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Blunt Abdominal Trauma In Prepubertal Children: ED Care In The Era Of Non-operative Management

A 4-year-old boy who was an unrestrained passenger in a rollover motor vehicle collision arrives by ambulance to your busy ED. He is awake, alert, and has normal mental status. He talks freely about his siblings, his pets, and his preschool. Paramedics report no loss of consciousness and that he has had no complaints at all. On physical examination, he has a small bruise on his right lateral leg and an abrasion on his right forearm. His head seems atraumatic and his neck and back are not tender. His pelvis is stable. His abdominal examination is normal, as are his vital signs. Several questions pass through your mind: "Should I let the eager technicians and students cut off his clothes?" "Do I need to do any x-rays?" "Should I perform an abdominal ultrasound examination?" "Does he need an intravenous line?" "The nurses are eager to send labs, including urine—should they?" "Does he need any monitoring?" Just then, a tearful mother arrives and wants to know how her son is and what is being done for him.

THE management of traumatized children can be emotional and confusing. Physicians who see few children in their daily practice may not be confident in assessing a child's mental status, vital signs, or abdomen. Routine procedures such as obtaining intravenous access and interpreting radiographs can be quite difficult. The obstacles mount when the child is preverbal, persistently cries, is uncontrollably frightened, or presents with a misleading history (as seen with child abuse). Furthermore, some mechanisms of injury may result in injuries to multiple systems or multiple organs, making the evaluation more challenging.

On the other hand, exciting advances in CT scanning and other technologies over the past few years have meant that far more children with blunt abdominal trauma can be managed non-operatively than in decades past. Identifying those children for whom CT scanning can be most benefi-

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CME Objectives

Upon completing this article, you should be able to:

1. implement evidence-based management strategies in the care of children with blunt abdominal trauma;
2. discuss the benefits and limitations of commonly used diagnostic studies in managing children with blunt abdominal trauma; and
3. describe indications for surgical consultation, admission, or discharge in children with blunt abdominal trauma.

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See "Physician CME Information" on back page.

cial and identifying those children who may harbor serious intra-abdominal injuries despite relatively normal CT scans are currently some of the greatest challenges for emergency physicians dealing with traumatized children.

This issue of *Pediatric Emergency Medicine Practice* examines the evidence regarding the management of prepubertal children who may have sustained blunt abdominal trauma. With this evidence, emergency physician will be best equipped to handle potential abdominal injuries in all children—from those who have sustained the most severe multi-system trauma to the cases with a request of "just wanting to get checked" after a "minor fender-bender" in a parking lot.

Critical Appraisal Of The Literature

In many ways, it is difficult to study blunt abdominal trauma in children. Variability in the mechanisms of injury result in substantial heterogeneity in study populations. In "pediatric" studies, "children" from birth to 21 years of age may be included, adding an additional layer of heterogeneity to the study population. Many cases occur in the setting of multi-system trauma, such that there are multiple confounding variables affecting the patient's overall outcome and physiological status. Quite a few studies use the results of computed tomography (CT) scans as the criterion standard. This may lead to substantial bias because the authors did not perform CT scans on all possible study subjects.[1]

There are several examples of these problems in the pediatric blunt abdominal trauma literature. One good example, by Holmes et al, appeared in the *Annals of Emergency Medicine* in May 2002.[2] In this study, the definitive tests to determine intra-abdominal injuries were CT scan, ultrasound, diagnostic peritoneal lavage (DPL), laparotomy, and autopsy. There were 1095 subjects enrolled in the study, but only 664 (61%) of them underwent any of the definitive tests. Given the invasiveness of DPL and laparotomy, the radiation exposure seen with CT scanning, and the obvious downsides of undergoing autopsy, it was considered unethical to have all of the children in the study undergo definitive testing. Children who did not undergo definitive testing were followed up with phone calls to assess for problems identified after the ED visit. In this case, a child with a minor splenic injury may have been discharged home without having undergone CT scanning. Since the natural history of minor splenic injuries is that they typically heal on their own without intervention, this child would be categorized as not having an intra-abdominal injury when, in fact, he or she did (a "false-negative"). This study also included children from 11 days to 15.9 years of age, thereby including wide physiologic variability in their study subjects. There are other examples that demonstrate similar methodological problems.[3-5]

Another problem with the pediatric abdominal trauma literature involves study design. Many of the studies are retrospective studies, case series, or prospective observational studies. As a representative example, consider studies in which the authors attempted to determine what number of red blood cells (RBCs) seen on microscopic urinalysis should prompt the ordering of radiographic studies to assess for genitourinary injuries in traumatized children. Currently, the radiographic study of choice is a CT scan. Prior to the late 1980s, however, the study of choice was the intravenous pyelogram. As a result, these studies offer very confusing results:

- Two studies suggest that any degree of microscopic hematuria should prompt radiographic imaging.[6,7]
- Two studies suggest that the threshold for ordering radiographic imaging should be 20 or more RBCs per high power field (hpf) on microscopic urinalysis.[3,8]
- Three studies conclude that a threshold of 50 RBC / hpf was most appropriate.[9-11]
- One study concluded that a threshold of 100 RBC / hpf was the most appropriate for radiographic imaging to assess for renal injury.[12]
- Five articles suggest that the microscopic urinalysis should not be relied upon as an indication for radiographic imaging.[13-17]

The methodological problems in these 13 articles lead to the conflicting results. Some studies exclusively included children who underwent radiologic evaluation and could therefore determine the sensitivity but not the specificity of the RBC count in the microscopic urinalysis for identifying pediatric genitourinary injuries.[8,11,12,16,17] Some studies exclusively included children with identified renal injuries.[6,7] These studies, like those that included children who underwent radiologic testing, can only assess the sensitivity of the microscopic urinalysis, not the specificity. One study included all children who presented with blunt abdominal trauma over a two-year period to a Level I trauma center, but only 25% of the study population had a urinalysis performed.[15] The best-designed study was a prospective study[3] performed to validate a prior retrospective study.[8] Unfortunately, this prospective study included only 32 patients ranging from 2 to 19 years of age, and only 16 of these subjects underwent radiographic imaging.[3] There were four positive, but clinically insignificant findings, including three renal contusions and one incidental finding of renal papillary necrosis. Conclusions based on small, unrevealing studies such as this are problematic.

Given the paucity of well-designed, prospective, interventional studies regarding the ED management of pediatric trauma, it remains challenging to base clinical practice on evidence. With a thoughtful and critical reading of the available literature, however, clinical decision-making can be enhanced.

Epidemiology, Etiology, And Pathophysiology

Epidemiology

Trauma is the leading cause of death in children between the ages of 1 and 18 years.[18] More than 20,000 pediatric deaths per year in the United States are directly related to trauma.[19,20] While head and thoracic injuries are the most common causes of trauma-related death, abdominal

trauma is the leading cause of initially unrecognized fatal injury in children.[19,21,22] Blunt abdominal injuries comprise 90% of pediatric abdominal injuries. Solid organ injuries including the kidney, spleen, and liver are the most common intra-abdominal injuries identified.[23] Blunt gastrointestinal injuries are relatively uncommon in children, occurring in fewer than 1% of children.[24] Significant abdominal injury occurs in only about 5% of child abuse cases, but it is the second most common cause of death after head injury in these patients. Common mechanisms of injury in children include motor vehicle collisions, auto-pedestrian events, falls, sports injuries, and abuse.

Etiology

The etiology of blunt abdominal trauma in children is really just the mechanism of injury. In one prospective study of over 1000 traumatized children up to 16 years of age considered at risk for intra-abdominal injuries, the following mechanisms of injury were identified: motor vehicle collision (39%), automobile vs. pedestrian (24%), fall (17%), automobile vs. bicycle (9%), fall off bicycle (6%), crush injury (3%), assault (3%), child abuse (1%), and other causes (1%).[2] Injuries involving motor vehicles, bicycles, and falls are the most common mechanisms.

While ED management of children with blunt trauma has traditionally emphasized mechanism of injury as a decision node, more recent research has shown that this may not be as accurate a predictor of injury severity in abdominal trauma as compared to, for example, head trauma or orthopedic trauma. Over-reliance on mechanism of injury in determining the clinical management of children with blunt abdominal trauma is a potential pitfall.

Motor Vehicle Collisions

In children who have been involved in motor vehicle collisions, the most clinically relevant factor is probably whether or not the child was properly restrained.[25] Research indicates that seat belt use is better than nothing, and that age-appropriate booster seats work the best. Children who are not restrained are 2.7 times more likely to sustain an injury than restrained children are.[26] In a prospective study of 168 children 4-14 years of age who were involved in motor vehicle crashes, children in regular seat belts were 2-10 times less likely than unbelted children to die or sustain at least moderately severe injuries.[27] In a recent large, cross-sectional study of children 4-7 years of age, the incidence of injury for children restrained in regular seat belts was compared to that of those in age-appropriate belt-positioning booster seats.[28] Overall, injuries were uncommon, occurring in fewer than 2% of the subjects in the total study population. However, there were no injuries to the abdomen in the group that was properly restrained with a booster seat, while some abdominal injuries occurred in the regular seat belt group.

Ejection from a motor vehicle and rollover accidents are uncommon but serious. In a prospective study of children involved in severe car crashes in Canada, only 0.2% of 5.5 million motor vehicle accidents involved a child who was ejected from the vehicle, and 2.2% involved rollover accidents. These two groups, however, accounted for more than half (3756 of 6570 [57%]) of reported fatalities.[29]

Automobile vs. Pedestrian

Motor vehicle collisions involving pediatric pedestrians are most common in densely populated areas. In one seven-year study of all motor vehicle collisions occurring in New York City, 32,578 children were injured by being struck by a vehicle.[30] This represents 4.7% of all motor vehicle crashes during the study period. Factors suggested to be associated with more severe injuries included vehicle speed greater than 30 miles per hour, pedestrian age less than 5 years, and busier roads.[31] A separate analysis for abdominal injuries is not available.

One relatively uncommon mechanism of injury is to have a car roll over a child in a residential driveway. In one study of 3971 traumatized children, only 26 (0.7%) had a car roll over them. Two children died, but the majority of the patients were managed non-operatively. Intra-abdominal injuries in these children seem to have a secondary role to head injuries in the severity of the morbidity associated with this type of injury.[32]

Falls

Trauma team activation criteria have traditionally included falling from a certain height.[33] This would suggest that falling from a certain height places a patient at a greater risk of an operative injury, and that the height of a fall might predict intra-abdominal injuries. However, in a study published in 2001 of 729 cases of children who presented to one of two major trauma centers after falling, the authors reported that children who had sustained falls from a height of less than 15 feet were just as likely to sustain an abdominal injury as those who fell from a greater height.[34] Differences were appreciated in the rate of intracranial and orthopedic injuries, but not abdominal injuries. In other studies of children sustaining falls from heights of at least 10 feet, abdominal trauma was seen in a small minority of cases.[35,36]

Bicycle Injuries / Direct Blows To The Abdomen

Blunt force delivered to a relatively small area of the abdomen—for instance, via a sharp kick or via bicycle handlebars during a collision or fall—can certainly lead to clinically important injuries. Although solid organs can be injured just as in other mechanisms of injury, and intra-abdominal injuries involving the liver and spleen are well described in bicycle accidents,[37-39] direct blows to the abdomen seem to have a higher incidence of pancreatic and bowel injuries.[40,41]

Even so, pancreatic injuries are relatively rare in pediatric blunt trauma. In one study of over 14,000 pediatric trauma admissions, only 18 (0.1%) significant pancreatic injuries were identified.[42] In one small study of 32 children who had experienced the handlebars of their bicycles striking them in the abdomen, 7 (22%) sustained clinically significant pancreatic injuries.[40]

Sports Injuries

Sports-related or recreational injuries account for a low incidence of abdominal injuries in children. Trauma registry data of 4921 children demonstrated abdominal or genitourinary injuries in 0.73% of patients as a result of recreational activities. Kidney injuries were most common (44.4%), followed by spleen (36.1%) and liver (19.5%) injuries.[43]

Abuse

Recognized abuse accounts for approximately 4% of injured children seen in pediatric EDs.[44] In general, children with abuse-related abdominal trauma are younger than most pediatric trauma patients (mean age, 2-3 years) and have more severe injuries.[45] Mortality is very high (45%-50%) because of delays in presentation and the magnitude of the injuries.[46,47] The most common injuries are to the liver and spleen, followed by duodenojejunal rupture, pancreatic, vena caval, and renal injuries.[46] Other associated injuries include soft-tissue injuries, head trauma, and fractures.[46] Unfortunately, the diagnosis of abdominal trauma may be delayed due to a false or misleading history.

Pathophysiology

The pathophysiology of trauma is seemingly straightforward. A force is delivered to the trunk resulting in internal structural disruption. The spleen sustains a force, the internal structure is disrupted, and it bleeds until the bleeding stops spontaneously (common) or through operative intervention (much less common). However, given that intra-abdominal trauma is usually seen in the context of multi-system trauma, the pathophysiology of intra-abdominal trauma is best understood in this overall physiologic context. In multi-system trauma, multiple inflammatory mediators are released, and a clinical triad of hypothermia, acidosis, and coagulopathy develops.[48] This physiologic concept may be clinically important for those children with moderate-to-severe injuries and the basis for management strategies such as keeping the trauma patient warm and administering fresh frozen plasma as a coagulopathy develops.

Differential Diagnosis

The differential diagnosis of abdominal trauma primarily revolves around specific organ injuries. Although it is convenient to discuss each organ separately, it is important to note that to varying degrees, multiple organs can be injured simultaneously.

Kidney

The kidneys have been reported to be the most commonly injured solid organ in pediatric blunt abdominal trauma, if the retroperitoneum and posterior abdomen are included.[49,50] However, more recent studies suggest that kidney injuries are less common than other solid organ injuries.[2] The most common etiology of renal injury is the motor vehicle collision. In a 1994 study of pediatric blunt abdominal trauma, 28% of 1754 patients were found to have a renal injury.[51] Kidney injuries are most commonly associated with a deceleration mechanism or blunt trauma to the trunk.[52-54] (See **Figure 1**.) Isolated renal injuries are uncommon, as they are usually found in conjunction with other injuries.[52]

Physical findings associated with renal injuries include abdominal tenderness, flank tenderness, rib fractures, vertebral fractures, and abdominal or flank contusions.[55] The kidneys of the pediatric patient are more likely to be injured in blunt trauma than the adult patient with a similar mechanism.[56] Unrecognized congenital anomalies may increase the risk of injury as well.[54,57]

Ureter

Ureteral injuries from blunt trauma are rare. The incidence is less than 1% of all urologic injuries.[58] The typical mechanism of ureteral and ureteropelvic junction disruption in blunt trauma involves rapid deceleration, forcing the kidney to be displaced upwards against a relatively fixed ureter. Fractures of lumbar spine transverse processes should raise suspicion for these injuries, due to the anatomic proximity.[58-61]

Bladder

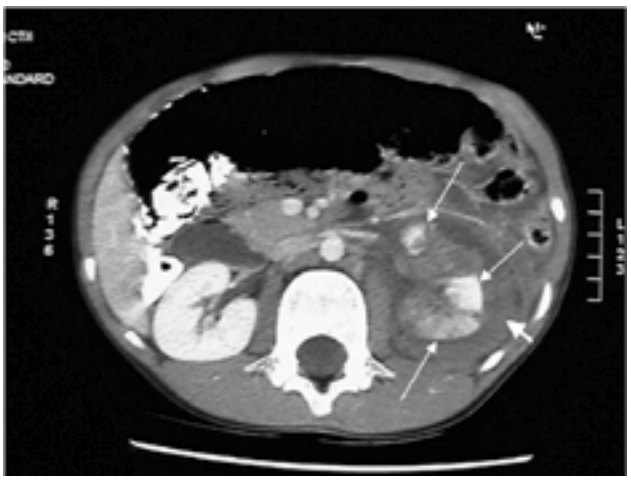
Bladder injuries are relatively rare in children, and cases of bladder rupture are most commonly associated with pelvic fractures. In one retrospective study of 8021 patients, 212 subjects had sustained pelvic fractures, and of these, only one child was diagnosed with a bladder rupture.[62] This child had gross hematuria. In another study of 1500 consecutive traumatized children who underwent CT scanning of the abdomen and pelvis, only seven were diagnosed with bladder rupture.[63]

Spleen

The spleen is probably the second most frequently injured intra-abdominal organ in children who sustain

Figure 1. Kidney Injury.

Image from the abdominal CT scan of a 12-year-old boy who presented with gross hematuria after falling down multiple stairs at school. Note the ruptured left kidney (thin arrows) with surrounding hematoma (thick arrow). The pediatric surgeons who admitted this child successfully managed this injury non-operatively in a pediatric intensive care unit.



blunt abdominal trauma.[2] Most spleen injuries are due to motor vehicle collisions. Diseases that increase the size of the spleen (e.g., mononucleosis, lymphoproliferative disorders, lupus) predispose patients to splenic rupture, even as a result of minor trauma.[18]

Liver

The liver is also a commonly injured abdominal organ. (See **Figure 2**.) In one relatively large prospective series, the liver was the most commonly injured intra-abdominal organ.[2] As opposed to injuries to other intra-abdominal organs, blunt liver trauma is thought to be primarily responsible for the greatest number of fatalities where abdominal trauma is the primary cause of death.[51] In one retrospective review of 328 children with liver injuries admitted to a pediatric trauma center, the most common mechanisms of injury resulting in liver injury were automobile vs. pedestrian (39%), motor vehicle collision (34%), falls or discrete blows to the abdomen (13%), bicycle injuries (5%), and non-accidental trauma (5%).[64]

Pancreas

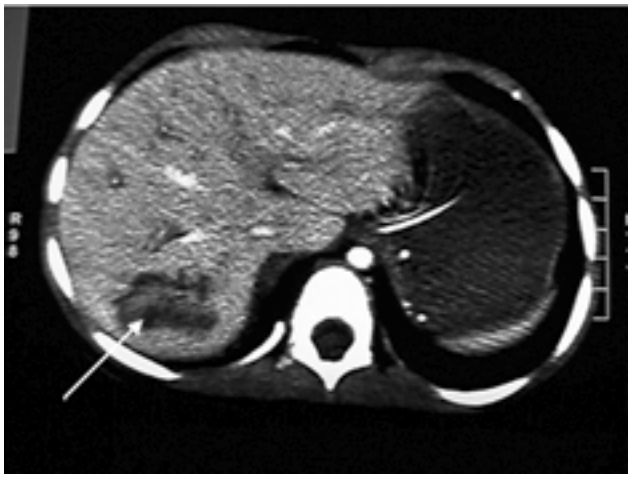
Pancreatic injuries are rare in children. In one study of 11,794 consecutive admissions to a pediatric trauma center over a 13-year period, only 56 children (0.4%) with pancreatic injuries were identified.[65] Some of these children had their pancreatic injury identified at autopsy, suggesting that multi-system trauma dominated the clinical picture. A retrospective medical record review spanning 14 years at a pediatric trauma center identified only 26 cases of pancreatic injury.[66] Eleven of these pancreatic injuries were due to the handlebar of a bicycle directly impacting the abdomen.

Gastrointestinal Tract

Gastrointestinal injury following blunt trauma is uncommon in children. Of 1095 traumatized children presenting to a trauma center, 25 gastrointestinal injuries (2%) were identified.[2] The jejunum is the most commonly injured segment of bowel, followed by the duodenum, ileum, and cecum.[67]

Figure 2. Liver Injury.

Image from the abdominal CT scan of a 4-year-old boy ejected through the windshield during a motor vehicle collision. Note the dark area within the liver (arrow) indicating laceration and contusion. The pediatric surgeons who admitted this child successfully managed this injury non-operatively in a pediatric intensive care unit.



Adrenal Glands

Clinically significant adrenal injuries are exceedingly rare in blunt pediatric trauma and do not appear to occur in isolation. However, evidence of adrenal injury identifiable on CT scan may be relatively common. In one series of 1120 patients (including adults), 20 (1.8%) had evidence of adrenal injury on CT scan.[68] However, only one subject (0.08%) in this study developed adrenal insufficiency, and this subject had bilateral adrenal injuries.

Prehospital Care

Emergency medical service (EMS) providers manage serious pediatric trauma infrequently. In one study performed in four states over the course of two years, over 1.5 million patient care reports were filed.[69] Of the patients transported, 4% were children, and 1.6% were blunt trauma cases. There was insufficient information in this study to identify how severely the children were injured or which of them had sustained abdominal trauma. However, if 10% of pediatric blunt trauma cases transported by EMS providers have intra-abdominal injuries,[2] then EMS providers would expect one out of each 625 patient transports to involve a child with an intra-abdominal injury.

Prehospital care providers frequently use the mechanism of injury to determine the potential for serious injury. Although historically and commonly used to determine hospital destination and trauma team activation for traumatized children, investigators have only recently begun to evaluate the relationship between mechanism of injury and the need for prompt surgical intervention.[33,70] Dowd et al reported that of the 492 traumatized children transported to their facility by prehospital personnel, none of 107 children who met trauma team activation solely by mechanism of injury criteria required volume resuscitation, a chest tube, intubation, resuscitation drugs, or an operation.[33] Qazi et al reported that of 143 traumatized children who had trauma team activations solely for mechanism of injury, none required thoracotomy, laparotomy, or craniotomy, and 86 of the children were discharged home from the ED.[70] From the results of these modestly sized studies, it would appear that the mechanism of injury is not as predictive of serious injuries as previously assumed.

Emergency Department Evaluation

The ED encounter in children who have sustained blunt abdominal trauma is described in the Clinical Pathway on page 11. The priorities are:

- initial stabilization;
- identifying multi-system trauma;
- identifying hemodynamic instability, and obtaining immediate surgical consultation in those for whom fluid resuscitation is not effective;

- identifying indications for CT scanning of the abdomen and pelvis; and
- identifying persistent abdominal symptoms requiring surgical consultation and admission.

While the history, physical examination, and diagnostic studies all contribute to the clinical picture, it may be impossible to perform them sequentially, especially in more severe cases.

History

The utility of the history in the evaluation of traumatized children has not been directly evaluated in the literature. In many cases, it may be difficult or impossible to obtain a history from the parents—for instance, if the parents, who are usually a helpful source of information in the ED and a calming influence on a child, are not present in the ED or are unable provide the necessary information due to injury, intoxication, or emotional distress.

In cases in which it is feasible to obtain a history, certain components have been suggested as helpful in the evaluation of children who have sustained blunt trauma.

Past Medical History

Most children who sustain trauma are previously well, active children. The past medical history rarely affects management decisions. Pertinent points that may be gleaned from the child's parents—or past medical records, if they can be obtained—include any factors that increase the risk of bleeding, such as hemophilia, congenital cardiac disease with anticoagulant use, or other conditions that would place the child at a higher risk for bleeding.[71] It can also be helpful to know if a child is developmentally delayed or autistic prior to assessing the patient's neurologic status in the ED. A history of past injury / surgery or concurrent illnesses (such as infectious mononucleosis) that result in splenomegaly may also be informative in that they can increase the likelihood of splenic rupture.

Current Complaint

Useful questions may include the following:

- *How did the trauma occur?* There is evidence to suggest that the mechanism of injury is inadequate in identifying children with intra-abdominal injuries. However, some useful information may become available if a report can be obtained from paramedics, police, family members, or other witnesses. For example, if the injury occurred as the result of a motor vehicle collision and the child was not properly restrained, serious injury is more likely (as discussed in the Etiology section). Direct blows to the abdomen, such as handlebar injuries, can be associated with a higher incidence of pancreatic or bowel injuries. Finally, be sure to screen very carefully for non-accidental trauma. These injuries can be harder to detect on physical examination, although they are often more severe. If child abuse is the cause of the injury, misinformation in the patient history and delays in seeking treatment may confound the clinical picture.
- *When did the injury occur? What symptoms has the patient had? How long have the symptoms lasted?* Ask witnesses / parents specifically whether there was any loss of consciousness at the scene or prior to presentation in the ED, whether there was visible blood in the urine before the patient presented to the ED, and whether there has been prolonged pain and / or vomiting since the injury, as all are worrisome signs.

Physical Examination

There are three main areas of focus in examining a child with suspected intra-abdominal injury: an assessment for shock, the mental status and gross neurologic examination, and the abdominal examination.

Assessment For Shock

Although a child can be in shock and still maintain a normal blood pressure, signs of shock may be indicative of an intra-abdominal injury. Holmes et al reported that traumatized children with a low systolic blood pressure were four times as likely to have an intra-abdominal injury compared to normotensive children.[2] Pallor, peripheral vasoconstriction (prolonged capillary refill), and tachycardia, although suggestive of compensated shock and probably indicative of an intra-abdominal injury, have not been studied adequately to make evidence-based recommendations.

Mental Status And Neurologic Examination

Assessing the mental status of a young child is a key feature to examining the abdomen of a traumatized child. If a child who has sustained multi-system trauma has altered mental status, intra-abdominal injury cannot be ruled out on physical examination findings alone.[72] If the mental status is normal, the physical examination of the abdomen may be quite helpful. A child who has sustained a spinal cord injury and is insensate may have a deceptively normal abdominal examination even if he or she is harboring a serious intra-abdominal injury.[73]

Abdominal Examination

A few physical examination features have been associated with intra-abdominal injuries. In a prospective study of over 1000 pediatric patients with blunt torso trauma, Holmes et al noted that children with abdominal tenderness were nearly six times as likely to have an intra-abdominal injury as those who did not have abdominal tenderness.[2] Bruising or abrasions on the abdomen or flank also appear to be associated with intra-abdominal injuries.[4,39] Abdominal distention by itself has not been studied, but clinical experience suggests that distention can occur in the setting of swallowed air from crying and may not predict an intra-abdominal injury. Children who sustain lumbar fractures are more likely to have intra-abdominal injuries regardless of their abdominal examination.[74] Although it has traditionally been taught that a rectal examination should be performed in individuals at risk for intra-abdominal injuries, there is no literature to support this practice in children (or adults).

Diagnostic Studies

Radiologic Tests

The diagnostic armamentarium available to emergency physicians treating traumatized children is reasonably good. The greatest advance in identifying intra-abdominal injuries in traumatized children has been the ready availability of rapid CT scanning. Simultaneous advances in procedure-related sedation have allowed uncooperative young children to undergo necessary testing in a safe and timely fashion.[75]

Computed Tomography

CT has become the imaging study of choice to evaluate the abdomen in blunt pediatric trauma patients. The indications for CT scanning in the setting of blunt pediatric trauma have not been definitively established. However, based on a careful reading of the literature, some indications can be suggested. These cannot be considered evidence based, but are, for the most part, "literature supported." (See **Table 1**.)

These criteria are explored in a few studies that have directly examined the indications for CT scanning in traumatized children. Holmes et al initially performed a retrospective study of children with blunt trauma to identify high- and low-risk groups with respect to intra-abdominal injuries.[76] Building on this work, they then performed a prospective study to evaluate risk factors for intra-abdominal injuries.[2] In this study, they concluded that abdominal tenderness, femur fracture, elevated serum aspartate aminotransferase (> 200 units / liter) or serum alanine aminotransferase (> 125 units / liter), or a urinalysis with at least 5 RBC / hpf were associated with intra-abdominal injuries. Unfortunately, a prospective study evaluating the clinical utility of these criteria is not available. Using similar methodology (logistic regression), Taylor et al also attempted to identify indications for abdominal and pelvic CT scanning for traumatized children.[4] Findings associated with intra-abdominal injuries in this study included abdominal tenderness, lap belt injury, gross hematuria, and assault or abuse as the mechanism of injury. This group went so far as to develop an Abdominal Injury Score,[77] but this score, developed by radiologists, has not been prospectively validated or widely accepted and cannot be recommended at this time.

CT scanning of the abdomen and pelvis has many desirable qualities. The positive impact CT scanning has had on the care of blunt trauma patients has been recognized for nearly 20 years and includes decreased utilization of invasive DPL, decreased rates of negative laparotomies, and rapid identification of solid organ injuries.[78] Especially in children, the use of CT scanning has allowed for the development of non-operative management of solid organ injuries.[6,79-82] In addition, serial CT scanning can be used to re-evaluate a patient if clinical deterioration occurs.[83] CT scanning appears to be safe even for sedated children who receive enteric contrast orally or by nasogastric tube.[84-86] (For further discussion on the utility of oral contrast, see the "Controversies / Cutting Edge" section later in this article.)

The limitations of CT scanning are few. In hemodynamically unstable children who cannot tolerate a brief period of interruption in their resuscitation (other than to be transported to the operating room), CT scanning cannot safely be performed. Fortunately, this situation is relatively uncommon.[80-82] Historically, CT scanning has not been considered sensitive in identifying mesenteric or bowel injuries.[73] Newer helical CT scanning technology, however, has been reported to have an overall sensitivity of 94% in detecting bowel injury and 96% in detecting mesenteric injury.[87] Radiation exposure has also been raised as a concern with CT scanning, but if proper machine settings are provided for the smaller size of pediatric patients, this risk can be minimized.[88]

Unfortunately, there is no literature on which to base decisions on when to obtain CT scanning in awake and alert preverbal children who have sustained torso or multi-system trauma. It seems intuitive that unconscious but hemodynamically stable toddlers ejected from a motor vehicle should undergo CT scanning and those children who are awake, alert, eating, and running around after tripping over a toy should not. Selection of

Table 1. Suggested Indications For CT Scanning Of The Abdomen And Pelvis For Traumatized Children.

Reasonably well-supported indications

- Intubated children undergoing mechanical ventilation
- Altered mental status
- Children with spinal cord injuries resulting in loss of abdominal sensation
- Gross hematuria
- Abdominal tenderness
- Persistent complaints of abdominal pain
- Free fluid on bedside ultrasound FAST examination
- Abdominal or flank bruising
- Suspected non-accidental trauma to the abdomen
- Seat belt mark above the iliac crests
- Direct blow to the abdomen from bicycle handlebars or kicking

Controversial indications

- Microscopic hematuria
- Elevated liver transaminases
- Isolated femur fracture
- Preverbal children with mild-to-moderate injuries

Reasonably well-supported contraindications

- Persistent hemodynamic instability despite adequate fluid resuscitation* (especially in the setting of a positive FAST scan)—in this case, bypass CT and go to the operating room

*What constitutes "adequate" fluid resuscitation has not been satisfactorily defined.

preverbal children with injuries between these two extremes cannot be made based on evidence, as none is currently available.

Ultrasound (The FAST Examination)

The Focused Assessment with Sonography for Trauma (FAST) examination is a standardized four-view ultrasound examination of the abdomen (and pericardium) used in trauma evaluations.[89] For those unfamiliar with the examination, there are references designed specifically for emergency physicians who would like more information on the background, techniques, uses, credentialing, and limitations of the FAST examination.[90,91] This section presents some of the literature specifically addressing the use of the FAST examination in traumatized children.

Although some of the earliest reports of the use of ultrasound to evaluate the abdomen of traumatized children date from the mid-1980s,[92,93] the role of ultrasound remains unclear. The main purpose of performing ultrasound is to identify free intraperitoneal fluid, which, when identified in the setting of blunt pediatric trauma, is presumed to be blood.[94] Various sensitivities and specificities for FAST examinations in blunt pediatric trauma have been reported, but the outcome variable and the standard against which ultrasound were compared also varied. For example, Coley et al compared the FAST examination to CT scanning in identifying solid organ injuries with or without free intraperitoneal fluid for 107 hemodynamically stable traumatized children.[95] In this study, because injuries that did not produce free intraperitoneal fluid were included, the sensitivity of FAST scanning was reported as only 55% and the negative predictive value was 50%. This analysis suggests that FAST scanning is not a very good test for assessing traumatized children for intra-abdominal injuries.

Partrick et al come to a different conclusion using a different study design.[96] In their study, the outcome variable of interest was identifying "significant" free intraperitoneal fluid, and the criterion standard was the results of CT scanning. They identified 12 children with intra-abdominal injuries visible on CT scanning, and all five children with "significant intraperitoneal fluid" were successfully identified by FAST scanning. The other seven patients had solid organ injuries that were not identified by FAST scanning, and they were managed non-operatively. In this study, the authors note that even though FAST scanning identified fewer than half of all cases of intra-abdominal injury, FAST scanning identified all "significant" cases of intra-abdominal blood and therefore is an effective triage tool. Thourani et al studied 196 traumatized children who underwent ED FAST scanning. In this study, the outcome variable was free intraperitoneal fluid, and the criterion standard was operative findings, CT scanning, or clinical observation.[97] In this study, the sensitivity of the FAST scan was 80%, and the specificity was 100%. FAST scanning has also been reported to be inadequate in identifying bowel or mesenteric injuries.[98]

In an overall assessment of FAST scanning, the value of the scan depends on the outcome expected. It seems that FAST scanning is a reasonably good test for detecting free intraperitoneal fluid, but it is not a good test for identifying all clinically important intra-abdominal injuries.

Given that most solid organ injuries in children are managed non-operatively whether or not there is free intraperitoneal fluid,[80-82] the clinical circumstances in which FAST scanning adds to the management of pediatric blunt trauma is unclear. There is some evidence that FAST scanning has the greatest utility and the best test characteristics when traumatized children are hypotensive. In one small study, FAST scanning was 100% sensitive and 100% specific in identifying hemoperitoneum in seven hypotensive, traumatized children.[99]

Diagnostic Peritoneal Lavage And Laparoscopy

Although DPL had an important role in the era before CT scanning and before non-operative management became common, DPL no longer has a central role in the management of blunt abdominal trauma. A DPL involves introducing a catheter (or two) into the abdominal cavity and determining whether blood is present. As one can imagine, in an era without prompt CT scanning, this procedure offered important information. Because intra-abdominal bleeding was treated operatively during this era, a positive DPL meant that the patient needed to go promptly to the operating room. A negative DPL meant that the patient did not need to go to the operating room to have their abdomen explored. The DPL was an important decision node.

Several factors have made this decision process relatively archaic. First, the abdominal cavity is no longer a mysterious "black box." CT scanning has become available. However, emergency physicians do not need to have been in practice too many years to remember a time when CT scans took about an hour to complete. This length of time away from the ED could be critical. In addition, operative management was still common during this era. DPL made sense. The question asked by the emergency physicians and surgeons was, "Is there blood in the belly?" DPL could answer this question quickly and with reasonable accuracy.[100] It was felt that waiting an hour for the CT scanner to provide this answer was dangerous. Given the distance between CT scanners and EDs back then, it probably was. The management approach was clear: Do the DPL, and if there is intra-abdominal blood, go to the operating room. Over the years, CT scanners have become very fast, and hospital administrators with newer EDs have recognized the importance of CT scanning in the management of ED patients by placing CT scanners in close proximity to the ED. So now instead of an hour-long procedure far away from the ED, patients can undergo CT scans that take just a few minutes and involve moving the patient to the adjacent room. The second major factor in this decision process involves non-operative management.[80-82,101] If "blood in the belly" is no longer the deciding factor on

when to go to the operating room,[102] the results available from a DPL become much less important.

Finally, the management of a traumatized child with a critical head injury and a possible intra-abdominal injury has become clearer. Since children suspected of harboring a critical head injury universally undergo head CT scanning, a rapid non-contrast CT scan of the abdomen can be performed at the same time.[72] If the assessment of the abdomen needs further clarification, a DPL may be performed in the operating room. However, laparoscopy may be assuming this diagnostic role.[101,103-105]

In developing countries without ultrasound or CT scanning capabilities, operative management is probably the most reasonable approach, and DPL still plays a diagnostic role in managing blunt pediatric trauma in these parts of the world.[106]

Laboratory Tests

For previously healthy, acutely traumatized children, the usefulness of routine laboratory tests is questionable. This section examines the literature that addresses individual tests and their utility.

Hematocrit/Hemoglobin

The greatest utility of the hematocrit is in monitoring children with known solid organ injuries. Shafi et al retrospectively reviewed serial hematocrits in children with blunt splenic injuries.[107] These authors report that for the children with splenic injuries in their study, the initial mean hematocrit was 37% and dropped to 31% within 24 hours. The typical pattern was for the hematocrit to stabilize and remain at about 31% for five days and then to return to baseline by hospital day 13. In the case of a known solid organ injury, it appears that although the initial hematocrit does not differentiate operative from non-operative injuries,[108] the pattern of sequential hematocrits is clinically useful to the surgeons managing these children as inpatients. For the emergency physician ordering a CT scan for suspected intra-abdominal injury, it may be prudent to have a baseline hematocrit drawn. Then, if the CT scan identifies a solid organ injury, there is a baseline value for subsequent comparison.

However, the utility of a single hematocrit (or serial hematocrits) when abdominal and pelvic CT scans are *not* performed is not straightforward. At first, it seems intuitive that anemia suggests that bleeding has occurred, and worsening anemia suggests ongoing bleeding. Unfortunately, the available evidence does not support this simple and intuitively appealing concept. In 1999, Holmes et al examined a variety of physical and laboratory features in an attempt to identify risk factors for intra-abdominal injury.[76] Their data regarding the hematocrit are quite interesting. For those children with intra-abdominal injury, the mean initial hematocrit was 36.1%, while the mean for the children without intra-abdominal injuries was similar, at 36.8%. There was no statistically significant difference between the means. For repeat hematocrit values (drawn an average of 1.9 hours after the first specimen), the means were again similar, at 34.8% and 35.5%. The percentage of patients who had a fall in hematocrit of at least five percentage points was also similar (1 of 20 [5%] in the intra-abdominal injury group and 24 of 425 [6%] in the group without intra-abdominal injuries identified). For those children with an initial hematocrit less than 30%, the percentages were also similar (1 of 22 [5%] in the intra-abdominal injury group and 9 of 459 [2%] in the group without intra-abdominal injuries). Although they report their results in less detail, Isaacman et al also found that a hematocrit obtained in the ED had limited utility.[109]

From the available evidence, it appears that the emergency physician should obtain a hematocrit when he

Cost-Effective Treatment Strategies For Children With Blunt Abdominal Trauma

1. Do not order a "trauma panel" on every child brought in on a backboard from a motor vehicle accident.

Each laboratory test should be drawn for a specific purpose. If the child has no indication for CT scanning of the abdomen and pelvis or a negative CT scan, has no ongoing symptoms related to the abdomen, and has no significant "extra-abdominal" injuries, laboratory testing should be very limited. (See text.)

2. Be selective about which patients have a blood bank specimen sent.

If a child is hemodynamically stable, has no other injuries, has no complaints referable to the abdomen, and would be sent home if the abdominal and pelvic CT scans reveal no identifiable intra-abdominal injury, a blood bank specimen is initially unnecessary. If the CT scan reveals an intra-abdominal injury, a blood bank specimen would be indicated at that time.

3. Do not order plain abdominal radiographs in blunt trauma patients.

A plain abdominal radiograph (a "KUB") does not rule in or rule out intra-abdominal injuries.

4. Work with local surgeons to determine evidence-based trauma team activation criteria for children.

Trauma team activations can be costly to patients. The exact criteria for trauma team activations are determined locally. Since the mechanism of injury poorly predicts which children will require emergent operative interventions, historically accepted trauma team activation criteria relying on mechanism of injury should be critically evaluated and modified based on available evidence, including locally derived data. ▲

or she orders a CT scan or at the time that the CT scan reveals a solid organ injury. In this manner, a baseline value is available for later comparison. This will help in the inpatient management of the patient. Hematocrits obtained during the first couple of hours in the ED do not adequately differentiate children with and those without intra-abdominal injuries. Therefore, the emergency physician cannot reliably use the hematocrit to decide whether to obtain a CT scan. Instead of using the hematocrit to decide whether to order a CT scan, it is the ordering (or results) of the CT scan that determines whether the emergency physician should order a hematocrit. Given past practices, this approach may seem counterintuitive to clinicians unfamiliar with this literature.

Coagulation Studies

A single study has directly examined the international normalized ratio (INR) and activated partial thromboplastin time (PTT) in the setting of blunt pediatric trauma. In 2001, Holmes et al retrospectively reviewed the medical records of 830 traumatized children who underwent coagulation testing.[110] In this study, the authors noted that hypotension, altered mental status with a Glasgow Coma Scale score of 13 or less, open or multiple bony fractures, and major tissue wounds were associated with elevations of coagulation studies. Abdominal tenderness was not associated with elevated coagulation studies. Given these limited data, it seems that coagulation studies are indicated in cases when shock, substantial multi-system trauma, or altered mental status is present. Other indications for obtaining coagulation studies are unclear at this point.

Urinalysis

Obtaining a urine specimen in trauma is common—and probably commonly misunderstood. The reason to order a microscopic urinalysis is presumably to decide if a CT scan of the abdomen and pelvis should be ordered. The purpose of the CT scan, in this case, is to identify injuries to the urethra, bladder, ureters, or kidneys. There are quite a few methodological problems with this small body of literature, as discussed earlier in the article.[3,6-17] Not only are there studies that specifically assess the utility of a microscopic urinalysis to identify urologic injuries, some studies concluded that red cells in the urine are a marker for *any* intra-abdominal injury.[2,76,109,111] Why an injury to the spleen would cause red blood cells in the urine has never been adequately explained. The use of a small number of red blood cells in the urine to identify any intra-abdominal injury leads to some interesting cases in the literature. For example, in a fairly complex logistic regression model, Holmes et al identified low systolic blood pressure, abdominal tenderness, femur fracture, elevated liver transaminases, an initial hematocrit < 30%, and more than 5 RBC / hpf to be associated with intra-abdominal injuries.[2] These six findings, therefore, were recommended as indications for CT scanning. One subject lacked all of these findings except 5 RBC / hpf but still had an intra-abdominal injury (splenic laceration) requiring laparotomy. Notably, this 15-year-old also had an initial GCS of 14, had a seizure in the ED, and was promptly intubated. Clinical experience suggests that this adolescent's indication for CT scanning had little to do with his urinalysis findings.

There is currently inadequate evidence to advocate any particular RBC / hpf threshold as the sole indication for CT scanning of the abdomen and pelvis for traumatized children. The scenario of greatest interest is the child who has a perfectly normal physical examination, is up walking around, and then provides a urine specimen that contains a small to modest number of RBC / hpf. Should this child then undergo prompt CT scanning of the abdomen and pelvis to identify urologic injury, or be discharged home without radiologic imaging? No study currently answers this question. One solution to this problem is to visualize urine to establish that gross hematuria is not present and forego a microscopic analysis. There is little convincing literature to support this practice, either. One thing is quite clear: If CT scanning of the abdomen and pelvis is being obtained for another indication, the results of a microscopic urinalysis have negligible utility in the ED.

Amylase And Lipase

In recent years, the clinical utility of serum amylase and lipase testing has been directly addressed with respect to blunt pediatric abdominal trauma.[65,112,113] Nadler et al evaluated 51 children with blunt pancreatic injuries seen over a 10-year period.[112] The primary analysis in this study was the comparison between those pancreatic injuries managed operatively and those managed nonoperatively. Because this study only included subjects with pancreatic injuries, the authors are unable to assess the specificity of elevated amylase and lipase levels. These authors also used elevated amylase and lipase values as diagnostic of pancreatic injury. This methodological problem makes assessing the utility of amylase and lipase problematic. Although the authors conclude that markedly elevated amylase and lipase levels, when combined with the physical examination, are useful in the diagnosis of pancreatic injuries, their methodological problems make this conclusion difficult to incorporate into clinical practice. Jobst et al, who performed a similar analysis evaluating 56 children with pancreatic injuries, have similar methodological problems, including the use of elevated amylase as a diagnostic criterion for pancreatic injury.[65] These authors conclude that initial amylase levels do not correlate with severity of pancreatic injury. In a study of adults, Takishima et al reported that for patients with pancreatic injuries, elevations of amylase may be delayed more than three hours after presentation.[114] This delayed elevation of amylase and lipase has been mentioned in a few cases of pediatric blunt abdominal trauma as well.[76]

The best designed study to date is by Adamson et al.[113] In this study, the authors performed a retrospective review of 1821 pediatric traumas. Of these, 507 subjects

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Clinical Pathway: Management Of Blunt Abdominal Trauma In Prepubertal Children

Initial stabilization
- Assess the airway and intubate as indicated
- Assist ventilation as indicated
- Assess oxygenation and administer oxygen if indicated
- Assess vital signs
- Address immediate multi-system trauma issues (e.g., head injury, ongoing scalp laceration bleeding, etc.)

Is the child hemodynamically unstable?

YES

Fluid resuscitation
- Fluid resuscitation with 20 cc/kg normal saline or Ringer's lactate solution (may repeat crystalloid x 2)
- If insufficient hemodynamic improvement with crystalloid, administer 10 cc/kg packed red blood cells
- Reassess vital signs and hemodynamic stability after each fluid bolus

(Class II)

After two crystalloid fluid boluses and the administration of packed red blood cells, if the child is still not hemodynamically stable, proceed as below.*

NO

Are any of the following present?
- Intubated child undergoing mechanical ventilation
- Altered mental status
- Spinal cord injury with loss of abdominal sensation
- Gross hematuria
- Abdominal tenderness or pain
- Free fluid on bedside ultrasound FAST examination
- Abdominal or flank bruising
- Suspected non-accidental trauma to the abdomen
- Seat belt mark above the iliac crests
- Direct blow to the abdomen from bicycle handlebars or kicking
- Microscopic hematuria (controversial)
- Elevated liver transaminases (controversial)
- Femur fracture (controversial)
- Preverbal children with mild-to-moderate injuries (controversial)

YES

CT scanning of the abdomen and pelvis
(Class II)

Is an injury identified?

Surgical consultation
Prompt surgical consultation with the expectation of possible operative intervention. Continue administration of packed red blood cells. **(Class II)**

NO

NO

YES

Are there persistent abdominal symptoms?
(e.g., persistent pain or vomiting)

YES

Admission
- Continue monitoring
- Surgical consultation

(Class II)

NO

Assess for other "extra-abdominal" injuries
Have all other indications for admission been excluded, have all other injuries been addressed, and has the period of ED observation been deemed adequate?†

NO

Admission
- Continue monitoring
- Surgical consultation

(Class II)

YES

Discharge home
(Class II)

* There is some recent work on the role of CT scanning of the abdomen and pelvis in hemodynamically unstable adults. (Petridis A, Pilavaki M, Vafiadis E, et al. CT of hemodynamically unstable abdominal trauma. *Eur Radiol* 1999;9:250-255.) The safety and utility of this approach are currently unclear.

† This remains undefined.

The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page.
Class I: Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Continued from page 10

had admission serum amylase or lipase levels obtained. There were six children of these 507 who were identified as having pancreatic injuries. Five of these six children had elevated pancreatic enzymes on presentation. Of the 501 children who did not have pancreatic injuries, 111 had elevated pancreatic enzymes from the initial laboratory tests. This yields a sensitivity of 83%, a specificity of 78%, a negative predictive value of 99.7%, and a positive predictive value of only 4%. In other words, if a patient has a normal amylase or lipase level, the odds are 99.7% that this patient does not have a pancreatic injury. However, if a patient has an elevated amylase or lipase, the odds are only 4% that the patient has a pancreatic injury. In addition, the authors note that the degree to which the amylase and lipase were elevated did not correlate with the degree of pancreatic injury. There are problems with selection bias and work-up bias in this study given that less than a third of the study subjects underwent testing of amylase and lipase. There are also problems with confounding injuries. The authors report that all of the children with pancreatic injuries had clinical indications for CT scanning other than amylase and lipase values.

From the available evidence, several conclusions about amylase and lipase testing can be drawn. Amylase

Ten Pitfalls To Avoid

1. "The FAST exam was negative. We felt that we had ruled out any serious intra-abdominal injury."

A negative FAST exam does not exclude intra-abdominal injury. FAST scanning is reasonably good at detecting free intra-abdominal fluid, but it is not good for detecting solid organ injuries without free fluid, retroperitoneal injuries, pancreatic injuries, or bowel injuries that present without free fluid.

2. "The child was approaching hemodynamic instability, and the ultrasound showed free fluid in Morrison's pouch. Unfortunately, the child crashed in the CT scanner."

No patient who is becoming unstable should be removed from the resuscitation area to obtain a CT scan or other diagnostic study. Fluid resuscitation, including the administration of packed red blood cells, may be needed to stabilize the patient prior to obtaining a CT scan. Surgical consultation in these patients is prudent as they will likely be admitted to the PICU or taken to the operating room.

3. "The child complained of only mild epigastric pain after his bicycle wreck. We felt safe discharging him home with close follow-up after only a clinical exam."

Handlebar injuries apply substantial force to a small area of the abdomen. This can lead to bowel and pancreatic injuries. CT scanning is recommended, and if there is persistent abdominal pain or tenderness, the child should be admitted and observed for pancreatic or bowel injuries.

4. "We knew that the child had a serious head injury that needed immediate surgical intervention—there wasn't time to fully evaluate the abdomen."

A child can exsanguinate from an abdominal injury while undergoing a craniotomy. If an emergent craniotomy is indicated, a FAST scan should be performed in the ED, or the surgeons can perform a DPL or laparoscopy in the operating room.

5. "The radiographs, FAST exam, CT scan, and labs were all negative for any acute intra-abdominal injury. We were confident that the child's continuing abdominal pain was attributable to musculoskeletal injury and anxiety."

Hollow viscus injury may be very difficult to diagnose at the time of initial evaluation for an injury. In time, the child's symptoms and physical examination may indicate an ongoing, yet undiagnosed problem.

6. "There were no external signs of abdominal injury."

A child can exsanguinate from an abdominal injury and not have an abrasion or bruise on their abdominal wall. This is particularly true in cases in which non-accidental trauma is involved.

7. "The child was tachycardic for some time, but all of a sudden he decompensated. We thought his tachycardia was just from fear."

Children have excellent vascular tone and maintain their blood pressure until hemorrhagic shock becomes overwhelming. Early shock does not manifest itself with hypotension in children.

8. "I know the kid was abused, but how could he have had a bowel injury? There wasn't a mark on the abdomen."

Victims of non-accidental trauma may be shaken, squeezed, or punched in a manner that leaves no external signs of injury. In a child who is comatose or has other signs of abdominal injury, a CT scan of the abdomen and pelvis may be indicated even in the absence of abdominal skin findings.

9. "His initial hematocrit was normal, and so was the one a couple hours later. I figured that I had ruled out ongoing bleeding."

Although intuitively appealing, following hematocrits is not a reliable method for ruling in or ruling out intra-abdominal injuries.

10. "I just couldn't get him to stop thrashing around, and so I couldn't get a CT scan of the abdomen and pelvis."

When a CT scan of the abdomen and pelvis is indicated, it needs to be performed in a timely fashion. Emergency physicians are well-versed in procedure-related sedation and should be able to sedate children to obtain a CT scan. If, for some reason, adequate sedation cannot be achieved, a child may need to undergo rapid sequence intubation in order to obtain a timely CT scan. The child's life may depend on the airway skills of the emergency physician. ▲

and lipase testing results in many false-positive tests and, if used as the sole indication for CT scanning, would lead to many unnecessary CT scans. Physical examination findings and other indications for CT scanning are present in children with pancreatic injuries; thus, the added utility of drawing an amylase or lipase on presentation to identify pancreatic injuries is minimal. Initial amylase and lipase values may be helpful for those children with a high likelihood of pancreatic injuries (e.g., bicycle handlebar blow to the epigastrium) who will undergo CT scanning and are likely to be admitted to the hospital for observation. Follow-up amylase and lipase values obtained more than three hours after presentation may reveal elevations not previously appreciable.

Transaminases

There has been a growing body of literature examining the role of transaminases (AST and ALT) in the setting of pediatric blunt abdominal trauma. In one early report, Oldham et al noted that of 95 hemodynamically stable traumatized children, 44 had "immediate elevation of hepatic enzymes." Of these 44 children, 19 were noted to have "significant" liver injuries, and none of the children with liver injuries had normal hepatic enzymes.[115] These data suggest a sensitivity of 100% and a specificity of 67% for elevated liver transaminases in identifying liver injuries. Hennes et al performed a similar study but used elevated transaminases as the inclusion criteria. A sensitivity of 100% was obtained, and although a specificity is reported by the authors, their selection bias limits the meaningfulness of this value.[116] Coant et al also noted elevated liver transaminases in the setting of non-accidental trauma where children had no clinical signs of abdominal trauma.[117] In this study, 49 children without clinical signs of abdominal trauma were brought to an ED by child protective services for a medical evaluation. Of these 49 children, four had elevated transaminases and three of these four children were discovered to have liver lacerations on CT scanning. Holmes et al reported data that AST elevations greater than 200 units/liter and ALT elevations greater than 125 units/liter each had an approximate sensitivity of 62% and specificity of 95%.[76] These findings must be understood in the context that only children who underwent CT scanning are included in the study. In later prospective work, these same researchers found that elevated liver transaminases were independently predictive of intra-abdominal injuries in traumatized children.[2]

Because all of these studies only included children who had undergone CT scanning and because it is considered unethical to CT scan all traumatized children due to potentially needless radiation exposure, a few central questions remains unanswered. Which traumatized children should have liver transaminases drawn? Should a child who meets no other criteria for CT scanning be held in the ED awaiting liver transaminase results to see if he or she should undergo CT scanning? The study that would answer these questions would be a prospective validation study of the study by Holmes et al published in the *Annals of Emergency Medicine* in 2002.[2] Until this study is performed and the utility of liver transaminases for identifying children with liver injuries who meet no other criteria for CT scanning is determined, the use of liver transaminases cannot be recommended as the sole indication for CT scanning.

Electrolytes

Although probably common in "trauma panels," electrolytes have limited utility in the ED management of pediatric blunt abdominal trauma.[111] Abnormalities have been described, including hyponatremia (3% of subjects), hypokalemia (5%), hyperkalemia (3%), mildly elevated creatinine (1%), and hyperglycemia (19%), but none of these are reported as clinically significant.[109]

Treatment

Given that pediatric blunt trauma is often multi-system in nature, the treatment of blunt abdominal trauma often takes place in the setting of treating other "extra-abdominal" injuries, such as orthopedic injuries, facial injuries, and head injuries. The treatment of isolated intra-abdominal injuries is relatively straightforward in the ED. If a child is hemodynamically unstable despite aggressive fluid resuscitation—especially if a FAST scan reveals free fluid—emergent surgical consultation is needed, with the expectation of prompt exploratory laparotomy either before or after a CT scan. If the child is hemodynamically stable and CT scanning reveals a solid organ injury, surgical consultation and repeat hemoglobin determinations in the ED are indicated. (See Figure 1 on page 4 and Figure 2 on page 5.) If the child appears to be continuing to hemorrhage, as evidenced by progressively worsening tachycardia, the development of hypotension, or a progressively falling hemoglobin or hematocrit, transfusion with packed red blood cells is also indicated. If CT scanning does not reveal any intra-abdominal injury, no immediate treatment is required specifically for the abdomen. Persistent symptoms referable to the abdomen (e.g., vomiting, persistent abdominal pain) may suggest a pancreatic or bowel injury that was not identifiable on the initial CT scan. No specific ED care is required for these potential injuries other than surgical consultation with the expectation of admission for observation, serial abdominal examinations, and possible exploratory laparotomy during hospitalization.

Special Circumstances

Pre-existing Splenomegaly

A single study addresses adult patients with blunt splenic injuries in the setting of known prior splenomegaly.[118] In this prospective study, 11 patients with isolated spleen injuries identified by CT scan and stable hematocrits were managed non-operatively. Eight of these adults had HIV disease, one had acute leukemia, one had infectious mononucleosis, and one had sickle cell anemia. All 11 of these patients were successfully managed non-operatively. It appears that pre-existing

splenomegaly may predispose individuals to splenic injuries, but the management approach is similar once the injury is identified on CT scan.

Absence Of CT Scanning Capability

Due to the presence of tele-radiology, many remote, rural facilities can now have CT scanning and other radiographic tests performed and interpreted any time of the day. If CT scanning is unavailable, the management of children with blunt abdominal trauma becomes quite a bit more challenging. A stable child with persistent abdominal pain can be transferred to a facility with the capacity to perform a CT scan of the abdomen and pelvis. An unstable child will require fluid resuscitation, including the administration of packed red blood cells, and prompt surgical consultation with the expectation of operative intervention to stabilize the child. Transfer to a large, pediatric referral hospital may require operative stabilization prior to transfer. Close consultation with the local surgeon is prudent when CT scanning is unavailable.

Controversies / Cutting Edge

Is Pediatric Trauma A Surgical Disease?

By far the most controversial writing about blunt pediatric trauma in recent years was an editorial by Green and Rothrock in the May 2002 edition of the *Annals of Emergency Medicine*.[119] In this editorial, the authors note that the widespread use of CT scanning has allowed non-operative management of solid organ injuries in blunt pediatric trauma to become commonplace. In a kind of mini-meta-analysis, the authors pool data from three large studies of blunt pediatric abdominal trauma[80-82] and present results from the 7801 subjects. In this analysis, a laparotomy was required only 26 times, with an average frequency of one laparotomy every seven months. The key and controversial question is then posed: "If the only unique role of the surgeon (i.e., going to the operating room) is applied perhaps only twice per year even in a major pediatric trauma center, how necessary is it that these specialists arrive quickly and routinely for all trauma alerts?"[119] In other words, do automatic trauma team activations make sense in the era of CT scanning and non-operative management? This question is not new and has been indirectly posed by prior authors in both the emergency medicine[33] and surgical literature.[70,120] Nonetheless, strongly worded letters from pediatric surgeons appeared shortly afterward.[121,122] One of these pediatric surgeons even created a study in response to the editorial.[123] This study did not directly address trauma team activation but reported that many of the 87,424 children were retrospectively deemed to require a surgical evaluation. The political nature of this dialog was revealed in one of the quotes in the commentary following this article:

> "With the exception, perhaps, of the Salvation Army, the surgical profession is considered by many to be one of the most charitable organizations. For we have given away endoscopy and helped jump-start a subspecialty called gastroenterology. We have given away emergency medicine, which was once under our umbrella. And many feel that we are at the point now of maybe giving away critical care. That is why we are considered a charitable organization! We can ill afford at this point to allow trauma management, adult or pediatric, to slip away from under the umbrella of the American College of Surgeons."
> —Dr. James A. O'Neill, Jr., Nashville, TN[123]

This political dialog will probably continue for some time. Further technological advances and greater acceptance of non-operative management practices may lead to changes in the manner in which blunt pediatric trauma is viewed by surgeons, pediatric intensivists, and emergency physicians in the future.

Can I Throw Away Yellow Urine?

The limitations of using microscopic urinalysis in clinical decision-making in the setting of blunt pediatric trauma has already been addressed in this article. As the literature is inadequate to offer an evidence-based answer to this question, this debate will likely continue into the foreseeable future.

Is FAST Scanning Truly Useful In Blunt Pediatric Trauma?

It is clear that FAST scanning is reasonably good at identifying free intra-abdominal fluid in the setting of trauma. Unfortunately, many clinically significant intra-abdominal injuries in children do not produce free fluid. Therefore, a negative FAST scan does not obviate the need for CT scanning. And, because most solid organ injuries that cause free intra-abdominal fluid visible on ultrasound are managed non-operatively, a positive FAST scan does not indicate that a pediatric patient should go directly to the operating room. It is becoming clear that FAST scanning offers some information but does not act as a critical decision node.

Is A Rectal Examination Necessary?

There is no literature to support the practice of performing a rectal examination in the setting of blunt pediatric trauma. The time-honored practice of a digital rectal examination in the awake, neurologically intact child, followed by the ritualistic recitation, "Okay, no gross blood, normal tone," has never been critically evaluated. If a study were to show that this practice does not change management or add any meaningful information, could we stop doing this to awake, neurologically intact children?

Should Trauma Team Activations Be Based On Mechanism Of Injury?

With regard to blunt trauma, no studies have provided data supporting the practice of pediatric trauma team activations based solely on the mechanism of injury. A day may come when most blunt pediatric trauma cases, regardless of the mechanism of injury, receive treatment and consultation based on the emergency physician's assessment after the patient arrives in the ED.

Should The CT Scan Be Performed With Oral Contrast?

There is debate regarding the need for contrast when a CT scan of the abdomen and pelvis is used to evaluate a traumatized child. Shankar et al directly tried to assess the utility of oral contrast in the setting of blunt pediatric trauma.[124] Since the purpose of oral contrast is to evaluate the gut, the authors assessed the frequency with which the duodenum had contrast seen within the lumen and compared findings at laparotomy with those of the CT scans with oral contrast. The findings did not support the use of oral contrast. Thirty-seven of the 60 scans of children who received oral contrast did not have adequate contrast opacification of the duodenum. Based on the CT findings, four children were suspected of having intestinal injury, but two of these children had negative laparotomies. One patient had two negative CT scans, but was noted to have rupture of the splenic flexure of the colon at laparotomy. This relatively small study suggests that oral contrast may fail to accurately identify intestinal injuries. The studies in adults are more numerous and support the concept that oral contrast is unnecessary.[125-129]

Disposition

The disposition of the child suspected of having an isolated intra-abdominal injury is relatively straightforward. (See the Clinical Pathway on page 11.) If a child has a CT scan that reveals an intra-abdominal injury, surgical consultation is indicated with the expectation of admission, observation, non-operative management of most solid organ injuries, and operative management of bowel injuries. Depending on the severity of the CT findings, admission or transfer to a pediatric intensive care unit may be appropriate. If a child has a normal or equivocal CT scan, yet still has ongoing symptoms referable to the abdomen, including persistent pain, surgical consultation is indicated with the expectation of admission, observation, and serial abdominal examinations. If a child has a normal CT scan and is asymptomatic, discharge home is indicated, as the risk of rapid, subsequent deterioration requiring operative intervention is very low.[130,131]

Unfortunately, intra-abdominal injuries most often occur in the setting of possible multi-system injuries, as seen in motor vehicle collisions and falls. The most appropriate disposition of the traumatized child depends on the overall global assessment.

Summary

The management of blunt abdominal trauma in children has evolved considerably over the past few decades. We now have the capacity to peer into the "black box" of the abdomen with the advent of current-generation, rapid, high-resolution CT scanners. The common use of CT scanning has allowed for the development of non-operative management techniques. Studies are emerging that are critically evaluating prior dogma and critically examining our prior practices. By reviewing and becoming familiar with this growing body of literature, emergency physicians will be able to offer the safest, most thoughtful, most evidence-based care to the acutely injured children seen every day. ▲

References

Evidence-based medicine requires a critical appraisal of the literature based on 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. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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Key Points In Pediatric Blunt Trauma

- CT scanning is the most effective and definitive test in evaluating children with blunt abdominal trauma.
- FAST scanning is reasonably good at identifying free fluid in the abdomen—but the presence of free fluid is not an indication for laparotomy, and the absence of free fluid does not rule out serious abdominal injuries.
- Gross hematuria is the only degree of hematuria that is a clear indication for CT scanning of the abdomen and pelvis.
- Initial and repeat hematocrits drawn in the ED are neither sensitive nor specific for identifying intra-abdominal injuries in children.
- Persistent abdominal pain or other symptoms referent to the abdomen (e.g., vomiting) indicate the need for ongoing observation and evaluation, even if the initial CT scan is normal.
- Trauma team activation criteria based on the mechanism of injury are neither sensitive nor specific for children who require prompt surgical intervention.
- A child at risk for multi-system injury and who has altered mental status should undergo CT scanning of the abdomen and pelvis while they are getting their head CT. The CT scanning should not be delayed for the administration of oral contrast. ▲

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Physician CME Questions

1. Which of the following regarding pediatric blunt abdominal trauma is true?

a. All children in motor vehicle accidents should undergo CT scanning of the abdomen and pelvis.
b. Pediatric blunt abdominal trauma requires care only available at specialty centers.
c. FAST scanning is rapidly replacing CT scanning of the abdomen and pelvis in most pediatric centers.
d. The most valuable tool in evaluating children at risk for intra-abdominal injuries is the CT scanner.

2. Which of the following is the most controversial indication for CT scanning of the abdomen and pelvis in children who sustain blunt abdominal trauma?
a. Coma requiring intubation
b. Diffuse abdominal tenderness
c. Free fluid on FAST scan
d. Microscopic hematuria

3. The non-operative management of blunt pediatric abdominal trauma:
a. is contraindicated in solid-organ injuries.
b. is currently unsupported in the literature.
c. is increasingly common.
d. is indicated for bowel rupture.

4. In pediatric blunt abdominal trauma, the mechanism of injury:
a. does not serve as an evidence-based basis for trauma team activation.
b. indicates whether ultrasound or CT scan is better at identifying retroperitoneal injuries.
c. is often unknown.
d. predicts which children will need emergent operations within one hour of arrival in the ED.

5. Which of the following injuries is characteristically associated with a handlebar injury sustained while falling off a bicycle?
a. Adrenal contusion
b. Aortic intimal flap
c. Diaphragmatic rupture
d. Pancreatic injury

6. FAST scans:
a. are better than CT scans for detecting bowel injury.
b. are primarily used to rule out intra-abdominal injury.
c. are relatively sensitive in detecting free fluid in the abdomen.
d. have not been approved for use in young children.

7. In a child who has been involved in a motor vehicle collision, which of the following would be associated with the best prognosis?
a. Age-appropriate booster-seat use
b. Seat belt use
c. Ejection from vehicle
d. Rollover accident

8. Of the following, which is the most commonly injured organ in pediatric blunt abdominal trauma?
a. Ureter
b. Liver
c. Adrenal glands
d. Bladder

9. CT scanning is required based on any of the following findings *except*:
a. altered mental status in a child with multi-system trauma.
b. gross hematuria.
c. injury from a 10-foot fall.
d. persistent abdominal tenderness or pain.

10. In pediatric blunt trauma patients with persistent hemodynamic instability despite adequate fluid resuscitation, the appropriate course of action is:
a. CT scanning of abdomen and pelvis.
b. FAST scanning.
c. immediate surgical consultation.
d diagnostic peritoneal lavage.

11. CT *cannot* be safely performed:
a. in hemodynamically unstable children.
b. in children with femur fractures.
c. in intubated children undergoing mechanical ventilation.
d. in children with lap belt injuries.

12. Given that most solid organ injuries in children are managed non-operatively whether or not there is free intraperitoneal fluid, the clinical circumstances in which FAST scanning adds to the management of pediatric blunt trauma is unclear.
a. True
b. False

13. In children with blunt abdominal trauma, DPL is the preferred diagnostic study when:
a. both CT and ultrasound are unavailable.
b. child abuse is strongly suspected.
c. gross hematuria is present without pelvic fracture.
d. a pancreatic injury is seen on CT scan.

14. In children with possible blunt abdominal trauma, the hematocrit:
a. can identify patients with intra-abdominal injuries vs. those without intra-abdominal injuries.
b. can differentiate operative from non-operative injuries.
c. is useful in monitoring children with known solid organ injuries.
d. is only useful when serial levels are drawn.

15. In the physical examination of a child with blunt abdominal trauma, which of the following is *not* necessary?
a. Assessment for shock
b. Mental status / neurologic examination
c. Abdominal examination
d. Rectal examination

16. **According to the literature, in children with blunt abdominal trauma:**
    a. any degree of microscopic hematuria should prompt radiographic imaging.
    b. radiographic imaging should be ordered only if the urinalysis shows levels of 20 RBCs / hpf or greater.
    c. radiographic imaging should be ordered only if the urinalysis shows levels of 100 RBCs / hpf or greater.
    d. the ideal microscopic hematuria "threshold" for ordering radiographic imaging remains controversial.

Coming in Future Issues:

Child Abuse • Difficulty Breathing In Children
Pediatric Sinusitis

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

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case-control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA* 1992;268(16):2289-2295.

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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 ACEP; and evaluation of prior activities for emergency physicians.

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