Use Of Bedside Ultrasound In The Pediatric Emergency Department

As a pediatric emergency physician who takes pride in keeping up to date with the latest literature and technology, you’ve been pushing your division chief to initiate emergency department ultrasound. After a particularly exciting shift where your chief treated a child with blunt abdominal trauma, a child post-cardiac repair with concern for pericardial effusion, a teenager with abdominal pain and a positive pregnancy test, a critical patient who required a difficult central IV access, and a child with an eye injury, they are quickly becoming more open to the concept. They task you to learn what ultrasound is most useful for in this population and what needs to be done to bring ultrasound to your pediatric emergency department…

Ultrasound for medical use has evolved dramatically, with early machines requiring the patient to be immersed in a bath of water and more recent technology creating better images and even three-dimensional images of some objects. Simultaneous with the advancement of technology, the indications for the use of ultrasound have exploded. Emergency medicine has been on the forefront of clinical use and research of new ultrasound techniques, particularly in adult patients. Ultrasound has become an extension of the physical exam in some centers. Pediatric emergency medicine has been slower to embrace ultrasound, but has had the luxury of adapting some of the proven uses to the pediatric population. This article hopes to expand the knowledge of the reader on the background physics, indications for emergency bedside ultrasound…
in the pediatric patient, and some of the nuances to starting and maintaining an emergency ultrasound program in a pediatric emergency department.

Abbreviations Used In This Article

AAA: Abdominal Aortic Aneurysm
ABEM: American Board of Emergency Medicine
ACEP: American College of Emergency Physicians
AHRQ: Agency for Healthcare Research and Quality
AMA: American Medical Association
ATLS: Advanced Trauma Life Support
CT: Computed Tomography
CVP: Central Venous Pressure
ED: Emergency Department
EM: Emergency Medicine
EP: Emergency Physician
ETT: Endotracheal Tube
EVS: Endovaginal Sonography
FAST: Focused Abdominal Sonography for Trauma
ICP: Intracranial Pressure
ICU: Intensive Care Unit
IUP: Intrauterine Pregnancy
IVC: Inferior Vena Cava
IVP: Intravenous Pyelogram
LVF: Left Ventricular Function
PALS: Pediatric Advance Life Support
PEA: Pulseless Electrical Activity
PEM: Pediatric Emergency Medicine
SAEM: Society for Academic Emergency Medicine
SPA: Suprapubic Aspiration
US: Ultrasound

Critical Appraisal Of The Literature

As with many fields of both pediatrics and emergency medicine, the use of emergency bedside ultrasound has rapidly increased. This has largely been the result of increasing research and has also inspired additional research examining new indications and methods for use of ultrasound in the emergency patient. In the emergency department, bedside ultrasound has primarily originated in use with adult patients. This knowledge has since trickled down to the pediatric patient, and, as will be described, has resulted in pediatric-specific indications. Within each section of this text is a critical appraisal of the literature for its respective use.

Epidemiology, Etiology, And Pathophysiology

Epidemiology And Etiology

Bedside ultrasound in the emergency setting has evolved in two directions. First, ultrasound has expanded its reach and acceptance into the hands of more emergency physicians than ever before. Second, the indications for use of ultrasound have expanded; thus, there is more reason for ultrasound to be used by emergency physicians.

As directed by the “Model of the Clinical Practice of Emergency Medicine,” emergency medicine residents are now required to have bedside emergency ultrasound as a component of their education. In 2003, Counselman et al surveyed emergency medicine (EM) residencies and found that 95% teach bedside ultrasound in some form, and 89% possess a dedicated ultrasound machine.1 Bedside ultrasound is not presently a part of pediatric emergency medicine fellowship training, but as indications in pediatric patients expand so will the need for formal training requirements. A recent abstract by Chen and Santucci, using a survey of PEM fellowships, noted that only 39% of fellowships had access to and routine use of bedside ultrasound, with lack of expertise noted as the most frequent rationale for not performing ultrasound.2

Similarly, bedside emergency ultrasound has slowly permeated into community general emergency departments. In 2006, Moore et al reported that 19% of ED’s had an ultrasound machine immediately available, and an additional 15% had access to a machine in some capacity, according to emergency department directors.3 In this study, they reported that the most common applications were for trauma examinations, cardiac arrest situations, and to check for pericardial effusion.

As bedside ultrasound has entered emergency departments, physicians have found acceptance of ultrasound as an adjunct for emergency physicians. A survey of emergency department physicians in Ireland noted that 87% agreed that emergency physicians should be performing ultrasound in their emergency departments, though only 7% were presently using bedside ultrasound. Not surprisingly, only 20% of these physicians had formal training in emergency ultrasound, but 91% would support national guidelines to do so.4 Durham described several cases
of significant time savings and clinical benefit, specifically in cases of ectopic pregnancy, ruptured abdominal aortic aneurysm, and pericardial effusion. As would be expected, emergency physician-performed ultrasound eventually resulted in fewer formal radiology studies performed; though, interestingly, Jacoby et al observed a four year increase in formal studies after emergency ultrasound was introduced as physicians were confirming their findings as they became more experienced. The percentage of studies performed then decreased.

In general emergency departments, the most common indications for bedside ultrasound include blunt abdominal trauma, right upper quadrant pain, abdominal aortic aneurysms (AAAs), and first trimester pregnancies. As experience has increased, indications for ocular ultrasound, soft tissue infections and foreign bodies, deep vein thrombosis evaluations, central and peripheral line placements, and renal and bladder studies have also proven useful.

Pathophysiology
The “pathophysiology” of ultrasound must consider the physics of ultrasound and how it interacts with the body to provide diagnostic information. In the interest of promoting retention of this material, the goal will be to be brief while clear and useful.

Sound is a form of energy that is non-ionizing, and thus generally safe in use in vivo. “Ultrasound” is sound that is defined as frequency above 20,000 Hertz (Hz), with Hertz being the number of wavelengths of sound per second. The wavelength is the distance the sound wave travels per cycle. Medical ultrasound is most often used in the 2 to 12 MHz (million Hz) range. Ultrasound machines use a transducer to create and receive the ultrasound waves as they interface with the patient. Within most modern transducers, a burst of electrical current is applied to the collection of multiple piezoelectric crystals in its face, causing them to deform slightly and creating 2 to 5 wavelengths of sound in an ultrasound beam. As the beam is reflected, it returns to the transducer and the sound energy causes the crystal to again deform, creating electrical potential (the piezoelectric effect) that can then be interpreted by the ultrasound machine into an image. Furthermore, the ‘pulse-echo principle’ uses the amount of time the beam takes to return to the transducer to calculate the depth of the object that reflected it.

As ultrasound travels from one medium (or type of tissue), energy is reflected back primarily when it meets the interface with the next medium or tissue. This is the reason why ultrasound provides the best examination at these borders between tissues. Different tissues transmit the sound waves with varying efficiency. Liquids allow sound waves to travel well, and human tissue is mostly liquid in varying quantities. Liquid tissues, such as the bladder, gall bladder, and cysts, transmit the ultrasound beam well, and appear black on the monitor because there is little reflection (anechoic). Muscle transmits sound better than fat (and therefore reflects varying amounts of sound waves); calcified objects, such as bone, reflect the majority of sound waves. The former tissues create varying amounts of intensity on the image, and the latter create even more intensity. Air and fat are particularly prohibitive at obtaining ultrasound images because they do not transmit waves well. On the ultrasound monitor, when one object appears whiter than the neighboring tissues, the term ‘hyperechoic’ is used. Similarly, when the object is darker than the neighboring tissues, it is considered ‘hypoechoic.’ These terms are useful to describe the appearance of objects as they are examined.

As the ultrasound beam travels through the tissue, it progressively loses power, a concept termed ‘attenuation.’ High frequency transducers cause beams that are more unidirectional and focused with shorter wavelengths, so they produce high resolution images but attenuate more quickly and, thus, penetrate less deeply. These transducers are most useful for superficial studies, such as soft-tissues and small body parts. Conversely, lower frequency transducer beams are more multidirectional and have longer wavelengths. These attenuate less quickly and penetrate into the tissues better, and, as a result, provide imaging of deeper structures but with less resolution. These transducers are most useful for deeper structures, such as cardiac or abdominal.

There are many types of artifacts associated with the technology of medical ultrasound, and they are not all a disadvantage. While a description of each is outside the realm of this text, acoustic shadowing and mirroring are the most helpful in providing accurate evaluation of the images. Shadowing most frequently occurs when the sound beam encounters a reflective object and the majority of the beam is reflected back to the transducer and very little continues past the object. As a result, a dark ‘shadow’ that is hypoechoic behind the object can indicate that
the object is actually present. Mirroring occurs when objects appear to occur on both sides of a strong reflector. The sound waves pass through the more superficial object and are reflected back. The ultrasound machine interprets the reflected image as a mirrored image on the deeper side of the reflector. The most common use for this artifact is the mirrored image of the liver across the diaphragm, which is normal. Loss of the mirrored image indicates a change in the medium deep to the diaphragm, such as a pleural effusion, where there would normally be aerated lung.\textsuperscript{13}

The last concept important for this discussion is the different modes of ultrasound imaging. B-mode is the most common view; it is a two-dimensional image with the horizontal axis of the image representing the waves formed by the length of the probe, and the vertical axis representing the amount of time from pulse generation to echo reception (the presumed depth of the object in the tissue). The “B” is short for brightness, and, in this mode, the intensity of the object in the image demonstrates the amplitude of the echo.\textsuperscript{11, 12} M-mode, or the time-motion mode, simultaneously presents the B-mode image plus a waveform depicting the motion of the tissue on the vertical axis. (Figure 1) This is useful for such indications as documenting the movement of the fetal heart on first-trimester pregnancy scans.\textsuperscript{12, 13}

Doppler ultrasound is a newer and valuable tool with several forms. To be simplistic, as an object moves, the frequency of the ultrasound beam as it echoes is made higher if the object is approaching the transducer and lower as the object moves away (Doppler shift). Continuous-wave Spectral Doppler occurs by having a continuously energized ultrasound beam and is good for high velocity objects (like arterial blood flow), but cannot be controlled for depth. Conversely, Pulsed-wave Spectral Doppler occurs similar to B-mode and uses pulses of ultrasound beams, so the examination can be controlled for depth and is more effective for lower velocity objects (like venous blood flow).\textsuperscript{13, 15} Color Doppler allows for a visual interpretation of the Doppler-assessed movement of the tissue in question using colors. (Figure 2)

**Equipment And Cost Considerations**

This section of the text is best devoted to discussing the different types of ultrasound equipment available, and some of its nuances. Specific equipment choices and differences between manufacturers are dependent on the individual department needs and are beyond the scope of this article. Emphasis should be placed on the actual ultrasound machine, transducers, peripherals, and consumable equipment.

Most emergency physicians are now inundated with advertisements and mailings from a variety of ultrasound manufacturers. As the indications and wide-spread use of emergency ultrasound has expanded, so have the number of options for equipment. With regards to the actual ultrasound machine, perhaps the best way to stratify the machines is by size and price. Typically, the highest quality ultrasound machines used by radiology departments that have the most advanced technology with the most ability to fine tune the image are also very heavy and large; thus, they are not very portable or well suited for ED bedside evaluation.
and they cost over $100,000. In few cases is this equipment the appropriate choice for the ED; however, if such equipment were available as a ‘hand-me-down’ from another hospital department or other source, it would likely serve the purpose well. The next tier of machine is smaller, though it can still weigh hundreds of pounds. These continue to have many of the newer technologies and produce high-quality images, but can cost as much as $50,000 to $100,000. These are often popular choices in the ED for their relative portability and high-quality output. Lastly, the generation of portable ultrasound machines has brought simple bedside use, decreased cost (approximately tens of thousands of dollars, but can increase quickly with added probes), and has fewer adjustments to muddy the diagnostic waters, but somewhat less image quality.

In 2004, Blavias et al compared a middle-range machine with a portable ultrasound unit and noted small but statistically different image quality and resolution favoring the larger unit, but discussed that these differences were not likely to be clinically significant. Also important to note, this study was performed several years ago and, since that time, advances in technology for all types of ultrasound machines have likely improved quality. Today, most of the latest ultrasound technologies are available in the mid-range and portable units, though likely with less user-adjustable control; perhaps a good thing considering the typical pediatric ED utilization.

There are several types of ultrasound transducers available, and likely more than are generally necessary in the pediatric ED. As a gross generalization, typical ED transducers include curvilinear, linear, and mechanical sector transducers. Curvilinear transducers can come in several sizes and generally have ultrasound bandwidth ranging from 2 to 7 MHz. These are generally used for abdomen and chest ultrasounds. A challenge for the pediatric ED is the variety of sizes of patients; a large curvilinear transducer for adults and adolescents may be too large for toddlers, and, similarly, a smaller transducer would limit the field of view on a larger child. Linear transducers also come in several sizes and use high ultrasound frequencies of 5 to 10 MHz or beyond. These are generally used for soft tissue studies, vascular and line placement studies, and ocular exams due to their high resolution and shallow penetration. Lastly, endovaginal probes are mechanical sector transducers generally used for pelvic ultrasounds, but, as will be described, can have other purposes. Choice of transducers will be dependent on the needs of the pediatric ED, but, considering that each probe costs thousands of dollars, prudence and flexibility is probably warranted. In the Children’s Hospital Boston ED, we have invested in a larger curvilinear probe, a smaller curvilinear probe, and a linear probe, choosing to forego the endovaginal probe as our need for ED pelvic ultrasounds is relatively low.

Not surprisingly, there are several peripheral options available for these pieces of equipment. Options such as second or larger monitors may help with image evaluation, particularly in a teaching situation. Today’s technology generally has image data storage on some sort of digital format, and options will include hard disk, removable optical storage, such as CD or DVD, and removable memory chips. There is often an option for the equipment and software to download images directly to a personal computer or to a radiology computer system. There are also several types of printers that can be mated with these systems, each with their own strengths and weaknesses.

Lastly, consumable items, such as ultrasound gel, printer paper, and sterile probe sheaths used during invasive procedures such as line placement, are a must to maintain use of your investment.

### Differential Diagnosis

This brief section serves to give the reader an introduction to the different usage of emergency medicine...
ultrasounds, most of which will be discussed later in the text. (Table 1)

The introduction of the FAST exam was the first and most widely studied application to date. The purpose of the FAST, a rapid focused exam looking for free fluid/blood in an unstable patient, is to quickly determine the need for a laparotomy. Adult studies have shown the ability of EP’s to effectively perform the exam with sensitivities of 95% or more, and to reduce time to operative intervention to 64% of non-ultrasound patients.\(^1\) This appears less consistent in pediatric patients, where sensitivities between 30% and 100% have been reported.\(^2^0\)\(^-\)\(^2^5\)

These findings may be influenced by the fact that there is no established standard for what constitutes a positive study in pediatric patients.

In adults, a positive FAST in an unstable patient is a strong indicator for operative exploration.\(^2^6\) In pediatric patients, the presence of free fluid is much less of a factor in determining operative intervention, as most decisions are based on the amount of solid organ injury and serial exams. For the evaluation and grading of solid organ injuries or imaging of the retroperitoneal space, CT remains the study of choice.\(^2^7\)\(^-\)\(^2^8\)

The use of bedside ultrasound to rapidly detect and evaluate cardiac activity or screen for a pericardial effusion has been demonstrated in adult and pediatric studies,\(^2^9\)\(^-\)\(^3^1\) as has the effective use of US guided pericardiocentesis.\(^3^2\)

Ultrasound is the study of choice for the evaluation of first trimester pain/bleeding or ectopic pregnancy. It is rapid and safe, can be repeated as often as needed, and doesn’t risk unnecessary radiation exposure to the mother or fetus.\(^3^3\)\(^-\)\(^3^6\)

Flank pain is a common complaint in the ED, with renal colic being a frequent concern. In adults, up to 5% of the population might be affected by nephrolithiasis. The numbers in children, however, are much lower, with estimates between 1 in 1000 to 1 in 76,000 admissions; therefore, there is less potential for use.\(^3^7\)\(^-\)\(^3^8\) IVP was the original gold standard for diagnosis of renal abnormality until helical CT became widely available. The sensitivity and specificity of CT has been placed as high as 98% and 100% respectively, and it is able to provide detailed information about other structures outside the renal system.\(^3^9\) In a study by Palmer et al, US was shown to be less accurate, failing to detect calculi in 41% of pediatric patients.\(^4^0\) There have been reports of US use in combination with other tests or symptoms that suggest its value as a screening tool.\(^4^1\)\(^-\)\(^4^2\)

Certainly, with the increased availability of bedside US, its noninvasive nature, and its ability to give immediate feedback to those with experience, it warrants further research.

Doppler US is the current standard for testicular pain or pathology, especially when considering the diagnosis of torsion.\(^4^3\)\(^-\)\(^4^4\) The use of Doppler US by EPs has been described in a few case studies and reports. Those studies describe using Doppler flow to ascertain “no or reduced flow” (suggesting torsion), vs a “hyperemic testicle” (suggesting orchitis/epididymitis). The level of technical skill and knowledge required to perform this accurately currently remains a challenge to many EP ultrasonographers.\(^4^5\)\(^-\)\(^4^7\)

Ocular ultrasound is a relatively new application that became more practical in the 90’s with the introduction of high-resolution sonography. Its advantage in the ED is with rapid evaluation of ocular pathology, especially trauma, foreign body detection, and central artery/vein occlusion. A few case studies have described its use by EP’s in the diagnosis of elevated ICP by measuring the increased diameter of the optic nerve sheath.\(^4^8\)\(^-\)\(^5^0\)

The issue of bedside ultrasound for the diagnosis of appendicitis is a controversial one and beyond the scope of this article. A Medline search (November 2006) referenced over 500 articles addressing the accuracy, efficacy, and appropriateness of various imaging modalities with and without clinical indicators. A meta-analysis published in 2006 by Doria et al reported a sensitivity of 88% and 94% with ultrasound and 94% and 95% respectively for CT in pediatric patients.\(^5^1\) A single study by Chen et al described the accuracy of ED ultrasound in diagnosing acute appendicitis. In this Taiwanese study, published in 2000, bedside ultrasound findings by EP’s were compared to clinical impressions of surgeons. They reported a sensitivity of 94% and a specificity of 67% with ultrasound, compared to 86% and 37% by surgical bedside exam.\(^5^2\) Both ultrasound and CT offer advantages and drawbacks that will take further study to sort out.

Ultrasound guidance for suprapubic taps, vascular access, foreign body location, and even ETT confirmation has been described.\(^5^3\)\(^-\)\(^5^5\) The advantage of US over the traditional landmark process is the ability to directly observe the structure either prior to the procedure or in “real time.” In 2001, the AHRQ (Agency for Healthcare Research and Quality) published their report on patient safety.\(^5^6\) In it, they listed US guided central venous access as one of 11 practices that should be widely implemented. The
procedural use of US to accomplish crucial tasks may be one of the areas where bedside US becomes essential in pediatric EDs.

The diagnosis and successful incision and drainage of a peritonsillar abscess can be a challenge at any age, but especially so in children. The use of bedside ultrasound may provide valuable assistance and has been reported as early as 1993 by Haeggestrom et al. Blavis, in 2003, and Lyon, in 2005, described using an endocavitary probe (usually a 5 MHz) placed on the affected tonsil. Once the presence of an abscess was documented, along with its depth and proximity to carotid artery, a 14 to 18 gauge needle with a guard cut to the appropriate depth was inserted, and the abscess drained. The CT scan remains the standard for imaging of peritonsillar abscesses.

**Emergency Department Management**

**FAST**

One of the earliest uses of bedside ultrasound in the emergency department was in blunt trauma to the abdomen. Focused Abdominal Sonography for Trauma (FAST) is primarily designed to identify the presence of free fluid in the abdominal cavity, which, in the setting of blunt trauma, is likely to be blood. Because the trauma patient is generally supine, the free fluid is found in the most dependent areas of the abdomen. This technique has additional indications that will be noted later in the text, as identifying free fluid in the abdomen could have other strengths. For example, noting free intraperitoneal blood in patients with ectopic pregnancy, abdominal aortic aneurysm, or undifferentiated shock may alter diagnostic accuracy and expedite treatment.

The first use of ultrasound in abdominal trauma was a single view of the hepatorenal or Morrison’s pouch, inspecting for free fluid. There are now different methods to perform the FAST scan, with the classic and most commonly used being the four-view style. In this style, the four views are: 1) The right upper quadrant examining Morrison’s pouch between the kidney and liver for free fluid, 2) The left upper quadrant, examining for free fluid in the area of the spleen, 3) The subxiphoid view of the heart to identify pericardial effusion, and 4) The suprapubic region to identify free fluid around the pelvis and bladder. (Figure 3) Some institutions add additional views to the FAST scan (an ‘extended FAST’ scan), such as inspection of the pleural space.

![Figure 3: Most Common FAST Images](image-url)
for hemothorax and pneumothorax or the epigastric region for free air or fluid. There may also be a role for inspecting the organ closest to the free fluid more thoroughly to attempt to identify solid-organ injury, as is performed at some institutions.

There have been many publications regarding the use of ultrasound in the adult trauma patient. As a generality, the FAST scan has been found to have significant sensitivity for free abdominal fluid in blunt abdominal trauma patients, reported between 63 and 100%. There was also respectable specificity reported. In 1996, Pearl and Todd performed a prospective review of trials examining FAST scans and found multiple methodological concerns across the 11 included studies, raising the question of the validity of studies until that point. More recently, Stengel et al, in 2001, performed a systematic review of available literature and observed higher specificity but lower sensitivity than expected, resulting in unacceptably high post-test probabilities. In that study, there were concerns about study quality. In a repeat study in 2003, Stengel et al included more recent studies and observed slightly fewer quality concerns, but there continued to be high specificity and “insufficient sensitivity to reliably rule out intraabdominal injury.” Nevertheless, most trauma centers have found utility in using bedside FAST scan in blunt abdominal trauma patients as one of many diagnostic tools in the trauma evaluation, particularly in the hemodynamically unstable patient. Experience has also taught physicians several caveats to FAST scans. First, an empty bladder makes examination of the pelvis for free fluid more difficult. This is not an uncommon occurrence because of the frequent placement of Foley catheters. Thus, the bladder should be refilled with saline to obtain appropriate ultrasound windows. Second, free fluid in the pelvis of reproductive-age women in isolation may, in fact, be physiologic, and clinical correlation may be indicated. Third, the amount of free fluid in the abdomen will affect both the size of the anechoic stripe and the accuracy of the study. In one report, 400 mL of fluid artificially infused into an abdomen during diagnostic peritoneal lavage only presented with free fluid in Morrison’s pouch in 10% of cases, while 1000 mL caused visible free fluid in 97% of cases. Similarly, as the anechoic stripe in the different views was thickened, the diagnostic accuracy for FAST increased. Lastly, ultrasound is operator dependent, and increasing training and experience results in higher diagnostic accuracy. In one study, accuracy improved greatly after only ten studies performed by the physician. Also of note, FAST scans do not appear to be as sensitive for free peritoneal fluid in penetrating trauma, although the specificity in this abstract was 92%.

The FAST exam in pediatric blunt abdominal trauma may have a slightly different value than in adult patients. As a generalization, pediatric trauma patients do not suffer from as severe intraabdominal trauma, and recent trends in trauma care have tended to watch many children with mild to moderate injuries expectantly, rather than rush to the operating room. As a result, a hemodynamically stable child with a FAST scan that notes intraperitoneal free fluid may not be operated on, so the urgent triage that FAST offers may be less valuable.

Sensitivity and specificity appears to be less in the pediatric population than the adult population, with representative studies reporting sensitivities of 40 to 93% and specificities of 79 to 100%. Of note, studies that stratified their results by also reporting a subset of scans that evaluated for both free fluid and solid organ injury reported sensitivities of 65 to 68% and sensitivities of 70 to 99%. These were improved results when compared to the subset of patients examining for free fluid alone. Similarly, Suthers et al reported that FAST scan coupled with physical exam findings, noting abnormality in either, improved sensitivity for intraabdominal injury from 70 to 100%. Also, in the subset of thirteen patients that were hypotensive, Holmes et al reported that FAST scan correctly identified all seven patients who had intraperitoneal free fluid confirmed on CT or exploratory laparotomy, and similarly identified all six patients who did not have free fluid. It is difficult to compare the different studies because some were examining for free fluid alone while others were examining for any intraabdominal injury. This is notable as several studies make note of solid organ injuries without intraperitoneal free fluid, so a negative FAST scan for free fluid may miss significant injuries. Also, the studies varied in the definition of a ‘gold standard,’ with CT, exploratory laparotomy, and clinical observation all being used. In summary, a systematic review of eight studies of abdominal ultrasound in pediatric trauma reported a variable amount of accuracy but high specificity, so FAST scans may be a useful piece of the diagnostic tools used in these cases.

In this author’s opinion, there is an important role for the FAST scan in the work-up of a pediatric trauma patient.
trauma patient, particularly when they are hypoten-
sive. It is apparently not an appropriate lone tool,
but, when combined with physical examination and
clinical suspicion, may alter the care in certain cases
when early CT may not be appropriate or possible.
Baka et al used a questionnaire survey regarding
ultrasound use in pediatric versus adult patients and
reported that physicians caring for adults had ultra-
sound more readily available, that 92% found it very
useful in adult patients, and that 77% considered it
useful in pediatric patients. Only 57% of pediatric
emergency physicians surveyed perceived FAST as
useful in pediatric trauma evaluations. This result
is likely due to a combination of its weakness and
the relative lack of familiarity currently present in
the pediatric emergency community.

Critical Patients
The use of bedside ultrasound extends beyond the
radiology and emergency departments, and cardiol-
gy, urology, and intensive care units have found
unique uses for portable ultrasound units. As a
result, pediatric emergency medicine specialists can
explore this expertise for critical patients in the emer-
gency department.

As described in other sections of this text, ultra-
sound guided procedures, such as peripheral and
central venous access, bladder catheterization and
suprapubic aspiration, evaluation for pneumothorax
and pleural effusions, and evaluation of soft-tissue
infections, may all be useful in critical emergency
patients. While echocardiography also receives attention
elsewhere in this text, there is significant literature
on the use of bedside ultrasound in critical patients.
It is likely that the first use of emergency physician-
performed bedside echocardiography was in the car-
diac arrest situation to identify pericardial effusion
as a cause of asystole or pulseless electrical activity
(PEA) and to identify the presence of functional car-
diac motion, particularly in the face of PEA. As a
component of a FAST-style scan or a cardiac-specific
study, the evaluation of the pericardial space may
reveal effusion or pericardial tamponade from either
traumatic or non-traumatic causes. In 2003, Milner
et al reported on three cases of children with syn-
cope, hypotension, and altered mental status who
had pericardial tamponade on bedside ultrasound.
Of note, the cases included one case of acute trauma,
one case of syncope a day after trauma, and one that
was non-traumatic and likely due to viral pericardi-
tis. Lastly, the assessment of quality of cardiac
function, ventricular enlargement, and measurement
of the diameter of the inferior vena cava can be used
together in critical pediatric patients with concern for
hypovolemia, volume overload, and ineffective ven-
tricular activity due to causes such as myocardiitis.

Emergency patients with undifferentiated shock
(those in whom the cause of the shock is not yet elu-
cidated) represent a population who could benefit
significantly from bedside ultrasound. Because
shock has many causes, ultrasound can help differen-
teiate the gross mechanism of the illness leading to
their critical condition. The use of a FAST-style study
for this purpose can identify free fluid in the
abdomen or pericardium. Fluid in the abdomen may
due to previously unrecognized trauma, ascites,
or bleeding from a ruptured ovarian cyst or ectopic
pregnancy. In one case report by Pershad, a 10-year-
old girl with complaints of dizziness and abnormal
vital signs was noted to have free fluid in the
abdomen, soon attributed to a splenic laceration due
to a fall previously forgotten. Similarly, another
case report of two girls with symptoms of fatigue
dizziness (one also had abdominal pain) described the use of a FAST-style study, noting
intraperitoneal fluid later explained by massive hem-
orrhage from ruptured ovarian cysts. Lastly, a case
report describing a febrile, toxic-appearing seven-
week-old without obvious source of illness was
noted on a FAST-style scan to have no free intraperi-
teoneal fluid but gross hydrenephrosis, a right renal
hypoechoic mass, and a distended bladder. This
child’s sepsis was secondary to obstructive uropathy
and infection, caused by posterior urethral valves.

Bedside ultrasound in the critical patient is also
technically challenging and its limitations must be
recognized. These patients are often mechanically
ventilated, covered with bandages and tubing, and
are unable to be moved in positions that may make
ultrasound studies more effective and diagnostic. It
is unlikely that the use of bedside ultrasound will be
of benefit in every critical patient in the emergency
department, but the variety of diagnostic and ther-
apeutic indications and potential for clarifying the
cause of the undifferentiated shock makes the utility
of ultrasound in these patients obvious.

Ocular Ultrasound
Ocular emergencies or injuries are estimated to
account for 3% of all emergency department visits,
and ocular trauma is the cause for every third enucu
lation.\textsuperscript{48} Emergencies can range from blunt or penetrating trauma, to central artery/vein occlusion, to simple or complex infectious processes. However, rapid access to an ophthalmologist or advanced imaging can often be problematic and time consuming.

Eye injuries frequently result in swelling of the eyelid and may significantly limit an exam, especially in children.\textsuperscript{88} In addition, with some injuries, concerns about a possible ruptured globe precludes direct examination.

The use of ocular ultrasound was described in the 60’s and 70’s but didn’t come into common use until the 90’s, with development of high-resolution ultrasonography.\textsuperscript{89} Until recently, these studies have been performed almost exclusively by ophthalmologists.

In 2000, Blaivas published the first article describing the use of bedside ultrasound by emergency physicians.\textsuperscript{49} In it, he demonstrated that an EP could noninvasively evaluate a patient for vitreous detachment or the presence of a globe rupture and could rule out a retrobulbar hemorrhage. He followed up this report with a formal study two years later where 61 patients were evaluated for ocular pathology.\textsuperscript{48} Of the 61 enrolled, 26 (43%) were noted to have an abnormal exam, including penetrating globe injuries, retinal detachments, lens dislocations, central retinal artery occlusion, and vitreous hemorrhage or detachment. Eight EP’s (three attendings and five residents) participated and showed remarkable accuracy, with a sensitivity of 100% and specificity of 97.2%. The positive predictive value was 96.2%, and the negative predictive value was 100%. All ultrasound study findings were confirmed with orbital CT and ophthalmologic exam.

The technique described in these articles and ophthalmology texts is straightforward.\textsuperscript{48, 69, 85, 91} A large amount of gel is applied to the closed eye. This helps prevent direct contact with the eye, a concern with a possible ruptured globe, and enhances the image quality. A linear array probe (7.5 to 10 MHz) or specialized ocular probe is then applied and images obtained in the transverse and sagittal planes. Minimal power and gain settings are suggested due to the assumed increased levels of mechanical energy generated by spectral and color Doppler.\textsuperscript{92}

A recent Medline search (September 2006) revealed only a handful of studies or reports describing EP ocular ultrasound, only one of which involved pediatric patients.\textsuperscript{48-50, 93-96} In this study by Tsung, ocular ultrasound was used to measure optic nerve sheath diameter as a method of detecting elevated intracranial pressure in children with head trauma.\textsuperscript{93} This method of evaluation had been proposed in limited studies by Blaivas, Neulander, and Harbison, which were based on research published in ophthalmology and neurosurgery journals.\textsuperscript{97, 98}

The use of bedside ocular ultrasound in the pediatric or adult ED is still in its early stages of development. It has the potential to provide rapid answers to questions concerning ocular pathology as well as some intracranial pathology. The real question is whether this application can spread to a general ED setting and how much advanced equipment and training will limit it.

For a comprehensive review of the pediatric patient with an ocular injury, see the Pediatric Emergency Medicine Practice November 2006 article titled, “Ocular Trauma: An Evidence-Based Approach To Evaluation And Management In The ED.”

**Cardiac**

Emergent bedside echocardiography by emergency physicians has become more common in adult settings and has been reported in a few pediatric settings.\textsuperscript{30, 82} The indications for this procedure are similar to those recommended for adult patients: Diagnosis of pericardial effusion and evaluation of pulseless electrical activity and cardiac arrest. In addition, bedside ultrasound has been described in the evaluation of shock in pediatric patients.\textsuperscript{34}

Bedside echocardiography is a rapid, noninvasive tool that detects and possibly reverses critical conditions. Its use is supported as part of the FAST

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**Figure 4: Ocular Image Demonstrating Measurement Of Optic Nerve Sheath**

(A = Anterior chamber, R = Retina).

Courtesy of Dr. Audrey Le, LBCMCI, Memphis, TN.
exam in the Advanced Trauma Life Support (ATLS) course by the American College of Surgeons as well as the Pediatric Advance Life Support (PALS) program of the American Heart Association.99,100

**Technique:** The single subcostal (subxiphoid) view is the most common to EPs and the one included in the ATLS and PALS courses. This view is particularly useful for evaluating pericardial effusions and cardiac standstill. Two additional views, the right and left parasternal views, are sometimes obtained to provide additional information regarding cardiac function.

The standard subcostal view involves placing the transducer in the subxiphoid area and aiming it superiorly and towards the patient’s right shoulder. The notch is also oriented to the patient’s right. This orientation puts the right ventricle at the top of the screen followed by the right atrium and left ventricle. This view is often easier to obtain in young children due to their thin abdominal wall. If the transducer is rotated to the right, the inferior vena cava can be visualized. This view shows left sided structures on the right hand side of the screen, which is opposite of the standard cardiology images.

**Pericardial Effusion:** Echocardiography has become the procedure of choice for detecting pericardial effusions.101 Through the subcostal view, the effusion appears dark and easily identifiable. (Figure 5) The extent of the effusion and its effect on cardiac function can be immediately assessed, as can the effects of a guided pericardiocentesis.

The benefits of immediate, noninvasive visualization of the pericardium were dramatically demonstrated in Plummer et al’s study of 49 patients with penetrating cardiac trauma.102 In his study, 28 patients were emergently imaged with a 100% survival rate of the echoed group, compared to 57% of the non-echoed group. The time from diagnosis to surgery dropped to 15 minutes versus 42 minutes for the non-echo group. This study served as a prime example of the benefit of 24/7 bedside ultrasound and is often cited when requesting bedside ultrasound by EPs.

The adult literature contains numerous examples of the ability to detect and intervene utilizing echocardiography.103-105 Tsang et al reviewed echo guided pericardiocentesis in adults and found an 89% success rate with first attempt, an overall success of 97%, and a major complication rate of only 1.2%.32

**PEA And Cardiac Arrest:** Asystole and bradycardia are the most common serious resuscitation situations faced in the pediatric ED and are usually secondary to respiratory failure.106 However, along with asystole, PEA and pulseless VT or VF are reversible in the pulseless child. The use of echocardiography has been recommended to distinguish between “true” vs “pseudo” PEA.100 The presence or absence of which may serve to direct the resuscitative efforts.

In adult patients, Bocka et al utilized echocardiography to show that “synchronous myocardial wall motion” was in fact present in patients with PEA.107 Amaya and Langsam were able to identify VF, a condition which may respond to counter shock.108 The lack of cardiac activity on direct exam is also potentially predictive of ultimate outcomes. Salen et al looked at this in combination with capnography to show that only 3% of those without cardiac activity survived to admission. The underlying conditions of those with activity consisted of PEA, VT, and VF.109 In Blaivas and Fox’s study, none of the patients with absent cardiac activity survived their ED course.110

While this has not been directly studied in pediatric patients, these findings may be directly applicable to resuscitative decision making, especially once respiratory issues have been addressed.

**Undifferentiated Shock:** Patients presenting in shock, whether pediatric or adult, are a true dilemma. As described earlier, the differential is broad and may include hypovolemic shock, cardiogenic shock, distributive shock, or neurogenic shock.100,106 The determination, assessment, and response to interventions often has to rely on secondary methods, such as
physical exam or chest radiography. The use of invasive central venous pressure or pulmonary artery monitoring to direct and adjust treatment of shock and sepsis has been shown to be of benefit. Echocardiography has been used to evaluate critically ill patients to accurately detect cardiac output when compared to invasive monitoring. This has also been demonstrated in pediatric ICU patients.

Cardiac Function: The ability of EPs to accurately perform more advanced echocardiographic studies has been described in both the adult and pediatric literature. In Moore’s study, EP’s received six hours of goal directed training along with ten hours of observation and were able to obtain an 84% agreement with reviewing cardiologists of left ventricular function (LVF). Randazzo reported 86% overall agreement of LVF and 70% CVP, when compared to formal echo studies, after only three hours of training focusing on LVF and CVP.

The single reported pediatric study by an EP evaluated the ability of an EP with goal directed training to accurately assess LVF and IVC diameter. This study involved a single investigator who underwent three hours of directed training along with five proctored exams. The study was conducted in a pediatric ICU and enrolled 31 patients with a mean age of 5.1 years and a range of 23 days to 16 years. The focused echo performed by the EP was followed by a formal echo by a sonographer, completed within 60 minutes of the original. The studies were evaluated in blinded fashion with good agreement for estimation of the LVF (via shortening fraction r = 0.78, P < .001). There was a 4.4% difference between the EP and sonographer that was statistically significant (P = .003). The IVC estimates demonstrated good agreement (r = 0.8, P < .001), without statistically significant differences.

While this study and the others cited are encouraging, the small numbers, limited locations, and amount of training described leave the routine use of this procedure for emergent hypotension in question.

Bladder Ultrasound
Bedside ultrasound for examining the genitourinary system is well known and used in other aspects of medicine for many purposes. In the emergency department, ultrasound evaluation of the bladder is most commonly used to assist with obtaining urine for diagnostic or therapeutic purposes.

Historically, urine collection for analysis was performed by suprapubic aspiration (SPA) in a majority of patients, due to the belief that it was the least complicated by contamination. Unfortunately, blind SPA has a success rate of only 50%; thus, ultrasound was introduced as an adjunct. Early studies first confirmed the presence and volume of urine in the bladder, noting improved success at SPA to 79 to 90%. Ultrasound was then used to guide the SPA procedure with similarly good results. More recently, Aguileria et al described the use of ultrasound guidance in placing suprapubic cystostomy catheters in the emergency department in adults who required longer term bladder drainage due to urinary retention.

Because common practice has promoted the use of urethral catheterization in most patients, several studies have examined the use of ultrasound to confirm the presence of adequate urine volume in the bladder. Unsuccessful catheterization due to insufficient urine volume in the bladder may result in additional catheterizations to obtain adequate urine for study, and repeated catheterization increases the risk of traumatic injury or introduced infection. Therefore, the use of ultrasound to ensure successful catheterization should result in less discomfort and fewer complica-
tions of a frequently used procedure. These studies used slightly different definitions of adequate urine volume (2 to 5 mL) and different, although overlapping, ultrasound measurements, but two demonstrated that the ultrasound resulted in an increased success rate of urine catheterization and the third reported successful prediction of adequate bladder volume.53, 124, 125

Although not as frequently used in the pediatric emergency department, there is a large body of literature describing the use of ultrasound to identify the presence of urine in the bladder of patients with neurologic disease or spinal cord injury to avoid unnecessary catheterization, rather than using scheduled catheterizations. It is also useful in identifying post-void residual bladder volume, rather than using bladder catheterization.126

Used more frequently in the adult population than the pediatric population, ultrasound examination of the remainder of the genitourinary tract is useful in some patients. Ultrasound of the kidneys can identify hydronephrosis in cases of kidney stone or vesicoureteral reflux.41 Abnormalities such as abscesses or changes in the texture of the renal tissues may also be observed.127

OB/GYN
Female patients presenting with abdominal pain are an everyday occurrence in EDs. The differential is extensive and often problematic and becomes even more so with pregnancy.128 The ability to conclusively separate a possible surgical problem from a nonsurgical one is difficult based solely on physical exam, and some type of imaging is frequently ordered. Currently, ultrasound is considered the best method for initial imaging of female patients with abdominal or pregnancy related pain.

There are two approaches to pelvic ultrasound exams: Transabdominal (TA) and transvaginal (TV).129 Transabdominal sonography (TAS) is typically performed with a 2.5 to 5.0 MHz curvilinear probe and is initially placed just above the symphysis pubis and angled inferiorly in order to visualize the bladder. This is best done when the patient’s bladder is full and gives a broad view of the pelvis. Endovaginal Sonography (EVS) utilizes a specialized high frequency probe (7 to 10 MHz) inserted either transvaginally or transrectally.

The ability of EPs to perform bedside pelvic ultrasound has been discussed since the late 90’s.130 Currently, 78% of emergency medicine residencies report specific training in transabdominal exams and 59% report transvaginal training.131 Most ultrasound training courses present the transabdominal approach and it is probably the most familiar to EPs. The most immediate question that faces an EP is: “Where is the pregnancy – intrauterine or ectopic?” This is accomplished by either finding an intrauterine pregnancy (IUP) or evidence of an ectopic one. Although not absolute, the possibility of a heterotopic pregnancy (IUP and ectopic simultaneously) is extremely rare, with estimates ranging from 1 in 3889 to 1 in 30,000; for screening purposes, an IUP can serve to rule out an ectopic.132, 133 This is not true if fertility agents have been utilized, as the incidence of heterotopic pregnancies is reported at approximately 1.5%.133-135 These patients are at a high risk and require a complete formal pelvic ultrasound.

An intrauterine pregnancy can be confirmed by TAS at around five to six weeks by observation of the yolk sac, and the fetal pole by six to seven weeks. A cardiac flicker, within the fetal pole, can be seen at seven to eight weeks.136 The use of EVS allows detection about a week sooner and provides higher quality images.137 Any of these findings should help confirm an IUP.

<table>
<thead>
<tr>
<th>Gestational Age</th>
<th>B-hCG</th>
<th>TV ultrasound</th>
<th>TA ultrasound</th>
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<tbody>
<tr>
<td>5 weeks</td>
<td>1,000 to 2,000 mIU/mL</td>
<td>Gestational Sac</td>
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</tr>
<tr>
<td>5 to 6 weeks</td>
<td>Greater than 2,000 mIU/mL</td>
<td>YS +/- FP</td>
<td>Gestational Sac</td>
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<tr>
<td>6 weeks</td>
<td>10,000 to 20,000 mIU/mL</td>
<td>FP + FH</td>
<td>YS +/- FP</td>
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<tr>
<td>7 weeks</td>
<td>Greater than 20,000 mIU/mL</td>
<td>FP with fetal parts</td>
<td>FP + FH</td>
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(YS = Yolk Sac, FP = Fetal Pole, FH = Fetal Heart).
With the progression of the pregnancy, other features can be determined. Measurements of crown-to-rump and femur length can be made to determine gestational age and fetal heart tones can be recorded and measured. The heart rate for a fetus 5 mm is 100, 5 to 9 mm is 110, and 10 to 15 mm is 120. Fetal movement as well as major organs and structures can be noted.

According to the Morbidity and Mortality Weekly Report, the reported incidence of ectopic pregnancies in North America is 19.7 per 1000 and accounts for approximately 2% of all reported pregnancies. The report also noted that ectopic related deaths represented 9% of all pregnancy related deaths. On ultrasound, the finding of an empty uterus with free pelvic fluid suggests an ectopic, but the diagnosis is made when a gestational sac with a yolk sac or embryo is found outside of the uterus. If more than 400 mL of fluid is noted in Morrison’s pouch, a ruptured ectopic is likely and is a surgical emergency. The ability of EPs to rule out an ectopic in or out has been reported to be between 90 to 100% sensitive and 88 to 95% specific. Rodgerson et al reported the benefit of EP bedside ultrasound in 2001. They compared time to diagnosis and time to surgery for patients with ectopics that received ultrasound by EPs to those by radiology. The average time to diagnosis was 58 minutes for the EP group vs 197 minutes for the radiology group. The time to surgery was equally dramatic at 111 minutes for the EP group and 332 minutes for the radiology group.

The utility of pelvic ultrasound by EPs for non-pregnant patients has yet to be determined. The true emergent conditions of ovarian torsion, pelvic abscess, and ruptured ovarian cyst are limited and require significantly higher levels of skill, training, and experience.

Trauma in pregnancy has been reported to account for up to 50% of maternal deaths, and 6 to 7% of all pregnancies are complicated by trauma. Fortunately, less then 0.5% need hospitalization. As in the general population, blunt trauma is the most common cause of trauma in pregnancy. The use of ultrasound is an ideal screening tool, as it is noninvasive, quick, and imparts no radiation. A FAST exam, looking for free fluid, can be obtained, followed by a quick assessment of the gravid uterus to note fetal cardiac activity as well as an estimate of age. The exam can be performed with the same 3.5 to 5 MHz probe, saving time and possibly providing information needed for emergent care.

**Soft Tissue Ultrasound**

Inspection of the soft tissues is a newer application of emergency bedside ultrasound and shows great promise in improving outcomes. Using higher frequency linear probes (8 to 10 MHz), high resolution images of superficial tissues can be used to identify foreign bodies, abscesses, or soft tissue changes with inflammation. This application is of great significance in the pediatric emergency department, as children are often subject to skin infections and wounds, foreign bodies are often present, the patient may not be able to communicate their concern, and inadequate treatment can result in significant long term morbidity.

Because these foreign bodies are often very superficial and closer to the probe than the typical focal zone, adjuncts are often used. ‘Spacers’ or ‘Stand-offs’ are one technique to increase the hypochoic distance from the probe to the object in question, using commercial products or make-shift stand-offs by filling a glove or other sac with water and expelling all air (which would be hyperechoic and confuse the image). Another technique useful for the hand is to place the extremity in an emesis basin of water, and then place the probe on the surface of the water; thus, the water is acting as a stand-off. One case report also acknowledged the possibility of an ED not having a linear probe best suited for these studies, but used a high-frequency vaginal probe with a make-shift stand-off to identify a wooden foreign body from a child’s foot.

Retained foreign bodies in wounds are frequent and, if not removed, can result in significant infection, disability, and pain, as well as increased costs, medical visits, and surgeries. Furthermore, missed foreign bodies continue to be a leading cause of medical malpractice claims against emergency physicians. For that reason, the emergency physician must attend to wounds with vigilance, and ultrasound may play an important role. Traditionally, plain radiography is used when there is a concern of foreign body; however, the foreign object must be radio-opaque and large enough to be visible. These limitations result in some foreign bodies being missed, particularly those made of wood or plant matter and some plastics. One study reported that patient perception of a foreign body tends to overestimate the frequency of actual foreign body presence, but also increases sensitivity when combined with ultrasound as compared to plain radiography.

Foreign bodies on ultrasound tend to demonstrate a foreign body; however, the foreign object must be radio-opaque and large enough to be visible. These limitations result in some foreign bodies being missed, particularly those made of wood or plant matter and some plastics. One study reported that patient perception of a foreign body tends to overestimate the frequency of actual foreign body presence, but also increases sensitivity when combined with ultrasound as compared to plain radiography.

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comet-tail artifact in addition to the observed hyper-echoic body. Studies using ultrasound to identify suspected soft tissue foreign bodies first used in vitro models, such as beef cubes, with high sensitivity and specificity. Ultrasound use in vitro demonstrates a varying amount of sensitivity and specificity, likely dependent on operator experience, that approaches or exceeds 90%. Two separate reports recommend the combined use of plain radiography and bedside ultrasound, as together they increase the sensitivity over either alone.

A special comment should be reserved for the use of ultrasound of wooden foreign bodies. Within the soft tissues, wood is extremely inflammatory and tends to appear as a hyperechoic foci with posterior acoustic shadowing and surrounding hypoechoic halo. The awareness of wood having different ultrasonic appearance may assist in identifying the foreign body and prompt removal.

In cases of clinically apparent cellulitis, bedside ultrasound has been found to change management in cases towards more aggressive and less aggressive care. In a study by Squire et al, the diagnostic sensitivity of clinical examination was compared less favorably than ultrasound (86% versus 98%), as was the specificity (70% versus 88%). A more recent study by Tayal et al noted that ultrasound altered the management of cellulitis in 56% of cases. In cellulitis clinically thought to not need further drainage, 48% actually required drainage, further diagnostics, or consultation. Similarly, in cases thought to require drainage, ultrasound altered the management in 73%, with half of those cases eliminating drainage and the remainder having further diagnostics.

Interventional Ultrasound
Establishing central or peripheral vascular access in infants and children is a challenge, even in the best of circumstances. Compared with the traditional landmark-based practice, bedside US has the potential to significantly improve the speed and accuracy of vessel cannulation. Additionally, the AHRQ recommends its use.

To date, there have been only a few studies of ultrasound-assisted venous access in children. All of the trials were limited by small sample size (42 to 149 patients), were conducted by either pediatric anesthesia or cardiology, and did not include emergency department patients. The studies by Anderson and Vergheze were utilized in the 2003 NICE meta-analysis and showed an 85% relative risk reduction and 73% reduction in complications. Anderson reported a 100% success rate with US compared to 80% via traditional landmark use. Liberman et al also reported a 100% success rate in their case study of 45 patients undergoing electrophysiology studies. Leyvi et al conducted a comparison consisting of 149 patients, the largest to date. In this non-randomized study, the overall success rate for US guided cannulation was 91.5% vs 77.8% in the landmark group. Of note in this study was the drop in success rate for both US guided (77.8%) and landmark guided (60.9%) for infants less than one year of age.

The most recent study to date was conducted by Grebenik et al who prospectively studied the use of ultrasound guided central venous access based on the NICE guidelines. There were 124 infants and children enrolled in the study and patients were randomized to either the US guided arm or the landmark guided arm. Their findings were strikingly at odds with other studies that reviewed and reported better success rates with landmark guided cannulation (89.3%) vs US guided (78%). They also reported that arterial puncture rates were higher in the US group (11.9%) than in the landmark group (6.2%).

Ultrasoundography is most commonly used in the cannulation of the internal and external jugular veins, the subclavian vein, the femoral vein, and the brachial and cephalic veins, although theoretically any visualized vein could be cannulated. The two main methods of ultrasound guided venous access (the indirect and direct methods) are described as follows.

**Indirect Method:** The indirect method is more commonly used than the direct method and provides less true “guidance.” Once the vessel has been located with US, make a mark that corresponds to the vessel’s location beneath the surface on the skin. The optimal situation is usually one in which the mark is between the center of the transducer and the center of the vessel of interest. Before proceeding with cannulation, conduct a “compression” test (one in which the operator applies light pressure to the transducer) to confirm that the vessel is a vein (which easily compresses) rather than an artery (which resists compression). The indirect method requires only one person to perform it and does not involve any special preparations or equipment, such as a sterile transducer sleeve or sterile gel.

A variation of the indirect method is one in which two marks (one proximal and one distal,
about 1 cm apart) are made on the skin above a vein that was located by US and whose identity was confirmed by the aforementioned compression test. This approach allows the person attempting cannulation to “connect the dots.” When performing this variation of the indirect method, place the patient in the appropriate position for cannulation before the vessel is marked. Any movement after marking will change the location of the vessel.

**Direct Method:** In the direct method, US is used to directly visualize the placement of the needle in “real time.” This method can be done with one or two operators, and requires different preparation and equipment than does the indirect method. First, roll up a sterile sheath or cover whose tip is filled with transducer gel over the probe and secured. Take great care to ensure that the gel contains no air bubbles, which can distort the image. If necessary, use a sterile glove as a substitute. Place the transducer over the selected area and locate the vessel. If the image of the vessel is centered on the monitor’s screen, the transducer can function as the directional guide. Once the skin is punctured, the needle can be visualized by its “ring-down” effect. Just before the needle enters the vessel, it will appear to “tent” or become temporarily deformed.154, 165

The US transducer used to guide cannulation of a central or peripheral vessel should be a high-frequency (7.5 MHz) linear one. If unavailable, then the available probe with the highest frequency and smallest footprint should be selected. If a convex or curvilinear transducer is used, the image will be pie-shaped and its edges distorted. The orientation of the transducer (longitudinal or transverse) is a matter of preference and procedure. The longitudinal orientation gives information about depth and slope and helps with needle orientation, whereas the transverse orientation provides information about structures surrounding the vessel of interest.

The use of US to guide IV access is one of the most practical examples of the potential use of US to directly improve pediatric ED care. The possibility that this application could positively address the problem of obtaining IV access in pediatric patients is exciting, especially to the staff and parents who struggle with this daily. Studies directly addressing peripheral venous access are rare.162, 164, 166-168 Keyes et al were the first to demonstrate successful use of ultrasound to guide peripheral venous access. Her group reported an overall success rate of 91% and a first attempt success of 73%. The mean time for cannulation of the deep brachial or basilic vein was 77 seconds.164

In their 2005 study, Constantino et al prospectively studied the success rate of peripheral venous access utilizing US guidance vs the traditional landmark approach. They enrolled 60 patients who either had failed IV access by experienced nurses after three attempts or had a history of difficult access. The success rate for the US guided group was 97% vs 30% of the landmark group. In addition, the time to access of the US group was 13 minutes vs 30 minutes for the landmark group. They also reported fewer punctures and greater patient satisfaction with the US guided approach.166

The single pediatric study is an abstract by Bair, Rose, and Kupperman in 2005. This abstract describes a randomized trial of 44 children ages seven or younger that required IV access and had one failed attempt. Patients were randomized to either the US guided group or continued traditional methods. The ED physician localized the vein and the nurse made a mark on the skin. Cannulation was attempted utilizing this mark. The first-attempt venipuncture rate for the US group was 57% (13 of 23) and first-cannulation rate was 35% (8 of 23). These were similar to the traditional approach of 57% (12 of 21) and 29% (6 of 21), respectively.162

A similar study involving adults was conducted by Brannam et al. In this prospective, observational study, experienced ED nurses received a 45-minute lecture followed by hands-on practice utilizing a model. There were 321 patients enrolled, with an 87% success rate utilizing US. There were 41 (13%) that failed placement and 12 of those went on to require a central line. The rest of the patients eventually had access obtained by another nurse or physician, using US as a guide.168

**Fluid Collections:** Ultrasound is an ideal tool for assessing many of the abnormal fluid collections that present to the ED. It is noninvasive, quick, painless, and when performed at bedside, provides immediate answers. If a sonographic approach is feasible, then abnormal fluid collections from superficial skin abscesses to joint effusions to pericardial effusions can be addressed.

**Pericardial Effusion:** Pericardial effusions or tamponade are critical life threatening situations that often require immediate attention and intervention.
The signs and symptoms described by Beck of muffled heart tones, hypotension, and jugular venous distention are not specific enough to rule in or out an effusion and are present in only 40% of adult patients. The use of emergent echocardiography by EPs to detect pericardial effusions with efficiency and accuracy has been presented in several articles.

Pericardiocentesis has been traditionally taught and performed in a “blind” subcostal fashion based on landmarks. Complication rates as high as 50% have been described in some studies. The use of US guided pericardiocentesis has been described as long ago as 1985. More recently, Tsang et al described their experience over 21 years at the Mayo clinic with a success rate of 97% and a complication rate of only 4.7%. This article also provides a detailed description of performing the procedure. A similar study by Tsang et al, with pediatric patients, showed a success rate of 99%. The ability to directly visualize an effusion and guide a needle to relieve it is a major advantage over the traditional blind approach and has immediate applications in emergency medicine.

Thoracentesis, Paracentesis And Joint Effusions: The use of ultrasound to detect and guide aspiration of pleural effusions, peritoneal effusions, and joint effusions has been described. Most of these studies have been conducted outside the ED, either in the ICU or radiology. There are a handful of reported cases or studies by EPs. Valley and Summer described a guideline for the use of bedside US to detect joint effusions, while, in 1999, Smith presented a case of hip aspiration. Blaivas described the use of bedside ultrasound to perform a successful paracentesis in six critically ill patients. Despite the potential that US offers, very few ED oriented studies have been conducted.

Endotracheal Tube Confirmation: The use of ultrasound to confirm the placement of an endotracheal tube was initially described in the late 80’s. Two of these studies, Slovis and Poland and Lingle, described ETT confirmation in neonates by comparing tube position in relation to the aortic arch. In 2000, Drescher et al utilized cadavers with live controls to demonstrate the utility of bedside US to confirm placement. They provided a detailed description of the imaging process utilizing a high frequency probe, and described the hyperechoic shadowing or “comet tail” appearance of an intubated trachea.

In an abstract published the same year, Ma et al described a double-blinded cadaver study with a reported sensitivity of 97% and specificity of 100% in identifying esophageal intubations. In 2004, Hseih et al and Chun et al were able to confirm endotracheal tube placement and depth in pediatric patients by observing the symmetry of diaphragmatic excursion. In a recently published study, Weaver et al conducted a larger cadaver study (68 intubations) evaluating the effectiveness of the “sliding lung sign” which is the movement of the visceral and parietal pleura on each other with lung expansion. They reported a sensitivity of 95.4% to 100% and a specificity of 100% for determining esophageal versus tracheal intubation.

Galicinao et al conducted a two phased study of pediatric intensive care patients and emergency department patients to determine the utility of bedside ultrasound for confirmation of ETT placement. They reported confirmation of ETT placement in 49 of 50 phase I (Pediatric ICU) patients and in 50 of 50 phase II (ED) subjects. They noted that two views were needed for accuracy: The transverse view with the “comet head and tail” and the longitudinal view.
Ten Pitfalls To Avoid

1. Forgetting about the physics of ultrasound.

The physics behind medical ultrasound play a role in probe selection, image adjustment, presentation of artifacts, and, ultimately, the interpretation of the image. While the ultrasonographer needn’t be doing mental calculations, proper image interpretation requires keeping some concepts in mind.

2. Overutilization, underutilization, or just forgetting about artifacts.

Some artifacts can be used to help interpret the image obtained, while others can lead to misinterpreting the image. Knowing the difference and how to use them to your advantage is a key in ultrasound.

3. Misunderstanding your equipment.

The adjustments on the ultrasound machine are not for touching randomly. Every image requires a certain amount of adjustment to optimize it to be the most valuable for medical decision making, but, as the ultrasonographer becomes more savvy, the amount of misdirected button pushing will decrease.

4. Assuming your skill is too strong.

While enthusiasm to perform ultrasound is our goal, increasing experience will result in better images that are more useful. Making decisions on your studies before you have performed enough to be experienced can result in unacceptable inaccuracy. There is not firm agreement on the number of studies of a particular type required to gain proficiency.

5. Limiting your use of ultrasound to studies you are most comfortable.

One goal of this article is to discuss many of the indications for emergency bedside ultrasound. It is not uncommon for clinicians to feel comfortable with one or two types of studies, and then not expand their skills to other uses of ultrasound. Some departments only use bedside ultrasound for FAST scans and line placement when many other uses may benefit both the clinician and the patient.

6. Forgetting to trust your clinical instinct, instead focusing on your diagnostic ultrasound.

While some feel that bedside ultrasound can become an extension of the emergency physician’s hand, or at least an indispensable tool, it is only a piece of the clinical evaluation of a patient. Don’t let ultrasound supersede your clinical suspicion.

7. Forgetting that FAST scans do not have the same predictive value in children as in adults.

As emergency department and operative care of abdominal trauma has evolved in both adult and pediatric patients, the utility of FAST has proven less valuable in children. While it is not unreasonable to use it in your abdominal trauma patients, it may not have the same predictive value as in adults.

8. Not garnering the support of associated departments in your institution who may make or break your efforts

Although ultrasound is another technology that has been adopted and even improved by emergency medicine, it is amazing how many roadblocks can be placed by administration, radiology, and other forces. Planning, communication, and patience are all required for success.

9. Inadequate quality control and continuing education.

For success to continue once you’ve established your program, your staff must hone their skills, participate in continuing education, and maintain an effective quality control system to monitor the success of the program.

10. Now that your group is technically comfortable with ultrasound, neglecting to start billing for your services.

You are performing a diagnostic study and interpreting that study. While limited in its scope and by no means a formal study that the radiology department would perform, it is a billable procedure and you should be reimbursed for your skill.
showing two bright parallel lines of the ETT. The patient population ranged in age from 1 day to 17 years, and sensitivity and specificity were 100%. An additional finding was the time to confirming CXR (14 minutes) vs time to bedside US (17.1 sec). While it is not expected that bedside ultrasound will immediately replace traditional methods, it does provide additional benefits as a secondary method of confirmation or in prehospital or disaster situations.

Controversies & Cutting Edge

Emergency medicine is no stranger to controversy, as demonstrated by its initial struggle to be recognized as a distinct entity. In the same way, the introduction of bedside ultrasound into the ED has faced, and continues to face, challenges and a lack of acceptance by some specialties.

Despite the initial objections, bedside ultrasound has slowly grown in use to the point that it is now considered a critical component in emergency medicine training. As of 2003, approximately 95% of EM residencies required some type of training in bedside ultrasound. The same is not true of pediatric emergency medicine programs where there is currently no requirement for training.

Even though bedside ultrasound is generally accepted as a useful and even critical EM resource, it is not universally available. The use of bedside ultrasound in academic emergency departments is estimated to be around 92%. However, Moore, Molina, and Lin’s recent survey of community emergency departments revealed that 66% had no access and only 19% had exclusive access in the department. There are currently no estimates of bedside ultrasound use in pediatric emergency departments.

The process of acquiring training, gaining experience, and eventually establishing a program can be a daunting one even without the controversy and possible opposition by other departments, but, with some planning and perseverance, it can be achieved. Three broad components make up a viable program: Training and education, program development and credentialing, and quality improvement with coding and billing.

Where can I obtain training and how much do I need?

In 2001, ACEP published a policy statement that included pathways for ultrasound training. This policy established a dual pathway for ED physicians, one for residents, and the other for practicing physicians. The residents would participate in an established program with pre-defined components, supervision, and evaluation based on ACEP and American Board of Emergency Medicine (ABEM) guidelines. The practicing physician may attend a recognized training course and then perform studies under supervision with over reads until proficiency is obtained. Heller et al presented a consensus statement on incorporating ultrasound training into residency training and also included general guidelines on instruction, equipment, and experience that served as guidelines for program development in any setting.

A two-day comprehensive course that focuses on the primary applications of trauma ultrasound (FAST), pregnancy (ectopic and fetal cardiac movement), limited cardiac (arrest and shock), abdominal (AAA detection, biliary, and renal), and procedural ultrasound is desirable for those looking for an initial introduction. These courses are now offered routinely by national and regional professional organizations, at national conferences, by private groups, as well as by some equipment manufacturers. A web search easily returns multiple hits, and professional journals routinely list two to three courses a month. It is important that the course is one that provides a good overview of the basics of scanning along with the “knobology,” as well as hands on training, and that it meets the requirements for initial training published in ACEP’s Emergency Ultrasound Guidelines. Scanning experience on live models is essential for individuals starting out and should weigh heavily when selecting a course.

Single day courses may be an option for some if they are focused on a single subject like the FAST exam, OB, or procedures. The use of live models or advanced simulators is an important consideration.

How much experience is needed?

The amount of experience required to perform a “focused” exam is almost as controversial as whether it should be performed at all by non-sonographers. The American Institute of Ultrasound in Medicine proposed that 100 hours of diadactic instruction along with 300 studies be required, a number not likely to be achieved by a non-radiologist. The ACEP Emergency Ultrasound Guidelines of 2001 recommended a minimum of 25 practice exams per application or at least 150 exams, while the Society for Academic Emergency Medicine (SAEM) proposed 40 hours of teaching along with 150 exams. Both of
these were based on consensus, not evidence. A study by Mandavia et al indicated that EM physicians could achieve a high degree of accuracy (94%) with only eight hours of course work and eight hours of hands on training. Lanoix suggested that accuracy could be accomplished with as little as four hours of training. Clearly, this question has yet to be answered definitively. Numerous studies over the last ten years have demonstrated the ability of non-radiologists to perform focused ultrasound exams. Like any skill that requires a pairing of knowledge and experience, a number is less important than demonstrated accuracy and benefit to patients. Those operating in academic settings may find adherence to professional organization guidelines advantageous while others may utilize a consensus developed through negotiation and based on practice need. In any case, initial training of whatever length is merely the starting point, and a process for ongoing training, experience, and critical review is essential.

What are the arguments for bedside ultrasound in the ED?
Ours is a 24/7 business that requires specific accurate information in order to make critical decisions. A bedside ultrasound by an EM physician is intended to “enhance the physician’s ability to evaluate, diagnose, and treat emergency department patients” in a time critical manner. The exam is brief and highly focused and intended to answer a specific question, such as, “Is there a pericardial effusion?” It is seen as an extension of the physical exam but is never meant to replace a comprehensive exam performed by an ultrasound professional and interpreted by a radiologist.

Both ACEP (revised 2001) and SAEM (re-approved 2004) published guidelines and policy statements supporting the use of bedside ultrasound by trained EM physicians. Further, in 2000, the AMA passed Resolution 108 and reaffirmed Policy H-230.960. These resolutions provided general acceptance of bedside ultrasound by emergency physicians. The policy recognized that “ultrasound imaging is within the scope of practice of appropriately trained physicians” and not a specialty specific privilege. It went on to specify that the determination of who should perform ultrasound procedures is the function of a hospital’s medical staff with specific privileges listed in a department’s Delineation of Privileges. This is a key argument when privileges are sought at the medical staff level.

What if radiology objects?
It is true that radiology has often objected to the introduction of bedside ultrasound. In a survey of radiology directors in 1994, over 80% believed it was

<table>
<thead>
<tr>
<th>Table 3: Common Ultrasound Procedures And CPT Codes*</th>
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</thead>
<tbody>
<tr>
<td><strong>FAST Exam</strong></td>
</tr>
<tr>
<td>- 76705 -26 (limited Abdominal)</td>
</tr>
<tr>
<td>- 93308 -26 (limited Echocardiography)</td>
</tr>
<tr>
<td><strong>Pericardial Fluid</strong></td>
</tr>
<tr>
<td>- 93308 -26 (limited Echocardiography)</td>
</tr>
<tr>
<td><strong>Pregnancy – Known</strong></td>
</tr>
<tr>
<td>- 76815 -26 (Transabdominal)</td>
</tr>
<tr>
<td>- 76857 -26 (Transabdominal)</td>
</tr>
<tr>
<td>- 76830 -52-26 (Transvaginal)</td>
</tr>
<tr>
<td><strong>Biliary Disease</strong></td>
</tr>
<tr>
<td>- 76705 -26 (limited Abdominal)</td>
</tr>
<tr>
<td><strong>Renal Disease</strong></td>
</tr>
<tr>
<td>- 76775 -26 (limited Echography, Retroperitoneal)</td>
</tr>
<tr>
<td><strong>Vascular Access</strong></td>
</tr>
<tr>
<td>- 76937</td>
</tr>
<tr>
<td><strong>Pericardiocentesis</strong></td>
</tr>
<tr>
<td>- 76930 -26</td>
</tr>
<tr>
<td><strong>US guidance for needle placement</strong></td>
</tr>
<tr>
<td>- 76942 -26 (for biopsy, aspiration, injection)</td>
</tr>
</tbody>
</table>

* Always obtain professional guidance for appropriate coding and level of documentation.
bad idea." However, in a review of EM residency ultrasound programs in 2003, 32% reported that radiology participated in the training. The emphasis should remain on patient care and the limited focused nature of the study, as well as the need for 24/7 immediate access for critical patients. It is also helpful to enlist the support of other specialties, such as cardiology and OB/GYN, who have experienced similar objections, as well as surgery whose patient’s may be most affected by timely studies.

**How do I approach medical staff?**

There are numerous studies available that indicate the benefit of bedside ultrasound, from detecting AAA and ectopic pregnancies, to improving patient throughput, to complying with government policy guidelines. Have this data handy to counter common objections that may arise. Recall that the AMA supports emergency medicine’s position and rights as well as previous precedents set with the cardiologists and obstetricians.

Strongly consider requesting “Limited Emergency Ultrasound” to include the most crucial, best supported, and time sensitive studies. (Table 3).

Establishing an Emergency Ultrasound Committee to review initial studies and provide for quality improvement may provide medical staff members with an increased level of comfort. It is crucial to stay on point about patient care and the limited nature of the exam.

A great resource for those embarking on this journey is the ACEP Section on Ultrasound’s e-list (Ultrasound.section@elist.acep.org). The collected experience of individuals involved in emergency ultrasound across the country is accessible, including many who have successfully implemented programs in their departments.

**Can you bill for these procedures?**

Yes. Physicians who are appropriately trained and credentialed may bill for the procedures that they perform, including bedside ultrasound. Most of the ultrasound procedures performed by emergency physicians are described by the Current Procedural Terminology (CPT) codes. The selection of appropriate codes and modifiers for these procedures can be complex. The ACEP Ultrasound Section has produced a source document that extensively explores the basic terms, modifiers, codes, and additional resources; it is essential reading for those departments who are considering billing for their services.

In general, bedside ultrasound studies are “limited” studies focusing on a single problem or area, with specific CPT codes attached. Complete studies involve evaluating and commenting on all major structures contained in the description (i.e., Abdominal Ultrasound – 76700) and are usually associated with the studies performed by a radiologist.

In addition to the primary CPT codes, CPT modifiers are often used to add more information than the code alone might provide. There are numerous modifiers; their descriptions and use are best found in professional coding manuals (CPT, etc). Two of the most commonly used are “-26” (professional component modifier) and “-52” (reduced service modifier). The professional component modifier (-26) indicates the interpretation of the study or test and the preparation of a separate and distinct note. A hospital based emergency physician would attach this modifier to virtually all of the CPT codes submitted. The reduced service modifier (-52) indicates that the usual procedure, as described in the CPT code, was performed in reduced fashion. For example, some procedures do not have “limited” codes and, if performed in a focused fashion, would need to be reported in a “modified” manner, thus the additional code.

Even from this brief discussion, it is apparent that appropriate coding and billing for services performed can be a complex process. In Moore’s 2004 study of ultrasonography in academic centers, only 16% were billing for their service.

**Summary**

There are many steps and hurdles to bringing bedside emergency ultrasound to your department, but also many benefits to patient care and pediatric emergency department function. No two departments or institutions are the same and each will have different needs for emergency ultrasound. With patience, persistence, and the interest to use the ultrasound as much as possible to increase comfort and experience, most physicians find ultrasound to be an invaluable extension of your clinical evaluation.

**Case Conclusion**

You return to your division chief with this article, some supplemental readings, contacts with some ultrasound manufacturers, and hopefully a green light from administration and other departments. Now the fun begins!
References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available.

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CME Questions

1. The imaging study of choice for first trimester bleeding, pain, or suspected ectopic is:
   a. KUB
   b. CT Abd/Pelvis without contrast
   c. Transabdominal/Transvaginal ultrasound
   d. CT Abd/Pelvis with contrast

2. The preferred imaging study to evaluate solid organ injury in adult/pediatric trauma patients is:
   a. Plain x-rays
   b. FAST exam
   c. CT with and/or without contrast
   d. MRI

3. The most common ultrasound probe placement for a rapid cardiac exam is:
   a. Transesophageal
   b. Parasternal
   c. Apical
   d. Subcostal

4. With bedside ultrasound, a pericardial effusion appears as a bright white area.
   a. True
   b. False

5. An intrauterine pregnancy can be confirmed earliest by:
   a. Quantitative human chorionic gonadotropin (HCG)
   b. Endovaginal sonography (EVS)
   c. Transabdominal sonography (TAS)
   d. Doppler

6. The indirect method of venous cannulation using ultrasound guidance requires:
   a. Sterile transducer sleeve
   b. At least two people to perform
   c. Sterile gel
   d. One person without special preparations

7. The transducer of choice for ultrasound guided venous cannulation is:
   a. 3.5 MHz curvilinear probe
   b. 7.5 MHz convex probe
   c. 5 MHz curvilinear probe
   d. 7.5 MHz linear probe

8. The amount of experience and training required by a non-radiologist to perform a focused exam is:
   a. Not definitively established

9. Which of the following is not true?
   a. Ultrasound is defined as frequency greater than 20,000 hertz.
   b. Hypoechoic objects appear dark on the ultrasound screen.
   c. High-frequency ultrasound penetrates deeper into tissues than low-frequency ultrasound.
   d. Urine in the bladder will appear black because it does not reflect ultrasound waves well.

10. Which of the following is true?
    a. A-mode ultrasound is the most frequently used today.
    b. M-mode is a form of Doppler ultrasound.
    c. Color Doppler gives a quantitative measurement of flow.
    d. Doppler ultrasound is dependent on how the probe is held relative to the direction of the moving object.

11. A negative FAST scan of the abdomen guarantees a lack of traumatic injuries in the abdomen.
    a. True
    b. False

12. With respect to FAST scans, which of these statements are true?
    a. The most common practice uses four ultrasound views, but additional views are sometimes obtained.
    b. FAST scans are useful for identifying free fluid in the abdomen and somewhat less so for solid organ injury.
    c. A normal FAST scan may occur if there is not enough free intraperitoneal fluid to be detected.
    d. All of the above.

13. In the critical pediatric patient, bedside ultrasound may be useful for which indications?
    a. Central line placement
    b. Endotracheal tube placement
    c. Potentially identifying the cause of shock, such as pericardial effusion, peritoneal free fluid, or cardiac activity
    d. All of the above

14. The use of bedside ultrasound is useful in obtaining urine from the bladder. Which of the following is not true?
    a. The bladder is too small in infants to identify.
    b. Nurses or physicians could find this modality useful.
    c. Ultrasound could be used either prior to suprapubic aspiration (SPA) to identify bladder volume, or during SPA to guide the procedure.
    d. Ultrasound may reduce the number of unsuccessful urethral catheterizations by confirming adequate bladder volume prior to catheterization.

15. Choose the best statement.
    a. For soft tissue ultrasound, use of a curved ultrasound probe allows for better contact with the
skin.

b. A spacer or stand-off may help place the area of interest within the optimal focal zone of the ultrasound probe.

c. A low-frequency probe is most appropriate for evaluation of the superficial soft tissues.

d. Ultrasound is of no value in the evaluation of simple cellulitis.


a. Bedside ultrasound likely has a different role in a pediatric emergency department than a general emergency department.

b. Bedside ultrasound is equally valuable in children as adults for some indications.

c. The choice of probes for a new ultrasound machine should be based on the specific needs of your patient population and department.

d. All of the above.

Class Of Evidence Definitions

Each action in the clinical pathways section of Pediatric Emergency Medicine Practice receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness
- Levels of evidence:
  - Case series, animal studies, consensus panels
  - Occasionally positive results

Class II
- Safe, acceptable
- Possibly useful
- Study results consistently positive and compelling
- Levels of evidence:
  - One or more large prospective studies are present (with rare exceptions)
  - High-quality meta-analyses
  - Study results consistently positive and compelling
  - Levels of evidence:
    - Evidence not available
    - Higher studies in progress
    - Results inconsistent, contradictory
    - Results not compelling

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments
- Levels of evidence:
  - Generally lower or intermediate

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Credit may be obtained by reading each issue and completing the printed post-tests administered in December and June or online single-issue post-tests administered at EBMedicine.net.

Target Audience: This enduring material is designed for emergency medicine physicians.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACP; and evaluation of prior activities for emergency physicians.

Date of Original Release: This issue of Pediatric Emergency Medicine Practice was published January 1, 2007. This activity is eligible for CME credit through January 1, 2010. The latest review of this material was December 15, 2006.

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