic exam changed the management in only 12 cases (6%). In all other cases, the findings of the pelvic exam – even when not correctly predicted based on the history and standard physical exam – made no difference in the patients' ED management. In the subgroup of 24 patients who were admitted, only one had a pelvic exam with an unexpected result that changed the clinical plan. This patient was admitted with a diagnosis (anemia) that was not made as a result of the pelvic exam. This suggests that even in sicker patients requiring hospital admission, the pelvic exam rarely changed clinical management.

To our knowledge this is the first study to prospectively evaluate the role of the pelvic exam in managing patients in the ED, but prior research has questioned the use of the exam in general. Close et al[1] reported that the inter-rater reliability of ED physicians performing pelvic exams was poor: emergency physicians agreed on the presence of cervical motion tenderness only 17% of the time and of the presence of an adnexal mass only 23% of the time. Even under ideal exam conditions - an anesthetized patient being examined for an adnexal mass by a gynecologist – the pelvic exam had a positive predictive value of 0.26-0.69.[2] Dart et al[13] concluded that no constellation of physical findings could confirm or exclude the diagnosis of ectopic pregnancy with certainty. The claim that the pelvic exam is a reliable decision aid in ED patients with abdominal pain or bleeding has been called a "medical myth."[14] We believe that its role in the ED should be questioned still further as a result of our findings, but there are at least two ways to interpret our findings. The first is to conclude that since 6% of patients had a finding on pelvic exam that changed the clinical plan, the exam is important and needs to be performed in *all* patients with abdominal pain or vaginal bleeding. This position is not one that we entirely disagree with, and our findings do not suggest that the exam is to be entirely discarded in the ED. Rather, the results suggest the possibility that in many, or perhaps most patients, the exam added little or no new information beyond that already gathered by taking a medical history and performing a general physical exam. Another interpretation of our results is that since the pelvic exam changed the clinical management on only 6% of the cases, it should not simply be performed in all women with abdominal pain or vaginal bleeding. By analogy, in the early evaluation of the need to obtain radiographs in every patient with an acute ankle injury, one study found that the yield for clinically important fractures was 13%, leading the authors to conclude that there was a "great potential for a more efficient use of radiography in ankle injury, possibly through the use of guidelines."[15] The suggestion was not that radiographs are useless, but rather that there are clinical situations in which they could safely be avoided. We believe that our results suggest a similar possibility regarding the use of pelvic exams.

It is certainly not our suggestion that this exam is uniformly unimportant. The pelvic exam plays a vital role in the prevention and diagnosis of many diseases, and as such must be part of every physician's skill set. Our findings do not suggest that women do not require a pelvic exam as part of their comprehensive health exam and have no bearing on the use of the pelvic exam as part of routine pre- or post-natal care. Our study addresses the role of this exam in the evaluation of women with undifferentiated abdominal or pelvic pain, as well as vaginal bleeding in the context of the ED. It is in this set of patients - those who formed the subjects in our prospective study - that the pelvic exam rarely changed the clinical plan that had already been made, based on information from the history and general physical exam. Of course the predictability of exam findings does not always mitigate the necessity of their verification. However, when this verification comes at an emotional cost or is accompanied by significant operational challenges, its necessity should be reconsidered.

Several reasons support the reevaluation of the need for a pelvic examination for every woman in the ED with abdominal pain. As we have already mentioned, logistic considerations make the exam both time consuming and labor intensive. The number of rooms in which a pelvic exam may be performed is usually limited to one or two in a typical ED, and it is often the case that several patients need to be moved in order for a room to become available. Moreover, some findings - such as adnexal tenderness or cervical motion tenderness - are often non-specific, and their presence or absence does not allow the ED physician to conclude with confidence that pelvic pathology (as opposed to an abdominal pathology) is present or absent. Finally, there is good evidence that the pelvic exam is both physically uncomfortable and emotionally distressing for many women. There have been various interventions studied with the aim of reducing the physical and psychological distress of the exam. These have tested alternative positions, foot rests, and using different types of gowns.[5,16,17] Despite these and other efforts, however, the exam remains uncomfortable: 41% of women who underwent a pelvic exam in the ED described the exam as being either moderately or severely painful.[18]

LIMITATIONS

Like any clinical study, our methods have limitations. First, we did not ask the providers to specify their management plan prior to or following the completion of the pelvic exam. Rather, providers were asked a more general question of whether the exam changed their management, without specifying the changes that may have occurred. Secondly, we did not record the way in which any unexpected finding changed the plan. As a result, we are not able to

determine how particular unexpected findings correlate with any change in management. Finally, we used no objective criteria to determine the need for cervical cultures, and this group was excluded from the analysis. Despite these limitations we believe our study raises some important questions about the role of a routine pelvic exam in the ED.

CONCLUSION

In this pilot study of women with acute abdominal pain or vaginal bleeding in the ED, the pelvic exam rarely offered additional information beyond that already obtained by history and a general physical exam. Further work with a larger sample of patients should be undertaken to determine if these results are valid in other ED settings, and if there is a group of women with abdominal pain or vaginal bleeding in whom the pelvic exam may safely be omitted. In its evaluation of the United States healthcare system in the twenty-first century, the Institute of Medicine identified both the provision of effective services and respect for a patient's physical comfort and preferences as two of its six core aims.[19] Reevaluating the importance of performing a pelvic exam in every woman with acute abdominal pain would certainly be in keeping with these recommendations.

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Molar Pregnancy with False Negative β-hCG Urine in the Emergency Department

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This case describes an atypical presentation of molar pregnancy in an emergency department patient with abdominal pain and vaginal bleeding. The patient demonstrated clinical features of hydatidiform mole, including acute discharge of a large, grape-like vesicular mass, despite multiple negative urine pregnancy tests. These false-negative qualitative human chorionic gonadotropin assays were likely caused by the "high-dose hook effect" and may have delayed proper care of the patient, who displayed pulmonary choriocarcinoma at the time of diagnosis. [West J Emerg Med. 2011;12(2):213-215.]

INTRODUCTION

Gestational trophoblastic disease encompasses a spectrum of tumors, including complete and partial hydatidiform mole (molar pregnancy) and locally invasive or disseminated choriocarcinoma.[1] Complete hydatidiform mole produces characteristic clinical features, including vaginal bleeding and uterine size beyond expected gestational age.[1] Many other clinical features of molar pregnancy, including hyperemesis gravidarum, hyperthyroidism and theca lutein ovarian cysts, are believed to be induced by markedly elevated serum human chorionic gonadotropin (β-hCG) levels produced by the trophoblastic tissue.[1] Thus, in addition to a complete physical and pelvic examination, complete blood count (CBC), blood chemistry and pelvic ultrasound, a hallmark of diagnosing hydatidiform mole is a positive β-hCG assay pregnancy test. Interestingly, sandwich chromatographic immunoassays, such as qualitative β-hCG assays, may produce false-negative results in the presence of excessively high antigen concentrations in a phenomenon known as the "high-dose hook effect." We report a case of molar pregnancy and subsequent malignant choriocarcinoma presenting as abdominal pain and vaginal spotting with multiple false negative urine pregnancy tests, ultimately delaying care.

CASE REPORT

A previously healthy 19-year-old Gravida 0 Para 0 female presented to the emergency department (ED) with seven weeks of abdominal pain, vaginal spotting, nausea and vomiting. The abdominal pain was described as cramping in the mid-epigastric and pelvic regions. The patient denied fever, dysuria or diarrhea. She was sexually active without contraceptive use and described a history of irregular periods since menarche but no recent passage of tissue. Four weeks before presenting she took a home pregnancy test that was negative. Two weeks prior she was seen at a different facility where she had a negative urine pregnancy test and a pelvic examination that revealed tenderness. At that time she was treated with azithromycin and ceftriaxone for presumed cervicitis, but her symptoms continued.

The physical examination revealed an oral temperature of 98.3° F, heart rate of 99 beats/min, respiratory rate of 16 breaths/min, blood pressure of 169/96 mmHg and oxygen saturation of 100% on room air. She was alert and oriented but uncomfortable with pain and retching. The cardiac exam was normal, and the lungs were clear. The abdomen was diffusely tender but soft without rebound or guarding. In the lower abdomen, a firm, palpable uterus was present. Pelvic examination revealed a closed cervical os with blood clots in the vaginal vault and a 20-week sized uterus with cervical motion and adenexal tenderness. The patient was noted to have no tenderness at the costovertebral angles, no lower extremity edema, and no focal neurologic deficits. Point-of-care and laboratory qualitative urine β-hCG assays were negative. A pelvic ultrasound, CBC, blood chemistries and quantitative serum β-hCG were ordered. The patient was treated with analgesics and anti-emetics. As she was being

prepared for transport to the ultrasound suite, the patient discharged a large, fleshy, vesicular mass followed by profuse vaginal bleeding. Subsequent pathological examination of this mass found it to be a 777 gm, 20 x 15 x 16 cm aggregate of placental tissue mixed with abundant grape-like vesicular tissue and blood clot without fetal parts. Hemostasis was achieved with packing. Two large bores were placed intravenously, and a blood type and cross was performed for transfusion. An obstetrical/gynecological consult was called immediately. At this point the quantitative serum *β*-hCG level returned at 1,370,128 mIU/mL (normal <5-200,000). Initial complete blood count showed white blood cell count of 14.6 k/mm^3 and hemoglobin of 11.1 g/dL with a normal platelet count. Her coagulation and basic metabolic panels were within normal limits; however, her free thyroxine was elevated at 3.43 ng/mL (normal 0.00-0.05), with a corresponding low thyroid stimulating hormone level of 0.12 uIU/mL (normal 0.34-5.60). Once stabilized, she had an ultrasound showing enlarged uterus measuring 19.4 x 9.2 x 8.7 cm and a complex mass within the endometrium measuring 16.7 x 6.9 x 6.3 cm with small hypoechoic areas suspicious for molar pregnancy. There was also sonographic evidence of bilaterally enlarged ovaries with abundant cysts. She was taken to the operating room for emergent dilatation and curettage, which demonstrated hydatidiform mole. She was treated with blood transfusions for acute anemia, magnesium sulfate for pre-eclampsia and beta-blockers for hyperthyroidism. A subsequent work-up showed numerous pulmonary nodules in bilateral lungs likely due to metastatic choriocarcinoma. The patient had an uneventful hospital course and was discharged two days post operatively on Depo-Provera and Labetalol with instructions to follow up daily for methotrexate treatment. After completing chemotherapy, she was followed as an outpatient by the gynecological oncology team with serum *β*-hCG screening performed on a regular basis. One year after this presentation, the patient had complete remission of her choriocarcinoma.

DISCUSSION

Molar pregnancy is an uncommon cause of abdominal pain and vaginal bleeding in the ED that may lead to serious disseminated disease and death if left untreated. Molar pregnancy occurs in approximately one in 1,000 pregnancies in the United States. It is most commonly associated with pregnancy in the early (15-20 years old) and late (>35 years old) reproductive periods.[1-2] Hydatidiform moles are an anomalous growth of trophoblastic tissue categorized as complete or partial. Complete moles have diploid karyotype of solely paternal origin and a complete absence of fetal tissue.[1] Partial moles are characterized by triploid karyotype of both maternal and paternal origin and the presence of fetal/embryonic tissue.[1] A retrospective analysis of molar pregnancies reported that 75% of patients present with vaginal bleeding, while 54% present with enlarged uterus for gestational dates and 100% had excessively elevated *β*-hCG levels.[2] Here, we report a case of molar pregnancy and metastatic choriocarcinoma with multiple negative qualitative urine *β*-hCG pregnancy tests despite an extremely elevated serum *β*-hCG level.

Clinical decision-making regarding women of childbearing age with abdominal pain and vaginal bleeding is often dictated by pregnancy testing, specifically point-of-care qualitative urine hCG assays. These screening tools, along with over-the-counter home pregnancy tests, are chromatographic sandwich immunoassays in which two antibodies directed to different portions (for example, the α and β subunits) of the hCG molecule sandwich a single antigen to produce color change. Our ED uses the Clinitest® hCG Pregnancy Test from Siemens Healthcare Diagnostic Inc. for point-of-care testing. This lateral flow, chromatographic assay is reported to produce positive results with hCG concentrations ≥25 mIU/mL. A urine sample placed on the membrane reacts with migratory colloidal gold particles coated with anti-*β*-hCG antibodies. These antibody-bound particles then migrate by capillary action to the fixed detection line coated with either anti-α-hCG or goat-anti-mouse antibody (control). To induce color change a single hCG molecule must be bound by the antibodies to both subunits, forming a "sandwich" that attaches the gold particles for color change and binds the compound to the detection line. Despite the high sensitivity and specificity of the assay, our patient had repeatedly negative urine pregnancy tests at home, in an outside facility, and upon presentation to our ED. One explanation for the negative pregnancy test is the "high-dose hook effect," a rare phenomenon that occurs in sandwich immunoassays when the concentration of the antigen is sufficiently high to saturate both the solid migratory phase and fixed detection antibodies independently.[3] In this case, excessive levels of free antigen in the sample allow the anti-*β*-hCG and anti-α-hCG antibodies to each bind subunits of different hCG molecules rather than subunits of the same molecule, preventing them from forming the "sandwich." As a result, the gold particle necessary for color change is never bound, leading to a false-negative test. A 1:10 to 1:1000 dilution of the antigen sample may overcome the hook effect by reducing the concentration and allowing the antibodies to properly bind to two portions of the same molecule.[4-5]

There have been reports of false-negative urine, serum and both urine and serum *β*-hCG pregnancy tests in hydatidiform mole.[6-11] In each of these reports, the serum *β*-hCG levels were determined to be greater than 1,000,000 mIU/mL, and the likely cause for false negative results were reported to be the "high-dose hook effect."[6-11] Those cases with false-negative serum assays required dilution of the samples and re-testing after ultrasound demonstrated sonographic evidence of molar pregnancy.[9-11] In some reports, the diagnosis of molar pregnancy was already suspected prior to the false-negative test because of ultrasound evidence or a

previous positive pregnancy test.[6,7,10,11] In our case, the patient discharged a large, vesicular mass characteristic of hydatidiform mole prior to the completion of quantitative β-hCG testing or ultrasound evaluation. A retrospective analysis has suggested that the positive predictive value of transvaginal ultrasound for molar pregnancy is 100%.[2] However, often this procedure is delayed or not considered when a pregnancy test is negative, as was likely the case when our patient was initially seen at an outside facility. Since her screening pregnancy test was negative, an ultrasound was never performed, making the correct diagnosis difficult. These rare reports underscore the importance of quantitative β-hCG assays and sonographic evaluation in patients with negative pregnancy tests where clinical suspicion of pregnancy remains high.

Management of molar pregnancy in the ED is largely supportive and dependent on disease severity. Abdominal pain and vaginal bleeding are caused by the mass of trophoblastic tissue and fragile surrounding blood vessels.[1] Hyperemesis, hyperthyroidism and ovarian cysts are thought to be derived from excessive serum β-hCG levels secreted from trophoblastic tissue.[1] Therefore, the definitive treatment is either hysterectomy or dilation and curettage. Initial therapy consists of stabilization, hemostasis if indicated, analgesics and anti-emetics. Beta-blockers may be used for symptoms of hyperthyroid state. Some molar pregnancies will induce pre-eclampsia, which should be managed with magnesium sulfate, but true eclampsia is extremely rare in this patient population.[1] Choriocarcinoma may present as locally invasive non-metastatic or diffuse metastatic disease.[1] The World Health Organization (WHO) prognostic index score is used to determine severity of disease and likely response to treatment.[12] Nine prognostic factors are scored from zero to four to determine low, intermediate or high-risk gestational trophoblastic disease.[12] A WHO score of less than seven is usually treated with single agent chemotherapy, most commonly methotrexate.[12] A score of seven or higher requires combination therapy, typically the EMA-CO regime, including etoposide, methotrexate and actinomycin D administered in the first week of a two-week cycle, then cyclophosphamide and vincristine.[12] Post-treatment surveillance includes weekly serum β-hCG monitoring until levels become negative, and then monthly for six months.[12] With appropriate therapy survival approaches 100%.[1,12]

CONCLUSION

Molar pregnancy is an uncommon yet serious condition that may cause significant pain, hyperemesis, pre-eclampsia, hyperthyroidism and possibly metastatic disease. In addition to vaginal bleeding and excessive uterine size, a hallmark of diagnosis is elevated β-hCG. However, qualitative β-hCG assays may be falsely negative due to the high-dose hook effect if serum levels are extremely elevated. When suspicion exists for molar pregnancy, sonographic evaluation and quantitative β-hCG levels are necessary in the work-up. The ED therapy for molar pregnancy is supportive along with prompt gynecologic consultation with definitive treatment being operative.

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Warfarin Overdose in a Breast-feeding Woman

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We describe a case of a breastfeeding woman with an accidental warfarin overdose resulting in a markedly elevated prothrombin time. The breast-fed infant was evaluated and tested for ill effects. We discuss the use of warfarin while breast-feeding. [West J Emerg Med. 2011;12(2):216-217.]

We report a case of an accidental warfarin overdose in a breastfeeding 40-year-old woman. The patient had been prescribed warfarin at a dose of five milligrams per day to treat a pulmonary embolus that was diagnosed shortly after she underwent a caesarian section delivery. At the time of presentation, the patient had been taking warfarin for nearly two months. She had originally been given one-milligram tablets and instructed to take five tablets daily. However, one week prior to presentation, her refill prescription was dispensed as five-milligram tablets. Unaware of the change, the patient continued taking five tablets per day, for a total dose of 25 milligrams daily for seven days. The error was realized when she returned to the pharmacy requesting a refill after only one week, having completely run out of the medication.

Upon presentation, the patient was asymptomatic. Laboratory coagulation profile studies were markedly abnormal, with an international normalized ratio (INR) of greater than 10.0 (reference range 2.0-3.0 for standard anticoagulation, 2.5-3.5 for mechanical valve anticoagulation), a prothrombin time (PT) of greater than 100.0 seconds (normal range 9.3-11.2), and an activated partial thromboplastin time (aPTT) of 65.2 seconds (normal range 25.0-32.7). The previous INR, checked two weeks prior, was 2.3. Her complete blood count showed no anemia; in fact, the hematocrit was slightly higher than the last measured value two months prior. The patient was treated with a single five-milligram dose of oral vitamin K. Her warfarin was withheld for two days, after which the INR had decreased to 1.5 (subtherapeutic range).

Warfarin in therapeutic doses is generally considered safe in breastfeeding. Little information has been published on warfarin overdose during breastfeeding, whether in an acute setting (a single ingestion), or a prolonged exposure such as this one. We were concerned about the potential effects of the overdose on the patient's breast-fed infant. The patient had been breastfeeding during the week of warfarin overdose, up until a few hours before presentation. Since birth, the baby had been fed almost solely breast milk.

The patient's eight-week-old infant was brought in to the emergency department for evaluation and coagulation studies. History and examination revealed a healthy-appearing infant, with no signs or symptoms of bleeding. Coagulation studies revealed an INR of 1.0, PT of 10.3 seconds, and aPTT of 33.8 seconds. The aPTT was slightly high compared to the laboratory upper limit of 32.4 seconds. However, coagulation studies performed on the infant three weeks prior to the overdose revealed that the aPTT was 38.9 seconds, also slightly elevated above the laboratory reference range (PT and INR were within normal limits at that time). One week before the infant's first aPTT, the mother's INR was 3.3, and five days later it was 2.3. Given that warfarin is considered very safe at standard doses during breast-feeding,[1] it is unlikely that the infant's previously elevated aPTT was related to the mother's warfarin use.

Warfarin is known to pass the placental barrier during pregnancy and to cause birth defects as well as fetal and maternal coagulopathy. Fetal warfarin syndrome is characterized by skeletal abnormalities, including stippling of bones, nasal hypoplasia, and other abnormalities. However, warfarin is considered safe in lactation as it does not pass into breast milk to any measurable degree.[2,3] This is due to several of its molecular properties: warfarin is ionic, making it a polar molecule and thus nonlipophilic.[4] Less lipophilic compounds are unlikely to be excreted in breast milk. Additionally, warfarin is 99% bound to serum proteins, also associated with minimal transfer to breast milk.[5]

While few human studies exist, the results of a 1977 case series indicated that warfarin was not detectable in breast milk

in 13 lactating women.[6] The second part of the study evaluated seven breastfeeding infants whose mothers were taking therapeutic levels of warfarin. None of the seven infants had any change in plasma PT.

A MEDLINE search did not identify any case reports of a breastfeeding mother with a critically supratherapeutic INR. The pharmacokinetics of warfarin and prior case series indicate that warfarin is clinically undetectable in breast milk when the mother is taking standard doses. This case further suggests that warfarin, even in high doses resulting in a critically elevated maternal INR, does not cause a significant effect on the coagulation cascade or clinical bleeding in the breastfeeding infant.

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Takotsubo Syndrome in African American vs. Non-African American Women

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Objectives: Takotsubo syndrome (TTS) is a reversible cause of heart failure rarely described in African-American patients. This study aimed to compare and contrast the clinical characteristics of TTS in African-American (AA) and non-African-American (NAA) patients.

Methods: We retrospectively reviewed the charts of eight patients (four AA and four NAA) diagnosed with TTS, between June 2006 and August 2008, in four different teaching hospitals: St Michael's Medical Center, St Joseph's Medical Center, Trinitas hospital and St Louis' University Hospital. We compared the patients with regard to presenting symptoms, precipitating stressors, electrocardiographic findings, troponin levels, ejection fraction and in-hospital course.

Results: All patients were females (mean age 64 for AA and 67 for NAA). All patients experienced chest pain and had elevated troponin levels. Two AA and three NAA patients had associated shortness of breath and one NAA had syncope. All AA and three NAA had T-wave inversions. Three NAA and one AA had ST segment elevation. Three patients in both groups developed prolongation of the QT interval. Coronary angiograms did not reveal any significant obstructive coronary artery disease. Three patients, all NAA, needed hemodynamic support during their hospital stay but none died.

Conclusion: AA and NAA women with TTS have similar presenting symptoms but may differ in the electrocardiographic findings and in-hospital course of the disease. [West J Emerg Med. 2011;12(2):218-223.]

INTRODUCTION

Takotsubo syndrome (TTS) is a transient acute cardiac disorder with a similar presentation to ST-segment elevation myocardial infarction (STEMI).[1,2] TTS usually affects postmenopausal women and is characterized by a new cardiac motion abnormality that commonly involves the apex of the left ventricle in the absence of significant obstructive coronary artery disease.[3] This interesting syndrome was first described in Japan about 16 years ago. In Japanese, *takotsubo* is the name given to the fishing jar used to catch an octopus. This jar has a wide base with a narrow neck, similar in shape to that of the clinical entity seen on left ventriculography in TTS.[4] Many other names have been used for this syndrome, including transient left ventricular apical ballooning syndrome, stress-induced cardiomyopathy and ampulla cardiomyopathy.[5-7]

Awareness of this rare syndrome is increasing and cases of TTS have been diagnosed and reported in many areas of the world among different ethnic groups. Most of the case series and reports in the literature describe TTS in Asians and Caucasians, who are considered the most commonly affected ethnic groups.[8-11] However, to our knowledge TTS has been described in African-American (AA) patients in only one case series and few case reports.[12] To further investigate the nature of this syndrome and how it behaves in this ethnic group, we compared the clinical characteristics of TTS in AA patients with those in patients from other ethnicities.

METHODS

Institutions and settings

TTS is an infrequent syndrome that has been estimated to account for 1 - 2 % of patients diagnosed with STEMI.[11] In this retrospective chart review study, we included eight patients who were divided into two groups, the first consisting of four AA patients and the other of four non-African American patients (NAA). All patients had been diagnosed with TTS between June 2006 and August 2008 in the following four teaching hospitals:

1. Saint Michael's Medical Center, a 357-bed regional tertiary care, teaching, and research center in the heart of Newark, New Jersey
2. Saint Joseph's Medical Center, a 642-bed teaching tertiary medical center and Level 2 Trauma Center, providing care to the residents of northern New Jersey
3. Trinitas Regional Medical Center, a 531-bed teaching hospital in Elizabeth, New Jersey
4. Saint Louis University Hospital, a 356-bed academic teaching hospital in St. Louis, Missouri

All patients had serial electrocardiograms (ECGs), serial cardiac biomarker level measurements, transthoracic two-dimensional echocardiography (2-D Echo) and invasive coronary angiogram or coronary computed tomography angiogram. All patients had repeated follow-up 2-D Echo.

Criteria

All patients fulfilled the suggested Mayo Clinic criteria for diagnosis of TTS (Table 1).[2]

Table 1. Mayo Clinic criteria for diagnosis of Takotsubo Syndrome.

1. Transient, reversible akinesis or dyskinesis of the left ventricular apical and mid-ventricular segments with regional wall motion abnormalities extending beyond a single vascular territory on left ventriculography.

2. Absence of obstructive coronary artery stenosis > 50% of the luminal diameter or angiographic evidence of acute plaque rupture.

3. New electrocardiographic abnormalities consisting of ST-segment elevation or T-wave inversion.

4. Absence of:
- Recent head trauma
- Intracranial bleeding
- Pheochromocytoma
- Obstructive epicardial coronary artery disease
- Myocarditis
- Hypertrophic cardiomyopathy.

RESULTS

The demographics, clinical characteristics, ECG findings and echocardiographic results of the AA group are included in Table 2 and of the NAA group in Table 3. All patients were postmenopausal females.[3] The mean age of the AA group was 64 ± 14 years, and the mean age in the NAA group was 69 ± 11 years. All patients had complained of chest pain at presentation and five had associated dyspnea (two AA and three NAA).

All study patients reported either emotional or physical stress within a few hours before admission. The stressors included exacerbation of chronic obstructive pulmonary disease, thumb fracture with severe pain, intensive physical therapy, a heated argument, the death of a close relative or friend and a son who was injured in a traffic accident.

ST-segment elevation was observed in three NAA (3 of 4, 75%), but in only one AA patient (1 of 4, 25%). All AA

Table 2. Baseline characteristic of the African American patients with Takotsubo Syndrome.

	Patient one	Patient two	Patient three	Patient four
Age	71	57	49	80
Sex	Female	Female	Female	Female
Symptoms	Chest pain	Chest pain Dyspnea	Chest pain Dyspnea	Chest pain
Stressor	Physical therapy	Thumb fracture	Argument	Death of the son
HTN	Yes	Yes	No	Yes
DM	No	Yes	No	Yes
Smoking	Yes	No	Yes	No
ST elevation	Yes	No	No	No
T wave Inversions	Yes	Yes	Yes	Yes
QTc prolongation	Yes	No	Yes	Yes
Required hemodynamic support	No	No	No	No
Peak Tn I (ng/ml)	0.22	0.23	1.48	6.05

HTN, hypertension; *DM*, diabetes mellitus; *Tn I*, troponin I.
Troponin I Reported in ng/ml (normal less than 0.05 ng/ml)

Table 3. Baseline characteristics of the non-African American patients with Takotsubo Syndrome.

	Patient five	Patient six	Patient seven	Patient eight
Age	53	73	77	74
Sex	Female	Female	Female	Female
Symptoms	Chest pain/dyspnea	Chest pain/dyspnea	Chest pain/syncope	Chest pain/dyspnea
Stressor	Argument	The son had an accident	Death of a close friend	COPD exacerbation
HTN	No	Yes	Yes	Yes
DM	No	No	No	No
Smoking	Yes	No	Yes	No
ST elevation	No	Yes	Yes	Yes
T wave Inversions	Yes	No	Yes	Yes
QTc prolongation	No	Yes	Yes	Yes
Required hemodynamic support	Yes	Yes	No	Yes
Peak Tn I (ng/ml)	2.5	4.5	4.62	9.14

HTN, hypertension; *DM*, diabetes mellitus; *Tn I*, troponin I. *COPD,* chronic obstructive pulmonary disorder
Troponin I Reported in ng/ml (normal less than 0.05 ng/ml)

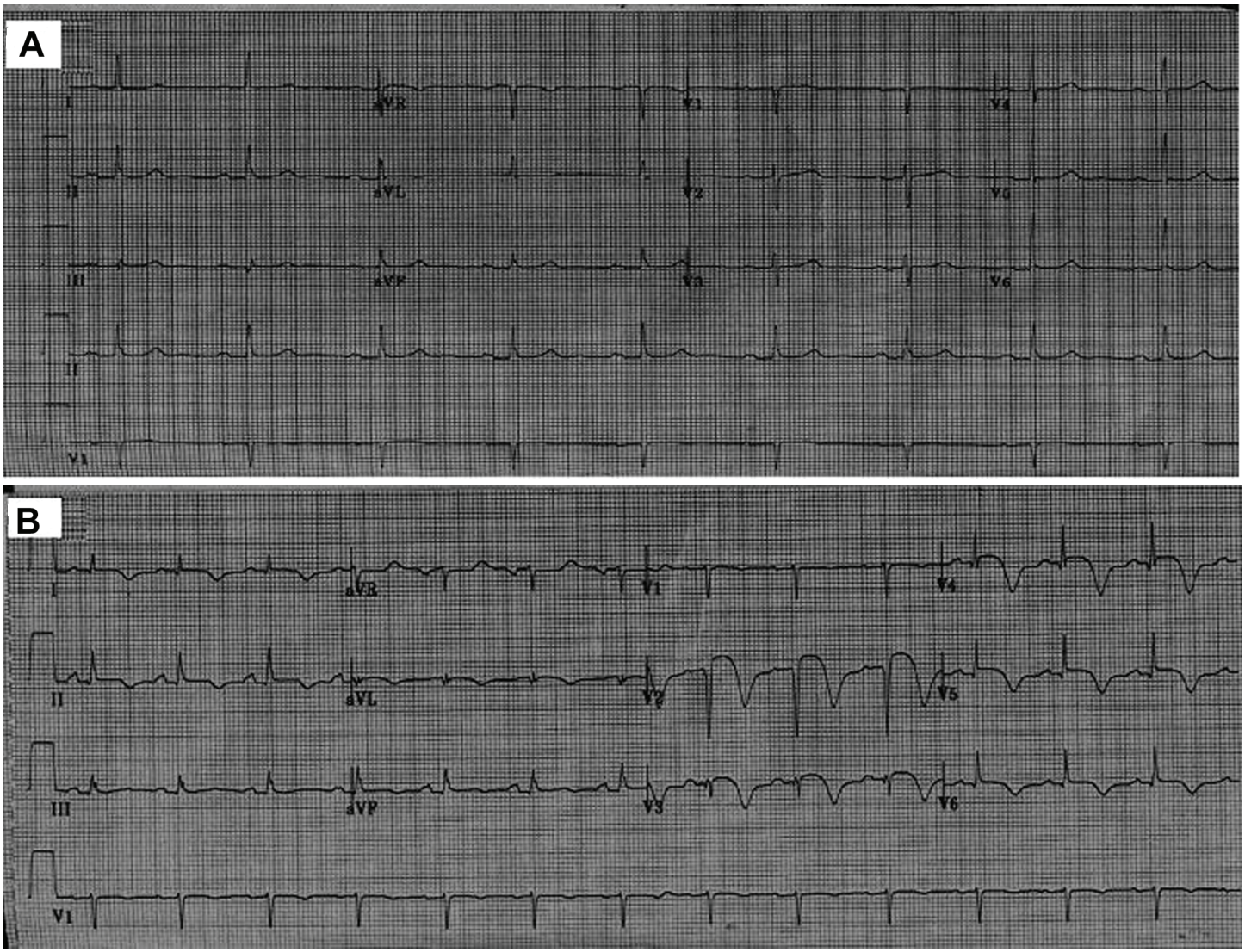

Figure 1. (A) Baseline electrocardiogram (ECG) of patient number one with sinus bradycardia done three months before presentation. (B) ECG of the same patient during the chest pain shows sinus rhythm, ST elevation and diffuse T-wave inversions with QTc prolongation.

patients (4 of 4, 100%) and three NAA (3 of 4, 75%) developed diffuse deep T-wave inversions (Figure 1). Prolongation of the QT interval was noticed with equal frequency in AA and NAA patients (3 of 4, 75%).

All patients had elevated cardiac biomarker levels, including troponin I. The mean peak troponin I level was 5.2 ng/ml in the NAA patients and 2.0 ng/ml in the AA patients.

All patients had 2-D Echo done at admission, and all had a low ejection fraction (EF) with a global wall motion abnormality of the left ventricle. The mean EF in AA patients was 25 ± 7% and that in NAA patients was 26 ± 5%.

All patients had an invasive coronary angiogram, except one AA patient who underwent a computerized tomography angiogram of the coronaries (the patient refused cardiac catheterization). None of the patients had evidence of significant obstructive coronary artery disease, and all patients who underwent an invasive coronary angiogram were assessed by left ventriculography, which confirmed a global left ventricular wall motion abnormality with apical ballooning (Figure 2 A and B). Of the eight patients, three (all NAA) developed hypotension and required hemodynamic support (intra-aortic balloon pump or vasopressors).

All patients improved clinically and the repeated 2-D Echo showed improvement of left ventricular function in all patients. The 2-D Echo of patient one showed resolution of the apical ballooning with improvement in EF from 20% to 35% within two weeks. In patient two, EF improved from 35% to 65% within 10 days. Patient three had an EF of 20% on admission that improved to more than 45% on repeated echo after six weeks. Patient four had an EF of 25% on admission that improved to 45% within two days. The EF of patients five and six increased from 20% and 30% to 65% and 60%, respectively, in two weeks. The EF of patient seven improved within six weeks (from 30% to 55%) and that of patient eight increased from 25% to 65% in about five weeks. The study results for the AA and NAA patients are summarized in Table 4.

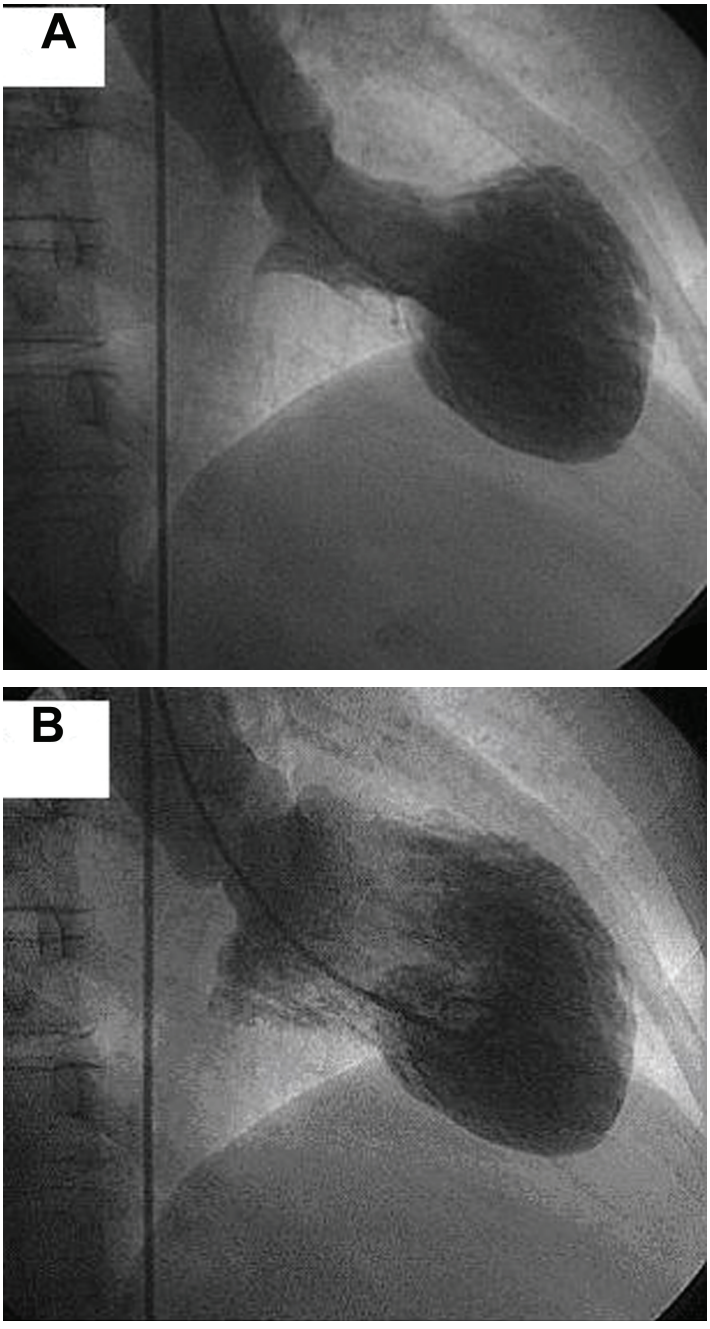

Figure 2. Left ventriculogram of patient seven in systole (A) and diastole (B) shows the classic apical ballooning and hypercontraction of the basal segments in Takotsubo Syndrome.

DISCUSSION

Because little has been reported to date about the nature and clinical characteristics of TTS in African-American patients, our study is helpful in understanding this syndrome.

Table 4. Baseline characteristics of the study groups.

	AA group	NAA group
Age (mean±SD)	64±14	69±11
Sex (Male/Female)	0/4	0/4
Chest pain	4(100%)	4(100%)
Dyspnea	3(50%)	3(75%)
HTN	3(75%)	3(75%)
DM	2(50%)	0(0%)
Smoking	2(50%)	2(50%)
Peak Tn I(ng/ml)	2	5.2
ST elevation	1(25%	3(75%)
T wave inversions	4(100%)	3(75%)
QTc prolongation	3(75%)	3(75%)
EF on admission	26±8	26±4
Required hemodynamic support	0(0%)	3(75%)

AA, African-American; *NAA,* non-African-American; *SD*, standard deviation; *HTN,* hypertension; *DM,* diabetes mellitus; *Tn I,* troponin I (normal value: < 0.05 ng/ml); *EF,* ejection fraction

We described TTS in this understudied ethnic group and highlighted the major differences observed in the characteristics of this group compared with those of patients from other ethnicities.

The most commonly reported presenting symptoms of TTS are chest pain and dyspnea, in 83.4% and 20.4% of patients, respectively.[1,11] Our data were consistent with those findings, showing that chest pain followed by dyspnea are the most common presenting symptoms in both AA and NAA patients. This finding differs from that reported in a recent study by Patel et al.[12] in which none of the AA patients experienced chest pain but most reported dyspnea at presentation.

Acute, severe emotional or physical stress is believed to be the main precipitating factor of TTS, but the exact pathogenesis is not well understood. Our data support this, with all patients in both groups reporting either major physical or emotional stressor preceding the onset of the symptoms. High catecholamine levels and microvascular dysfunction are thought to be important in TTS.[8,9] These factors could explain part of the clinical and histological findings of this syndrome, including the contraction-band necrosis and mononuclear infiltrates that have been described in the endomyocardial biopsies of some patients with TTS.[8]

The clinical presentation of TTS classically is similar to STEMI: patients experience chest pain and have elevated troponin levels and ST-segment elevation.[2] A recent systematic review of the literature found that ST-segment elevation was the most common ECG abnormality, reported in about 82% of patients, followed by T-wave inversion at 64%.[11] Our study was consistent with these data in the NAA group but not in the AA group, in which T-wave inversions were the most common ECG abnormality; however, ST elevation was an infrequent finding. The AA patients in our study were more likely to present as Non STEMI (NSTEMI), whereas the NAA were more likely to have the classic STEMI presentation.

The T-wave inversions in our AA patients involved multiple leads and were the most common ECG abnormality in this group. The deep and wide shape of the T waves looked similar to that of the NAA group. From these observations, we think that the T-wave abnormality in AA patients may not differ from that described in Caucasians and Asians with TTS and that the T waves in this interesting syndrome will be shown to have a characteristic shape.

Our observations are consistent with the QT prolongation that has been reported in many studies.[11-13] We found that QT prolongation in the AA group is as common as it is in the NAA group and that none of the patients in either group developed ventricular tachyarrhythmia during hospitalization, which has been reported in several case reports as a possible complication of TTS.[11] We think that serious tachyarrhythmias are not a common complication of TTS and that the prolonged QT interval associated with this syndrome generally has a benign course. However, larger follow-up studies are needed to form a solid conclusion about this issue and to report the incidence of this complication.

Several acute complications of TTS have been reported in the literature, including ventricular fibrillation, cardiogenic shock, pulmonary edema, and, rarely, left ventricular rupture.[11-16] In our study, three patients developed hypotension and cardiogenic shock, all of whom were NAA patients and all of whom required hemodynamic support by intra-aortic balloon pump or vasopressors. These findings differed from those suggested in several reports about TTS in Caucasians and Asians, where the authors considered TTS a benign disease. From these observations, we think that close monitoring of patients with TTS is crucial, and we suggest conducting larger studies to address the in-hospital course of the disease and the short-term morbidity and mortality rates associated with it.

On the other hand, our study showed that none of the AA patients developed cardiogenic shock, although the mean EF of this group is almost the same as that for the NAA group. Why the AA patients in our study tolerated TTS better than the NAA patients and why none of them had hypotension or cardiogenic shock is unclear. Genetic background may be important, but more studies of AA patients with TTS are required to answer these questions and to explain the major differences we found in our study.

LIMITATIONS

There were some limitations in this study with respect to sample size and the study design. The number of the patients was small and all patients were females. The study was retrospective, which lacks the follow up to determine the long-term morbidity and mortality associated with TTS, if any. In addition, solid conclusions are difficult to form in this study; however, reporting these findings and differences may help to understand the nature of this syndrome

CONCLUSION

AA women with TTS have similar presenting symptoms as NAA women, however they may not have the classic ST segment elevation at presentation and may be more likely to present as NSTEMI. TTS is not always a benign condition and hemodynamic instability is a possible complication. Our AA patient group tolerated TTS better than the NAA group, and fewer developed hypotension or needed hemodynamic support.

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Myocardial Ischemia with Penetrating Thoracic Trauma

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Penetrating trauma is a rare cause of myocardial infarction. Our report describes a 47- year-old female who presented with a gunshot wound from a shotgun and had an ST-elevation myocardial infarction. The patient received emergent coronary angiography, which demonstrated no evidence of coronary atherosclerotic disease but did show occlusion of a marginal vessel secondary to a pellet. The patient was managed medically for the myocardial infarction without cardiac sequelae. Patients with penetrating trauma to the chest should be evaluated for myocardial ischemia. Electrocardiography, echocardiography and cardiac angiography play vital roles in evaluating these patients and helping to guide management. [West J Emerg Med. 2011;12(2):224-226.]

INTRODUCTION

Penetrating trauma is a rare cause of myocardial ischemia but can occur as a consequence of shotgun wounds to the chest. Multiple case reports describe coronary artery occlusion from shotgun pellets.[1-5] Despite these multiple case reports, management of patients with gunshot wounds to the chest and signs of ischemia remains unclear. Electrocardiography (ECG), echocardiography and coronary angiography each play a role in evaluating this patient population. Medical management may be sufficient treatment for uncomplicated hemodynamically stable patients.

CASE REPORT

A 47-year-old female was intubated and brought in by air ambulance with a medium-range shotgun wound to the face, neck and upper thorax. The patient was noted en route to have ST segment changes on her ECG. Upon emergency department arrival, the patient was resuscitated with crystalloid and blood products for hypotension. She also had a severe soft tissue injury to the left forearm, which may have been a defensive wound suffered at closer range. A compressive bandage and direct pressure were applied to control bleeding from the tissue defect in the left upper extremity. Laboratory studies, a chest radiograph and an initial ECG (Figure 1) were obtained. A left chest tube was placed for a left-sided pneumothorax. The 12-lead ECG revealed sinus tachycardia and ST elevation in II, III, aVF, V5 and V6 with associated reciprocal depression in the precordial leads. Her initial hemoglobin was 7.2 gm/dl (reference range 120-16 gm/dl). Coagulation studies were within normal limits.

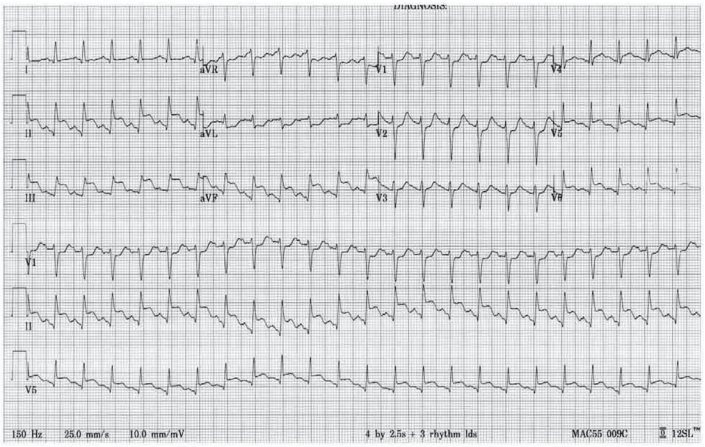

Figure 1. Initial electrocardiogram obtained on presentation showing inferior and lateral ST segment elevations.

Cardiology was consulted and subsequent transthoracic echocardiogram showed multiple pellets surrounding the heart. The exact location of the pellets relative to the

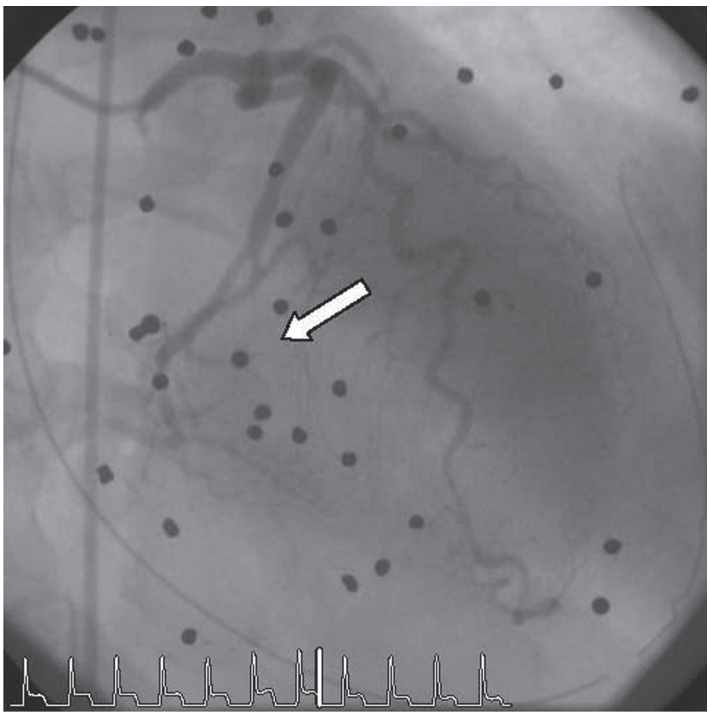

Figure 2. Left coronary angiogram (right anterior oblique cranial view), demonstrating an abrupt cutoff of the second obtuse marginal vessel secondary to a shotgun pellet.

myocardium and the pericardial space could not be definitively determined. There was a very small pericardial effusion without evidence of tamponade or wall motion abnormalities. The patient was taken for an emergent coronary angiography, which demonstrated occlusion of the second obtuse marginal vessel secondary to a shotgun pellet without other evidence of significant coronary atherosclerotic disease (Figure 2). Left ventricular function was good, with an ejection fraction of 55%.

The patient was managed medically and given aspirin for the myocardial infarction. Her troponin peaked at 45.82 ng/ml (reference range 0-0.08), and multiple follow-up echocardiograms revealed a stable pericardial effusion. Her extremity injury required ulnar artery ligation in the operating room, followed by saphenous vein graft repair of her left radial and ulnar arteries and a subsequent skin graft. The patient was discharged home after 11 days in the hospital with no reported cardiac sequelae at discharge or on follow up.

DISCUSSION

Cardiac manifestations of penetrating chest trauma can be difficult and complex to manage given concurrent possibilities of cardiogenic shock, hemorrhagic shock or obstructive shock. Cardiac injuries from penetrating trauma include myocardial rupture, contusion, laceration, pericardial insults, tamponade, coronary artery injury, valvular damage, arrhythmias and conduction abnormalities, with by far the most common being simple lacerations.[6] When evaluating a patient with penetrating chest trauma, myocardial ischemia should be considered. Pain from ischemia can be masked by other trauma and may not be detected unless an ECG is obtained. In one case, a patient's chest pain was attributed to the gunshot wound and no ECG was done. In that patient, death occurred secondary to myocardial ischemia from occlusion of the left anterior descending coronary artery by a single shotgun pellet discovered post-mortem with no evidence that his other injuries contributed to his death.[1] This case emphasizes that failure to obtain an ECG can be catastrophic. In our case an ECG was obtained, which led to further evaluation and diagnosis of an occlusive pellet in one of the coronary arteries.

In addition to an ECG, echocardiography and coronary angiography are other adjuncts to aid in diagnosis and management. Echocardiograms are easily obtained at bedside and can provide additional information regarding pericardial effusions, tamponade, wall motion abnormalities and pellet location. Echocardiography has been shown to identify and localize missile fragments and help identify issues in need of direct surgical intervention.[7] In our case we were able to localize the pellets and determine pericardial violation, rule out pericardial tamponade, and assess for wall motion abnormalities.

As for coronary angiography, some advocate for its essential role in pellet injuries with associated signs of ischemia.[8] It is vital to help differentiate between pellet embolization, luminal hematoma, atherosclerotic disease with plaque rupture or other causes of ischemia. This includes demand ischemia in the setting of significant blood loss. Computerized tomography and operative interventions fail to provide the same diagnostic capabilities and interventions.[8] Coronary angiography allows for evaluation of the aorta, identification of the culprit vessel and intervention with stenting if needed. In our patient, the aorta showed no evidence of injury, the culprit vessel was identified, and no intervention was needed and the pellet was left in place.

In the setting of a single pellet coronary lesion and absence of other cardiac complications, conservative medical management appears to provide good results with survival to discharge with no significant ongoing cardiac problems.[9] Several other case reports have described good outcomes from conservative medical management.[1-5] Factors which should be considered when deciding on medical versus interventional management include the location of the pellet, associated injuries, wall dysfunction, time to reperfusion and the vascular distribution of the affected vessel. In one case of operative management, a pellet located in the right coronary artery with associated proximal thrombus was removed.[8] The authors point out that operative management may not have been necessary given that the total ischemia time was already five hours, the infarction was well tolerated, and the associated hemopericardium had already been addressed. The concern was that the thrombus might migrate proximally, causing

greater ischemic insult. Also in this case, given the location and previous surgery to address the hemopericardium, the pellet was technically easy to remove. Most reported cases of pellet injuries to the coronary vasculature report injuries in the distribution of the right coronary artery. The one previous case with acute left coronary artery involvement, described above and initially unrecognized, resulted in death.[1] In the case described here, the pellet injury was in the left circumflex distribution in a small obtuse marginal vessel. Preserved ejection fraction, minimal pericardial effusion, a limited area of myocardial ischemia and the absence of multiple associated injuries allowed for conservative management and a good clinical outcome.

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The Impact of Cardiac Contractility on Cerebral Blood Flow in Ischemia

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Objective: In cerebral regions affected by ischemia, intrinsic vascular autoregulation is often lost. Blood flow delivery depends upon cardiac function and may be influenced by neuro-endocrine mediated myocardial suppression. Our objective is to evaluate the relation between ejection fraction (EF) and transcranial doppler (TCD) peak systolic velocities (PSV) in patients with cerebral ischemic events.

Methods: We conducted a retrospective cohort study from an existing TCD registry. We evaluated patients admitted within 24 hours of onset of a focal neurological deficit who had an echocardiogram and TCD performed within 72 hours of admission.

Results: We identified 58 patients from March to October 2003. Eighty-one percent (n=47) had a hospital discharge diagnosis of ischemic stroke and 18.9% (n=11) had a diagnosis of transient ischemic attack. Fourteen patients had systolic dysfunction (EF<50%). The mean PSV in patients with normal systolic function (EF≥50%) compared to those with systolic dysfunction (EF<50%) was as follows: middle cerebral artery 62.0 ± 28.6 cm/s vs. 51.0 ± 23.3 cm/s, p=0.11; anterior cerebral artery 52.1 ± 21.6 cm/s vs. 45.9 ± 22.7 cm/s, p=0.28; internal carotid artery 56.5 ± 20.1 cm/s vs. 46.4 ± 18.4 cm/s, p=0.04; ophthalmic artery 18.6 ± 7.2 cm/s vs. 15.3 ± 5.2 cm/s, p=0.11; vertebral artery 34.0 ± 13.9 cm/s vs. 31.6 ± 15.0 cm/s, p=0.44.

Conclusion: Cerebral blood flow in the internal carotid artery territory appears to be higher in cerebral ischemia patients with preserved left ventricular contractility. Our study was unable to differentiate pre-existing cardiac dysfunction from neuro-endocrine mediated myocardial stunning. Future research is necessary to better understand heart-brain interactions in this setting and to further explore the underlying mechanisms and consequences of neuro-endocrine mediated cardiac dysfunction. [West J Emerg Med. 2011;12(2):227-232.]

INTRODUCTION

Cerebral ischemic events (CIE) are a leading cause of death and morbidity in the United States with limited treatment options in the acute setting.[1-6] This type of central nervous system injury has been associated with hemodynamic perturbation secondary to myocardial injury and dysfunction but the mechanisms underlying this relationship are poorly understood.[5-7] Cardiac dysfunction in cerebral ischemia patients may have significant contributions in the pathogenesis of this disease. Within the territory of tissue affected by the ischemic insult, intrinsic autoregulation of the vasculature is lost rendering cerebral blood flow directly dependent upon cardiac output and contractility.[8,9]

The relationship between cerebral blood flow and cardiac contractility in the acute presentation of patients with acute cerebral ischemia has not been comprehensively evaluated. Our objective in this preliminary, retrospective study was to evaluate the relationship between left ventricular systolic

function and transcranial doppler (TCD) peak systolic velocities (PSV) in patients with CIEs defined either as an acute ischemic stroke (AIS) or transient ischemic attack (TIA).

METHODS

The Institutional Review Board for human research approved the study protocol and procedures. We conducted a retrospective chart review of CIE patients identified by our institutions TCD registry.[10] We included patients based on the following criteria: adult patients admitted within 24 hours of onset of a focal neurological deficit, record of both an echocardiogram and TCD performed within 72 hours of admission, and a discharge diagnosis of an AIS or TIA. Our exclusion criteria included age less than 18 years old, the presence of cerebral hemorrhage on initial neuro-imaging, or defined imaging parameters on echocardiography which could confound results. Echocardiogram exclusion criteria included the inability to measure the cardiac ejection fraction (EF) or the presence of severe left-sided stenotic or regurgitant valvular lesions that could potentially alter cardiac output.

Additionally, given that certain TCD vessel distributions are technically more difficult to measure, we established a quality control measure to exclude individual vessel distributions from analysis if PSV or pulsatility index (PI) measurements could not be acquired in greater than 50% of patients. PSV vessel distributions included the middle cerebral artery, anterior cerebral artery, posterior cerebral artery, internal carotid artery, ophthalmic artery and vertebral artery. We measured PIs only in the middle cerebral and vertebral artery territories.

A senior resident investigator, under the supervision of senior faculty investigators, used a standardized method of data collection to extract demographic and clinical data onto a data collection form. Echocardiogram reports were read by staff cardiologists and reviewed for the measured EF and the presence of severe left-sided stenotic or regurgitant valvular lesions. We considered an EF below 50% abnormal.[11]

TCD studies in the registry were read by one of the investigators, a staff neurologist certified in neurosonology, and extracted by the senior resident investigator in a supervised and standardized fashion from the electronic medical record. We reviewed PSVs in the following vessel distributions: middle cerebral artery, anterior cerebral artery, posterior cerebral artery, internal carotid artery, ophthalmic artery and vertebral artery. We reported one PSV for each territory of the cerebral vasculature. We calculated the mean PSV for each vessel territory by combining the left and right PSV values in all patients. We performed the calculation this way because the PSV reference range for left and right vessel territories is identical and prior literature has demonstrated PSV and PI responsiveness in both sides of the middle cerebral artery territory to cardiac augmentation in the setting of AIS.[12-14]

Similarly, we measured the PI for each territory of the middle cerebral artery and vertebral artery, and calculated their means. We did not measure PIs in other vessel distributions.

Table. Demographics of patient population.

Demographic	Number	Percentage
Male	39	67.2
Hypertension	30	51.7
Hyperlipidemia	15	25.9
Diabetes	15	25.9
Congestive heart failure	6	10.3
Coronary artery disease/myocardial infarction	7	12.1
Stroke/transient ischemic attack	6	10.3
Tobacco use	4	6.9
Atrial fibrillation	3	5.2
Respiratory disease	2	3.4
Hemodialysis/renal insufficiency	2	3.4
Seizure	1	1.7
Cancer	1	1.7

Prior literature has documented PSV and PI to correlate with cerebral blood flow.[14-20] For our primary analysis, we stratified patients into low (EF<50%) and normal (EF≥50%) contractility groups and calculated the mean PSV for each group. We performed a comparison of means using an un-paired t-test with statistical significance of the two-tailed P value being less than 0.05.

We reported the other results as the mean, standard deviation and 95% confidence interval where indicated. We used Fisher's Exact Test in sub-group analysis comparing demographical differences between groups. We indicated statistical significance by an alpha error <0.05.

RESULTS

We identified 197 TCD studies during from March to October 2003. Of these studies, 127 were excluded for including neurosurgical patients (n=63), neurology patients with conditions other than CIEs (n=37), and other patient populations (n= 27). We identified 70 CIE patients with both TCD studies and echocardiograms performed during their hospitalization. However, we excluded 12 of these patients because the TCD and echocardiogram were not performed within the first 72 hours of admission, or because echocardiograms revealed severely stenotic or regurgitant left-sided valvular abnormalities. Thus, 58 patients fulfilled our inclusion and exclusion criteria and were included into the study cohort.

In the identified 58 patients, 81.1% (n=47) had a hospital discharge diagnosis of AIS and 18.9% (n=11) had a diagnosis of TIA. Demographics of our patient population are summarized in (Table). Male patients made up 67.2% of patients. The mean age was 65.0 $\pm$ 14.8. The most common

co-morbidities were hypertension (51.7%), diabetes (25.9%) and hyperlipidemia (25.9%). Within the cohort, 10.3% of patients previously had an AIS or TIA and 10.3% of patients had a prior history of congestive heart failure. The mean initial NIH stroke scale for identified patients was 10.77 ± 7.29 (95% CI 7.54 to 14.00). The mean initial systolic blood pressure for patients was 168.7 mmHg ± 37.2 (95% CI 157.6 mmHg to 179.9 mmHg). The mean initial heart rate was 83.6 ± 16.7 (95% CI 78.4 to 88.7).

Of the total sample of patients, 24.1% (n=14) had evidence of systolic dysfunction with an EF below 50% on echocardiography, and the rest, 75.8% (n=44), had normal systolic function. Among patients with systolic dysfunction 14.3% (n=2) had a hospital discharge diagnosis of TIA. In the group with normal cardiac function 20.4% (n=9) had a hospital discharge diagnosis of TIA (p=1.0, Fisher's Exact Test).

For TCD quality control, we ensured an adequate amount of PSV and PI measurements for each vessel distribution. We found that all vessel distributions met our quality threshold except for PSV measurements in the posterior cerebral artery distribution. We were only able to obtain 50.0% (n=29) of those measurements and therefore excluded the posterior cerebral artery vessel distribution from analysis. We performed PSV measurements for the middle cerebral artery distribution in 91.4% of patients (n=53), the anterior cerebral artery in 86.2% (n=50), the internal carotid in 88.0% (n=51), the ophthalmic artery in 69.0% (n=40), and the vertebral artery in 96.6% (n=56). For PI measurements, 91.4% (n=53) had middle cerebral artery PI measurements, and 96.6% (n=56) had vertebral artery PI measurements.

The mean PI in patients with normal systolic function (EF ≥50%) compared to those with systolic dysfunction (EF < 50%) was as follows: middle cerebral artery 1.07 ± 0.35 vs. 1.19 ± 0.41, p=0.23; vertebral artery 1.18 ± 0.34 vs 1.21 ± 0.28, p=0.62. We did not measure PIs in any other vessel distributions.

The mean PSV in patients with normal systolic function (EF ≥50%) compared to those with systolic dysfunction (EF < 50%) was as follows (Figure): middle cerebral artery 62.0 ± 28.6 cm/s vs. 51.0 ± 23.3 cm/s, p=0.11; anterior cerebral artery 52.1 ± 21.6 cm/s vs. 45.9 ± 22.7 cm/s, p=0.28; internal carotid artery 56.5 ± 20.1 cm/s vs. 46.4 ± 18.4 cm/s, p=0.04; ophthalmic artery 18.6 ± 7.2 cm/s vs. 15.3 ± 5.2 cm/s, p=0.11; vertebral artery 34.0 ± 13.9 cm/s vs. 31.6 ± 15.0 cm/s, p=0.44.

DISCUSSION

A significant proportion (13-28%) of patients with cerebral ischemia may have impaired cardiac contractility either at baseline from existing congestive heart failure or as part of the pathogenesis of the disease.[21-23] The latter pathogenic mechanisms include catecholamine induced stunning or direct neuro-inhibition secondary to the ischemic insult.[24,25] Our data suggests that cerebral blood flow (based on mean TCD PSV) in the internal carotid artery vascular territory is higher in acute cerebral ischemia patients with preserved left ventricular contractility. Additionally, we observed a trend towards higher cerebral blood flow among patients with preserved cardiac contractility in the territories of the middle cerebral artery, anterior cerebral artery, ophthalmic artery and vertebral artery. These findings serve to strengthen the limited existing animal literature and human pilot studies evaluating the impact of cardiac function on cerebral blood flow.

Nearly two decades ago Keller et al[8] demonstrated in a primate model that cerebral blood flow in both ischemic and non-ischemic brain regions correlates with cardiac output.

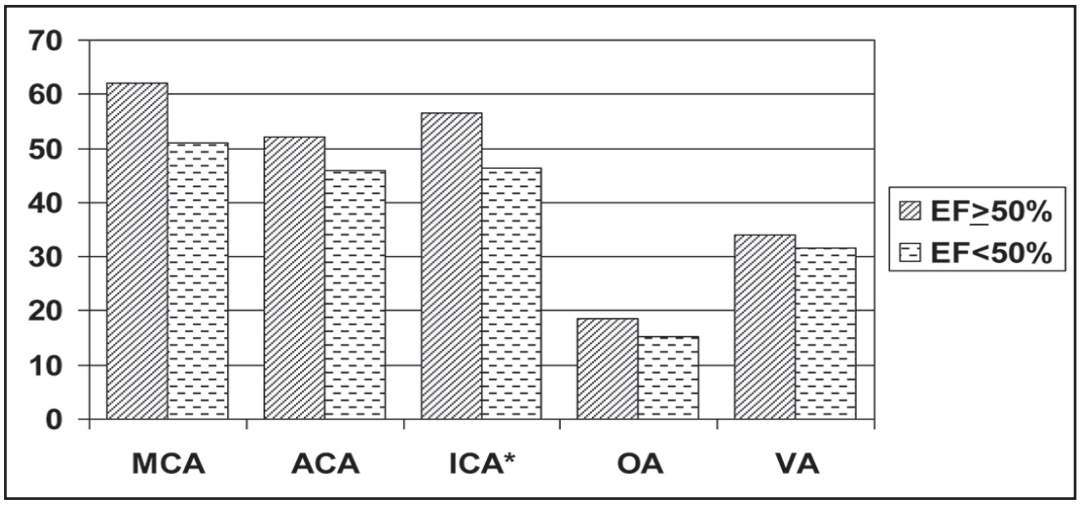

Figure. Mean peak systolic velocities (cm/s) in normal and low ejection fraction groups.

MCA, middle cerebral artery; *ACA,* anterior cerebral artery; *ICA*, internal carotid artery; *OA*, ophthalmic artery; *VA*, vertebral artery; *EF*, ejection fraction. (* indicates P<0.05).

Soon afterwards, Korosue et al[26] observed a 29% mean increase in cardiac output in ischemic stroke patients with isovolemic hemodilution associated with increases in regional cerebral blood flow.

More recently, Treib et al[14] performed a pilot study with hypervolemic hemodilution combined with dopamine or dobutamine infusion in 24 stroke patients with middle cerebral artery occlusions. They measured the influence of blood pressure and cardiac output on the TCD PSV in a single intracranial vessel, the middle cerebral artery. With therapy there was a 53% increase in cardiac output. In the unaffected hemisphere, there was a 27% increase in the systolic velocity. On the side of the lesion, there was an 11% increase. The relative diminished response on the affected side was believed to have been due to thrombus burden or counterregulatory pathways causing vasoconstriction. Additionally, they observed an increase in PI by 46% in the affected and 47% in the unaffected hemisphere. This differed from our study since we did not observe significant PI differences between the low and normal EF groups. A significant difference between our studies is that Treib et al's[14] patients received infusions of dopamine or dobutamine.

A translational question of important consideration is whether cardiac contractility correlates with functional neurological outcome. It is unknown if undifferentiated systolic dysfunction promotes expansion of the ischemic penumbra, or conversely whether hyperdynamic cardiac function enhances the risk of hemorrhagic transformation. Although relatively uninvestigated, Korosue et al[26] reported modest increases in neurological scores with cardiac output augmentation. Subsequent isovolemic hemodilution studies were not supportive, but to our knowledge they did not record cardiac output values.[27] No other studies have reported improved functional outcome with cardiac augmentation or hemodynamic optimization. Additionally, we found no studies relating higher cerebral hemorrhage rates to hemodynamic augmentation or hyperdynamic states.[28,29]

Nevertheless, in the stroke rehabilitation literature, Kevorkian et al[30] observed better functional recovery in acute stroke patients with normal cardiac contractility. Their design differed from ours as they stratified acute stroke patients into severely depressed (EF<35%) and moderately depressed or normal (EF≥35%) contractility cohorts. The latter group had higher hospital discharge functional scores and higher rates of functional status improvement from admission to discharge. While the authors conceded their study had several limitations, their results suggest that acute stroke patients with preserved systolic function may have better functional outcomes than those with severe systolic dysfunction.

Thus, it remains unclear which subgroups of cerebral ischemia patients could potentially benefit from cardiac output augmentation as suggested by prior authors.[31] Beyond impaired contractility, it is well-known that subgroups of cerebral ischemia patients may have serum troponin elevation and arrhythmias — which have been related to higher in-hospital mortality rates.[21,24,32,33] Currently there is a paucity of investigators evaluating the incidence, role, underlying mechanisms, and impact of myocardial and hemodynamic derangements in the setting of cerebral ischemia. The future development of adjunctive evidence-based hemodynamic guidelines is critical.

LIMITATIONS

A principle limitation of this study was the retrospective design and small sample size. In addition, echocardiograms performed by technicians in our institution's cardiovascular lab were susceptible to user variability. Another limitation was the heterogeneity of the defined CIE population. While there are neurovascular, physiologic and management differences between AIS and TIA patients, we postulated that the merging of these populations would not significantly impact our results for the sake of this preliminary analysis. For example, at our institution all AIS and TIA patients have echocardiograms and a cerebral vascular study performed prior to discharge. There are overlapping co-morbidities between each population, including diabetes, hypertension and hyperlipidemia. National AIS and TIA guidelines have overlapping recommendations for management, and at our institution AIS and TIA patients were admitted to the same clinical floors and clinician teams.[34,35] Thus, given the overlapping characteristics of stroke and TIA patients, we thought that the relation between cerebral flow velocities and cardiac function would be preserved.

Another limitation of our study was that we did not know the prior EF of patients to delineate the underlying mechanism for systolic dysfunction. It is possible that patients with elevated catecholamine levels from neuro-endocrine activation could potentially have myocardial stunning and other cerebrovascular perturbations that could alter echocardiogram findings and other variables measured in this study.

A methodological limitation of the retrospective design was that TCDs and echocardiograms were performed within 72 hours of admission, rather than simultaneously. Our study was also susceptible to selection bias since many patients undergoing TCDs may have had contraindications to magnetic resonance imaging or magnetic resonance angiography. Another limitation was that the majority of patients in our study did not have concomitant cerebral angiography performed in order to localize vascular occlusions in the AIS patients. Thus, our mean PSV or PI values could have been impacted if a patient had a partial or total occlusion of one of the large vessels being measured by TCD. For example, a patient could have a middle cerebral artery occlusion contrasted to a stroke syndrome caused by a more distal occlusion in the M1 or M2 portion of the middle cerebral artery territory. While our methodology to calculate the mean

PSV or PI would help to mitigate this issue, it is a limitation that we were unable to control for given the information in the medical records and the fact that the majority of these patients did not have cerebral angiography performed.

CONCLUSION

Cerebral blood flow in the internal carotid artery territory as measured by the mean PSV in cerebral ischemia patients appears to be higher in those with preserved left ventricular contractility. Future research is necessary to better understand the impact of myocardial contractility on cerebral blood flow in patients with acute cerebral ischemia.

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Vertebrobasilar Artery Occlusion

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The presentation of vertebrobasilar artery occlusion varies with the cause of occlusion and location of ischemia. This often results in delay in diagnosis. Areas of the brain supplied by the posterior circulation are difficult to visualize and usually require angiography or magnetic resonance imaging. Intravenous thrombolysis and local-intra arterial thrombolysis are the most common treatment approaches used. Recanalization of the occluded vessel significantly improves morbidity and mortality. Here we present a review of the literature and a case of a patient with altered mental status caused by vertebrobasilar artery occlusion. [West J Emerg Med. 2011;12(2):233-239.]

INTRODUCTION

Altered mental status is a common presenting complaint in the emergency department (ED). Cerebrovascular accidents (CVAs) are one of the most serious etiologies for altered mental status. Ischemic stroke accounts for 87% of CVAs.[1] Of these, approximately 20% are the result of vertebrobasilar artery occlusion (VBAO).[2-5] The mortality of VBAO can reach 80-95% without successful treatment.[3,6-8] Making the diagnosis can be difficult as patients present with a variety of nonspecific signs and symptoms. Furthermore, the posterior circulation is difficult to visualize, often requiring the use of computed tomography angiography (CTA), magnetic resonance imaging (MRI) or magnetic resonance angiography (MRA).[2-3] We present here a review of the literature and a case of a young patient with VBAO.

HISTORY

A 36-year-old Caucasian female presented to the ED with altered mental status. According to her family, the patient began complaining of headache and a stiff neck four days prior to admission. The headache was frontal and not relieved with ibuprofen. She had no history of trauma. Approximately 13 hours prior to admission, the patient was evaluated at an outside ED and found to have an elevated white blood cell (WBC) count. A head CT was recommended for her headache, but she refused further workup. A presumptive diagnosis of sinusitis was made and she was treated with amoxicillin and ciprofloxacin/dexamethasone otic suspension and discharged home.

After discharge, her symptoms failed to resolve. According to her family, she complained of blurred vision and

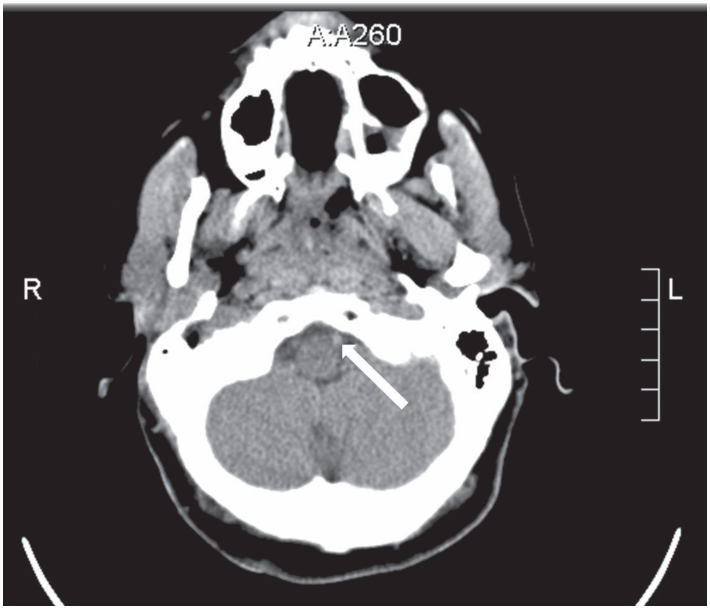

Figure 1. Initial head computed tomography. There is a high density signal in the distal left vertebral artery (solid arrow) secondary to possible thrombus versus slow flow.

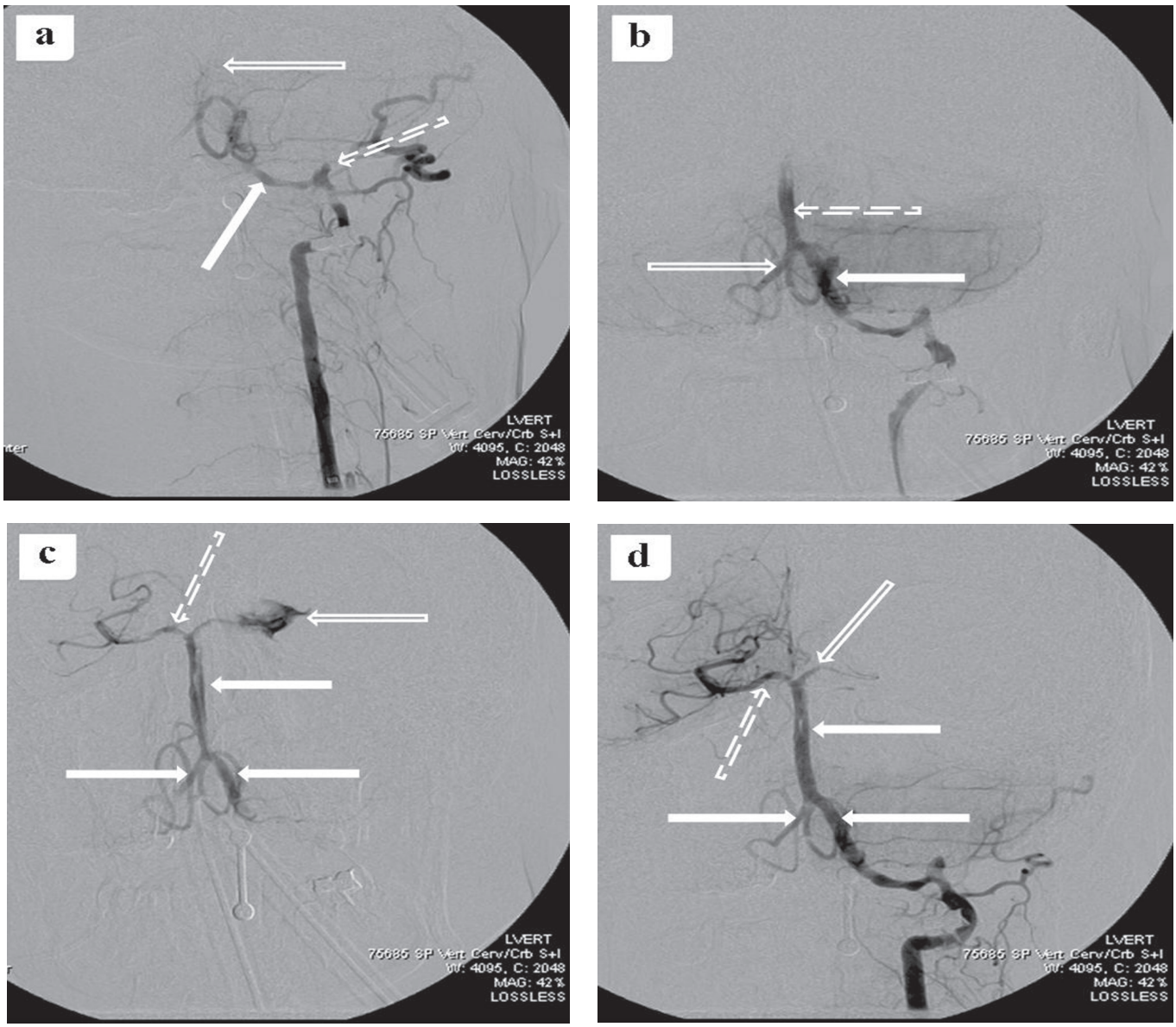

Figure 2. a. Initial angiogram. There is wall irregularity (solid arrow) and possible pseudoaneurysm (dashed arrow) in the distal cervical segment of the left vertebral artery. There is no opacification of the intra-dural segment of the left vertebral artery distal to the posterior inferior cerebellar artery (open arrow) secondary to possible dissection with thrombus. b. Follow up angiogram after mechanical thrombectomy. There is opacification of the left vertebral artery (solid arrow) and the distal basilar artery (dashed arrow). There is reflux opacification of the right vertebral artery (open arrow). c. Follow up angiogram after heparin administration. There is opacification of the bilateral vertebral and basilar arteries (solid arrows). There is opacification of the right posterior cerebral artery (dashed arrow). There is opacification of the left posterior cerebral artery with contrast extravasation (open arrow). d. Final post-thrombectomy angiogram. There is opacification of the bilateral vertebral and basilar arteries (solid arrows). There is opacification of the right posterior cerebral artery (dashed arrow). The left posterior cerebral artery is poorly opacified (open arrow). The contrast extravasation seen previously (Figure 2c) has been successfully treated after heparin reversal with protamine. Of note, the left vertebral artery appears to be the dominant vertebral artery in this patient; the right vertebral artery is considerably smaller than the left.

was noted to have unsteady gait and slurred speech. Prior to her call to emergency medical services (EMS), she called her family complaining that she felt "drunk." Upon EMS arrival, she was unconscious.

Her past medical history was significant only for Turner's syndrome. Her surgical history included breast reconstruction at age 15 years. She did not use ethanol, tobacco or illicit drugs. Home medications included amoxicillin, ciprofloxacin/dexamethasone, ibuprofen and pseudoephedrine.

PHYSICAL EXAM

Upon arrival to the ED, the patient was unresponsive. She was intubated and sedated. Blood pressure was 86/46 mmHg, heart rate 179 beats per minute, temperature 36.7˚C

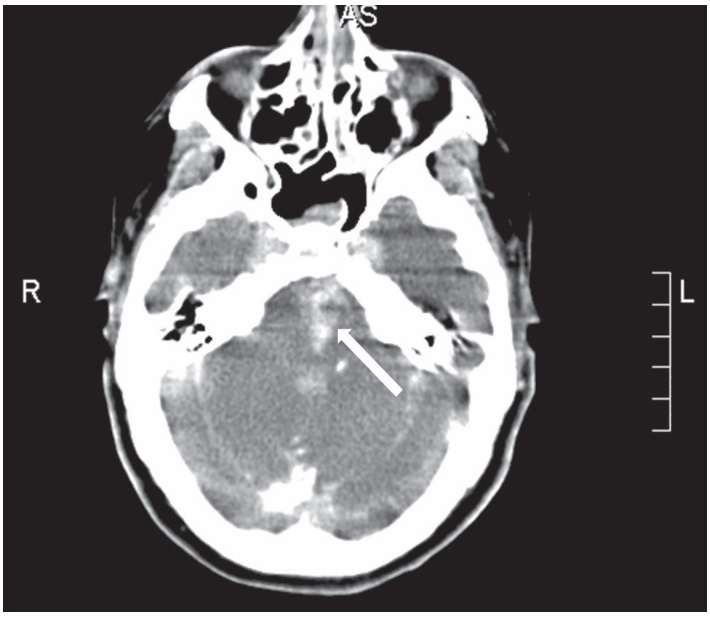

Figure 3. Post-thrombectomy head computed tomography. There is a high density signal in the left pons (solid arrow) consistent with a left pontine intraparenchymal hemorrhage. This imaging study also showed development of an intraparenchymal hemorrhage involving the left cerebral peduncle (image not shown).

and oxygen saturation 100% on oxygen after intubation. The pupils were 4mm, round and reactive to light; the oropharynx was clear; the neck was supple. The heart was regular and tachycardic and the lungs were clear bilaterally. The abdomen was soft, nontender and nondistended with active bowel sounds. The extremities showed no cyanosis, clubbing, nor edema, and peripheral pulses were palpated bilaterally. The skin showed no evidence of rash or lesions. The eyes were open and she was nonverbal with decerebrate posturing; the Glascow Coma Scale (GCS) score was seven. The gag reflex and corneal reflexes were grossly intact; doll's eye sign was negative. The deep tendon reflexes were hyperreflexic throughout.

DIAGNOSTIC TESTING

A complete blood count included a WBC count of 10,500 cells/mcL with 85% neutrophils, hemoglobin 14.5 g/dL and hematocrit 42.6%. Electrolytes were: sodium 141 mEq/L, potassium 3.7 mEq/L, chloride 103 mEq/L and carbon dioxide 21 mEq/L. Venous blood gas showed pH 7.41, pCO_2 32.1, pO_2 40.5 and bicarbonate 20.1 mEq/L. Renal and liver function tests, cardiac enzymes, coagulation cascade and urinalysis were normal. Blood alcohol and urine pregnancy tests were negative. Urine toxicology was positive for benzodiazepines, presumably from medications administered for sedation. A lumbar puncture was performed and cerebrospinal fluid (CSF) showed 179 red blood cells (RBCs) (tube #1), 56 RBCs (tube #4), 0 WBCs (tube #1), glucose 107 mg/dL and protein 32 mg/dL. The CSF was negative for West Nile Virus, Herpes Simplex Virus and Cryptococcus; no bacteria, viruses or fungi were isolated in culture.

The initial electrocardiogram (ECG) showed sinus tachycardia at 179 beats per minute and premature ventricular contractions. Following intubation, ECG showed sinus tachycardia at 124 beats per minute. A single view chest radiograph was negative. A head CT without contrast was initially read as negative by the overnight teleradiologist. An in-house resident's subsequent reading was positive for a high-density lesion in the left vertebral and basilar arteries, suspicious for thrombus versus slow flow (Figure 1). Incidentally, the CT also showed sinus mucosal disease. Follow-up CTA of the head and neck showed lack of opacification of the majority of the basilar artery and distal left vertebral artery.

The patient was taken immediately to the interventional radiology suite for vertebrobasilar artery (VBA) thrombectomy. Angiography of the VBA system showed dissection of the left vertebral artery with extensive thrombi in the left vertebral and basilar arteries. The thrombi were evacuated. Unfortunately, there was extravasation of contrast dye from the left posterior cerebral artery into the subarachnoid space (Figure 2). Post-procedure head CT showed evidence of reperfusion hemorrhage (Figure 3). After the procedure, the patient had further neurological decline and was transferred to the medical intensive care unit where she later expired. Autopsy confirmed VBAO as the cause of death. The patient had no abnormalities of the heart, including a normal foramen ovale.

DISCUSSION

Clinical Presentation and Etiology

The clinical presentation of VBAO varies with the area of ischemia and cause of occlusion. Vertigo, dizziness, nausea, vomiting and head or neck pain are the most common initial symptoms reported.[3,9-12] Other common signs and symptoms include weakness, hemiparesis, ataxia, diplopia, pupillary abnormalities, speech difficulties and altered mental status.[2-3,10,12]

Vertebral artery occlusion results in proximal VBA territory ischemia.[11,13] Occlusion near the origin of the vertebral artery (extracranial) causes ischemia in the medulla and/or cerebellum and commonly presents as brief transient ischemic attacks (TIAs).[3,14] Occlusion of an intracranial vertebral artery can cause ischemia in the lateral medulla resulting in Wallenburg Syndrome (decreased pain/temperature of the ipsilateral face and contralateral body, Horner's syndrome, limb ataxia, hoarse voice, dysphagia).[3] Dizziness, diplopia and signs of lateral medullary or cerebellar ischemia may result from extension of or embolism from an extracranial vertebral artery dissection (VAD) into the intracranial vertebral artery.[3,14] Ischemia in the middle VBA territory is usually caused by occlusion of the

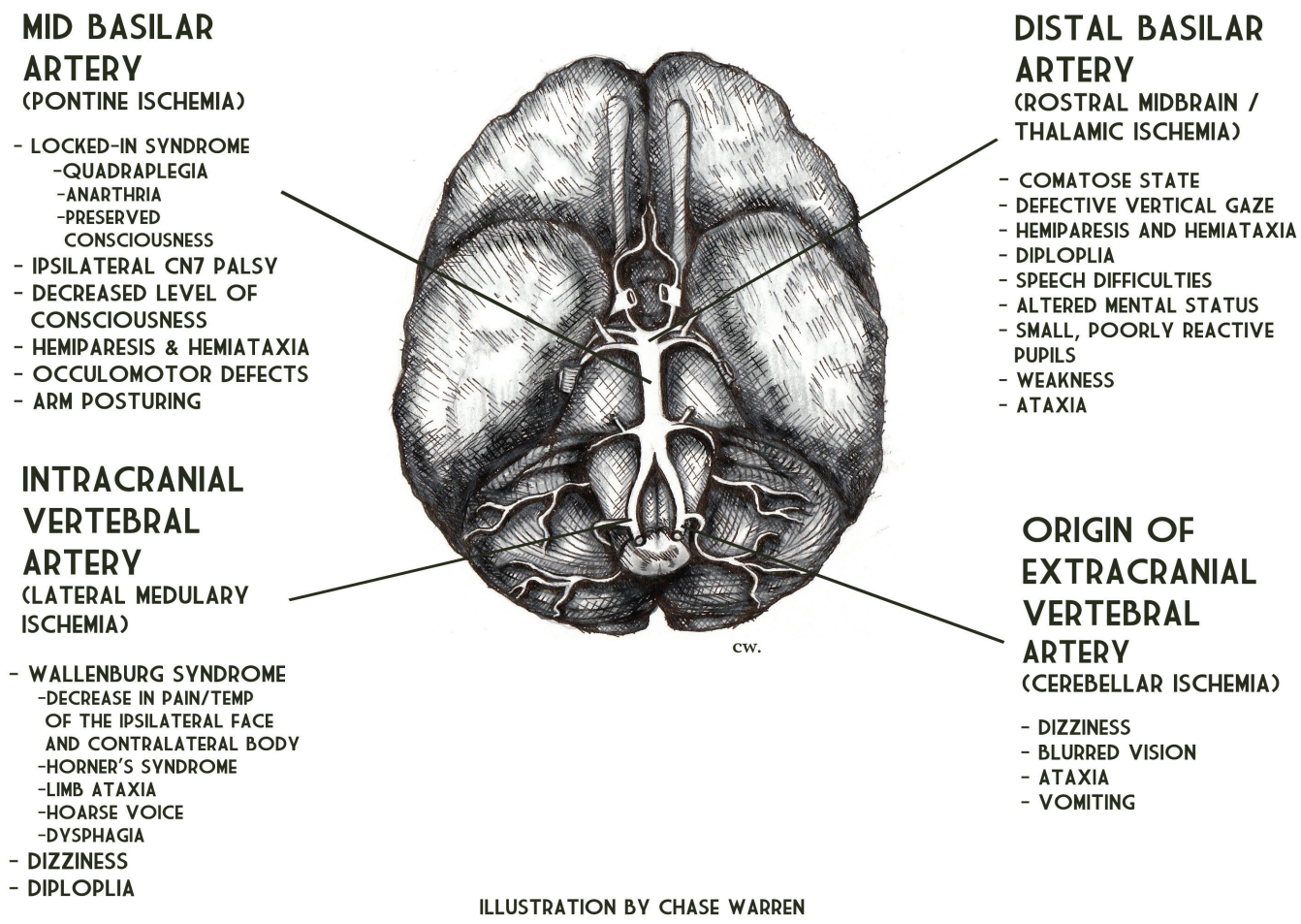

Figure 4. Vertebrobasilar circulation occlusions. The arteries of the vertebrobasilar circulation are illustrated. The area of ischemia and associated symptoms caused by occlusion of the major arteries are listed.

basilar artery. This can cause pontine damage resulting in "Locked-In Syndrome" (quadriplegia, anarthria, preserved consciousness).[13,15] Distal basilar artery occlusion is most commonly embolic, usually from cardiac or vertebral artery sources, and results in ischemia of the rostral midbrain and thalamus.[11,13] This presents with the characteristic "top-of-the-basilar syndrome" (coma, midbrain ocular-motor signs – small poorly reactive pupils and defective vertical gaze, hemiparesis, hemiataxia) (Figure 4).[2-3,9]

Embolism (30-40%), local atherothrombosis (15-35%) and VAD (approximately 5%) are the primary causes of VBAO.[3,13,16-17] In elderly patients, local atherothrombosis is the most common etiology.[9,11] These patients typically have multiple vascular risk factors and slow, progressive symptoms. TIAs weeks or months before the occlusion are common.[2-3,9-11] VBAO in younger patients is most commonly caused by embolism, usually from cardiac, aortic, or proximal vertebral and basilar artery sources.[2-3,9,11,13,16] These patients generally have few vascular risk factors and sudden symptom onset without prodromal TIAs.[9,11]

As in this case presentation, VAD occurs in the freely movable first and third segments of extracranial vertebral arteries and is commonly associated with minor trauma, such as coughing, sneezing, or vomiting, cervical chiropractic manipulation and whiplash injury.[18-22] However, there is little evidence that minor trauma is a true risk factor for VAD in healthy vessels. Many occur spontaneously, suggesting an underlying arteriopathy or multifactorial etiology.[18-19,21-23] Ehlers-Danlos syndrome, hyperhomocystinemia, recent infection and α1-antitrypsin deficiency have all been implicated.[18,21-22] Turner Syndrome (TS) may have been an additional risk factor in the case presented here. Aortic root dilation and dissection are well known cardiovascular complications of TS.[24-25] Some evidence suggests this may

be related to an underlying "connective tissue disorder" characterized by cystic medial necrosis, similar to that seen in Marfan's Syndrome.[24-25] Ostberg et al[26] demonstrated widespread structural vascular differences in women with TS compared to normal controls. To our knowledge, the case presented herein is the second reported case of spontaneous VAD in a patient with TS.[27] VBAO results from thromboembolism or propagation of the dissection into the intracranial vertebral artery.[3,10]

Diagnosis

The initial workup of VBAO includes a non-contrast head CT to rule out intracranial hemorrhage.[2,9,28] CTA is the most common subsequent study. MRI and MRA are alternative studies.[28-30] Transcranial Doppler ultrasound may identify a high-resistance flow pattern or sudden signal loss as indicators of VBAO, but this technique depends on a skilled operator and is vastly inferior to CTA.[2,9,29,31] While intra-arterial digital subtraction angiography is considered the criterion reference, it is invasive, time consuming, has limited availability, and may require general anesthesia.[2]

Recommended ancillary studies include echocardiography and rhythm monitoring to detect a cardiac source of embolism. Younger patients, those with prior occlusions, or those with no identifiable cardiac, aortic, or cervicocranial lesions, merit further workup for coagulopathy.[3]

Morbidity and Mortality

Recanalization of the occluded vessel is the most important prognostic factor in patients with VBAO.[6,8,32-35] With successful recanalization, mortality is reduced by approximately 50%, survival is as high as 60% at three months and eventual functional independence is achieved in greater than 50% of patients.[6,33-36]

Other factors associated with good prognosis include younger age (<60 years), involvement of a single posterior circulation territory, and less severe presentation on admission (GCS>10, lower NIH Stroke Scale score, and absence of coma).[6,11,13,16,32-33,37-38] Reports on the relationship between site of occlusion (distal vs. proximal) and prognosis are conflicting.[6,11,13,16,33,35-36,39] It is also debated whether shorter time from symptom onset to intervention improves morbidity and mortality. Most agree, however, that diagnosis delayed by as much as 48 hours should not preclude treatment.[7-8,17,35-37]

Our patient, although young, had a GCS of seven and involvement of two VBA territories, indicating a poor prognosis. Recanalization was achieved, but the patient suffered complications of thrombus evacuation, further worsening her prognosis. Treatment was initiated within 48 hours despite some delay in diagnosis.

Treatment

Available treatments include intravenous thrombolysis (IVT), local intra-arterial thrombolysis (IAT), endovascular thrombectomy and ultrasonic fibrinolysis.[40]

IVT and IAT are the most widely used strategies. IVT achieves recanalization in 43-67% of patients.[8,17,34] It is noninvasive, can be administered earlier, and is more widely available than endovascular techniques.[17,34] IAT may achieve recanalization in a higher proportion of cases (56-72%) than IVT, but does not necessarily improve patient outcome.[7,17,34-35] Consequently, many authors recommend IAT as first-line treatment but encourage providers to treat with IVT if IAT is unavailable or will result in significant delay.[7-8,17,34]

Transcranial Doppler ultrasound may enhance IVT, and microcatheters with built-in ultrasonic devices have been used in conjunction with IAT.[41-43] These studies demonstrate a trend toward higher rates of recanalization compared to controls treated with thrombolytic therapy alone. In the Mechanical Embolus Removal in Cerebral Ischemia (MERCI) trial, mechanical embolectomy achieved recanalization at rates comparable to those reported for IVT (46%) with a comparable risk of complication (13%).[44]

The safety and efficacy of these "thrombolytic adjuvants" for use in posterior circulation stroke are under investigation. Currently, most authors recommend reserving these treatments for patients ineligible for thrombolytic therapy.[40]

CONCLUSION

Altered mental status is a common presenting complaint in the ED. Ischemic stroke is an important differential diagnosis to consider even in younger patients. Arterial dissection must be considered as a potential etiology, particularly in patients with a known diagnosis of Turner Syndrome. The underlying connective tissue abnormality associated with Turner Syndrome may place these patients at much higher risk for spontaneous arterial dissection compared to the general population. VBAO, although a rarer type of ischemic stroke, can be devastating with mortality as high as 80-95% without successful treatment; early diagnosis therefore is crucial. Adequate visualization of the posterior circulation often requires angiography or magnetic resonance imaging. Intravenous thrombolysis and local-intra arterial thrombolysis are the most common treatment approaches used. Recanalization of the occluded vessel significantly improves the morbidity and mortality of VBAO.

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Artifact Simulating Fracture on Cervical Spine Computed Tomography

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We present the case of a 31-year-old trauma patient with computed tomography concerning significant C3-C4 subluxation. The abnormality is due to an artifact with which emergency physicians should be aware. [West J Emerg Med. 2011;12(2):240-241.]

A 31-year-old woman fell from a van traveling between 20-40 miles per hour. She briefly lost consciousness. She was immobilized on a backboard with towel rolls and tape because a standard extrication collar would not fit. The patient was confused and agitated with a Glasgow Coma Scale of 12. She moved all four extremities and had a large posterior scalp laceration. Computed tomography (CT) of her head was normal except for the laceration. The sagittal reconstruction of her cervical spine CT is shown (Figure 1).

The image was initially interpreted as a 4 mm of subluxation of C3 on C4. This was consistent with the presumed hyperflexion mechanism of injury. Physiologic subluxation of C2 on C3 is a normal finding in up to 9% of children under age seven years.[1, 2] This is probably due to

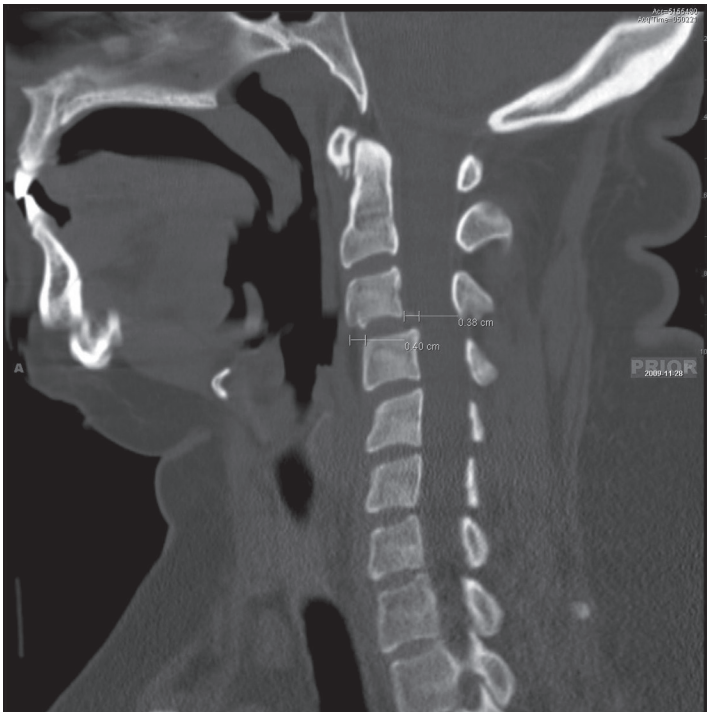

Figure 1. Lateral c-spine sagittal reconstruction from the computed tomography.

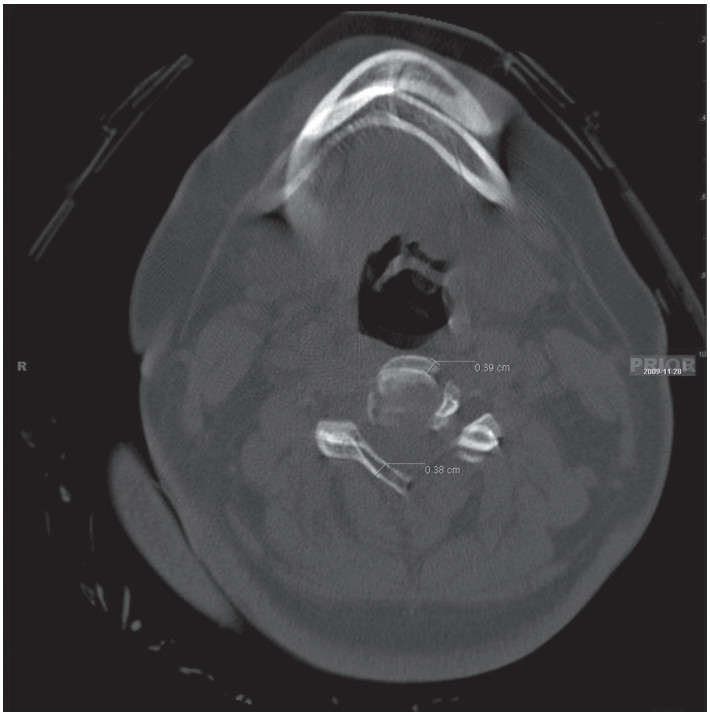

Figure 2. Axial image from the computed tomography at C3-C4.

immature muscular development and hypermobile spines. There is at least one published report of an adult with C2 on C3 pseudosubluxation.[3] However, C3 on C4 subluxation is always considered abnormal (Figure 2).

There are clues of a movement artifact on this image, such as the lack of soft tissue swelling, a sharply irregular line of the posterior pharynx, and an oddly shaped mandible. Examination of the axial image at the C3-C4 area revealed that the patient moved 4mm and assumed a new position for the remainder of the study. Recognition of this movement artifact is important in the accurate evaluation of spine CT scans.

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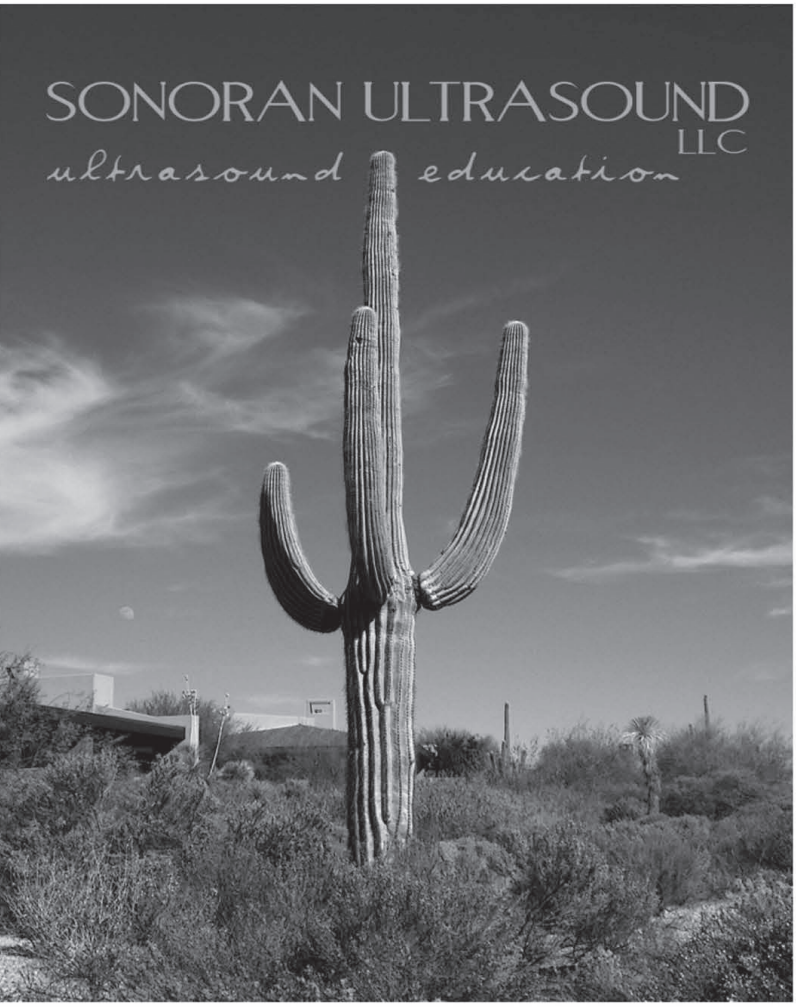

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