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Pediatric Blunt Abdominal Trauma In The Emergency Department: Evidence-Based Management Techniques

Abstract

Blunt abdominal trauma is the third most common cause of pediatric trauma deaths, but it is the most common unrecognized fatal injury. This issue discusses common mechanisms and injuries seen in children with blunt abdominal trauma and takes a closer look at current evaluation and management techniques. The mainstays of diagnostic evaluation include laboratory, sonography, and computed tomography studies. However, the routine use of these studies may not be necessary, and controversy exists as to which studies are beneficial and which are less valuable. The concern for radiation-induced malignancy has led to increased efforts to limit radiation exposure by decreasing the use of unnecessary computed tomography scans. The history and physical examination, combined with the mechanism of injury, should be used to develop a thoughtful and directed diagnostic workup.

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Case Presentations

A 10-year-old girl involved in a motor vehicle crash is brought to your ED. She was restrained in the rear driver's-side seat of the vehicle with a lap and shoulder belt when the vehicle was struck at high speed on the driver's side. On arrival to the ED, she is awake and alert, immobilized with a cervical collar and back board, and has the following vital signs: temperature 37.5°C; heart rate, 130 beats/min; blood pressure, 105/70 mm Hg; respiratory rate, 20 breaths/min; and oxygen saturation, 98% on room air. She is able to maintain her airway and has clear and equal breath sounds without increased work of breathing, and she has strong distal pulses. She complains of abdominal pain. Her abdomen is soft and nondistended, but she has localized tenderness in the left upper quadrant. There are no bruises or abrasions noted on the abdomen. Several questions are running through your mind: What fluids should I give her, how much, and how fast? What labs should I order? Should I perform a FAST exam? Should I order a CT of the abdomen/pelvis? Do I need contrast for the CT? Or does she need to go emergently to the operating room?

In the next room, a 9-year-old boy has presented to the ED for epigastric pain and 1 episode of nonbloody, nonbilious vomiting. He is awake and alert and has the following vital signs: temperature, 37°C; heart rate, 110 beats/min; respiratory rate, 24 breaths/min; blood pressure 95/55 mm Hg; and oxygen saturation, 98% on room air. He has no diarrhea, and there are no known sick contacts. While you are examining him, you note moderate tenderness with voluntary guarding of the epigastric area. On further examination, you notice a faint bruise to the epigastric area and ask the patient how it occurred. He remembers that he was riding his bicycle the day before, and fell onto the handlebars. You wonder if this could be the cause of his pain and vomiting. For what injuries is he at risk? What tests should you order? Do you need to obtain a surgery consultation? Should he be admitted to the hospital?

Introduction

Trauma remains the leading cause of childhood death and disability in children aged > 1 year.¹ While head and thoracic trauma account for most death and disability in children, abdominal injuries constitute the most common unrecognized cause of death.² Blunt injury accounts for 90% of abdominal trauma in children.² Common mechanisms include motor vehicle crashes (MVCs), falls, pedestrian injuries, bicycle and sports-related injuries, and nonaccidental trauma (NAT). Penetrating injuries are much less common in children than in adults.²

Management of pediatric trauma has unique challenges. The developmental stage of the patient, a lack of verbal skills in younger patients, and a lack of prehospital information create limitations

in managing the injured child.³ Similar to their adult counterparts, children can have an unreliable abdominal examination from an associated head injury and a decreased Glasgow Coma Scale (GCS) score. Additionally, children are more likely to have an unreliable abdominal examination secondary to crying and abdominal distension.²

The routine use of trauma panels and computed tomography (CT) scans of the head, neck, chest, abdomen, and pelvis should not be employed in the pediatric patient. Unnecessary radiation exposure in the pediatric patient carries an increased lifetime risk of fatal malignancy, in addition to an increased cost burden.^{4,5} Instead, as discussed in this review, a more thoughtful and focused approach to the child suffering from blunt abdominal trauma should be undertaken.

Critical Appraisal Of The Literature

A literature search of Ovid, Clinical Key, and PubMed was completed using the terms *pediatric blunt abdominal trauma*, *blunt abdominal trauma*, *pediatric trauma*, and *abdominal trauma* and specific organ injuries. The Cochrane Database of Systematic Reviews and the National Guidelines Clearinghouse were reviewed, but they had limited information on pediatric abdominal trauma. Additionally, ClinicalTrials.gov was reviewed for ongoing studies. The search was limited mostly to the last 15 years. Much research has been completed on trauma and on pediatric trauma, but the literature lacks strong randomized control trial data and prospective studies. Many of the studies on which our current evaluation and management strategies are based are retrospective reviews. There are a few prospective observational studies that validate the retrospective studies and an even smaller number of meta-analyses. For injuries with a low incidence of occurrence (such as adrenal injuries), case studies dominate the literature.

Etiology And Pathophysiology

Epidemiology

Unintentional injury is the leading cause of death in children aged > 1 year. In all age groups, MVCs are the most common cause of death.⁶ Injury is also a major source of morbidity, with an estimated 11.9 million injury-related ED visits for children and adolescents in the United States between 2009 and 2010. This represents approximately 35% of all ED visits by children and adolescents during that time period.⁷ Unintentional falls are the most common mechanism of nonfatal injury in children aged < 15 years.⁸ Blunt abdominal trauma is the third most common cause of pediatric trauma deaths, but is the most common unrecognized fatal injury.⁹

The spleen and liver are the most commonly

injured abdominal organs in children, followed by the kidney, small bowel, and pancreas.¹⁰⁻¹² Frequent causes of intra-abdominal injury in children include MVCs, auto-pedestrian or auto-bicycle collisions, and falls. Less common causes of intra-abdominal injury include a direct blow from bicycle handlebars, sports, all-terrain vehicle incidents, furniture and television tip-overs, and NAT. Although only 1% of children hospitalized for NAT sustain intra-abdominal injury, it is the second most common form of fatal physical child abuse.¹³

Etiology And Pathophysiology

There are several anatomic and physiologic differences between children and adults that may make children more susceptible to serious injury secondary to blunt abdominal trauma, while at the same time making injury more difficult to identify. In children, abdominal organs are relatively larger, abdominal muscles are poorly developed, there is less intra-abdominal fat to offer protection against injury. In addition, the ribcage is compliant, which allows direct transmission of force to the liver and spleen.^{2,10,11}

Injured children may cry secondary to pain or fear, causing a significant amount of swallowed air, which can lead to gastric distension.² While examining the abdomen, it may be difficult to differentiate crying due to pain and tenderness versus fear and abdominal distension due to injury versus swallowed air.

Though crying and fear may also cause elevated heart rate in injured children, it is important to pay attention to tachycardia, as it may be the only indicator of significant blood loss. A child's first physiologic response to blood loss is tachycardia, to increase stroke volume and cardiac output.^{10,14,15} Children may not manifest a decrease in systolic blood pressure until 30% of circulating blood volume is lost.¹⁴ Therefore, hypotension alone is a late indicator of decompensation, and a normotensive blood pressure is an inadequate measure of volume status or end point in resuscitation.^{14,15} Other signs of blood loss are a weakening of peripheral pulses, a decrease of pulse pressure to < 20 mm Hg, skin mottling or clammy skin, cool extremities, and a decreased level of consciousness.¹⁴ Assessing capillary refill may be unreliable due to the effect of environmental temperature, variability in patient response to hypovolemia, and inter-observer variation.¹²

The smaller body mass in children results in greater force applied per unit of body surface area, often leading to multiple injuries. The larger surface area can more easily lead to hypothermia, which can complicate the treatment of shock.^{12,14} For these reasons, frequent reassessment, high clinical suspicion, and knowledge of common injury patterns and mechanisms is vital in caring for a pediatric trauma patient.

Common Mechanisms Of Injury In Blunt Abdominal Trauma

Motor Vehicle Crashes

Although death is more commonly caused by associated head injury, MVCs are the most common cause of blunt abdominal injury in children.¹² Several factors affect the pattern of injury in children involved in MVCs, including the type of restraint used, the seating position, and the type of accident. The American Academy of Pediatrics has issued a policy statement with recommendations for child passenger safety, which is available at: <http://pediatrics.aappublications.org/content/early/2011/03/21/peds.2011-0213.full.pdf+html>.¹⁶ Seat belts and child safety seats are estimated to have saved > 12,000 lives in the United States in 2011 alone;¹⁷ however, a significant number of children remain unrestrained or suboptimally restrained, leading to injuries that can be prevented.

Children who are inappropriately restrained may suffer injury due to the restraint itself. Data from the National Trauma Database Pediatric Report 2013 show a significant number of injuries secondary to lap and shoulder belts.¹⁸ A cross-sectional study of children aged < 16 years found that optimally restrained children were more than 3 times less likely to suffer an abdominal injury compared to suboptimally restrained children. There were no abdominal injuries reported among optimally restrained children aged 4 to 8 years.¹⁹ Other studies have supported these findings and highlight the importance of following current child passenger safety recommendations.²⁰⁻²²

The type of impact may also affect the injury pattern. Data from the National Automotive Sampling System show side impacts account for more abdominal injuries (particularly to the liver and spleen) than frontal impacts.²³

Seat-Belt Syndrome

Inappropriate restraint with lap-only belts or lap-and-shoulder belts may lead to seat-belt syndrome. This was first described in adults in 1956, as a distinctive pattern of injuries associated with lap belts in serious crashes, including hip and abdominal contusions (see **Figure 1, page 4**), pelvic fractures, lumbar spine injuries, and intra-abdominal injuries to both solid organs and hollow viscera. Seat-belt syndrome in children was first reported in the 1980s.²⁴

During a 2-year study by Sokolove et al, 399 children with risk for intra-abdominal injury following an MVC presented to a level I trauma center.²⁵ Of those, 46 (12%) had a seat-belt sign, defined as an area of erythema, ecchymosis, and/or abrasion across the abdominal wall resulting from a seat-belt restraint. Patients with a seat-belt sign were more likely to have an intra-abdominal injury (relative

risk, 2.9). Specifically, there were much higher rates of gastrointestinal and pancreatic injuries in patients with a seat-belt sign than in those without (relative risk, 12.8 and 22, respectively). In this study, 6 of 46 children with a seat-belt sign did not have abdominal tenderness, and none of those 6 children had intra-abdominal injury. A retrospective chart review of 53 children with abdominal wall bruising after MVC found that 55% had intra-abdominal injuries.²⁶ The most common injuries were mesenteric or bowel, followed by spleen and liver.

Pedestrian Struck By Motor Vehicle

Pedestrian injuries may occur in the street or in driveways. Factors that may increase the risk for children being struck by motor vehicles include impulsive behavior, lack of parental supervision, young age, and male sex.²⁷

Urban centers have a higher incidence of pedestrian collisions, but injuries are more severe and are fatal a greater percentage of the time in rural settings. Injury patterns depend on several factors (including vehicle speed, angle of impact, center of gravity of the pedestrian, body part contacted by vehicle, part of vehicle impacted, and vehicle design).²⁷ A retrospective review of 5000 pedestrians injured by motor vehicles found that children aged < 15 years accounted for 38% of cases.²⁸ Among all patients, 3.9% had abdominal/pelvic injuries. A retrospective chart review of 4444 pediatric trauma patients (which included 465 patients struck by motor vehicles) found that only 2.4% had head, leg, and abdominal injuries (known as Waddell Triad).²⁹

Falls

Falls are the most common mechanism of nonfatal injury in children aged < 15 years.⁸ In a retrospective analysis of 729 pediatric patients treated for fall-related trauma, approximately 4% were found to have intra-abdominal injury (2.1% splenic injury, 1.1%

liver laceration, 1% bowel injury).³⁰ The authors defined a fall as either low (< 15 ft) or high (\geq 15 ft), and found that abdominal injuries were just as likely to occur after a low fall as after a high fall. However, the incidence of life-threatening abdominal injuries was greater in the high-fall group. Lallier et al performed a retrospective review of 1410 patients admitted after a fall from a minimum height of 10 feet, and found abdominal injury in 12% of the cases.³¹ Bulut et al found abdominal injury in 9% of trauma cases due to falls from a median height of 3.8 meters (12.46 ft).³² Common sites of falls include balconies, windows, stairs, walls, trees, and roofs.³⁰⁻³² The majority of falls occurred in private homes.^{30,31}

According to a meta-analysis, in 312 cases of small-intestine perforations, falls on stairs were not reported to be the mechanism of injury in any of the cases.³³ The authors found that, in 677 cases of falls on stairs, there were no reports of any intra-abdominal injury, including small-bowel perforation. This is important to note, as parents of abused children may report a fall on the stairs as the cause of injury. The emergency clinician should be highly suspicious of NAT in any patient with a small-bowel perforation due to a reported fall on stairs.

Bicycle Injuries

Bicycle injuries account for many ED visits by children, and one study has shown a trend toward more-severe injuries and an increasing number of abdominal injuries.³⁴ A 2010 retrospective review found that the number of patients with bicycle-related injuries in a pediatric intensive care unit of a Level II trauma center had increased significantly during recent years.³⁵ A total of 46 cases were reviewed, with 54.4% sustaining abdominal injury. The median age of patients with abdominal trauma was significantly younger than those without abdominal injury, and the most common mechanism of injury was falling from a bicycle (88%), with the majority impacted by the handlebars.

Injuries caused by direct impact with a handlebar require a high index of suspicion for intra-abdominal injury, as patients may have delayed presentation. Alkan et al found the mean delay in presentation from the time of accident for patients with severe abdominal injury secondary to trauma from a bicycle handlebar was 34.5 hours.³⁶ In a retrospective review of 40 patients aged < 16 years with a handlebar injury, potentially harmful injuries were found in 20 patients, and 8 required operative intervention.³⁷ A retrospective review of 462 children aged < 17 years with trauma from a bicycle incident found that abdominal handlebar injuries represented 9% of bicycle injuries.³⁸ However, the handlebar injuries contributed to 19% of all internal-organ injuries, 45.4% of solid-organ injuries, 87.5% of hollow-viscous injuries, 66.6% of vascular or lymphatic

Figure 1. Seat-Belt Sign



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injuries, and 100% of pancreatic injuries. Handlebar injuries were 10 times more likely to cause severe injury versus other bicycle injuries, and more than half were misdiagnosed at initial presentation.

Sports Injuries

An Australian study of 513 children with abdominal injury found that 33 (6%) were due to sports.³⁹ Males were more commonly injured than females, and rugby was the most common sport involved, followed by soccer, cricket, and baseball. Twenty-three percent of patients with sports-related abdominal trauma had a single, solid-organ injury, with the spleen being the most commonly injured, followed by the kidneys and liver. Fifteen percent of patients had hollow-viscus or multiple-organ injuries.

In the United States, the National Pediatric Trauma Registry data identified abdominal injury due to contact sports in only 0.56% of patients.⁴⁰ The sports most commonly involved were football, hockey, baseball, soccer, and basketball. Adolescents had a higher rate of abdominal injury than preadolescents. The spleen was the organ most commonly injured, followed by the kidney. In a review of children with soccer injuries severe enough to require trauma activation, 20% sustained abdominal injury (including splenic laceration, liver laceration, pancreatic transection, and duodenal hematoma).⁴¹ Snowboarders are also at risk for abdominal organ injury, with splenic injury being the most common.⁴² It is important to recognize the intra-abdominal organs that are most commonly injured due to sports in order to direct management.

Nonaccidental Trauma

A retrospective chart review of 6186 trauma patients aged < 18 years identified that 7.3% of patients had injury secondary to NAT.⁴³ Compared to patients with accidental trauma, these patients were younger, more severely injured, and required both a longer intensive care unit stay and overall hospital stay. Abdominal exploration was necessary more than twice as often in patients with injury secondary to NAT. Although solid-organ injuries are the most common in children with inflicted injury, NAT patients are also more likely to suffer hollow-viscus injury, more likely to suffer combined hollow-viscus and solid-organ injury, and there is often a delay in seeking care, compared to those with accidental trauma.¹³

Prehospital Care

Prehospital providers must immediately assess and manage the patient's airway, breathing, and circulation. They must control external hemorrhage and initiate spine immobilization and fluid resuscitation as necessary.¹⁴ Transfer to definitive care should not be delayed.

Effective communication between first responders and the receiving facility is crucial in the transfer of the injured patient. The mechanism of trauma, pertinent physical examination findings, and vital signs should be given to the receiving facility. This information is important in pediatric trauma where a parent is often not initially present and the child is frequently unable to communicate effectively. The brief report provided by emergency medical services can aid the emergency clinician in establishing which injuries to suspect and in directing a purposeful, logical workup.⁴⁴

Emergency Department Evaluation

Primary Survey

Evaluation of the child with blunt abdominal trauma begins with the primary survey.¹⁴ Priorities include maintaining or supporting the airway, breathing, and circulation while rapidly identifying and treating any life-threatening or limb-threatening injuries and preventing neurological compromise. The patient must be fully undressed in order to evaluate for possible injuries while also making an effort to avoid hypothermia.¹⁴ In the setting of multisystem trauma, history, physical examination, diagnostic studies, and treatment all typically occur simultaneously. The focused assessment sonography in trauma (FAST) is a tool utilized during the primary survey and will be discussed later on page 8.¹⁴

Focused History

A history may be difficult to obtain due to several factors. Preverbal children will not be able to provide a history, and caregivers may not be present, may not have seen the event occur, or may be unreliable in the setting of abuse. Young children may have difficulty describing the event or symptoms. Adolescents may give false information to avoid getting in trouble, or they may be impaired due to drugs or alcohol. Altered mental status or impaired memory due to associated brain injury may also occur. The "AMPLE" acronym emphasized in the Advanced Trauma and Life Support (ATLS) guidelines focuses the history to include only important information, without delaying initiation of other interventions: **A**llergies, **M**edications, **P**ast illnesses, **L**ast meal, and **E**vents/Environment related to the injury.¹⁴

Important information to gather includes how and where the injury occurred and deaths on the scene, as well as details about restraint, seating position, and impact type, if relevant. Details about the body parts struck, how the patient landed, and any symptoms experienced immediately after the incident or at the time of evaluation are also essential. In addition, the emergency clinician should have a high index of suspicion for NAT in patients with an

inconsistent history, delay in presentation, or other features concerning for abuse.

It is important to identify any underlying conditions that may predispose the child to more severe injury or make him or her more difficult to evaluate. Children with bleeding disorders, or those on anti-coagulants or antiplatelet therapy may have more severe bleeding. Children with any type of anemia may have a low baseline hemoglobin and hematocrit. This is helpful to identify in order to avoid unnecessary testing.

Children with pre-existing organomegaly may be at risk for more severe injury. This may include children with certain types of malignancies or bleeding disorders, underlying liver or metabolic disease, or infection with Epstein-Barr virus (mononucleosis). Children with prior abdominal surgeries may have preexisting abnormalities on imaging studies that make them more difficult to interpret, especially if a previous study is not available for comparison. Children with underlying liver disease or obesity may have abnormal liver transaminases at baseline, and children with underlying renal disease may have hematuria unrelated to the injury.

It is important for the emergency clinician to be made aware of any allergies and any medications the child is taking to avoid allergic reactions and medication interactions. Children with developmental delay or autism may be more difficult to evaluate, and it is important to know the child's baseline mental status in order to evaluate for any evidence of neurologic injury.

Secondary Survey

The secondary survey is a head-to-toe examination to evaluate for additional injuries that are not immediately life-threatening. A rectal examination is no longer routinely recommended in pediatric trauma patients. The ATLS guidelines recommend a digital rectal exam (DRE) be performed selectively before inserting an indwelling urinary catheter,¹⁴ although certain studies question its utility. In a chart review of pediatric patients, Shlamovitz et al found a lack of evidence for DREs.⁴⁵ They concluded that the DRE has poor sensitivity for the diagnosis of spinal cord, bowel, rectal, bony pelvis, and urethral injuries. According to a prospective study by Esposito et al, the DRE is, at best, equivalent to, and in most cases, inferior to other clinical indicators of injury. Omission of routine DREs appears to be permissible, safe, and advantageous.⁴⁶

Physical Examination Findings Suggestive Of Abdominal Injury

Any abdominal abnormality or other associated comorbid injuries discovered on examination should increase suspicion for an intra-abdominal injury.¹ Cotton et al identified abdominal tenderness, ec-

chymosis, and abrasions as positive predictors of intra-abdominal injury.⁴⁷ However, a negative examination and the absence of comorbid injuries do not completely rule out an intra-abdominal injury.¹

Several important physical examination findings have been associated with intra-abdominal injury in the setting of blunt abdominal trauma. In a prospective observational study by Holmes et al, patients with low systolic blood pressure for age were 4 times more likely to have intra-abdominal injury, and patients with abdominal tenderness were almost 6 times as likely to have intra-abdominal injury.⁴⁸ However, the absence of abdominal tenderness did not definitively rule out intra-abdominal injury, as it was present in only 58% of children with intra-abdominal injuries. Even in children with a GCS score > 13, abdominal tenderness was only present in 77% of patients with intra-abdominal injury. In the Holmes study, falls off bicycles, crush injuries, assault, and abuse were less common mechanisms of injury. Therefore, results may not be generalizable to patients with those mechanisms of injury. In a follow-up prospective study by Holmes et al to validate the clinical prediction rule developed in the aforementioned study, hypotension and abdominal tenderness were, again, found to be strong predictors of intra-abdominal injury, with relative risks of 4.4 and 2.2, respectively.⁴⁹

In a prospective study of 147 children admitted for blunt abdominal trauma, abdominal pain, signs of peritoneal irritation, and hemodynamic instability each had a relative risk of 5 for abdominal organ injury.⁵⁰ A retrospective study performed in the Netherlands to externally validate the score developed from the Holmes study also found that abdominal pain, peritoneal irritation, and hemodynamic instability occurred significantly more often in pediatric trauma patients with abdominal injury versus those without abdominal injury.⁵¹ Another retrospective study from Canada found that any concerning abdominal findings (including tenderness, distension, shoulder tip pain, and abdominal wall contusion or abrasion) were significant predictors of clinically important intra-abdominal injury, with an odds ratio of 12.6 for any of the findings.⁵² These studies highlight the importance of abdominal examination findings in the evaluation of children who have sustained blunt abdominal trauma. However, care must be taken in the interpretation of the abdominal examination in patients with decreased mental status, as the examination may be unreliable due to an altered ability to perceive or communicate pain.⁴⁸

In children involved in MVCs, it is important to evaluate for abdominal wall bruising or the seat-belt sign. A study analyzing a crash surveillance database found that restrained children involved in a MVC who sustained abdominal bruising were 232 times more likely to have a significant intra-abdominal injury when compared to those without bruising.⁵³

Initial Management

Initial management of a trauma patient involves rapid diagnosis and treatment of potentially life-threatening injuries. The hemodynamically stable patient can undergo a thorough secondary survey, laboratory tests, and imaging studies, as indicated.

Children who have hemodynamic signs of blood loss or instability require fluid resuscitation. This is typically based on the child's weight, which can be estimated using the Broselow® Pediatric Emergency Tape. An initial bolus of 20 mL/kg of warmed isotonic crystalloid solution is recommended and can be repeated for a total of 3 boluses, or 60 mL/kg. Packed red blood cells (PRBCs) at an initial dosage of 10 mL/kg should be considered at any point that the child deteriorates during the resuscitation and especially if the child remains hemodynamically unstable after the third bolus. Surgical consultation should be initiated (if this has not already been done) in any child who does not become hemodynamically stable after the first bolus.¹⁴ A bedside FAST should be completed on any unstable patient to identify hemoperitoneum or hemopericardium. The child should be taken to the operating room for emergent laparotomy if those conditions are found.^{12,54}

Diagnostic Studies

Laboratory Tests

The routine use of extensive trauma panels are no longer recommended, but there are some laboratory tests that may be helpful in assessing the trauma patient.^{1,55} The benefit of laboratory testing has been controversial. Wegner noted that there are 2 reasons for performing laboratory testing. The first is to immediately treat a potentially unstable patient by ordering a type and cross match and administering blood. The second is to screen a stable child for a possible intra-abdominal injury.¹ The most useful tests are the complete blood count (CBC), liver function tests (LFTs), and urinalysis (UA). However, the physical examination and mechanism of injury should guide the evaluation.

In 2004, Cotton et al determined that the combination of abdominal tenderness and an aspartate aminotransferase (AST) > 131 U/L correctly predicted the presence of intra-abdominal injury with a sensitivity of 100% and a specificity of 87%.⁴⁷ Hynick et al found that hematuria (gross or microscopic), elevated serum alanine aminotransferase (ALT) > 125 U/L, and documentation of clinically concerning abdominal findings were significant predictors of a clinically important abdominal injury.⁵²

However, in a retrospective review of 382 patients, Capraro et al found that there was no single laboratory test that had a sufficiently high sensitivity and negative predictive value (NPV) to provide a clinically useful screen for abdominal pathology.⁵⁵

No test had a high enough positive predictive value (PPV) to be useful as a predictor of abdominal pathology. Additionally, the decision to obtain a CT scan was made before the return of routine trauma panel laboratory test results and was based more on the mechanism of injury and physical examination findings, which left them questioning the necessity of the laboratory tests. One limitation of the study was that it did not correlate laboratory results with physical examination findings.

In 2002, Holmes et al sought to determine the utility of laboratory testing in the identification of children with intra-abdominal injuries after blunt torso trauma. They developed a prediction rule and looked specifically at 6 high-risk variables: low age-adjusted systolic blood pressure, abdominal tenderness, femur fracture, increased liver enzyme levels (serum AST > 200 U/L or serum ALT > 125 U/L), microscopic hematuria (> 5 RBC/high-power field), or an initial hematocrit level < 30%.⁴⁸ After adjusting for physical findings of tenderness or abnormality on abdominal examination, they found that laboratory testing significantly contributed to the identification of children with intra-abdominal injuries. Increased liver transaminases and microscopic hematuria offered the best initial risk stratification of patients. Pediatric patients with any of these risk factors should be considered to be at significant risk for intra-abdominal injury and should undergo further testing. Patients with none of these risk factors are considered to be at low risk for intra-abdominal injury, and CT scan may be deferred. This study was externally validated in 2009 by a prospective observational study of 1119 patients, with a sensitivity of 94.9% (149 of 157; 95% confidence interval [CI], 90.2%-97.7%) and specificity of 37.1% (357 of 962; 95% CI, 34%-40.3%). The 8 patients not identified by the prediction rule did not require any therapeutic interventions.⁴⁹

Amylase and lipase values have not proven to be a helpful predictor of intra-abdominal injury. A multicenter review of 131 pediatric trauma patients with pancreatic injuries found that neither initial nor peak amylase or lipase values correlated with the grade of injury, and neither predicted length of stay or mortality.⁵⁶ Adamson et al performed a retrospective study of 1821 pediatric trauma patients examining serum amylase and lipase levels.⁵⁷ They found that 48% of patients with elevated amylase and lipase levels had no clinical or CT evidence of intra-abdominal injury. Seventy-four patients with elevated amylase/lipase levels underwent abdominal and pelvic CT scanning, and 38 (51%) had completely normal scans. In patients with pancreatic injury, there was no correlation between amylase/lipase values and pancreatic injury severity. The authors concluded that serum amylase and lipase determinations may support clinical suspicion in the diagnosis of pediatric pancreatic trauma,

but they are not reliable or cost-effective as screening tools. Obtaining these values should be considered in cases of clinical or radiographic suspicion of pancreatic injury.

Focused Assessment With Sonography In Trauma

FAST enables the emergency clinician to rapidly detect the presence of hemoperitoneum, which is indicative of intra-abdominal injury.¹⁴ Studies in the adult population have found sensitivities for detection of intra-abdominal organ injury as high as 86% to 97%.^{14,58-60} However, its use in the pediatric population is not as prevalent. According to a 2012 study, bedside ultrasonography in only 45% of pediatric trauma centers compared to 74% to 96% of adult settings.⁶⁰ Advantages of FAST are that it is noninvasive and repeatable, it can be rapidly completed at the bedside, and it does not expose the patient to ionizing radiation.¹⁴ According to the ATLS guidelines, ultrasound has sensitivity, specificity, and accuracy in detecting intra-abdominal fluid comparable to diagnostic peritoneal lavage.

Recent concerns regarding radiation-induced malignancy from CT scans have led to increased use of FAST in the pediatric population. However, the validity and usefulness of FAST in the pediatric population has been controversial.⁶¹ For example, FAST cannot identify an intra-abdominal injury in the absence of hemoperitoneum, and approximately 26% to 35% of patients with an intra-abdominal injury do not have hemoperitoneum.⁶¹ The meta-analysis performed by Holmes et al in 2007 found the sensitivity of FAST to detect hemoperitoneum in children to be 80% (95% CI, 76%-84%).⁶¹ However, when looking only at studies graded at level I or level II methodology, the sensitivity dropped to 66%. In patients with intra-abdominal injury (with and without hemoperitoneum), FAST had a sensitivity of 50%. The specificity of identifying hemoperitoneum was 96% (95% CI, 95%-97%) with a positive likelihood ratio of 22.9 (95% CI, 17.2-30.5). They concluded that a negative FAST examination is not sufficient to rule out the presence of an intra-abdominal injury, but a positive FAST examination should prompt an immediate abdominal CT scan in a hemodynamically stable patient.

Multiple other studies echo these findings, and conclude that a negative FAST examination aids little in decision making and should not be used as the sole diagnostic test in the hemodynamically stable patient.⁶²⁻⁶⁴

Retzlaff et al retrospectively looked at patients diagnosed with intra-abdominal organ injury after blunt trauma and found that ultrasound, combined with physical assessment, proved to be effective in establishing a diagnosis and led to appropriate surgical decision making in > 97% (34/35) of patients.⁶⁵

They argue that a negative FAST may miss a small percentage of patients with free fluid or parenchymal injury, but the clinical significance of these injuries is not clear given that nonoperative management of blunt abdominal trauma in hemodynamically stable children is a widely accepted practice.

However, a prospective study by Emery et al in 2001 found 7 of 17 liver and spleen injuries (41%) without fluid on screening sonography were grade III, indicating that one cannot assume that injuries without fluid are necessarily trivial.⁶⁶ They also found that 34% of patients had intra-abdominal injury detected by CT without free fluid, thus unidentifiable by FAST. Stassen et al showed that FAST cannot reliably exclude intestinal injuries. In their retrospective review, 78% of patients with lap-belt marks and significant intestinal injuries had negative or equivocal FAST examinations at presentation.⁶⁷

Several studies have attempted to improve the sensitivity of FAST by combining it with other factors. A study by Suthers et al combined FAST with physical examination.⁶⁸ An examination was considered positive when either the FAST or the physical examination was suggestive of intra-abdominal injury. FAST alone had a sensitivity of 70% and a specificity of 100%, but, when combined with physical examination, sensitivity rose to 100% and specificity decreased to 74%. A study by Sola et al combined FAST with liver transaminase level tests.⁴ When FAST was combined with AST or ALT levels > 100 U/L, it had a sensitivity of 88% and a specificity of 98% with an NPV of 96% for identifying intra-abdominal injury. It should be noted that not all patients had FAST, AST/ALT levels, or CT scans. They concluded that FAST combined with liver enzymes is an effective screening tool for intra-abdominal injury in children after blunt abdominal trauma.

A positive FAST in the pediatric population suggests hemoperitoneum and requires further diagnostic evaluation. Regardless of the results of the FAST, unstable patients require emergent intervention.^{54,69} Ultrasonography has the best test performance for children who are hypotensive, with a sensitivity of 100%, and it should be obtained early in the ED evaluation.⁶⁹ However, FAST is operator-dependent, likely to be inconclusive in cases of increased bowel gas and subcutaneous air distortion, and poor at identifying bowel, diaphragm, and pancreas injuries.¹⁴ A negative FAST cannot rule out an intra-abdominal injury and will likely aid little in the diagnosis and medical management of the pediatric trauma patient.

Computed Tomography

CT scans with intravenous contrast have become the gold standard in diagnostic imaging for abdominal injuries after blunt trauma in hemodynamically stable patients.^{5,70} Oral contrast may be indicated in

rare instances, such as with suspected pancreatic or hollow-viscus injury.^{70,71} CT has a high sensitivity for the detection of solid-organ injuries and for the detection and quantification of peritoneal or extra-peritoneal fluid.⁵ Additionally, it is relatively sensitive in detecting the risk of hollow-viscus injury, with sensitivities ranging from 87% to 95% and specificities ranging from 48% to 84%.^{5,71}

In a meta-analysis comprised of 2596 patients with prospectively collected data, the overall rate of intra-abdominal injury after a negative abdominal CT scan was 0.19% (95% CI, 0.08%-0.44%).⁷² The overall NPV of abdominal CT was 99.8% (95% CI, 99.6%-99.9%). However, there are no current recommendations for the highest tolerable miss rate of an intra-abdominal injury.

Risks Of Computed Tomography In Pediatric Patients

The major risk of CT is ionizing radiation exposure and radiation-induced malignancy. Malignancy risk from radiation exposure during CT scanning in children was first broadly publicized by Brenner et al in 2001.⁷³ The growing tissues and organs of children are more sensitive to radiation than those of adults.⁷⁴ It is estimated that the risk of a fatal cancer from radiation is 1 per 1000 pediatric CT scans in young children and 0.18% lifetime risk for abdominal CT in a 1-year-old child.^{4,73,74} This has led to the development of radiation dose-reduction strategies and the institution of as-low-as-reasonably-achievable (ALARA) principles when CT scanning is necessary.⁵ The risk of an adverse reaction to intravenous contrast is extremely rare.⁵

Determining Which Patients Do Not Need Computed Tomography

Holmes et al performed a large multicenter prospective observational cohort study of 12,044 children with blunt torso trauma.⁷⁵ A prediction rule was derived to identify children at very low risk for intra-abdominal injuries that would require acute intervention and for whom CT could be obviated. The prediction rule consisted of 7 history and physical examination findings. The children considered at very low risk (in descending order of importance) had: (1) no evidence of abdominal wall trauma or seat-belt sign; (2) a GCS score > 13; (3) no abdominal tenderness; (4) no evidence of thoracic wall trauma; (5) no complaints of abdominal pain; (6) no decreased breath sounds; and (7) no vomiting. The rule had an NPV of 99.9% (5028 of 5034; 95% CI, 99.7%-100%), a sensitivity of 97%, and a specificity of 42.5%. The study did not include laboratory testing or abdominal ultrasonography (FAST). It failed to identify 6 patients with intra-abdominal injury, but all 6 of those patients had hemoperitoneum that would likely have been identified by FAST. Five of the 6 children not identified also had laboratory abnormalities that would have suggested the pos-

sibility of an intra-abdominal injury. The authors of the study emphasized that patients with ≥ 1 of the prediction rule variables do not necessarily require CT scan. In such cases, clinical judgment is required. The addition of laboratory testing, FAST, and/or observation instead of abdominal CT may be used in patients with ≥ 1 variables of the rule and who appear to be at low risk clinically.⁷⁵

Karam et al developed the Blunt Abdominal Trauma in Children score, which utilized 10 parameters covering physical examination, laboratory tests, and ultrasound.⁵⁰ The score was recently studied by de Jong et al, who attempted to predict patients who might benefit from CT scan and patients in whom it can be avoided. However, the applicability of the study is limited because of a low sample size and the large number of parameters.⁵¹ Sola et al found that patients with a negative FAST and liver transaminases < 100 U/L should be observed rather than subjected to the radiation risk of CT scanning, with an NPV of 96%.⁴ In 2009, Holmes et al identified 6 high-risk variables for intra-abdominal injury.⁴⁹ Patients with none of these variables can likely forgo abdominal CT. If the clinical decision rule was applied to the study sample, 365 (32.6%) abdominal CT scans could have been avoided.

Despite the extensive use of CT imaging, clinical findings remain a predominant factor in deciding which patients require exploration.⁷¹ Operative management is primarily decided based on clinical criteria and hemodynamic status of the patient, not on CT findings.⁵ The most common indication leading to exploration was abdominal pain that persisted or progressed to peritonitis.⁷¹ A repeat CT scan is unlikely to confidently exclude a bowel injury in children with a worsening abdominal examination, especially in the presence of findings suggestive of a bowel injury on initial imaging.⁷¹ In cases of children with equivocal initial imaging and those who cannot provide a reliable examination secondary to a brain injury or multiple distracting injuries, repeat imaging may be helpful, but observation and serial examinations are an acceptable alternative.^{64,71}

Children who are initially evaluated with abdominal CT scans at community hospitals frequently undergo repeat scans after transfer to pediatric trauma centers, increasing their radiation exposure.⁶⁴ Cook et al found that 80% of pediatric patients transferred to a Level I trauma center had repeat abdominal CT scans that were potentially preventable.⁷⁶ As per the ATLS guidelines, transfer should not be delayed for diagnostic imaging to be performed at the referring hospital if results will not affect the need for transfer.¹⁴ Additionally, it is important to avoid repeat CT scans at the receiving facility unless it will directly impact management.

Treatment

The treatment of patients with blunt abdominal trauma is first guided by initial stabilization and then ultimately, by diagnosis. Pain control is an important step in initial management that can be easily overlooked in a complex case. In a hemodynamically unstable patient, fluid resuscitation should begin with crystalloid and then progress to blood, as explained previously. Patients with low systolic blood pressure despite fluid resuscitation should be taken for emergent laparotomy. A positive FAST in this case can aid in determining whether the bleeding is originating from the abdomen. However, a negative FAST should not delay surgical exploration. A hemodynamically stable patient can undergo diagnostic testing and can be observed with the use of serial abdominal examinations to monitor for any changes.

Most solid-organ injury can be managed nonoperatively.⁵ Children have smaller blood vessels and appear to have an enhanced vasoconstrictor response, which usually allows bleeding to stop spontaneously.⁵ In a multicenter study of 312 children with isolated Grades I to IV hepatic or splenic injuries, only 1% required laparotomy.⁷⁷ Another multicenter study of 1880 children by Holmes et al found the failure rate of nonoperative management to be 5% and failure typically occurred within 12 hours of injury.⁷⁸ Specific management strategies for the most common injuries in blunt abdominal trauma patients are outlined here.

Management Of Specific Organ Injuries

Injury grading scales specific to each organ can be found on the American Association for the Surgery of Trauma website and are available at: <http://www.aast.org/library/traumatools/injurygrading-scales.aspx>. As a general rule, grades IV to VI solid-organ injuries represent vascular injury and fractured or shattered organs.

Splenic Trauma

The spleen is the most frequently injured abdominal organ in blunt trauma in children and it accounts for up to 45% of all visceral injuries.^{79,80} Injuries to the spleen are often associated with other intra-abdominal injuries.⁸⁰ Children have less body fat and soft tissue to absorb traumatic impact, compared to adults. The common mechanisms of splenic trauma are MVCs, falls, sports injuries, and bicycle accidents.^{80,81} NAT should also be considered if the mechanism reported is inconsistent with the injury.⁸⁰

Diagnosis

Injuries to the spleen may present with left upper quadrant pain and/or tenderness. The patient may also present with generalized abdominal pain. Pain that radiates to the left shoulder may indicate a

splenic injury secondary to diaphragmatic or phrenic nerve irritation.⁸⁰ Patients with massive bleeding can present with shock and/or peritoneal signs. Laboratory data are nonspecific for spleen injury; therefore, if suspected, the patient should undergo imaging evaluation. CT of the abdomen and pelvis with intravenous contrast is the diagnostic modality of choice; however, hemodynamically unstable trauma patients who do not respond to crystalloid and blood transfusions should be taken to the operating room immediately.

Management

In the hemodynamically stable patient with blunt splenic trauma, the standard of care has shifted to nonoperative management.^{80,82} Several decades ago, patients would undergo immediate splenectomy.⁸⁰ However, in addition to immediate operative and postoperative complications, patients who have undergone splenectomy are at long-term risk for overwhelming infection and sepsis. Davies reviewed management of blunt splenic trauma over 50 years and found decreased mortality, decreased blood transfusions, and decreased length of hospital stay with nonoperative management.⁸³ Feigin et al demonstrated decreased inpatient mortality with nonoperative management of liver and spleen injuries.⁸⁴ Out of 156 patients who did not require immediate surgery, Bond et al found an overall efficacy rate of 97.4% for nonoperative management of pediatric patients with liver or spleen injury.⁸⁵ Patients treated nonoperatively were placed on strict bedrest, were closely monitored, and had serial hematocrits. It is important that patients who are not immediately taken to the operating room (based on surgical consultation) be closely monitored and have serial physical examinations.

Liver Trauma

The liver is the second most commonly injured organ in pediatric blunt abdominal trauma.⁷⁹ The vascular supply of the liver and its proximity close to the inferior vena cava predisposes the liver to the risk of hemorrhage in the setting of trauma. Prognosis is related less to the grade of injury than to the overall injury severity score and associated injuries.⁷⁹

Diagnosis

The standard approach to patients with suspected liver injury includes physical examination, laboratory screening, and CT scan with intravenous contrast. Multiple studies have shown the utility of elevated liver enzymes to be significant predictors of clinically important abdominal injury.^{1,47-49,52} Particularly, ALT > 125 U/L and AST > 200 U/L are concerning for abdominal injury and warrant further workup (except in cases of possible NAT, where transaminase levels > 80 U/L should affect management).^{48,49,86}

Management

Nonoperative management has become the standard of care for patients who are hemodynamically stable or who respond to crystalloid fluid resuscitation and do not require > 40 cc/kg blood transfusion.⁸⁷⁻⁹⁰ Complications of nonoperative care include biloma, hepatic artery pseudoaneurysm, and necrotic gall bladder. Most complications occur with higher-grade injuries.⁸⁹ When less-invasive procedures (such as arterial embolization) are included in conservative management, more patients can avoid laparotomy.⁸⁸ Angiography, endoscopic retrograde cholangiopancreatography, and ultrasound-guided percutaneous drainage can be useful techniques to facilitate nonoperative management.⁸⁹

Since hemodynamic instability is currently the main indicator for operative management, contrast blush on CT has been studied as a possible predictor of the need for intervention in liver injury. Contrast blush on CT scan refers to active extravasation of intravenous contrast and indicates sites of active bleeding. In addition to hemodynamic instability, contrast blush may be a predictor of patients for whom nonoperative management will fail. Eubanks et al reviewed a group of 77 pediatric patients with blunt liver trauma and found a similar length of hospitalization and intensive care unit stay between the blush versus no-blush groups. The group with a blush required a greater volume of transfused blood, yet they still rarely required operative management.⁹⁰ Van der Vlies et al reviewed 9 studies describing 117 patients.⁹¹ Based on the available data, they concluded that patients with a contrast blush were more likely to require intervention, whether operative or via angioembolization. Emergency clinicians should consider contrast blush when managing the patient with blunt liver and spleen injury, but this is an area for further research.

Renal Trauma

Renal injuries are less common than liver or spleen injuries in children, but they occur more frequently than in adults.⁹² Renal injuries account for approximately 10% of blunt abdominal trauma injuries in children, and associated injuries are found in 90% of patients with renal trauma.^{93,94} Due to the location and size of their kidneys, children are more susceptible to blunt renal injury than adults.⁹⁵ Additionally, children have less perirenal fat, more-compliant ribs, and relatively smaller abdominal muscles.⁹⁶ In a review of pediatric renal trauma, the most common mechanisms of injury were MVCs, pedestrian versus motor vehicle collisions, and falls.⁹⁷

Diagnosis

For suspected renal injuries, the diagnostic test of choice is CT scan of the abdomen and pelvis.⁹⁸ CT is superior for detection of renal injuries compared to other modalities, especially for lower-grade injuries.

⁹⁵ Determining which children need a CT scan is the more challenging question. Indications for CT scan include a mechanism of injury that placed the child at risk for renal trauma, contusion or ecchymosis of the flank, and fractures of the lower ribs or thoracolumbar spine.⁹⁸

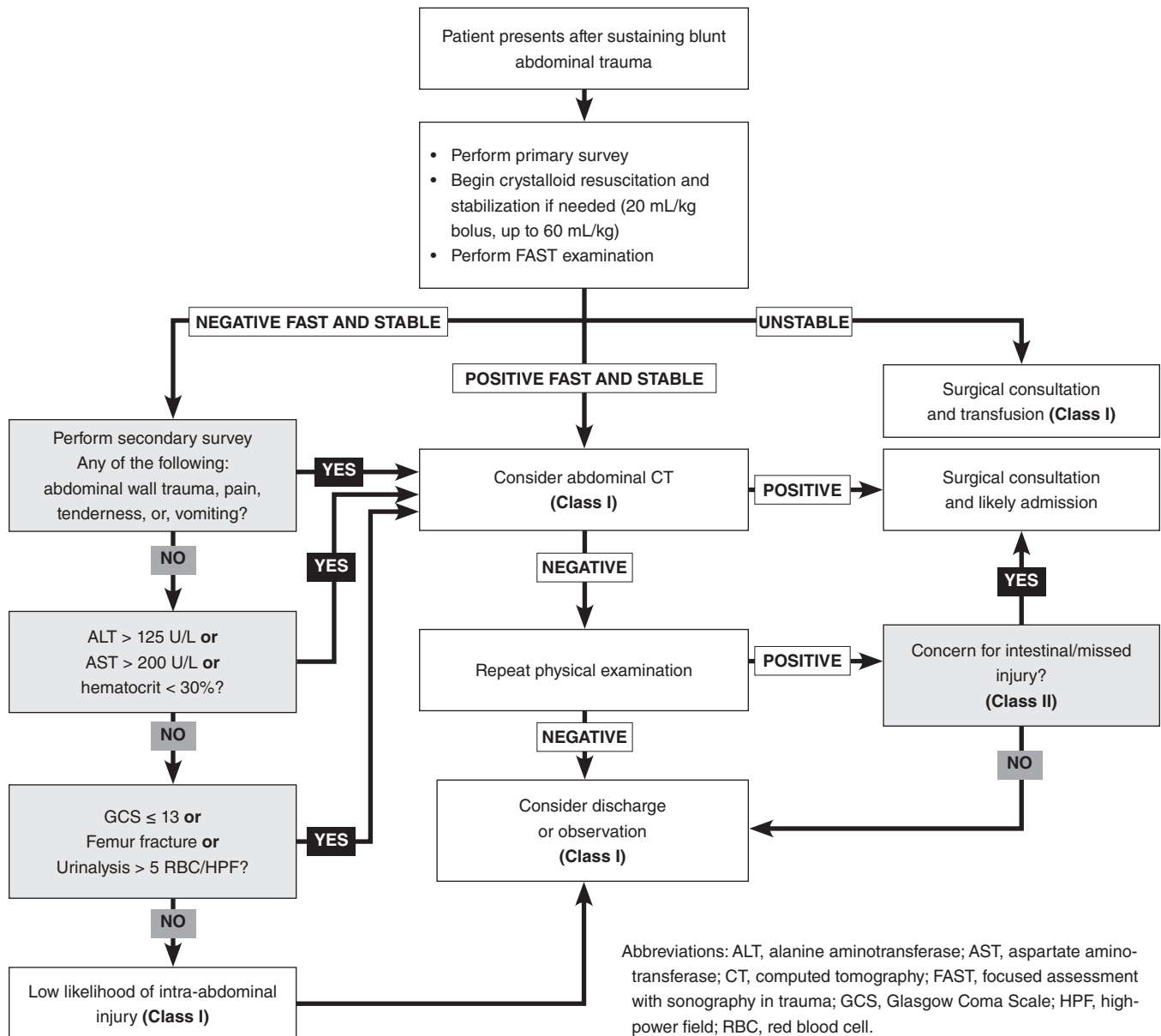
Gross hematuria is a definite indication for imaging; microscopic hematuria is more controversial.⁹⁴ In adults, gross hematuria alone or microscopic hematuria in the context of shock are indications for further imaging. In children, this is less clear.^{95,99} According to Fraser's review of renal trauma, CT imaging of all pediatric patients with hematuria is recommended.⁹⁵ Buckley et al used an imaging threshold of 50 RBC/high-power field on urinalysis in patients with blunt trauma, and found a sensitivity of > 98% for detecting \geq Grade II injuries.¹⁰⁰ Holmes et al used microscopic hematuria of > 5 RBC/high-power field to define which patients were not at a low risk for injury.^{48,49} However, the absence of hematuria does not rule out renal injury.⁹⁸

Additionally, pediatric patients may also have an undiagnosed congenital anomaly. Abou-Jaoude et al retrospectively reviewed 100 patients from the trauma registry who had sustained blunt abdominal trauma.⁹⁹ Twenty-seven patients had a renal injury or anomaly, and 89% with an injury or congenital anomaly had a least 1 positive examination finding (including abdominal or flank tenderness, pelvic instability, or blood at the urethral meatus). The authors of the study also found that microscopic hematuria was not a good predictor of injury, and using a threshold of > 20 RBC/high-power field would have missed 7 injuries or anomalies. Thus, the mechanism of injury, the physical examination, and clinical judgment remain important elements in determining the need for CT scan for suspected renal injury.⁹⁸⁻¹⁰⁰

Management

Over the last 25 years, nonoperative management has become the mainstay of treatment for hemodynamically stable patients with blunt renal trauma, particularly in patients with grades I to III injuries.⁹² The goal of management is preservation of renal function and decreased morbidity.⁹³ He et al reviewed 84 cases of children with blunt renal injury and found that all children with grades I to III injuries were successfully managed nonoperatively.¹⁰¹ Of those with grades IV or V injuries, 61% required surgery. Umbreit et al reviewed the literature regarding grade IV injuries that were not renovascular and found that 68 out of 95 patients did not require an intervention and 81 out of the 95 patients did not require laparotomy.⁹³ Those with nonsurgical interventions were managed percutaneously or endoscopically. In their meta-analysis, overall, 72% of patients were managed without any invasive procedure.

Clinical Pathway For Management Of The Pediatric Patient With Blunt Abdominal Trauma



Class Of Evidence Definitions

Each action in the clinical pathways section of *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
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- 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

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.

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ture. Fitzgerald et al performed a prospective study of patients evaluated for renal trauma and found 39 cases, confirmed by CT, that were initially managed conservatively, and 97% of the patients were successfully managed nonoperatively.⁹⁴

Similar to other blunt organ trauma, patients who are managed supportively are hospitalized on a trauma service and closely monitored, initially placed on bed rest, transfused as needed, and undergo follow-up imaging as required. In patients with renal trauma who are treated nonoperatively, long-term follow-up requires monitoring for hypertension. A lack of quality studies limits our knowledge of the true risk of hypertension in the setting of renal injury.

Pancreatic Trauma

Pancreatic trauma occurs in up to 12% of blunt pediatric abdominal trauma, though most report this to be < 10%.^{102,103} Despite being the fourth most frequently injured organ, overall, pancreatic trauma is uncommon in children.¹⁰⁴ In general, the mechanism is due to a large deceleration force, with an object impacting the epigastrium.¹⁰⁴ The most common mechanisms are MVCs, bicycle handlebars striking the abdomen, and NAT.¹⁰²⁻¹⁰⁶ Pancreatic injuries cause significant morbidity, and management is controversial.¹⁰⁷ Complications of pancreatic trauma include pseudocysts, pancreatic fistula, and pancreatitis.^{102,104}

Diagnosis

The diagnosis of pancreatic injury can be challenging. Patients may complain of midepigastria pain.⁸¹ However, the examination can be normal and laboratory studies nonspecific.^{108,109} Over a period of 14 years, Arkovitz et al reviewed 26 cases of children with pancreatic injuries.¹⁰² Though admission amylase levels were usually elevated, this was not predictive of length of stay, grade of injury, injury severity score, or development of pseudocyst. In children, laboratory studies may be less helpful than in adults, as there is a lower total rise of pancreatic enzymes, and the rise can be delayed by many hours.¹⁰³

As with other intra-abdominal injury, CT scan with intravenous contrast is the diagnostic test of choice. However, a normal CT scan does not exclude pancreatic trauma.¹⁰⁶ The use of endoscopic retrograde cholangiopancreatography has been recommended as an adjunct to assess pancreatic trauma, especially if the CT results are questionable.^{106,109,110}

Management

The treatment of pancreatic trauma has trended toward nonoperative management. However, injuries of greater severity that involve the pancreatic duct still require further study to reach a consensus on management.¹⁰⁶ In light of the rarity of pancreatic trauma (especially higher grade injuries), quality prospective studies are difficult to perform, and the

current literature is limited by small sample size and the mostly retrospective nature of the data.

Over a period of 10 years and at 3 institutions, Cuenca et al reviewed 79 cases of children with blunt pancreatic trauma.¹⁰⁴ Most of the patients had associated injuries, and although amylase and lipase levels were typically elevated, they were not predictive of the grade of injury or the need for surgery (27 children underwent surgery for a pancreatic-specific indication). An increasing grade of injury strongly correlated with the need for surgical management. Of the surgeries performed, 75% were on patients with grades II to V injuries. Overall, there were fewer surgeries in the second 5 years of the study, indicating a trend toward nonoperative management as has been noted with other solid-organ blunt trauma.¹⁰⁴ In Sutherland's study of 91 patients with pancreatic injury, the overall operative rate was 13%, and those patients tended to have sustained higher grade injuries.¹⁰³

The conservative management of pancreatic injury includes placement of a nasogastric tube, total parenteral nutrition, and antibiotics.¹⁰⁵ All 36 patients in the study by Abbo et al were managed without laparotomy. Of these patients, 30% developed a pseudocyst, mostly with grades III and IV injuries. Five patients required invasive procedures (including endoscopic cystogastrostomy or percutaneous drain placement), but avoided open laparotomy.¹⁰⁵ Conversely, Beres et al noted the increased risk of pseudocyst for patients with grades III and IV pancreatic injuries (ie, pancreatic transection or ductal injury) that were managed nonoperatively.¹⁰⁷ These patients also required more prolonged total parenteral nutrition than the nonoperative patients. The authors of that study suggested operative management for the higher grade pancreatic injuries.¹⁰⁷ Similarly, Mattix et al conducted a multi-institutional retrospective study and found that, out of 173 pancreatic injuries, higher grade injuries were more predictive of failure of nonoperative management. They also concluded that patients with ductal injury should be managed more aggressively.¹¹¹ In general, while the approach to grades I and II pancreatic injuries tends to be nonoperative, the best management of higher grade injuries remains controversial.

Gastrointestinal Trauma

Blunt intestinal trauma is more common in children than adults, but it occurs less commonly than most solid-organ injuries.¹¹² Common mechanisms of intestinal injury are MVCs with improper child restraint use and bicycle accidents.⁷¹ The most common mechanisms for duodenal injury are NAT, handlebar injuries, and MVCs.^{113,114}

Diagnosis

Gastrointestinal injury can be more difficult to diagnose than solid-organ trauma, and this may

delay diagnosis.^{72,115} This delay increases the risk of peritonitis. In detecting gastrointestinal injury, emergency clinicians must combine physical examination findings on serial abdominal examinations with CT findings. For example, a seat-belt sign should be interpreted as concerning for intra-abdominal injury (especially intestinal injury), and further workup is imperative.¹¹⁵ CT scanning with intravenous contrast is the standard. CT findings suggestive of intestinal injury include free fluid, free air, and bowel wall thickening. In the Chartoorgoon et al study, the most common indication for surgery was worsening abdominal pain rather than CT findings.⁷¹

Management

In a retrospective review of pediatric blunt intestinal injuries that were confirmed in the operating room, the authors compared patients with nondelayed diagnosis to a group whose diagnoses were delayed.¹¹⁵ Overall, 78% of children (25) were taken to the operating room on the basis of physical examination. The delayed diagnosis group was defined as having undergone laparotomy ≥ 12 hours after presentation. In the delayed group, 10 out of 12 patients were initially evaluated at a hospital that was not a trauma center. The average hospital stay was 3.5 days less in the nondelayed group. The authors concluded that, when intestinal injury is present, the physical examination will be abnormal initially or on reassessment. This study is limited by small sample size, but it does support the importance of the physical examination in the assessment and reassessment of the alert pediatric trauma patient.

Duodenal injuries carry a high risk of morbidity and mortality and can be difficult to diagnose and manage. Gutierrez reviewed 54 cases of hospitalized patients with operative duodenal injuries.¹¹³ In this study, 90% of patients who required surgery did have abnormal physical examination findings that indicated a potential abdominal injury (including abdominal abrasions or contusions, seat-belt sign, handlebar marks, and tenderness to palpation or percussion). Delayed detection of duodenal injury also leads to prolonged hospital stay and more complications.¹¹⁴

Adrenal Trauma

Adrenal trauma is very rare in the setting of pediatric blunt trauma, occurring in $< 1\%$ of patients.¹¹⁶ The adrenal glands are protected by surrounding structures. The mechanism is usually direct compression of the abdomen as occurs in an MVC. Typically, the injury only affects 1 gland, and adrenal insufficiency does not occur unless both adrenal glands are injured. Patients with bilateral adrenal trauma will need further evaluation for adrenal insufficiency.¹¹⁶ Adrenal injuries usually do not cause hemodynamic instability or specific symptoms, and

are unlikely to be an indication for surgical management in a blunt trauma patient.^{116,117} However, an adrenal injury implies a mechanism with significant force and is usually associated with other injuries, the liver being most commonly injured.^{116,118}

Special Populations/Circumstances

Nonaccidental Trauma

In abdominal injury due to NAT, the external examination may be normal. Thus, a high index of suspicion is required, especially in cases of associated inflicted injury. It has been noted that as few as 12% of children with inflicted abdominal injuries will have bruising of the abdominal wall.¹¹⁹ Of concern, abusive abdominal injury has a higher morbidity and mortality rate than nonabusive abdominal injury.¹¹⁹ Blunt injury to the liver and intestine are the most frequent injuries in NAT. Additionally, NAT is the leading cause of duodenal perforation, which rarely occurs due to accidental injury.¹¹⁹ Unusual injuries (such as isolated adrenal injury) should raise suspicion for NAT as well.¹¹⁸

Lindberg et al reviewed the use of liver enzyme testing to screen children in whom there is concern for NAT, and they recommended that children with transaminase levels > 80 U/L or with abdominal bruising, tenderness, or distension should undergo definitive testing.⁸⁶ CT scan with intravenous contrast is the imaging modality of choice for detecting NAT to the abdomen. Nonaccidental injuries are more likely to have a delayed presentation than accidental injuries and are more likely to require surgical management.¹¹⁹

Obesity

There are limited data evaluating how obesity affects children who sustain blunt abdominal trauma. In a study primarily evaluating obesity and lower-extremity long-bone fractures, obese patients (weight $> 95^{\text{th}}$ percentile for age/sex) sustained more intra-abdominal solid-organ injuries (24.4% vs 13.5%, $P = .02$) and hollow-viscus injuries (3.9% vs 0.0%, $P = .0105$) injuries.¹²⁰ However, another study looking at children involved in MVCs found no increased abdominal injuries in obese children aged 2 to 13 years compared to nonobese children, and found decreased abdominal injuries in obese children aged 14 to 17 years.¹²¹ A retrospective study of 1314 pediatric trauma patients at a Level I trauma center also found a lower incidence of intra-abdominal injuries in obese versus nonobese patients (6% vs 11%, $P = .023$).¹²²

Obese patients are likely to be more difficult to evaluate and detect abdominal tenderness. Obesity may compromise the quality of ultrasound images and make the images more difficult to interpret.¹²³

Although obese children may have elevated ALT levels secondary to nonalcoholic fatty liver disease, a cross-sectional study of obese children aged 6 to 14 years found that ALT levels above the normal limits was not common, with only 12% of the obese children having an elevated ALT.¹²⁴

Inappropriate restraint of obese children can significantly increase the risk for intra-abdominal injury. Unfortunately, there are a limited number of child safety seats with weight limits to accommodate obese children, and they are often expensive.¹²⁵ In addition, many children who meet the height recommendation for the use of booster seats may exceed the maximum weight.¹²⁶

Postmenarchal Females And Pregnancy

It is important to consider the possibility of pregnancy in any postmenarchal female being evaluated for blunt abdominal trauma and to obtain urine pregnancy testing. Trauma in pregnancy is the leading cause of nonobstetric maternal death and remains a major cause of fetal demise. Although penetrating trauma has a significantly higher rate of fetal demise compared to blunt trauma, no significant difference was found for maternal mortality rates. Blunt trauma to the abdomen increases the risk of placental abruption,^{127,128} and abortion is the most common complication after blunt abdominal trauma (5%).¹²⁹ Rh immunoglobulin therapy should be administered in all Rh-negative pregnant patients with abdominal trauma.¹⁴

Initial evaluation and resuscitation should always be maternally directed. Once maternal stability is established, vigilant evaluation of fetal well-being becomes warranted. Continuous fetal heart monitoring, ultrasonography, CT, open peritoneal lavage, and/or exploratory laparotomy may be indicated in a case of obstetric trauma.¹³⁰

Although CT is the mainstay for evaluation of blunt abdominal trauma,¹³¹ ultrasound may be useful. A study of 89 patients undergoing routine obstetric ultrasound without an early history of trauma found that only 6.7% had free fluid in the cul-de-sac.¹³² This suggests that the likelihood of the presence of pelvic free fluid in pregnant patients without antecedent trauma is very low. Thus, after blunt abdominal trauma, the presence of free fluid in the pelvis of a pregnant patient may not be physiologic, especially if it is > 2 to 4 mm. A retrospective review of 208 pregnant patients with blunt abdominal trauma admitted to a Level I trauma center found that 127 patients (61%) had an abdominal ultrasound during the initial ED evaluation.¹³³ Ultrasound had a sensitivity of 83% and a specificity of 98%, similar to rates seen in nonpregnant patients. However, when CT scanning is indicated, imaging should not be delayed.¹²⁷

Controversies And Cutting Edge

Massive Transfusion Protocols

Massive transfusion generally refers to > 10 units of PRBCs within the first 24 hours of admission.¹⁴ Protocols have been developed to rapidly control bleeding and reduce the detrimental effects of coagulopathy, hypothermia, and acidosis.¹⁴ Improved survival has been found in adults with early administration of PRBCs, plasma, and platelets, while minimizing aggressive crystalloid administration, but pediatric data are inconclusive.¹⁴ There has been an overall trend towards a 1:1 ratio of fresh-frozen plasma (FFP):PRBC in massive transfusion protocols. A meta-analysis of 16 retrospective studies confirmed a significantly lower mortality rate in patients treated with the highest FFP and/or platelet ratio when compared with the lowest FFP and/or platelet ratio.¹³⁴ However, few studies have examined the impact of balanced resuscitation in pediatric trauma patients requiring massive transfusion. A retrospective review of 105 massively transfused pediatric trauma patients found that higher plasma/PRBC and platelet/PRBC ratios were not significantly associated with increased survival rates.¹³⁵ Further prospective studies are needed to establish the optimum ratios of blood products for massive transfusion in children.

Thromboembolization

Angiographic embolization is a well-established technique for controlling hemorrhage in adults with blunt abdominal trauma. However, there are limited data on its use in children. Kiankhooy et al reviewed 127 patients with 149 blunt injuries to the spleen, liver, or kidney.¹³⁶ Angiographic embolization was performed in 7 patients and was successful in all cases with no procedure-related complications. In 2014, Vo et al reviewed 97 pediatric patients with blunt trauma who underwent abdominal or pelvic angiography.¹³⁷ Embolization was performed for ongoing hepatic, renal, splenic, or nonvisceral retroperitoneal injury. Pelvic angiography was performed for ongoing hemorrhage secondary to pelvic fracture. A total of 54 patients required embolization involving 62 separate sites. The rate of success for hemorrhage control was 87%, mortality was 4%, and the rate of major complications was 6%. The number of PRBC units required before angiography was found to be a significant predictor of less favorable hemorrhage control. These studies show that angiographic embolization may be a safe and effective treatment option in children and may help to identify the population in which it may be most successful.

Contrast-Enhanced Ultrasound

Contrast-enhanced ultrasound is beginning to show usefulness in adult medicine. With a few exceptions, limited information is available regarding its uses

in pediatrics. The contrast is a microbubble agent that remains in the vascular space.¹³⁸ In light of the concerns about ionizing radiation with CT scan and the limitations of FAST, studies with contrast-enhanced ultrasound in trauma management should be considered, especially in the long-term follow-up of patients with intra-abdominal trauma.¹³⁹

Decreased Time On Bed Rest

In 1999, guidelines for patients with spleen and liver injury were published, and hospitalization was recommended with days of bed rest equal to the grade of injury plus 1.¹⁴⁰ St. Peter et al prospectively studied patients in order to determine whether bed rest duration could be decreased safely.¹⁴¹ They implemented a protocol of overnight bed rest for grades I and II injuries and 2 nights of bed rest for higher grades. Patients were allowed to ambulate after this time unless a transfusion was required, at which point bed rest duration was reset to time zero. They found that an abbreviated bed rest protocol safely decreased length of hospitalization. This is an area for further study to develop updated guidelines.

Abdominal-Only Computed Tomography

Investigators in an ongoing study proposed an alternative and complementary strategy to decrease radiation by selectively eliminating the pelvic imaging portion of the abdominopelvic CT scan in low-risk patients. They hypothesized that, in stable, alert patients without clinical evidence of pelvic or hip fractures, abdominal CT imaging alone (diaphragm to iliac crest) identifies clinically significant intra-abdominal injury as accurately as routine abdominopelvic imaging (diaphragm to greater trochanter) and results in a clinically important decrease in radiation exposure. This is a prospective, observational cohort study including both pediatric and adult patients, and is estimated to be completed in February 2015. If results of this study find that CT of the abdomen alone accurately identifies intra-abdominal injury and decreases radiation exposure, this may become a standard option in appropriately selected patients in the future.¹⁴²

Disposition

The disposition of the hemodynamically unstable patient with blunt abdominal trauma who does not respond to initial resuscitation efforts is straightforward. The child will be immediately taken to the operating room for laparotomy.¹⁵ Any hemodynamically stable patient with a documented intra-abdominal injury will likely be admitted, and most will undergo nonoperative management.¹⁵ However, variation in management still exists in the case of an asymptomatic patient with minor CT findings.¹⁴³

The hemodynamically stable patient without evidence of intra-abdominal injury presents more of a challenge. Routine admission for serial abdominal examinations and subsequent laboratory testing in patients with a normal abdominal CT scan is likely unnecessary. These patients can likely be discharged safely from the ED.⁷² Patients who meet low-risk criteria based on the Holmes et al 2013 study, in addition to negative laboratory tests and a negative FAST, are also likely safe to be discharged from the ED.⁷⁵ However, for patients who do not meet strict "low-risk" criteria, but are still considered to be at low risk and may not need a CT scan, clinical judgment is necessary. Observation with serial abdominal examinations may be of benefit in those patients.⁷⁵ Identifying a stable and supportive home environment, the ability to follow up closely, and the ability to follow discharge instructions with indications for when to return for medical care should be considered at the time of disposition.^{72,75}

Summary

The diagnosis and management of pediatric abdominal trauma can be challenging, even for experienced clinicians. Details from the history and physical examination, combined with the mechanism of injury, should be used to develop a thoughtful and purposeful diagnostic workup. A history of improper restraint use in a vehicle, a direct blow to the abdomen, or concerns for abuse should heighten suspicion for intra-abdominal injury, even in the context of a normal examination. While the routine use of trauma panels is not recommended, certain laboratory values may be of benefit when determining which patients are at risk for intra-abdominal injury. The risks and benefits of abdominal CT scanning must be weighed and should be discussed with the parent or caregiver when a clear indication for CT does not exist. Guidelines are available to aid in deciding when a CT scan can be avoided, and they may help to decrease the number of scans and prevent radiation-induced malignancy. Being aware of current evidence-based practices will enable emergency clinicians to confidently provide optimal care to patients.

Case Conclusions

You administered a rapid 20 mL/kg bolus of isotonic fluid for the 10-year-old-girl, ordered a CBC, AST, ALT, and urinalysis, and performed a bedside FAST. Her heart rate decreased to 95 beats/min after the bolus, her blood pressure remained normal, and all laboratory tests and the bedside FAST were normal. She continued to have left upper quadrant abdominal tenderness, so you decided to order a CT of the abdomen/pelvis with intravenous

contrast. The results of the CT scan showed a grade II splenic laceration. You obtained a surgery consultation, and the surgeon agreed to admit her to their service for observation.

After recalling the literature you have read on handlebar injuries, you realized that the 9-year-old boy was at significant risk for intra-abdominal injury, based on the mechanism of injury and the examination findings. You ordered a CT of the abdomen/pelvis with intravenous contrast. The preliminary read on the CT was negative, and you considered discharging him home. However, on repeat physical examination, he continued to have epigastric tenderness and vomited once more. You remembered that injuries to the small bowel and pancreas may occur secondary to handlebar impact, and CT does not always identify these injuries. You obtained a surgery consultation, and they agreed to admit the patient to their service for observation.

Time- And Cost-Effective Strategies

- Do not perform a “trauma panel” or head-to-toe CT scan on every patient.**
Use the history and physical examination to guide the workup. Ordering laboratory tests and imaging studies that are unnecessary will lead to increased costs and unnecessary radiation exposure.
- If a patient has worsening abdominal pain, he or she should be taken to the operating room, not for repeat imaging studies.**
A repeat CT scan is unlikely to confidently exclude a bowel injury. Patients with increasing abdominal pain should be taken to the operating room to exclude other injuries.⁷¹
- As per the ATLS guidelines, the referring hospital should not obtain a CT scan in order to avoid duplication of imaging, unless it would somehow alter management.**
Transfer should not be delayed for diagnostic imaging to be performed at the referring hospital if the results will not affect the need for transfer. Imaging prior to transfer ultimately delays transfer to the trauma facility. Additionally, images can be lost in transport or the referring and receiving imaging systems are incompatible and images are not able to be viewed.
- Recognize which patients are safe to discharge.**
Patients who are asymptomatic, tolerating oral liquids, and ambulating without difficulty are likely safe to discharge as long as they have proper discharge instructions and can follow up with a primary care provider. Clinical judgment should guide decision making.⁷²

References

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

To help the reader judge the strength of each reference, pertinent information about the study will be included in bold type following the reference, where available. The most informative references cited in this paper, as determined by the author, will be noted by an asterisk (*) next to the number of the reference.

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Risk Management Pitfalls In The Management Of Blunt Abdominal Trauma In Pediatric Patients (Continued on page 19)

1. **"The patient's blood pressure was fine, and I thought his high heart rate was just due to crying, so I didn't start fluids."**
Hypotension is a late indicator of hemodynamic instability in children. Although tachycardia may be secondary to pain or fear, it is also the first indicator of blood loss in injured children. Fluids should be initiated in any child who has suffered blunt abdominal trauma and has an elevated heart rate. If pain or fear is thought to be the cause, comforting measures should be implemented. If tachycardia continues, additional fluid boluses should be given and transfusion considered. If the heart rate remains elevated despite these measures, the patient should be considered hemodynamically unstable and undergo immediate surgery consultation.
2. **"He had normal laboratory tests and a normal CT scan, so I thought he could go home even though he still had pain. I was surprised when he returned to the ED the next day with worsening abdominal pain."**
Persistent pain, abdominal tenderness, or vomiting are important indicators of possible abdominal injury in children. Serial examinations are important in any child who has suffered blunt abdominal trauma. Surgical consultation should be obtained, and hospitalization or prolonged observation with serial examinations should be strongly considered.
3. **"The FAST was negative, so I didn't think there was an intra-abdominal injury."**
Several studies in children have shown that sensitivity of FAST alone is only approximately 50%. FAST can adequately detect hemoperitoneum; however, up to one-third of intra-abdominal injuries in children do not cause hemoperitoneum and are undetectable by ultrasound. A negative FAST in children is not sufficient to rule out intra-abdominal injury. In any child with a concerning mechanism of injury or examination findings, other diagnostic tests and serial examinations should be obtained to further evaluate for intra-abdominal injury.
4. **"I ordered a chest x-ray for the baby who had difficulty breathing. I was shocked when I saw rib fractures, and I knew the baby had been abused, but she had a normal abdominal examination, so I wasn't concerned about intra-abdominal injury."**
Children who suffer NAT may have associated intra-abdominal injury even with a normal examination. These injuries have a high rate of morbidity and mortality. Screening liver enzymes should be obtained, and a CT of the abdomen and pelvis with intravenous contrast should be ordered if transaminase levels are > 80 U/L.

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Risk Management Pitfalls In The Management Of Blunt Abdominal Trauma In Pediatric Patients (Continued from page 18)

5. **"I knew he was having a lot of pain from his femur fracture, and he never complained of abdominal pain, so I wasn't worried about an intra-abdominal injury."**
Children who have suffered major trauma may have multiple injuries, including intra-abdominal injuries. Other injuries may be more obvious, and may be distracting. Careful attention must be paid to the abdominal examination, and any abnormal findings should be further evaluated.
6. **"He kept crying, and I couldn't tell if it was due to pain or fear because his parents weren't there, so I just ordered the CT scan, which was normal. When the parents arrived, he calmed down and had a normal abdominal examination."**
It may be difficult to differentiate crying secondary to pain or fear in a young child who has suffered blunt abdominal trauma. Attempts should be made to comfort the child while awaiting the arrival of family members, and pain should be treated, if present. In the hemodynamically stable child, imaging could be delayed until family members arrive, and the examination is more reliable. If there continues to be concern for abdominal pain or tenderness after fear has been addressed, it is appropriate to obtain imaging at that time.
7. **"I knew her blood pressure was dropping, but our CT scanner is so fast that I thought it would be best to just get it before consulting surgery."**
Hypotension is a late indicator of hemodynamic instability in children, and must be aggressively treated, if present, as rapid deterioration and death may occur. CT scanning should be avoided in any hemodynamically unstable child; she should be taken immediately to the operating room.
8. **"I knew the little girl wasn't properly restrained at the time of the motor vehicle crash, and I saw the lap belt marks on her abdomen, but her CT scan was normal, so I discharged her home."**
Injuries to the pancreas and gastrointestinal tract require a high index of suspicion, as they may have delayed presentation, and laboratory tests and CT scans may be normal. Therefore, the emergency clinician should be aware of mechanisms that have a higher risk of injury to these organs, including inappropriate restraint with lap-belt only, direct blow to the abdominal wall (such as in handlebar injuries or in some sports injuries), and NAT. If injury to the pancreas or hollow viscus is suspected, surgical consultation should be obtained, and the child should be hospitalized for serial examinations and observation.

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CME Questions



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- The most common cause of blunt abdominal trauma in children is:**
 - Falls
 - NAT
 - MVCs
 - Sports-related injuries
- Physical examination findings that may indicate intra-abdominal injury include:**
 - Abdominal tenderness
 - Abdominal wall bruising
 - Hypotension
 - All of the above
- Which of the following statements is TRUE?**
 - Gastrointestinal injury is easier to diagnose on CT than solid-organ trauma.
 - Patients with suspected NAT and transaminase levels > 120 U/L should undergo definitive testing, such as CT of the abdomen/pelvis with intravenous contrast.
 - Most blunt solid-organ trauma can be managed nonoperatively in hemodynamically stable children.
 - The anatomy of children and adults place them at similar risk for types of intra-abdominal injury.
- The current gold standard imaging technique in pediatric blunt abdominal trauma is:**
 - CT scan with intravenous contrast
 - Magnetic resonance imaging with and without contrast
 - FAST
 - Intravenous pyelogram
- Which of the following are possible indications to order an abdominal CT scan after blunt abdominal trauma?**
 - Hematuria
 - Abdominal pain
 - Elevated ALT and AST levels
 - Abdominal wall bruising
 - All of the above
- Which of the following is the best indicator for a repeat abdominal CT scan?**
 - A hemodynamically stable child with a CT scan from an outside, transferring facility.
 - A hemodynamically unstable child with worsening abdominal pain after a previously equivocal abdominal CT scan.
 - A hemodynamically stable child with a brain injury and a previously equivocal abdominal CT scan.
 - A hemodynamically stable child with an initially negative CT scan who has been asymptomatic after observation in the ED for 6 hours.
- All of the following mechanisms have higher risk for pancreatic or hollow viscus injury EXCEPT:**
 - Handlebar/direct blow to abdomen
 - NAT
 - Inappropriate restraint with lap belt only
 - Pedestrian versus motor vehicle

8. Which of the following patients could be safely discharged home?
- A 10-year-old boy with persistent epigastric tenderness after a handlebar injury and a normal CT scan
 - A 5-year-old girl who was appropriately restrained in an MVC with no complaint of abdominal pain, no vomiting, and normal abdominal examination, vital signs, FAST, screening laboratory tests, and repeat abdominal examination
 - A 4-month-old boy with spiral femur fracture and a normal abdominal examination
 - A hemodynamically stable 3-year-old girl with a grade I splenic injury
9. Which patient is most likely to require operative management?
- A 5-year-old with blood pressure of 100/70 mm Hg, heart rate of 110 beats/min, and a grade III liver laceration
 - A 2-year-old with blood pressure of 97/60 mm Hg, heart rate of 115 beats/min, and a grade III splenic laceration
 - A 16-year-old with an initial blood pressure of 90/40 mm Hg, heart rate of 120 beats/min, who responds well to 1 L of normal saline, and had a grade III liver laceration
 - An 8-year-old with blunt abdominal trauma and blood pressure of 80/40 mm Hg and heart rate of 130 beats/min after 2 intravenous fluid boluses and 40 cc/kg PRBCs

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Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Objectives: Upon completion of this article, you should be able to: (1) Identify the common patterns of injury that can occur in children with blunt abdominal trauma. (2) Perform an evidence-based diagnostic workup in children with blunt abdominal trauma. (3) Distinguish the management of specific organ injuries. (4) Discuss the indications for surgical consultation, admission, and discharge in children with blunt abdominal trauma.

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