PRACTICAL SUMMARIES IN

ACUTE CARE

*A Focused Topical Review of the Literature for the Acute Care Practitioner*

# Thoracoabdominal Trauma: Diagnostic Dilemmas

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## Introduction

Thoracoabdominal trauma, both from blunt and penetrating etiologies, poses a diagnostic dilemma for the physician. Is CT scanning sufficient to diagnose a pneumothorax? Is the FAST exam reliable in the multiply injured trauma patient? Are there management differences for the pediatric patient versus the adult patient?

The mechanism of penetrating thoracoabdominal trauma must be considered before beginning the physical examination. Surface lesions can be falsely reassuring for penetrating trauma; the size and shape of such lesions does not provide any definitive information regarding the tract of the blade/ object used to stab. Similarly, the size of bullet lesions does not provide information about the path of the bullet and structures it may have encountered in the body. Thermal injury also can result from gunshot wounds, particularly when the victim is shot at close range.

The initial examination should rule out a tension pneumothorax. The presence of distended neck veins, hyperresonance on the affected side, and tracheal deviation away from the area of hyperresonance should be considered diagnostic. Immediate needle thoracostomy is required, followed by conversion to tube thoracostomy. It is particularly important to remember that pneumothoraces that result from penetrating trauma have associated hemothoraces in up to 80% of cases.[1] Persistent hypotension after thoracostomy should prompt consideration of pericardial tamponade. This can be detected clinically by the presence of distended neck veins and distant heart sounds (Beck's triad) and quickly diagnosed via bedside ultrasound. Pericardiocentesis can be a life saving procedure in these cases. Patients who have sustained injuries to the great vessels and the heart rarely make it to the medical setting for evaluation due to the rapidity of blood loss. However, if such a patient does arrive, the presentation is similar to that seen with tamponade.

While these injury patterns are relatively easy to identify on clinical examination, diaphragmatic injuries pose a greater challenge.

The majority of stab wounds to the abdominal cavity occur on the left side of the body, based on the fact that most assailants are right handed and such attacks occur in a face-to-face manner. This statistic, combined with the belief that the liver provided a degree of protection to the right hemi-diaphragm, led to the theory that left-sided diaphragm injuries were more common. However, recent literature[2] has started to question that belief. Large diaphragmatic injuries are relatively easy to diagnose based on the presence of abdominal contents in the chest cavity on routine chest x-ray. Smaller defects pose more of a dilemma as CT scan is neither very sensitive nor specific in this case, and diagnosis often necessitates


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invasive diagnostic procedures.

Blunt trauma to the thoracoabdominal region poses its own set of diagnostic dilemmas. Pressure changes in the thoracoabdominal cavity can result in hemopneumothorax or visceral rupture. Contusions to critical structures (heart, lungs, abdominal organs) must be considered. Unfortunately, pulmonary contusions often are not visible on initial chest x-ray. The physician must maintain a high suspicion for this condition when the trauma patient has persistently low oxygen saturation. Similarly, cardiac contusions often do not result in significant ECG changes or elevations in cardiac enzymes. Clinical suspicion is again the key to make this diagnosis. A variety of imaging modalities are available to assist in the diagnosis of intra-abdominal injuries.

In addition to the above-mentioned concerns, management of trauma in the pediatric population is confounded by two factors. First, younger patients have greater chest wall compliance. This can magnify the forces transmitted to key organs and structures, particularly in blunt trauma. Second, children have substantially greater hemodynamic reserves than adults; this allows them to compensate for significant blood loss for considerably longer periods of time than a similarly injured adult. It is imperative that the examining physician considers these key factors when evaluating the pediatric trauma patient to ensure that injuries are not missed.

The studies reviewed here were chosen based on their relevance to current standards of clinical practice and their potential to address developing controversies in trauma management.


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## Do penetrating chest trauma victims need repeat CXRs after chest CT?

**Source:** Magnotti LJ, et al. Initial chest CT obviates the need for repeat chest radiograph after penetrating thoracic trauma. *Am Surg* 2007;73:569-572; discussion 572-573.

This paper sought to determine if a repeat chest x-ray (CXR) at six hours from time of presentation is necessary to detect delayed pneumothoracies in victims of penetrating thoracic trauma. All trauma patients presenting to the emergency department (ED) underwent an initial CXR as part of ATLS protocol and subsequently had non-contrast chest CT scans. All patients with initial studies that did not require immediate intervention then had repeat CXRs at six hours. The study group enrolled 118 patients (89 stab wounds and 29 gun shot wounds). All initial CXRs were negative, while the chest CT scan identified six pneumothoraces and one hemothorax. Of these patients, two required operative intervention. Repeat CXRs performed on those with initially negative studies failed to show any change or finding at the six hour mark. The authors concluded that changing practice to include a chest CT scan instead of repeat CXRs would decrease the length of ED stay, thus decreasing health care costs and ED overcrowding.

### Commentary

The authors of this study attempt to identify aspects of the ATLS protocol which, if modified, could decrease health care costs, ED length of stay, and ED overcrowding. This prospective study does show that initial chest CT scan is able to identify pneumothoraces better than plain CXR. However, this finding is of questionable clinical significance. The argument could be made that if a pneumothorax is too small to show on plain radiograph, it would likely resorb with only supplemental oxygen therapy. Furthermore, some would question the decision to use non-contrast CT scan, as most trauma surgeons advocate CT scan with contrast to further identify any vascular injuries that may have been sustained.

## CT scan versus angiography for hemorrhage detection in trauma patients

**Source:** Maturen KE, et al. Contrast-enhanced CT accurately detects hemorrhage in torso trauma: direct comparison with angiography. *J Trauma* 2007;62:740-745.

Maturen and colleagues performed a retrospective study to evaluate the efficacy of contrast CT scan for determining active bleeding in patients who sustained thoracoabdominal and/or pelvic trauma. Any trauma patient who underwent initial CT scanning followed by angiography within the first 24 hours of admission was eligible for inclusion. Angiography technique was based on the patient's exam and findings on previous radiologic studies. Over a 30-month study period, 48 subjects (33 males, 15 females) were identified. Comparing CT findings to angiography findings, they found that CT had a sensitivity and specificity of 94% and 92%, respectively, for identifying bleeds relative to angiography. This related to a negative predictive value (NPV) of 97.6% for active hemorrhage and a NPV of 92.1% for identifying patients who need further intervention.

**Commentary**

This study, although retrospective, significantly bolsters the role of CT scanning in the trauma patient. Unlike the Magnotti study, patients in this paper underwent contrast enhanced CT scan, which is consistent with protocols at most trauma centers. Subjects in the study only underwent angiography based on positive CT scan findings, thus small bleeds may have been missed. However, as this did not correlate with negative outcomes in the study population, the question of clinical significance of such potential findings must be considered. Finally, these findings, when combined with the clinical presentation of the patient, may significantly lower the rate of angiographic studies; this may spare patients from unnecessary radiation and dye loads without compromising outcome.

## Utility of FAST exam for hemoperitoneum in patients with pelvic fractures

**Source:** Friese RS, et al. Abdominal ultrasound is an unreliable modality for the detection of hemoperitoneum in patients with pelvic fracture. *J Trauma* 2007;63:97-102.

Although the FAST exam frequently is used to determine the presence of hemoperitoneum following thoracoabdominal trauma, its efficacy in the multiply injured patient has recently been questioned. Friese and colleagues attempted to determine if the FAST examination is reliable when evaluating patients with concurrent pelvic fractures. This retrospective 15-month study included all patients with a pelvic fracture and at least one of the following risk factors for significant hemorrhage: age $\geq$ 55; systolic blood pressure < 100 mmHg; and unstable fracture pattern.

Surgery residents performed all FAST exams, and all studies were confirmed by an attending surgeon. Both residents and attending surgeons had undergone a training and certification program in ultrasound, before this study period began. FAST findings were compared to laparotomy or CT scan. Of the 146 patients who met inclusion criteria, 126 had a FAST examination as part of the original evaluation. Of these patients, 104 had a confirmatory test performed; eight of these were subsequently eliminated from the study group as a diagnostic peritoneal lavage was performed before the definitive study could be completed. Thus, the final study group consisted of 96 patients. FAST exams in these patients yielded 11 true positive, 52 true negative, 2 false positive, and 31 false negative studies. This translates into a sensitivity of 26%, a specificity of 96%, a positive predictive value (PPV) of 85%, and a NPV of 63%.

**Commentary**

This paper highlights a potential weakness of the FAST exam. It is critical that the physician consider the limitations of ultrasound when using it as a screening test. The high association of pelvic fractures with intra-abdominal bleeds must be factored into the evaluation algorithm for a patient with a negative FAST exam, particularly if the patient is hemodynamically unstable. Although this is a retrospective study, it serves as a powerful reminder to consider the mechanism and the clinical picture when evaluating the trauma patient with a pelvic fracture.

## Should radiation exposure be considered during trauma evaluation?

**Source:** Huda W. Radiation doses and risks in chest computed tomography examinations. *Proc Am Thorac Soc* 2007;4:316-320.

The dose length product (DLP) was used to quantify the amount of radiation to which a patient was exposed during chest CT scanning using the 16 slice technique from 4 major (and commonly used) equipment vendors. The DLP was then converted into an effective dose (E). The effective dose was then used to estimate cancer risks based on the standards established by the Committee of the Biological Effects of Ionizing Radiation. Effective radiation doses ranged from 1.7 millisievert (mSv) for the newborn to 5.4 mSv in adults. Put in practical terms, an effective dose of 0.55 mSv in a 5-year-old child correlates to a 1.5 cancers/10,000 people risk.

**Commentary**

The author uses a series of mathematical formulas to evaluate the radiation exposure to which a trauma victim is subjected during the course of the ATLS protocols. This article should do much to alleviate physician and family concerns regarding cancer risks, particularly in those patients who have sustained multiple traumas over the course of time.

## Is laparoscopy alone sufficient to exclude diaphragmatic injury in penetrating abdominal trauma?

**Source:** Friese RS, et al. Laparoscopy is sufficient to exclude occult diaphragm injury after penetrating abdominal trauma. *J Trauma* 2005;58:789-792.

This prospective study aimed to determine if laparoscopy is sufficient to diagnose occult diaphragmatic tears following penetrating thoracoabdominal trauma. Thirty-four consecutive hemodynamically stable patients who sustained penetrating thoracoabdominal trauma (37 stab wounds, 1 gunshot wound) were enrolled; a total of 38 penetrating injuries were sustained. All patients underwent diagnostic laparoscopy followed by either laparotomy (30) or video assisted thoracoscopy (4). There were seven true positive, 30 true negative, no false positive, and one false negative laparoscopies. This relates to a specificity of 100%, sensitivity of 87.5%, and NPV of 96.8%. The authors note that the one missed diaphragmatic injury was in a patient with significant hemoperitoneum, thus obscuring any laparoscopic attempts at sufficient evaluation.

**Commentary**

This paper marks a significant advancement of the role of laparoscopy in the evaluation of the victim of penetrating trauma. Although small, this prospective study included a comparison to a gold diagnostic standard. The study population sustained diaphragmatic injuries at a rate consistent with that previously reported in the literature, giving further credibility to the study. One potential weakness of the study is that the majority of injuries (35/38) were sustained on the left side of the body. Right sided diaphragmatic injuries are notoriously harder to detect due to the tamponading effect of the liver. Of the identified injuries, seven of eight were left sided. However, it also is important to consider that the majority of stab wounds to the abdomen are sustained on the left side of the body due to the significantly higher percentage of right hand dominant people in the population.

Finally, the authors comment that any patient in whom adequate visualization of the diaphragm cannot be obtained laparoscopically should be further evaluated with either an open procedure or thoracoscopy. This study is an important addition to the penetrating trauma literature.

## Can characteristics of a crash increase thoracoabdominal trauma risk?

**Source:** Nirula R, et al. Predicting significant torso trauma. *J Trauma* 2005;59:132-135.

Nirula and colleagues applied multivariate logistic regression to data derived from the National Automotive Sampling System to determine if crash characteristics could be used to determine the likelihood of thoracoabdominal injury. Among the 56,466 drivers included in the study, airbags were deployed in 15.6% of crashes and the driver was restrained in 60.7% of cases. Significant thoracoabdominal injuries were sustained by 2,796 patients. Several factors were associated with a significantly higher likelihood of injury: age, ejection from the vehicle, avoidance techniques, restraints, velocity at the time of impact, passenger side impact, rollover, and lower vehicle weight. These associations were significant even though velocity data was missing on almost half of the collisions (46.7%) and the most common site of impact was frontal (59.5%).

**Commentary**

The work of Nirula et al incorporates developing technology. The automatic crash notification system, on which this study is based, uses a combination of sensors and wireless communication to alert local EMS systems of a motor vehicle collision

(MVC). Currently, certain vehicles contain sensors that detect airbag deployment, significant change in velocity, rollover, and direction of impact to trigger EMS notification. By identifying collision characteristics likely to lead to thoracoabdominal injury, the authors feel that crash notification systems could be further enhanced and improved. Nirula and colleagues estimate that with the enhanced systems, EMS notification could occur within 45 seconds of the crash. Considering that the sooner the EMS activation occurs, the greater portion of the "golden hour of trauma" the patient can spend in the trauma center, this potentially decreases morbidity and mortality.

This paper only addresses potential injury to the driver; separate studies are needed to address both front and back seat passengers. This technology, while still not widely produced in vehicles, may significantly improve patient outcome in motor vehicle collisions. In the interim, physicians should incorporate the identified collision characteristics into the history of trauma patients.

## Can fluid resuscitation needs predict severity of pediatric trauma?

**Source:** Vella AE, et al. Predictors of fluid resuscitation in pediatric trauma patients. *J Emerg Med* 2006;31:151-155.

This retrospective study performed at Children's Hospital Los Angeles included 152 patients (median age, 6; range, 4 months to 17 years) who presented for trauma evaluation. Mechanisms of injury included MVC (49%), fall (37%), crush (8%), gunshot (5%), and stab wounds (1%). Penetrating thoracoabdominal injuries accounted for 6% of all injuries, while 88% of subjects had a closed head injury. Prehospital IVs were placed in 59% of patients, and 48% of patients had one IV placed. Fluid resuscitation included no bolus in 70%, one bolus in 20%, two boluses in 7%, and > two boluses in 3%. Vital signs remained stable in 59%, improved in 34%, and deteriorated in 7%. T-tests were not able to correlate the mechanism of injury with the number of IVs or with the amount of fluid resuscitation the patient received. Patients with higher Injury Severity Scores (ISS) were more likely to receive a second IV. Also, the Revised Trauma Score (RTS) was the only means of identifying those likely to have worsening vital signs.

**Commentary**

This study raises several interesting points. First, it is another in a long line of studies questioning the general applicability of ATLS guidelines. Second, it highlights the difficulty of obtaining vascular access in the pediatric population. Finally, it serves as a reminder that even in the urban population, blunt trauma is still the major cause of pediatric trauma. However, the retrospective nature of the study renders its main points difficult to apply clinically. The authors calculated both the ISS and the RTS as the means to predict those who would likely need a second IV and those who were more likely to have worsening vital signs. However, neither of these scores is calculated in the immediate trauma resuscitation. Given the hemodynamic reserve of children and their ability to compensate for blood loss far longer than their adult counterparts, it may be prudent to start a second IV and weight-based fluid resuscitation until a more reliable clinical indicator is identified.

## Can pediatric rib fracture occur secondary to CPR?

**Source:** Worn MJ, Jones MD. Rib fractures in infancy: establishing the mechanisms of cause from the injuries—a literature review. *Med Sci Law* 2007;47:200-212.

This study uses biomechanical analyses of cardiopulmonary resuscitation (CPR) techniques in an attempt to identify the cause of rib fractures in the infant population. This is of particular importance in this age group given the possibility of child abuse and the need to adequately protect patients in such cases. The study compares the "two finger" (index and middle finger) CPR to the recently proposed "two thumb" (with the resuscitator wrapping the hands around the infant's torso) method. Through a series of biomechanical evaluations, they determined that the two finger method of compressions remains below the forces required to fracture ribs while the two thumb method inflicts significantly higher forces to the chest wall and, thus, may result in rib fractures. While these forces may be beneficial in providing blood flow in an arrest situation, these data can be extrapolated to potential abuse conditions and need to be considered in the differential for rib fractures in infants that require CPR.

**Commentary**

The work of Worn and Jones is an important first step in the possible identification of rib fracture etiology. However, it is a lab-based study that was done on mechanical-computer models. As more such studies are performed and the findings applied to the clinical setting, more practical guidelines are likely to follow. In the interim, it is important for the physician to consider the similarity of the two-thumb CPR method and the typical way a child is held when being shaken while evaluating injuries. It is crucial that the physician search for other sequelae of abuse in an infant with rib fractures, including retinal injuries and intracranial pathology.

## How does seat belt use contribute to abdominal injuries in the pediatric patient?

**Source:** Arbogast KB, et al. Mechanisms of abdominal organ injury in seat belt-restrained children. *J Trauma* 2007;62:1473-80.

The authors used pre-established and validated crash investigation protocols in an attempt to identify factors that may predispose children to intra-abdominal injury during a motor vehicle collision. Biomechanical factors, collision details, and child anthropomorphic data were used in the calculations and determinations. Twenty-one cases in which a belted child sustained an intra-abdominal injury were included in the study group. This data set was compared to a second group of belted children (matched for age, gender, and body type) who sustained no injury in the course of a motor vehicle collision. The following characteristics were identified as leading to intra-abdominal injury following MVC:

- Belt compression directly over the abdomen (instead of compression over the hip);
- Poor child posture; and
- Misuse of the shoulder belt.

It is important to note that among the group of injured children, 60% of the drivers and 90% of other children in the vehicle at the time of collision sustained little or no injury.

**Commentary**

Arbogast and colleagues highlight the precarious position of children in motor vehicle collisions. This study illustrates the need for properly fitting seat belts and reinforces the idea that children under a certain age and/or physical size should not be in the front seat of a car (standards vary state to state). This further advocates the use of booster seats when necessary. The authors also mention the potential role of commercially available tension limiting devices that may be applied to the lap belt in seats frequently used by children. Finally, this study emphasizes the need for the physician to inquire further into the collision history details (when possible) when performing the initial trauma evaluation.

## Is non-operative management of splenic injuries appropriate in the pediatric population?

**Source:** Kristoffersen KW, Mooney DP. Long-term outcome of nonoperative pediatric splenic injury management. *J Pediatr Surg* 2007;42:1038-1041; discussion 1041-1042.

Conservative management of the hemodynamically stable patient with a splenic injury has long been the standard of care, but is there any impact on the long-term outcome? Kristoffersen and Mooney attempt to address this issue in their retrospective cohort study. They reviewed all trauma patients over an 11-year period and were able to identify 266 children who sustained a splenic injury. Of these patients, 228 were interviewed for this study (86%). The mean time between injury and interview was 5 +/- 3 years. Only one complication, a splenic pseudocyst, was identified (0.44% incidence), leading the authors to conclude that non-operative management of hemodynamically stable splenic injury patients is appropriate in the pediatric age groups.

**Commentary**

Although this is a retrospective study, the authors do a reasonable job of contacting all potential study subjects. However, one must wonder if the remaining subjects may have had complications and, therefore, if the true incidence of post injury complications is as low as is reported here. This paper does add validity to the practice of non-operatively managing splenic injuries in the pediatric population.

## Can commercially available chest protectors prevent commotio cordis?

**Source:** Doerer JJ, et al. Evaluation of chest barriers for protection against sudden death due to commotio cordis. *Am J Cardiol* 2007;99:857-859.

Commotio cordis is the R on T phenomenon that leads to ventricular fibrillation and often sudden cardiac death following blunt chest trauma. It is typically seen in patients younger than age 10 due to the increased chest wall compliance in this age group. This compliance allows for forces delivered to the anterior chest wall to be more aggressively transmitted to the myocardium. This scenario is particularly common in youth sports.

Doerer and colleagues retrospectively reviewed the U.S. Commotio Cordis Registry to determine the number of cases involving commercially available chest protectors such as those typically worn by baseball catchers. The registry documented 182 cases of commotio cordis, with 47% (85 cases) occurring during organized sports. Thirty-two of these cases (38%) occurred while the affected individual was wearing what was thought to be protective equipment. These individuals were participating in hockey (13), football (10), lacrosse (6), and baseball (3). The authors identified two key risk factors for commotio cordis despite protection: inadequate coverage of the precordium and direct contact with the pad.

**Commentary**

Commotio cordis is one of the most feared complications of youth sports. The work of Doerer et al serves as a careful reminder that commotio cordis is possible even with what is perceived to be adequate coverage. This paper should serve to remind parents, coaches, and officials that chest protection should be properly fitted to the individual wearing it. Second, the upkeep of the chest protection is important, as normal wear and tear may significantly increase the young athlete's susceptibility to commotio cordis.

This paper also should be used as a reminder that automated external defibrillators (AED) should be present at youth sporting events, and particularly those involving high velocity activities.

## Conclusions

Thoracoabdominal trauma remains a diagnostic challenge for the physician performing the initial evaluation. Maturen and colleagues showed that CT scan with contrast is as reliable for detecting injuries as the angiogram. This development may facilitate trauma evaluation and lower the dye load to which the patient is exposed.

Magnotti et al showed that CT scan without contrast is as effective as plain radiography in identifying pneumothoraces following trauma. Considering that these scans were done without contrast, which is contrary to protocol at most trauma centers, it is believed that studies with contrast could detect even more injuries.

The work of Huda should further reassure the physician that the diagnostic process for trauma patients is likely not causing a significant radiation exposure, even for the victim of repeat trauma. This has implications for the long-term morbidity associated with trauma.

Friese and colleagues determined that laparoscopy is sensitive and specific for ruling out diaphragmatic injuries, providing full visualization of the structure is possible. This study should decrease the number of thorascopic examinations performed in the trauma evaluation. Given the recent emphasis on ultrasound in the trauma evaluation, Friese and colleagues' second paper serves as a powerful reminder that the FAST exam is not reliable in certain patient populations, particularly those with concurrent pelvic fractures.

Evaluation and management of pediatric thoracoabdominal trauma victims remains challenging. Vella and colleagues raise the question of whether standard ATLS protocols are valid in the injured child. The retrospective nature of the study and the reliance on measures not traditionally calculated in the acute setting render the results less than convincing. By identifying factors that predispose to seat belt injuries, Arbogast and colleagues highlight the need for proper use of child safety seats in motor vehicles and the injuries associated with their improper use. Kristoffersen and Mooney evaluated the long-term outcome of non-operative management of splenic injury in the pediatric population, and concluded it

## CME OBJECTIVES

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was appropriate; however, their retrospective study may have missed several complications. Finally, despite the use of chest protectors, children who sustain blunt chest trauma may still succumb to commotio cordis.


## References

1. Ordog GJ, et al. Asymptomatic stab wounds of the chest. *J Trauma* 1994;36:680-684.
2. Brown GL, Richardson JD. Traumatic diaphragmatic hernia. *Ann Thorac Surg* 1985;39:172.


## CME QUESTIONS

**57. Which of the following is not a risk factor for seatbelt injury in the pediatric population?**
A. Misuse of the shoulder belt
B. Poor child posture
C. Belt compression over the hips
D. Belt compression directly over the abdomen

**58. Which of the following is *not* a risk factor for decreased sensitivity and specificity of FAST in abdominal trauma?**
A. Systolic blood pressure < 100
B. Unstable pelvic fracture
C. Age ≥ 55
D. Age ≤ 55

**59. The NPV of laparoscopy for identifying diaphragmatic injury following thoracoabdominal trauma is:**
A. 96.8%.
B. 87.5%.
C. 93.7%.
D. 100%.

**60. Which of the following is a risk factor for significant thoracoabdominal trauma?**
A. High vehicle weight
B. Driver side impact
C. Lack of rollover
D. Avoidance techniques

**61. Which of the following sports places the young athlete at the greatest risk for commotio cordis?**
A. Golf
B. Hockey
C. Baseball
D. Tennis

Answers: 57. C; 58. D; 59. A; 60. D; 61. B