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Considerations in Pediatric Thoracic and Abdominal Trauma

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Trauma is the single greatest cause of morbidity and mortality in the pediatric and adolescent populations. Management of pediatric trauma patients is highly specialized, requiring a team approach of nurses, technicians, therapists, social workers, and physicians. Special considerations must be made for pediatric trauma, as children cannot be treated as "small adults." Superior survival outcomes have been demonstrated for the most severely injured children when treated at a dedicated pediatric trauma center.[1]

The initial assessment of pediatric trauma proceeds much like that for adults as outlined in the Advanced Trauma Life Support (ATLS) course of the American College of Surgeons.[2] *The primary survey, with immediate correction of life-threatening problems, is followed by a detailed secondary survey and imaging studies of the cervical spine, chest, and pelvis.*[3] *Next, additional imaging and laboratory testing may be ordered on a case-by-case basis, depending on the findings of the data gathered during the initial resuscitation.*

There is growing concern about the use of CT scanning in the pediatric and adolescent population due to exposure to ionizing radiation and the potential development of excess cases of neoplastic disease.[4] *Ideally, imaging would be tailored to each individual patient instead of being applied in an algorithmic fashion, subjecting those not likely seriously injured to the potential hazards of unnecessary testing.*

In this issue, the authors focus on trauma to the pediatric chest and abdomen. Specifically reviewed are the pediatric mechanisms of injury, potential injury patterns, physical exam findings, and initial stabilization, concluding with a look at imaging and some of the controversies surrounding management of these patients.

— The Editor

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Epidemiology

In children, death by injury exceeds all other causes of death combined. Injury is the leading cause of death of children older than the age of 1 year, and, in this population exceeds all other causes of death combined. Injury results in more years of life lost than sudden infant death syndrome, cancer, and infection combined together.[5] Most deaths in the youngest children are from unintentional injury, but homicide and suicide become more prevalent as the population nears young adulthood. The Centers for Disease Control and Prevention report that more than 50,000 children died in motor vehicle accidents from 1999 to 2006, the largest single cause of death in the pediatric and adolescent population.[6]

Non-fatal injuries take an even greater toll on the pediatric population. Nearly 30 million children visit an emergency department (ED) every year in the United States alone. Male children have a higher rate of visits than females, while younger children have higher visit rates than older children.[7] About 40% of the yearly ED visits are for traumatic injury. The International Classification of Diseases (ICD) codes for "unintentional fall" and "unintentional struck by/against" account for most of these visits.[6,8]

The aftermath of these injuries can be staggering, psychologically, financially, and physically. Nearly a decade ago, Miller and colleagues estimated that childhood injuries resulted in $1 billion in resource expenses, $14 billion in lifetime medical spending, and $66 billion in present and future work losses.[9] In 1996, injury left more than 150,000 children and adolescents with a permanent disability, which in many cases will require lifelong medical care. Trauma continues to be a costly and devastating disease among the youngest and most vulnerable of our population. Trauma and accidental injury claim many lives and dramatically impact on many more.

Etiology

Pediatric thoracic trauma is overwhelmingly caused by blunt mechanisms.[10] The most common causes of pediatric blunt chest trauma are motor vehicle collisions (MVCs), pedestrians struck by vehicles, and falls. The vast majority of these are deemed accidental. There are patterns that are somewhat predictable based on age. MVCs and abuse are the leading causes of chest trauma for infants and toddlers. Once children start to attend school, pedestrian accidents come into play; impulsivity can lead them to run into the paths of cars, or their inquisitive nature causes them to play or hide around cars. As they age, skateboarding and cycling start to emerge as causes of significant trauma.[10] Pulmonary contusions, rib fractures, pneumothorax, and hemothorax are the most common injuries after blunt thoracic trauma.[10-12] Aortic, esophageal, diaphragmatic, cardiac, and tracheobronchial injuries are uncommon in children.[10,11] Unfortunately thoracic trauma is rarely a child's only injury, as more than 50% will have more than one intrathoracic injury while about 70% will have additional extrathoracic injuries.[12] Peclet and colleagues report that in children with multiple injuries, death is 10 times more likely if a thoracic injury is present.[13]

Likewise, the vast majority of pediatric abdominal trauma is from blunt mechanisms. The most common causes are associated with MVCs, handlebar injuries, and intentional injury. The pattern of injury changes with age. Children younger than 2 years of age are the most likely to suffer intentional injury, while older children are typically involved in physical activities that may lead to injury. They may suffer collisions during bicycling, sledding, snowboarding, sporting activities, or aggressive play. The solid organs, namely liver and spleen, are most frequently injured.[11,14,15] Bowel, bladder, and kidney injuries also occur, but are much less frequent.[16]

Penetrating thoracic and abdominal trauma, when it does occur, is usually the result of violence. Stabbing and gunshot wounds are the most common mechanisms seen as the pediatric population approaches adulthood.[17] The majority of these types of injuries will likely require operative intervention. Simultaneous assessment and resuscitation of the patient should occur in parallel with preparation of an operating room. If necessary, arrangements to rapidly transfer the patient should be made during the initial assessment and resuscitation.

Pathophysiology

Children differ considerably from adults anatomically and physiologically. Proportionally different, children have larger heads than adults, raising their centers of gravity and contributing to different patterns of injury than seen in adults.[18] Thoracic trauma accounts for about 5% of injuries in hospitalized chil-

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dren, but is the second leading cause of death in pediatric trauma.[11,12,18] Differing injury patterns are partially due to the flexibility of pediatric thoracic structures. The chest wall of a child is elastic and pliable due to increased ligamentous laxity, less rib mineralization, and incomplete ossification of the ribs. Instead of breaking, children's ribs bend when compressed, transmitting more energy to the lungs and thoracic contents.[10,12] In addition, the mediastinum of children is more mobile. Consequently large pneumothoraces or hemothoraces can cause dramatic mediastinal shift resulting in more respiratory or vascular compromise than adults.[11] Lastly, the higher metabolic demands and decreased pulmonary function residual capacity of children results in faster development of hypoxemia.[12]

Abdominal trauma accounts for about 10% of all pediatric trauma admissions, and the abdomen ranks second in the list of most commonly injured sites.[16,19] The abdominal walls of children are thinner, with less developed musculature and fat, than those of adults. This provides less protection to the abdominal organs, allowing the transmission of greater force to the abdominal and retroperitoneal organs.[14] Proportionally, the abdominal organs of a child are also larger, providing a greater surface area over which to absorb force.[14,16] Additionally, the mesentery is less adherent in children, allowing for greater mobility of some organs, possibly contributing to greater bowel injury in deceleration type trauma such as MVCs or falls from a height. Seemingly minor injuries involving handlebar-to-abdomen impacts are associated with injuries to the small bowel and pancreas and are actually a greater risk for injury than flipping over the handlebars.[20] The bladder of very young children is partly located in the abdomen, descending into the pelvis as they age. Thus, bladder injury should also be considered in the younger child presenting with abdominal trauma.[16]

Abdominal trauma in children should also raise concern for spine injury. The spinal columns of children have significantly greater ligamentous laxity, less supporting musculature, and a higher fulcrum of flexion than those of adults.[21] Children restrained only by a lap belt may suffer the so-called "lap belt syndrome" of abdominal wall injury, intra-abdominal organ injury, and vertebral fracture.[22]

The physiological differences between children and adults can lull us into a false sense of security based on "normal" vital signs taken out of context with the overall picture of the patient. Children's vital signs vary significantly with their age and it is important to realize that normal vitals signs in one age group may be an ominous sign in another group.[23] *(See Table 1.)* A minimum systolic blood pressure can quickly be calculated by multiplying the age in years of the child by 2 and adding 70 to the result.[23] The finding of hypotension in an injured child is ominous, as children have a greater capacity to compensate for volume loss, and may occur later in children than it does in adults. Normal or nearly normal vital signs do not exclude significant hypovolemia secondary to blood loss. Children may lose 30% of their blood volume before showing the obvious signs of shock.[17] Frequent vital sign checks are imperative. Simply having a child on continuous monitoring may be insufficient, as the numbers may be deceivingly reassuring. Altered mental status, tachycardia, tachypnea, and diaphoresis may also be indicators of hypoperfusion with impending decompensation. Speaking with the child, if he or she is verbal and old enough, may better allow the additional assessment of perfusion of the brain based on mental status. Helping calm an otherwise frightened and anxious child is an additional benefit.

Table 1. Pediatric Vital Signs by Age Group

AGE	PULSE (UPPER LIMIT)	RESPIRATORY RATE (UPPER LIMIT)	SYSTOLIC BP (LOWER LIMIT)
0-1 mo.	180	60	60
2-12 mos.	160	50	70
1-2 yrs.	140	40	75
2-6 yrs.	120	30	80
6-12 yrs.	110	20	90
> 12 yrs.	100	20	90

Key: BP = blood pressure

Clinical Features

The clinical features of pediatric thoracic and abdominal trauma are very similar to those of adults. Unfortunately, the history and physical exam in pediatric patients may not be reliable and is often more difficult. Depending on the child's age, history may be provided exclusively by those around the child, or it may not be available except as reported by the emergency medical technicians (EMTs), paramedics, or flight crew. The physical exam, especially in those younger than 5 years old, is often hampered by a child's lack of verbal skills, fear, apprehension, and separation from family. Other injuries are extremely distracting and may influence the physical exam.[14,24]

Physical exam findings on children with thoracic injuries may include chest crepitance, subcutaneous emphysema, nasal flaring, diminished or absent breath sounds, tachypnea, dyspnea, or low oxygen saturation.[12] Children with significant thoracic injury may have very little in the way of external signs of trauma due to compliance of the chest wall.[17] Remember that a normal external superficial exam does not exclude significant internal injury.

Signs of abdominal injuries include abrasions, abdominal tenderness, or distention, Cullen's sign (ecchymosis in the periumbilical region), Turner's sign (lateral abdominal wall ecchymosis), and vomiting.[14] There is debate about the importance of the "seat belt sign," which is abdominal erythema, ecchymosis, or abrasions across the abdomen. While Sokolove and colleagues showed the seat belt sign is more common in those with intra-abdominal injuries than in those without injuries after MVCs, Chidester's retrospective study of 331 pediatric patients with abdominal trauma discovered that children with seat belt sign were 1.7 times more likely to sustain abdominal injury, but that it was not statistically significant.[25,26] At the very least, signs of external abdominal injury should alert the team to the potential presence of internal injury that will necessitate further examination and possible imaging or lab studies to assess for injury.

Diagnostic Studies

The ultimate question for all trauma patients is, "Does this patient have injuries that require immediate operative intervention?" Additionally, if you are at a hospital without full surgical capabilities, transfer may be required for definitive care.

The decision to perform surgery is based mainly on clinical findings and potential deterioration, not imaging studies. Computed tomography (CT) scans, however, do affect diagnosis, management plans, and level of monitoring.[11] To this end, the use of CT scanning for pediatric trauma patients should not be a knee-jerk response, but rather a calculated decision. Imaging should be guided by a review of the mechanism of injury, vital signs, and physical examination. Many adult trauma centers employ the "pan-scan" approach, scanning the head, neck, thorax, abdomen, and pelvis of all trauma patients. There is evidence to suggest that this approach may be beneficial in adults.[27] In children, however, there is less literature on the subject. It is undisputed that the use of CT scan uncovers many injuries, but does the detection of these injuries effect management and, ultimately, outcomes of patients?[28,29]

Of all CT scans, the chest CT is the least commonly used to evaluate trauma patients. Despite this finding, Fenton and colleagues showed that CT scans of the chest are most likely to show injury in excess of a screening chest x-ray.[4] Similarly, a retrospective review of 333 pediatric trauma patients by Markel and colleagues found that conventional chest x-ray remained an acceptable screening tool to evaluate for thoracic trauma. Of the six patients that required emergent surgery for cardiac or arterial compromise, all the injuries were seen on chest x-ray or the scout view of the chest CT. Unfortunately, 5% of chest x-rays in their series falsely reported normal findings that may have ultimately altered management.[30]

There are similar findings when abdominal trauma is considered. In the past, abdominal injuries were diagnosed and managed mainly through an exploratory laparotomy. Today, however, about 95% of children with liver or spleen injuries are managed non-operatively.[31] Holmes and his group reported that 95% of 1,818 patients with solid organ injury were managed non-operatively. The median time to failure (requiring operative intervention) for the remaining 5% was only three hours.[32] The non-operative approach decreased lifetime risk of asplenic sepsis and was associated with shorter hospital stays, fewer blood transfusions, and decreased overall mortality.[31] As most abdominal injuries are managed expectantly via cautious observation, the question becomes "Is any imaging necessary initially?" The decision to operate should ultimately be based on the patient's physiologic response to the injury, not the imaging findings.

Although CT scans provide invaluable information, are there alternatives for the detection of serious thoracic and abdominal injuries? As outlined above, the routine chest x-ray, combined with physical examination, provides excellent information about the likelihood of serious thoracic injury. The use of ultrasound and diagnostic peritoneal lavage (DPL) for the evaluation of abdominal injury requires further evaluation.

The use of ultrasound assessment of the abdomen is routine in many adult trauma centers and the focused abdominal sonography for trauma (FAST) exam is an adjunct to the ATLS protocols for management of trauma patients. Intuitively, pediatric patients seem ideal for a FAST exam as they have small abdominal cavities without large abdominal fat deposits.[4] However, there is considerably less evidence of the utility of FAST in assessment of pediatric trauma.

A paper by Eppich and Zonfrillo reviews the literature regarding management of blunt abdominal trauma.[33] In this review, based on four papers, they note that FAST in children for the detection of blunt abdominal trauma demonstrates variable sensitivity (55%–92.5%) and negative predictive value (50%–97%) but consistently good specificity (83%–100%) when compared to abdominal CT scanning. While the FAST exam does miss some patients with free fluid, the clinical significance of this is not clear given that most abdominal injuries in children are managed expectantly. One of the four papers, that by Soudack and colleagues, concludes that a positive FAST exam necessitates further "definitive imaging."[24]

More recently, Holmes and colleagues conducted a meta-analysis of the use of ultrasonography in pediatric blunt abdominal trauma.[34] Their analysis included 3,838 children from 25 articles. They concluded that a negative ultrasound exam has "questionable utility as the sole diagnostic test to rule out the presence of IAI [intra-abdominal injury]" and go on to state that a positive ultrasound in the hemodynamically stable child should lead to immediate CT scanning. They additionally conclude that children with a moderate pretest probability of intra-abdominal injury should undergo abdominal CT scanning regardless of the findings on abdominal ultrasound.

One of the criticisms of the FAST exam is its inability to identify solid organ injury that may not produce hemoperitoneum. In the meta-analysis by Holmes, it was found that the additional ultrasound evaluation of solid organs only slightly increased the sensitivity of the standard FAST exam in pediatric patients, to 82% from 80%. However, the question was raised concerning the ability of non-radiologists to ultrasound solid organs.[34]

The use of DPL has fallen out of favor given the discomfort to the patient and lack of specificity of the exam. It is not recommended for the assessment of an isolated abdominal injury, but is useful to diagnose children with abdominal trauma who sustained multiple injuries and require immediate surgery for another injury, often a subdural or epidural hematoma.[14]

Can laboratory testing help in identifying children who should undergo CT scans for injuries? Capraro, Mooney, and Waltzman examined the utility of the "trauma panel" in the assessment of blunt abdominal trauma.[35] In a retrospective review of 382 pediatric patients, they found that none of their regularly tested chemical or hematological parameters had sufficient sensitivity or negative predictive value to be helpful as a screening tool. Cotton and Beckert considered both clinical and laboratory data. They determined that 23 variables were potentially associated with intra-abdominal injury.[36] Logistic regression identified four positive predictors for injury: tenderness, abrasions, ecchymosis, and elevated ALT. Holmes and colleagues published two papers in May 2002 addressing this subject in both abdominal and thoracic trauma.[19,37] They derived clinical decision rules to identify children with thoracic or intra-abdominal injuries after blunt trauma. The prospective series for abdominal trauma enrolled 1,095 children younger than 16 years with blunt trauma. They identified 107 patients with intra-abdominal injuries. Statistical analysis identified six findings associated with abdominal injury: low systolic blood pressure, abdominal tenderness on exam, femur fracture, serum AST >200 U/L or serum ALT >125 U/L, urinalysis with >5 RBCs per high-powered field, and an initial hematocrit of less then 30%. Of the 107 children with an intra-abdominal injury, 105 had at least one of these findings, while absence of any of the six was seen in all but two children with injury. The authors acknowledged some limitations, as they did not evaluate the use of ultrasound in their decision rule and not all of the children with abdominal trauma underwent imaging due to "ethical considerations."[19]

In another series, the Holmes group applied the same type of analysis to children with thoracic injury.[37] Nine-hundred-eighty-six patients with thoracic trauma were enrolled, and 80 of them were found to have injuries. Analysis identified the following predictors of thoracic injury: low systolic blood pressure, elevated age-adjusted respiratory rate, abnormal thorax exam, abnormal chest auscultation, femur fracture, and Glasgow Coma Scale (GCS) score of < 15. Seventy-eight of the 80 injured patients had at least one of these findings, while two did not have any of these findings. The two missed cases did not require intervention for their thoracic injuries.

Holmes and colleagues have recently published a paper on validation of their derived prediction rule for blunt torso trauma.[38] In this series of 1,119 children with blunt torso trauma, they identified 149 of 157 injured children. Of the eight patients that were missed, only one underwent laparotomy for a serosal tear and mesenteric hematoma that did not require "specific surgical intervention." Application of their decision rule would have resulted in a reduction of CT scans by 33%. They conclude that further refinement of their prediction rule is needed before it is ready for widespread use.

Management

The management of pediatric abdominal and thoracic trauma is similar to that of adults. Standard ATLS protocols should be followed.[3] In the primary ATLS survey, all life-threatening injuries must be identified and addressed before progression with the detailed secondary survey. *(See Table 2.)* All pediatric patients being assessed for trauma must be continuously monitored for blood pressure, heart rate, respiratory rate, and blood oxygen saturation. In addition, every child should have a recorded temperature and be protected from hypothermia. Supplemental oxygen should be provided. Adequate intravenous (IV) access is imperative. If two peripheral IV lines cannot be rapidly secured, intraosseous access or central venous access should be considered.

Table 2. Immediately Life-threatening Thoracic Injuries

- Airway obstruction and injury
- Lung and chest wall injuries
- Open pneumothorax
- Tension pneumothorax
- Hemopneumothorax
- Flail chest
- Widened mediastinum / aortic disruption
- Cardiac tamponade

Any signs of shock should be treated aggressively with fluid resuscitation. First-line fluids should be crystalloids given in 20 mL/kg boluses. Packed red blood cells (PRCBs) should be transfused at 10 mL/kg if the blood pressure does not respond to two fluid boluses.

After the initial resuscitation is complete, a thorough secondary survey should evaluate for other injuries. A head-to-toe examination is undertaken for signs of injury and disability. The entire surface of the child's body must be exposed for this examination. It is important to remember to examine the child's back, as well. Vital signs should be reassessed frequently throughout the resuscitation. Any deterioration in the condition of the patient should prompt immediate reassessment, starting with the primary survey. During this time, the physician should attempt to gain additional knowledge concerning past medical history, allergies, and medications. The AMPLE mnemonic is useful for this purpose.[3] *(See Table 3.)*

As previously discussed, non-operative management with close observation is now the mainstay of most pediatric thoracic and abdominal trauma. Nearly 90% of blunt pediatric chest injuries can be managed non-operatively or with a thoracostomy tube.[12] Indications for a thoracotomy include tracheobronchial injuries, esophageal injuries, diaphragmatic rupture, major vascular injury, retained hemothorax, return of 20%–30% of a child's blood volume through a chest tube, or persistent hemorrhage (defined as continued bleeding of 2–3 mL/kg per hour over a four-hour period).[12]

Greater than 90% of pediatric abdominal trauma is successfully managed non-operatively. If a patient is hemodynamically stable without peritoneal signs, non-operative management should be attempted.[39] The argument has also been made that the hemodynamically unstable child who responds to boluses

Table 3. The AMPLE History

A	Allergies
M	Medications
P	Past illness
L	Last meal
E	Events related to injury

of PRCBs may avoid the operating room.[40] Failure of non-operative management usually occurs within four hours and nearly always within 12 hours of presentation. Children with severe or multiple solid organ injuries and pancreatic injuries are nine times more likely to require operative intervention.[41] Despite previous perceptions, a cohort study by Tataria and colleagues of 2,944 children with blunt abdominal trauma showed that delayed operative management or failure of non-operative management does not change outcome in terms of mortality, ICU length of stay, hospital length of stay, or blood transfusions.[39]

Figures 1 and 2 summarize a general approach to assessing the child with thoracic or abdominal trauma. These figures are meant to serve only as a rough outline of a thought process that could be used to assess the victim of pediatric trauma, and not as specific protocols.

Current Controversies

Unnecessary Exposure to Radiation. There has been concern raised over the last two decades about the use of CT scanning in the both the adult and pediatric populations.[42] There are more than 60 million CT scans done each year in the United States. This is 20 times the number of scans performed in 1980. About four million of these are done in children.[42] Today, the medical imaging radiation dose, which is primarily from CT scans, is the largest source of radiation, besides background radiation, received by the U.S. population.[43] That CT scanning has altered diagnostic algorithms and made detection of injury more sensitive can not be argued. However, the risk of radiation is twofold: increased risk of cancer due to radiation exposure, and missing a diagnosis due to suboptimal image quality due to decreased radiation exposure settings.[44]

The authors of several papers, especially in the radiology literature, have looked at the increased risk of cancer due to radiation from CT scanning.[45-47] It has been estimated that the risk of developing a fatal cancer from a CT scan may be in the range of about 1 in 1,000.[45] In addition to their body tissues being more sensitive to radiation, children have a longer lifespan over which to develop a cancer.[46] While the risk to an individual is relatively small, this small risk multiplied by a large number of scans results in a relatively large number. Based on the above numbers, CT scans may be responsible for causing 4,000 fatal cancers a year. The number of non-fatal cancers is likely to be higher.

The Alliance for Radiation Safety in Pediatric Imaging launched the "Image Gently" campaign in 2007 to raise awareness of these important issues.[48] The "as low as reasonably achievable" (ALARA) principle is also promoted by this campaign. A recent paper by Arch and Frush finds that since a prior survey in 2001, the peak kilovoltage and tube current settings, the two principal parameters determining radiation dose from CT scanning, have decreased significantly for pediatric body multidetector CT.[49] It may be that increased awareness of the potential hazards of radiation is having an effect.

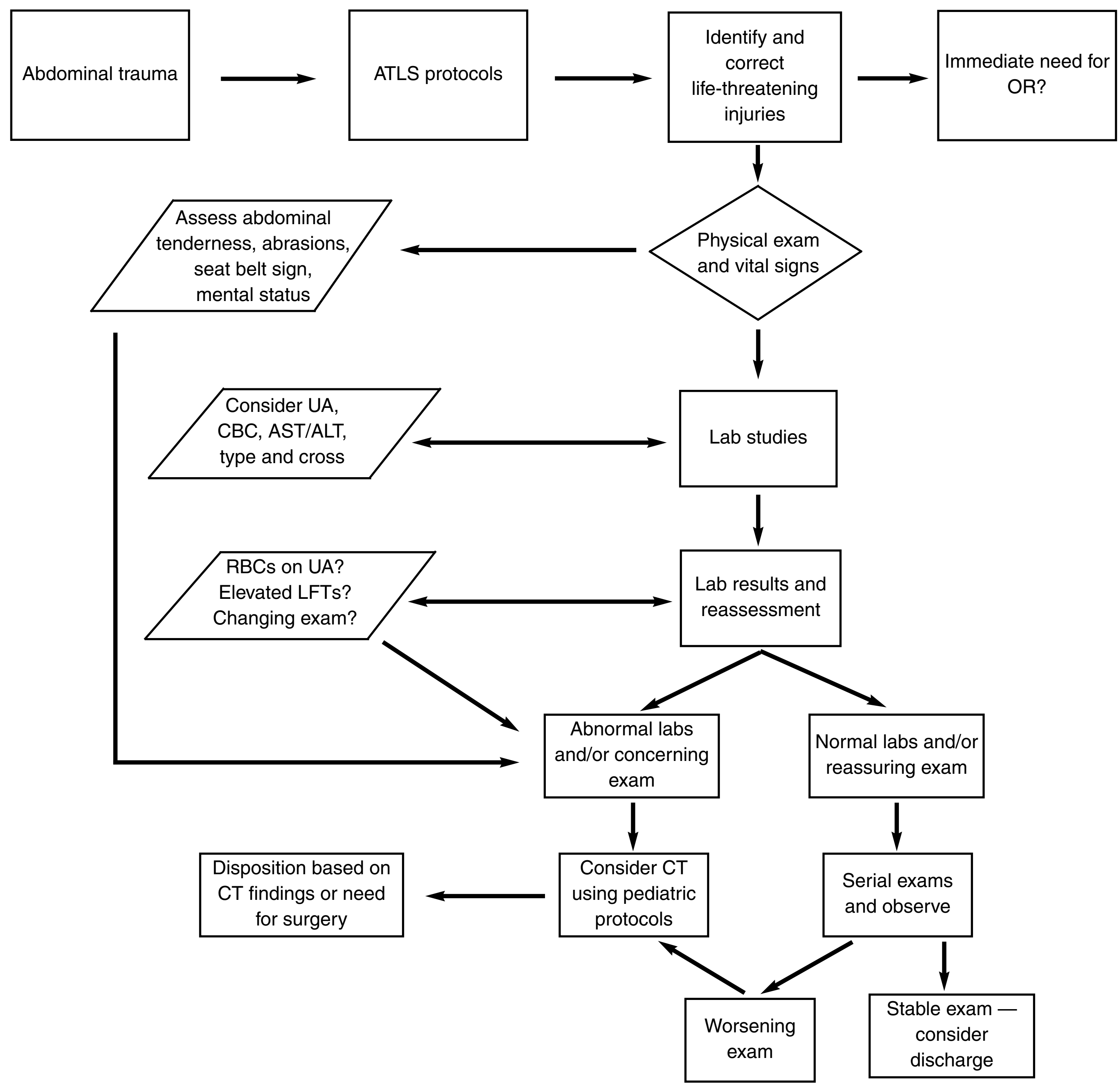
In an effort to reduce radiation exposure, Cohen raises an interesting point: How low can you reduce the dose before the radiologist becomes uncomfortable making an accurate diagnosis?[44] Lower radiation dosages equate to a lower risk of cancer, but this reduction comes with a possible reduction in diagnostic certainty. Where does the radiologist draw the line between diagnostic certainty and patient safety?

Obviously, the best way to reduce radiation exposure to pediatric trauma patients is to avoid unnecessary CT scans. While evidence based medicine and clinical judgment help determine which patients need CT scans, there are a number of other factors contributing to unneeded CT scans. Donnelly cites overcautious ordering of CT scans due to potential malpractice litigation, public pressure to use high-end technical exams, and Americans' need for immediate results as reasons for unnecessary CT scans.[50] Both physicians and the public will have to work together to decrease the number of unnecessary CT scans on children.

CT Scans and the Transfer of Pediatric Trauma Patients. When a pediatric trauma patient is being transferred to a tertiary facility for further care, should the CT scans be done at the referring facility or the receiving facility? ATLS recommends the transfer of appropriate patients without delay to a designated trauma center. Therefore, further diagnostic studies should not be undertaken, as they will not change the immediate care of the patient.[4] Additionally, just as a CT scan should not be used to determine if a patient requires the OR, a CT scan should not be used as a tool to determine if a patient should be transferred to a trauma center.[51] The decision to transfer a patient to a higher level of care is based on hemodynamic stability and the ability to provide care. The drawbacks in obtaining a CT prior to transfer include the inability to provide definitive care, the time delay in obtaining the scans, increased vulnerability of trauma patients if decompensation occurs in radiology or during transport, the lack of pediatric protocols to decrease radiation exposure at some referring facilities, and the possible need to repeat the study at the receiving facility.[4,51] Depending on location, transfer to a specialized pediatric trauma center may require a significant amount of time. Nance and colleagues recently published an interesting paper reporting that 71.5% of the pediatric population of the United States was within 60 minutes of a verified pediatric trauma center by either ground or air transport.[52] If only ground transport was considered, the percentage of the population that had access within an hour was only 43%. This percentage varies significantly from state to state and from rural to urban settings.

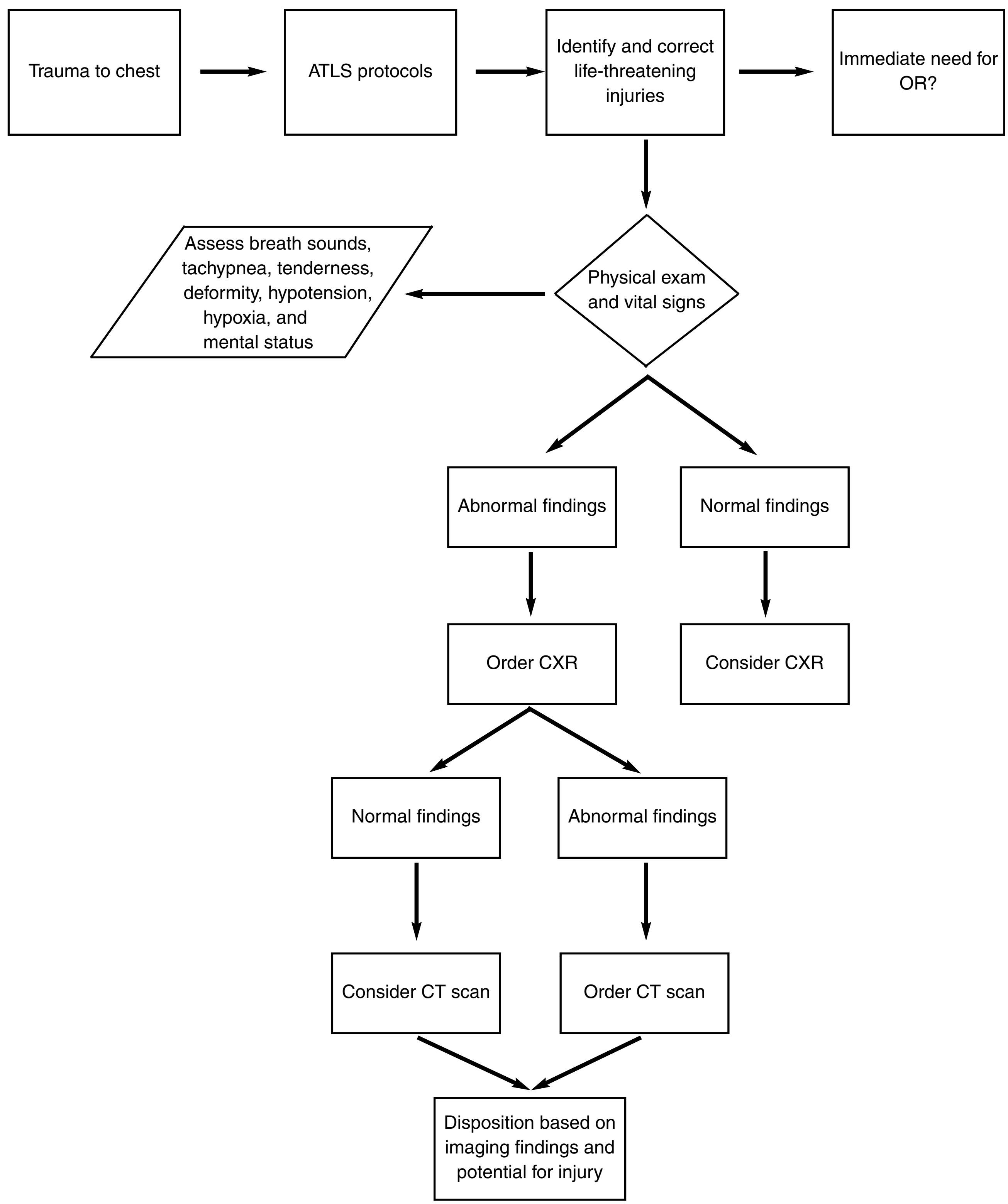
"Blush" on CT. A blush on CT indicates bleeding in or

Figure 1. Algorithm for the Evaluation of Blunt Abdominal Trauma



around an organ due to injury of a large arterial branch. While it has been described for the liver, kidney, adrenal gland, and mesentery, the spleen is the most common organ for a blush to be found.[53] In adults, the finding of a blush of a solid organ, specifically the spleen, on CT scan indicates a higher chance of non-operative failure and warrants early embolization or surgery.[53,54] In children, however, there has been controversy about whether there is a relationship between splenic blush and need for operative intervention. First, splenic blush is often missed on CT scan. In a retrospective study of 216 pediatric abdominal trauma patients, 27 whom had a splenic blush, the contrast blush was "frequently not identified" by the radiology resident and mentioned in "only a few" of the dictations by the attending radiologist.[54] Next, contrast blush can look identical on CT scan to areas of damaged splenic parenchyma or stable hematoma, making the diagnosis of a blush questionable.[54] Most importantly, studies surrounding splenic blush and the failure of non-operative management in children have been

Figure 2. Algorithm for the Evaluation of Blunt Thoracic Trauma



inconsistent. The largest study by Nwomeh and colleagues of 27 patients with splenic blush found a statistically significant correlation between contrast blush of the spleen and operative management as 46% of the children with blush went to the OR.[54] Two other smaller case series by Cox and Lutz had even higher rates of children with contrast blush requiring operative intervention.[40,53] In a case series of blunt splenic injuries, five pediatric patients with splenic blush were identified.[55] Only one of these required operative management due to hemodynamic instability. Despite conflicting results, the conclusion of all the authors is essentially the same: CT scan can accurately define the anatomic grade of an intra-abdominal organ injury, but cannot predict the failure of non-operative management of splenic injuries. The decision for operative intervention should be based on physiologic response to the injury rather than radiographic findings.

Patient Advocacy

Given the vulnerability of children, abuse should always be considered with pediatric trauma. Two thirds of the victims of abuse are younger than 3 years of age, and one third are younger than 6 months old.[56] In particular, child abuse should be considered with rib fractures, duodenal hematoma, pancreatitis, and pancreatic fractures.[11] Rib fractures occur in only 1%–2% of pediatric trauma; however, 82% of rib fractures in children younger than 3 years of age are related to child abuse.[10-12] There is no pathognomonic fracture indicative of abuse.[57] If there is no history of trauma, or there is a history of trauma that does not match the pattern of injury, child abuse should be suspected. The American Academy of Pediatrics 2007 guideline for the evaluation of suspected child physical abuse lists five circumstances that are concerning for intentional trauma.[58] They are:

1. No or vague explanations for significant injury.
2. Change in an important detail.
3. Explanation inconsistent with the pattern, age, or severity of the injury.
4. Explanation inconsistent with the child's physical and/or developmental capabilities.
5. Discrepancies among the stories of witnesses.

The presence of any of these circumstances should prompt further investigation and admission of the child until the details of the injury can be thoroughly investigated.

Disposition

Whether a pediatric trauma patient should be admitted is often based on clinical judgement. There have been a handful of studies evaluating whether a child who suffered from abdominal trauma with a normal abdominal CT scan can be safely discharged home. In a large, prospective, observational cohort study, Awasthi and colleagues followed 1,085 pediatric blunt trauma victims who had normal CT scans in the ED.[59] Of the 32% who were discharged to home, none returned to the hospital. Two of the 737 admitted for observation had an abdominal injury on repeat CT scan, but neither required intervention. They conclude that a child with a normal abdominal CT scan and a normal abdominal exam (no tenderness, distention, ecchymosis, or abrasions) can be discharged home, while a child with a normal abdominal CT scan and an abnormal exam should be carefully observed in or out of the hospital. To our knowledge, there are no studies that have directly evaluated the disposition of children after having a normal chest CT following trauma. If a child has undergone a CT scan to evaluate for potential thoracic trauma, he or she likely should be admitted for observation and repeat exams.

Prevention

It should not require stating that the best way to care for the pediatric trauma patient would be to prevent the trauma from ever occurring. Physicians and nurses are obligated to educate patients and their parents when given the opportunity to do so. A child sustaining a mild head injury in a fall from a bicycle should not be discharged without instructions for head injury. Likewise, if the child was unhelmeted, the importance of wearing a helmet should be addressed. If the child was wearing a helmet, reinforce the positive, and remind parents that the child needs a new helmet. Instruct parents on the proper use of car seats and seatbelts. Remind children to wear pads and helmets when skateboarding or rollerblading. There are numerous ways for all of us to educate; take a moment and do so.

Conclusions

Trauma is a significant cause of morbidity and mortality in children. A heightened awareness of potential thoracic or abdominal injuries can facilitate an appropriate diagnostic evaluation.

CT scanning is one of the most important medical advances in the last 100 years. However, improvements in imaging come with the increased risks associated with radiation, especially in the pediatric population. CT scanning undoubtedly saves lives, but imaging should be tailored to each patient after consideration of mechanism of injury, vital signs, physical examination and selected laboratory values. Further refinement of clinical decision rules may help to limit the number of questionably necessary CT scans performed for pediatric chest and abdominal trauma.

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CME Questions

1. What is the most common cause of morbidity and mortality in the pediatric population?
   A. Accidental trauma
   B. Non-accidental trauma
   C. Ingestions of toxins
   D. Congenital abnormalities

2. Which of the following injuries is immediately life-threatening, according to the ATLS Primary Survey?
   A. Chest contusion
   B. Airway obstruction

CNE/CME Objectives

Upon completing this program, the participants will be able to:
a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

CME / CNE Instructions

Physicians and nurses participate in this CME/CNE program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you <u>must</u> complete the evaluation form provided and return it in the reply envelope provided in order to receive a letter of credit.** When your evaluation is received, a letter of credit will be mailed to you.

C. Simple pneumothorax
D. Rib fracture
E. Head laceration

3. Which of the following types of trauma is the most common cause of death in the pediatric population?
A. Thoracic
B. Abominal
C. Head
D. Musculoskeletal

4. How is most pediatric blunt trauma managed?
A. Laparotomy
B. Laparoscopy
C. Celiotomy
D. Cautious observation

5. In which of the following groups is a systolic blood pressure of 70 mmHg acceptable as a minimum?
A. Older than 12 years old
B. 6–12 years old
C. 2–6 years old
D. 2–12 months old
E. Never acceptable

6. What percentage of the pediatric population lives within 60 minutes of a pediatric trauma center by either ground or air transport?
A. 20%
B. 30.5%
C. 50%
D. 71.5%
E. 95.6%

7. Based on the assumption that CT scanning causes one fatal cancer in 1,000 scans, about how many cancers in the pediatric population may be attributable to CT scanning each year?
A. 4
B. 40
C. 400
D. 4,000
E. 40,000

8. Which of the following is the most effective way to reduce radiation exposure from CT scanning in children?
A. Specific pediatric protocols
B. Lead shielding
C. Limiting CT scan to area of interest
D. Avoid CT scanning if possible

9. When compared to adults, the thoracic wall of the child is:
A. more rigid.
B. more protective.
C. more compressible.
D. more ossified.

10. What type of bony fracture is associated with the "lap belt syndrome"?
A. Femur
B. Rib
C. Pelvis
D. Vertebral

Answers: 1. A, 2. B, 3. C, 4. D, 5. D, 6. D, 7. D, 8. D, 9. C, 10. D

In Future Issues: Adult Thoracic and Abdominal Injury

Trauma Reports
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CNE/CME Evaluation — Vol. 11, No. 3: Pediatric Thoracic and Abdominal Trauma

Please take a moment to answer the following questions to let us know your thoughts on the CNE/CME program. Fill in the appropriate space and return this page in the envelope provided. **You must return this evaluation to receive your letter of credit. ACEP members — Please see reverse side for option to mail in answers.** Thank you.

CORRECT ● INCORRECT

1. In which program do you participate? ○ CNE ○ CME
2. If you are claiming physician credits, please indicate the appropriate credential: ○ MD ○ DO ○ Other __________
3. If you are claiming nursing contact hours, please indicate your highest credential: ○ RN ○ NP ○ Other __________

After participating in this program, I am able to:	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
4. Discuss conditions that should increase suspicion for traumatic injuries.	○	○	○	○	○	○
5. Describe the various modalities used to identify different traumatic conditions.	○	○	○	○	○	○
6. Cite methods of quickly stabilizing and managing patients.	○	○	○	○	○	○
7. Identify possible complications that may occur with traumatic injuries.	○	○	○	○	○	○
8. The test questions were clear and appropriate.	○	○	○	○	○	○
9. I detected no commercial bias in this activity.	○	○	○	○	○	○
10. This activity reaffirmed my clinical practice.	○	○	○	○	○	○
11. This activity has changed my clinical practice.	○	○	○	○	○	○

If so, how?____

12. How many minutes do you estimate it took you to complete this activity? Please include time for reading, reviewing, answering the questions, and comparing your answers with the correct ones listed. ______ minutes.
13. Do you have any general comments about the effectiveness of this CNE/CME program?

____

I have completed the requirements for this activity.

Name (printed) ________________________ **Signature**________________________

Nursing license number *(required for nurses licensed by the state of California)*____________________

Optional for ACEP members: In accordance with ACEP requirements, below we provide the option for ACEP members to submit their answers for this CME activity. If you wish to submit answers for this activity, please refer to this issue (Vol. 11, No. 3) and circle the correct responses.

1. A
   B
   C
   D

2. A
   B
   C
   D
   E

3. A
   B
   C
   D

4. A
   B
   C
   D

5. A
   B
   C
   D
   E

6. A
   B
   C
   D
   E

7. A
   B
   C
   D
   E

8. A
   B
   C
   D

9. A
   B
   C
   D

10. A
    B
    C
    D

Trauma Reports

2010 Reader Survey

In an effort to learn more about the professionals who read *Trauma Reports*, we are conducting this reader survey. The results will be used to enhance the content and format of *Trauma Reports*.

Instructions: Fill in the appropriate answers. Please write in answers to the open-ended questions in the space provided. Please insert this survey in the provided envelope along with your continuing education evaluation. Return the questionnaire by **July 1, 2010.**

1. Are the articles in *Trauma Reports* written about issues of importance and concern to you?

- A. Always
- B. Most of the time
- C. Some of the time
- D. Rarely
- E. Never

2. How would you rate your overall satisfaction with your job?

- A. Very satisfied
- B. Somewhat satisfied
- C. Somewhat dissatisfied
- D. Very dissatisfied

3. What are you most dissatisfied with in your job?

- A. staffing
- B. heavy workload
- C. low morale in your department or facility
- D. impact of cost-cutting on quality of care
- E. other ____________________

Questions 4-9 ask about coverage of various topics in *Trauma Reports*. Please mark your answers in the following manner:

A. very useful B. fairly useful C. not very useful D. not at all useful

4. Imagin in Pediatric Abdominal Trauma (July/Aug. 2009)	A	B	C	D
5. ATLS Update (Sept./ Oct. 2009)	A	B	C	D
6. Traumatic Brain Injury (Nov./Dec. 2009)	A	B	C	D
7. Hand and Wrist Injuries (Jan./Feb. 2010)	A	B	C	D
8. Genitourinary Trauma (March/April 2010)	A	B	C	D
9. Pediatric Thoracic and Abdominal Trauma(May/June 2010)	A	B	C	D

10. How do you receive *Trauma Reports*?

- A. I am a paid subscriber (proceed to question 11)
- B. I receive it as a supplement to another publication (skip to question 12)

11. Do you plan to renew your subscription to *TR*? A. yes B. no

If not, why? ____________________

12. How would you describe your satisfaction with your subscription to *TR*?

- A. Very satisfied
- B. Somewhat satisfied
- C. Somewhat dissatisfied
- D. Very dissatisfied

13. What is your title?

- A. Practicing emergency medicine physician
- B. Trauma surgeon
- C. Emergency department or surgical nurse
- D. Physician assistant
- E. Professor/academician
- F. Emergency medicine manager/director
- G. Resident

14. On average, how much time do you spend reading each issue of *TR*?

- A. fewer than 30 minutes
- B. 30-59 minutes
- C. 1-2 hours
- D. more than 2 hours

15. On average, how many people read your copy of *TR*?

- A. 1-3
- B. 4-6
- C. 7-9
- D. 10-15
- E. 16 or more

16. On average, how many articles do you find useful in *TR* each year?

- A. 1-2
- B. 3-4
- C. 5-6

17. How large is your hospital?

- A. fewer than 100 beds
- B. 100-200 beds
- C. 201-300 beds
- D. 301-500 beds
- E. more than 2,000

Please rate your level of satisfaction with the following items.
A. excellent B. good C. fair D. poor

18. Quality of newsletter	O A	O B	O C	O D
19. Article selections	O A	O B	O C	O D
20. Timeliness	O A	O B	O C	O D
21. Length of newsletter	O A	O B	O C	O D
22. Overall value	O A	O B	O C	O D
23. Customer service	O A	O B	O C	O D

24. What type of education credits do you earn from *Trauma Reports*?

O A. Continuing medical education
O B. Nursing contact hours
O C. I do not participate in the CNE/CME activity.

25. With which publication do you receive *Trauma Reports*?

O A. Emergency Medicine Reports
O B. Pediatric Emergency Medicine Reports

26. Would you subscribe to *Trauma Reports* if it were available as a 12-month subscription?

O A. yes
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27. To what other publications or information sources do you subscribe?

____

____

28. Please list the top three challenges you face in your job today.

____

____

____

29. What do you like most about *Trauma Reports*?

____

____

____

30. What do you like least about *Trauma Reports*?

____

____

____

31. What specific topics would you like to see addressed in *Trauma Reports*?

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____

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Contact information (optional): ______________________________

____