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Abstract: Abdominal trauma is the most frequently initially missed fatal injury in pediatrics. A high degree of suspicion is critical and early diagnosis is essential to minimize the morbidity and mortality associated with these injuries. The clinician must understand the mechanisms of injury that place the child at risk and the subtle physical examination findings, and develop an algorithmic approach to the diagnosis. The authors review the unique features and injury patterns associated with pediatric abdominal trauma.

— *The Editor*

Pediatric Abdominal Trauma

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Introduction

Trauma remains the number one cause of disability and death for children. Abdominal trauma is a major cause of severe injury in children and also is the most common cause of initially missed fatal injury.[1,2] This article will discuss the epidemiology of pediatric abdominal trauma, the differences between abdominal injury in adults and children, and the specific patterns of abdominal injury seen in children. Specific organ system injuries and their management will be systematically presented.

Background/ Epidemiology

Unintentional injury is the number one cause of death in the United States for children and adults ages 1-44. Use of the term "unintentional injury" as opposed to "accident" began two decades ago. Referring to something as an "accident" implies that the injury occurred without a cause. The term "unintentional injury" is now used to emphasize that many injuries can be prevented either by physical safety equipment, such as bicycle helmets and seat belts, or by regulations, such as slower speed limits. It is sobering to note that homicide and suicide, often carried out by traumatic mechanisms, remain the second and third most common causes of death in our society for young people ages 15-34.

Statement of Financial Disclosure

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While traumatic injury is common in children, the mechanism of injury depends upon the chronologic and developmental age of the child. Toddlers usually suffer from submersion injuries as well as falls. School age children more often experience pedestrian and bicycle injuries. Pedestrian injuries are the second most common cause of abdominal injury in children after motor vehicle collision (MVC). Morbidity in these cases is related to the degree of multiple injury, with the majority of deaths caused by head trauma.[3]

Adolescents incur injuries secondary to increased risk taking behavior, coupled with the ability to drive legally. Injuries in adolescents result from organized sports, firearms, recreational equipment, and motorized vehicles. Adolescents sustain the largest burden of injury mortality, with 48.5% of these deaths occurring between the ages of 15 and 19.[4] MVCs are the major cause of fatal injuries in adolescents, as well as the majority of serious injuries and death in the pediatric population. Although young adults ages 15-20 make up only 7% of licensed drivers, this group makes up 15% of all drivers killed in fatal crashes.[4] Per Loiselle, "the fatality per distance traveled is 4 times higher in this age group than all other ages combined."[4]

All terrain vehicles (ATVs) deserve special mention. Despite regulations developed in the 1980s mandating that children younger than age 16 cannot use ATVs without a helmet or adult supervision, there continue to be more than 20,000 injuries annually caused by ATVs, with more than 200 deaths per year.[5] Rollovers account for almost one-half of injuries, while falls and collisions account for the rest. Abdominal trauma accounts for 25% of injuries and 19% of deaths.[5,6]

Abuse is responsible for less than 4% of children with abdominal trauma cared for in urban EDs and accounts for less than 1% of children admitted to urban hospitals for abdominal trauma.[7,8] The children with abdominal trauma secondary to abuse are younger than a majority of trauma patients (mean age, 2-3 years) but they have more severe injuries than children who were injured by other mechanisms of abdominal trauma.[9] Up to 50% of mortality in abdominal trauma is due to delays in presentation (mean time to presentation, 13 hours) and extent of injuries.[7,8]

Abdominal injury in children is mainly due to blunt trauma, with more than 90% of pediatric injuries caused by blunt trauma such as MVCs.[10,11] Penetrating injuries such as gunshots and stab wounds account for only 1.5% of all trauma admissions nationwide; however, they account for 15% of children with abdominal trauma who are admitted to urban trauma centers.[9] These children are older and account for a disproportionate number of trauma-related deaths.

Differences Between Adult and Pediatric Abdominal Trauma: Children are not Small Adults

Unique developmental, anatomic, and physiologic factors in children compared to adults lead to differences in the type of injury and the management and outcome of abdominal trauma. In regard to overall injury management, since children often sustain head trauma or are unable to communicate accurately secondary to their level of development or fear, a history of the incident may be unavailable. Abdominal distention, which occurs from swallowing air when crying, can make the physical examination less reliable. A compliant rib cage may allow for internal injury without external evidence of these injuries.

Infants and young children are more prone to abdominal injury than adults. Since the solid abdominal organs are relatively larger, the abdominal musculature is less mature, the abdominal wall and internal organs have less fat than those in adults, and the internal organs are suspended by more elastic structures (especially the kidneys), the abdominal organs have an increased risk of direct injury and are more vulnerable to blunt injury.[12] The pediatric kidney retains fetal lobulations that might lead to easier separation and fracture.[12] In children, the splenic and hepatic capsules are tougher than those in adults, which is postulated to account for the ability to contain bleeding and manage injuries nonoperatively.[13,14] Because of a child's smaller size, a given force is applied over a relatively larger area, causing increased susceptibility to multi-organ injury.[12] In children, the compliant ribcage does not protect the liver and spleen from injury as it does in adults, and the bladder is an intraabdominal organ. Thus, the child's abdomen begins at the level of the nipples.

Physiologically, children can maintain normal vital signs even in the setting of significant blood loss. As much as one quarter of the blood volume can be lost prior to the onset of hypotension.[15,16] Clinical identification of hypovolemia is difficult. Heart rate varies with age, pain, temperature, and stress, and persistent tachycardia can be secondary either to these factors or to blood loss. Capillary

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Table 1. Mechanisms and Patterns of Injury Suggesting Increased Risk of Intra-abdominal Injury*

FALL

- Major factors in injuries incurred as a result of a fall:
  - — Height of fall
  - — Body position on impact
  - — Nature of contact surface
  - — Body orientation on impact
  - — Body mass
  - — Victims age
- Children younger than age 3 have less serious injuries than older children who fall the same distance (increased fat and cartilage and less muscle mass help younger children dissipate energy from the fall).[40,41]
- Mortality increases with falls from > 6 meters.

MVC

- Position in vehicle and use of seatbelts have an effect on seriousness of MVC injuries.
- Compared with unrestrained occupants, restrained occupants of MVCs may be at comparable risk for solid-organ intra-abdominal injury and greater risk for hollow viscous injury.[42,43]
- MVC with restraints and steering wheel deformity have increased risk of small bowel injury and pancreatic injury.
- Injury of thoracic cage and rib fractures should heighten suspicion for hepatic and splenic injury.[44,45]

* Adapted from: Potoka DA, Saladino RA. Blunt abdominal trauma in the pediatric patient. *Clin Ped Emerg* Med 2005;6:23-31.

refill, which often is cited as a useful predictor of blood loss, is unreliable given inter-observer variation, fluctuations with environmental temperature, and variability in technique.[17-20] A larger relative surface area in children younger than age 2 can promote hypothermia and complicate shock. Given that the diaphragm is a major muscle of respiration, abdominal injury or distention can cause severe respiratory distress, exacerbating other injuries.

Patterns of Pediatric Abdominal Injury

Children with an abdominal injury often have other associated injuries, depending on the mechanism of injury. Falls usually cause head and extremity injuries with a very small percentage of significant abdominal trauma.[9,12,15,21] Pedestrian injuries in toddlers are usually caused by low-speed cars backing into children and result in crush injuries to the trunk and head.[22,23] Pedestrian injuries in school age children who are struck crossing the street often cause multiple injuries, including injuries to the head (44%) and extremities (32%) as well as abdominal injuries (10%).[3] Bicycle injuries usually cause extremity and neck fractures; abdominal injuries in this instance are less common and more difficult to diagnose.

Waddell's triad refers to the pattern of a lower limb injury, left sided abdominal or chest injury, and head injury occurring as a motor vehicle hits a child who is running across a street. The vehicle hits the lower extremity first. Then the child's left chest/abdomen is impacted by the front of the car. After the child is thrown over the car, the head strikes the pavement, causing a closed head injury.[12,24]

Children in MVCs using restraints tend to have less massive head, thoracic, solid organ, and extremity injury than those who do not use restraints. Although the incidence of abdominal trauma may be more common among those who use restraints, overall mortality and morbidity are significantly lower.[12,25,26]

Lap belt complex injuries typically occur` in young children who wear seat belts improperly positioned over immature iliac crests. The restraint migrates onto the abdomen during rapid deceleration of the car.[12,27] Abdominal injuries (small bowel contusions and lacerations) and lumbar injuries can occur. Chance fracture is a flexion injury of the lumbar spine with distraction of posterior elements and anterior compression fractures. Chance fracture results from rapid deceleration with hyperflexion around a poorly fitted lap seatbelt.[12,27]

The seatbelt sign, or contusion of the abdomen secondary to the lap belt, is known to be a possible harbinger of more serious abdominal injury. However, in one study, only 45% of children with visceral injury had abdominal wall ecchymoses;[28] therefore, lack of a seatbelt sign cannot be used to rule out serious injury.

With the advent of airbags in cars, children are at risk of airbag injury. Airbags can deploy at speeds of 150 mph, causing significant injury to children. Both infants in rear-facing car seats and children sitting inappropriately in a seat with airbags can suffer serious injury, including death, head injury, C-spine injury, abrasions, and burns from the airbag deployment mechanism.[29-35] The middle back seat is, thus, the safest for children.

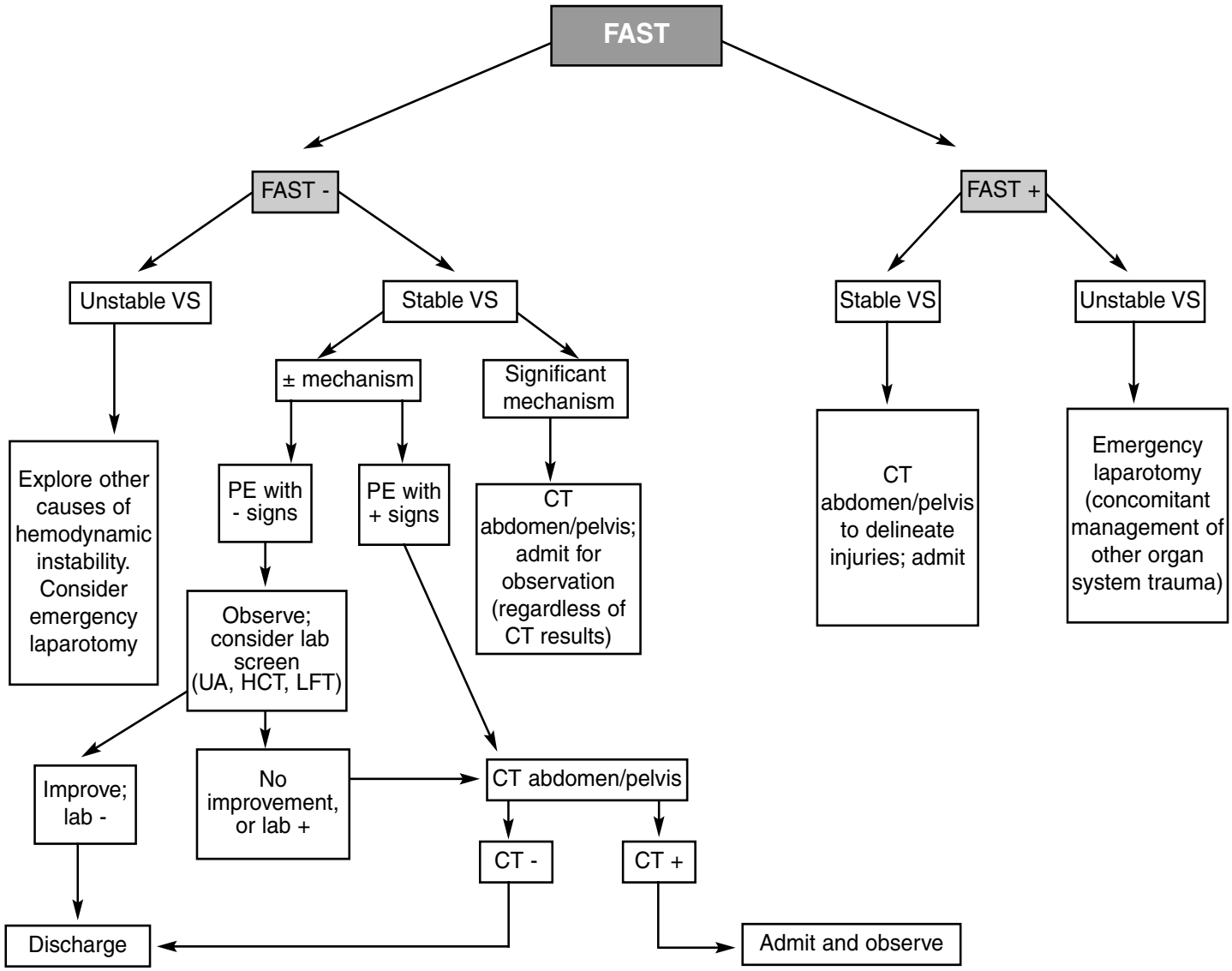
Handlebar injuries are not uncommon in children riding bicycles.[36-38] After a sudden stop, the child falls over the front of the bicycle and the handlebars hit the child's abdomen. The trauma in this instance can be considered trivial and the symptoms may initially be mild. The mean delay before injury diagnosis is approximately 23 hours.[39] Traumatic pancreatitis is the most common injury (33%) in these cases. Other handlebar injuries include renal and splenic trauma (17%), duodenal hematoma (13%), and bowel perforation (10%).[39]

Initial Management

Initial management of the child with trauma always begins with attention to the ABC's (airway, breathing, and circulation). It is important to always remember that the main cause of cardiac arrest in children is respiratory arrest. Oxygenation and ventilation must be the first priorities in pediatric trauma management. When assessing circulatory status, heart rate and end organ perfusion are important. While tachycardia can have many etiologies in a trauma situation, it also is a child's earliest response to hypovolemia. Blood pressure is not a reliable indicator of circulatory status. In regard to abdominal injury, the most important factor indicating the need for laparotomy in a child with trauma is hemodynamic instability.

Diagnosis. Diagnosis depends on understanding the mechanism of the injury, thorough physical examination and appropri-

Figure 1. Algorithm for Abdominal Imaging in Pediatric Trauma



Key: VS = vital signs; UA = urinalysis; HCT = hematocrit; LFT = liver function test

ate laboratory and imaging tests. Table 1 lists mechanisms that suggest an increased risk of intraabdominal injury.

Physical Examination. Physical exam of the child's abdomen in trauma has been generally considered an unreliable and inaccurate indicator of injury and has led to missed injuries.[2,46] Stage of development and inability to communicate verbally can impede the physical exam. Also, children with severe trauma have an increased incidence of concomitant brain injury compared to adults, which decreases the sensitivity of the physical exam.[12] Since abdominal trauma also is the most common cause of initially unrecognized fatal injury in the pediatric population,[1,2] children with serious mechanisms of abdominal injury usually undergo some imaging modality to identify these injuries.

Diagnostic Modalities. *CT Scan.* CT scan has become a valuable tool in the evaluation of abdominal and pelvic injury.[47-51] However, concerns about increased risk of cancer from radiation exposure in children have raised questions about possible overuse of CT imaging.[52-55] Overall, children are more radiosensitive than adults. A child also receives a larger radiation dose than an adult for a given procedure, and the use of helical CT is increasing faster in children than in adults.[55] Frush and colleagues estimated a risk of developing a fatal cancer secondary to radiation to be approximately 1/1000 pediatric CT scan examinations.[56] The recent literature has shown that children with mild and moderate trauma undergo more abdominal imaging for similar injuries than adults,[57] and that 67-75% of pediatric abdominal CT scans obtained are normal.[48,51,58]

Table 2. Grading of Splenic Injury: American Association for the Surgery of Trauma (AAST) Splenic Injury Scale[10]

GRADE 1

Subcapsular hematoma < 10% of surface area or capsular tear < 1 cm in depth.

GRADE 2

Subcapsular hematoma of 10-50% of surface area, intraparenchymal hematoma of < 5 cm in diameter or laceration of 1-3 cm in depth and not involving trabecular vessels.

GRADE 3

Subcapsular hematoma > 50% of surface area or expanding and ruptured subcapsular or parenchymal hematoma, intraparenchymal hematoma of > 5 cm or expanding, or laceration > 3 cm in depth or involving trabecular vessels.

GRADE 4

Laceration involving segmental or hilar vessels with devascularization of > 25% of the spleen.

GRADE 5

Shattered spleen or hilar vascular injury.

Reproduced with permission from: Potoka DA, Saladino RA. Blunt abdominal trauma in the pediatric patient. *Clin Ped Emerg Med* 2005;6:23-31

Focused Abdominal Sonography for Trauma (FAST). FAST has gained popularity in the adult trauma patient as an initial screening tool for identifying patients who are in need of immediate laparotomy. FAST is portable, easy, quick, and non-invasive. The specificity of FAST in children is cited at 95-100% for hemoperitoneum.[59-63] However, in the hemodynamically stable pediatric patient with blunt abdominal trauma, the sensitivity of FAST is 42-88%.[62,63] Solid organ injuries without free intraperitoneal fluid, delayed bleeds, as well as intestinal injuries that do not cause a large accumulation of fluid would not be picked up by FAST. A consensus conference on ultrasound in trauma developed the following practice paradigm:[64] positive FAST in a hemodynamically unstable patient should indicate immediate laparotomy while negative FAST in the same patient would warrant examination for an extraabdominal source of bleeding. Positive FAST in a hemodynamically stable patient should be followed by abdominal CT scan to better define injury. Negative FAST in the same patient should be followed with serial exams for six hours and then follow-up FAST or CT scan, depending on the clinical scenario.

In children, the use of FAST is controversial. A positive FAST exam in a hemodynamically unstable child would indicate the need for an emergent laparotomy.[65,66] Rose suggests that FAST exam can offer information about the timing and urgency of head CT, abdominal CT, and laparotomy in children with concomitant head and abdominal trauma.[67] He also suggests that FAST exam may be sufficient to obviate a CT exam in a child who has a low likelihood of intraabdominal injury.[63,67] However, a FAST exam, whether positive or negative, does not provide the same information as a CT scan. It is argued that many pediatric patients with traumatic injury do not have free fluid, and CT imaging is necessary to stage and identify these injuries to appropriately manage these patients.[65,68,69] Other work suggests using ultrasound in conjunction with physical examination and laboratory values to determine the need for further imaging studies.[58,60,62] *(See Figure 1.)*

Diagnostic Peritoneal Lavage. Diagnostic peritoneal lavage (DPL) historically has been used to identify intraabdominal injury in patients, including children who are too unstable to go to the CT scanner. Since the advent of FAST, which serves a similar diagnostic role, with the advantages of being quicker and non-invasive, the use of DPL has decreased in trauma.

Laboratory Tests. Aside from urinalysis, routine "trauma panels" are not sensitive or specific for identifying intraabdominal injury in children.[70-72] However, children with equivocal physical exam and low mechanism of injury can be screened with laboratory tests. Serial hematocrits are standard to monitor possible bleeding. Several studies found that elevation of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) are predictive of internal abdominal injury.[73-76]

Summary. In summary, the physical exam in pediatric abdominal trauma is not considered reliable. With high risk mechanisms of injury and abnormal physical exam, imaging is necessary to characterize injuries and develop a management plan. Although CT scan is very sensitive and specific, increasing awareness of the trade-off with radiation risks raises questions about appropriate imaging algorithms utilizing combination of physical exam, FAST, CT scan and laboratory tests. It also must be remembered that although helical CTs are increasing in quality, there are some injuries that can be missed by CT scan. Observation at a tertiary trauma center is the only intervention proven to decrease the risk of missed traumatic injury.[77]

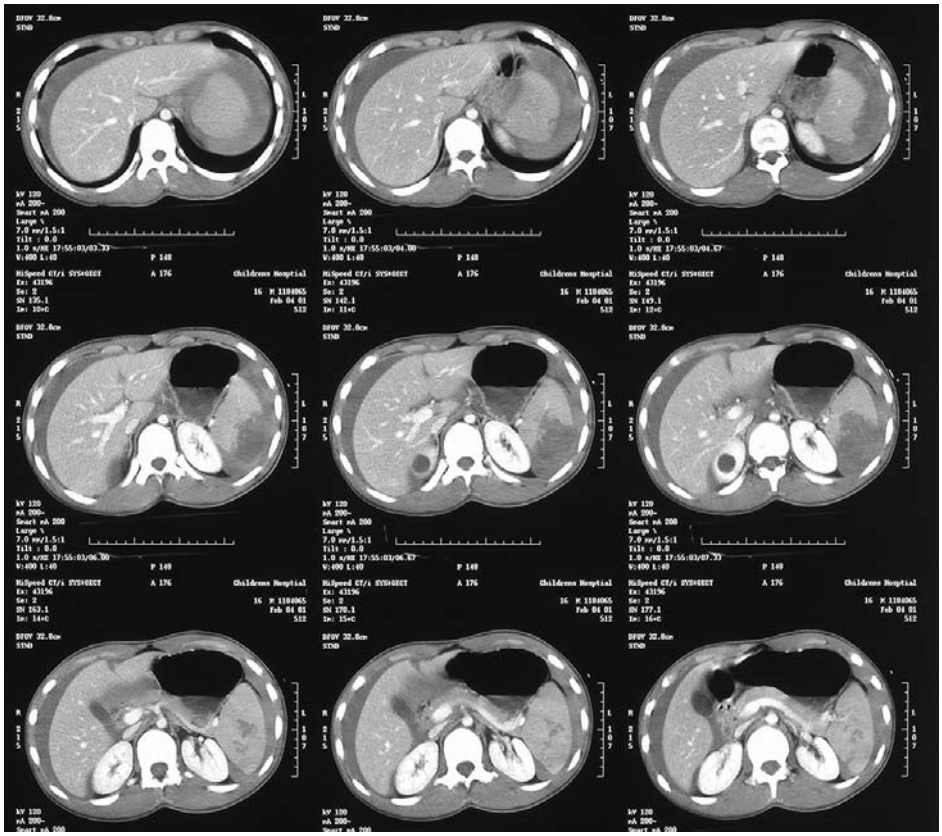
Splenic Injuries

Pediatric splenic injuries are the most common intraabdominal organ injury following blunt trauma. *(See Figure 2.)* They should be suspected in any child with significant mechanism of injury, abdominal pain, abdominal tenderness on exam (particularly in the left upper quadrant), left upper quadrant abdominal ecchymoses or contusions, or left rib fractures.

Diagnosis. In hemodynamically stable patients, abdominal CT scan is the best method for diagnosing and grading splenic injuries. *(See Figure 3.)* If contrast blush is seen on CT scan, this indicates active bleeding and a greater likelihood that surgical intervention will be necessary. In hemodynamically unstable patients, diagnosis should be made at laparotomy.[10] *(See Table 2.)*

Management. The current standard of care in pediatric splenic injury is that the spleen should be preserved whenever possible. Nonoperative management and splenic preservation techniques, including partial splenectomy and splenorrhaphy, have become the mainstay of splenic injury management. The presence of hemodynamic instability in a child with an irreparably damaged spleen does remain an absolute indication for

Figure 2. Splenic Trauma



splenectomy. Hemodynamically stable patients may be followed with serial abdominal exams and serial hematocrits, and do not need repeat imaging studies unless they remain symptomatic.

Nonoperative management should be attempted in any hemodynamically stable child with blunt splenic injury, regardless of grade, unless another intraabdominal injury necessitates exploratory laparotomy. Nonoperative management of pediatric splenic injuries leads to full recovery in 90-98% of patients. Nonoperative management has been associated with a decreased number of blood transfusions compared to operative management, and no increased risk of missing other intraabdominal injuries.[78-83] Splenic preservation prevents overwhelming postsplenectomy infection; this may occur in 2-11% of children following post-traumatic splenectomy, with a mortality rate of up to 50%.[84] It also has been shown to result in longer quality-adjusted life expectancy.[85]

A recent retrospective study by Stylianos and colleagues comparing operative rates for 3,232 patients with blunt splenic trauma at both trauma and non-trauma centers found that patients treated at trauma centers had a significantly lower rate of operation than those at non-trauma centers (15.3% vs. 19.3%, $p < 0.001$, for multiply injured patients, and 9.2% vs. 18.5%, $p < 0.0001$, for isolated injury). But rates at both types of centers exceed published American Pediatric Surgical Association benchmarks for all children with spleen injury (5-11%) and the subset with isolated splenic injury (0-3%).[86] Thus, although trauma centers do a better job of having reduced operation rates for splenic injuries, they still have rates 1.5 to 3 times higher than those set by the American Pediatric Surgical Association.

Figure 3. Spleen Fracture

Hepatic Injuries

Pediatric liver injuries *(see Figure 4)* are the second most common intraabdominal organ injury following blunt trauma. They should be suspected in any child with significant mechanism of injury, abdominal pain, abdominal tenderness on exam, right upper quadrant abdominal ecchymoses or contusions, or right rib fractures.

Paddock and co-workers retrospectively reviewed a multi-institutional pediatric trauma registry and found that hepatic injuries represent a higher mortality risk (2.5%) than splenic injuries (0.7%), and though rare, hepatosplenic injuries have the highest risk of mortality (8.6%).[87]

Diagnosis. In hemodynamically stable patients, abdominal CT scan with IV contrast is the best method for diagnosing and grading liver injuries. In unstable patients, diagnosis should be made at laparotomy.

Several studies have shown that AST (aspartate aminotransferase) greater than 400 IU/L or ALT (alanine aminotransferase) greater than 250 IU/L is predictive of hepatic injury.[73-76] Cotton et al used multiple logistic regression analysis in a study of 353 children to show that increased ALT was the only laboratory finding predictive of intraabdominal injury; in fact, ALT of

Figure 4. Liver Laceration

greater than 131 IU/L and the presence of abdominal trauma were indicative of intraabdominal injury with 100% sensitivity.[88] Thus, in cases in which no clear indication exists for imaging following initial assessment, measurement of hepatic enzymes may provide additional information. *(See Table 3.)*

Management. The hemodynamic status of the child should guide management. Hemodynamically stable patients can be managed nonoperatively by following serial abdominal exams, serial hematocrits, and if abnormal, serial liver enzymes. If a child is hemodynamically unstable despite fluid resuscitation or requiring blood transfusion, then an exploratory laparotomy may be required.

The majority of children (85-90%) with blunt hepatic and splenic injuries have relatively low-grade (grade 1-3) injuries and can be managed nonoperatively. In the management of higher-grade solid organ injuries, angiographic embolization is gaining acceptance.[88] Asensio and colleagues reported a significant reduction in liver-related mortality in patients with grades 4 and 5 liver injuries when using angiography and embolization in the initial evaluation and management (from 40-80% down to 8-22%).[89]

Pancreatic Injuries

Compared with other solid organ injury, pancreatic injury is relatively uncommon, occurring in 3-12% of patients with abdominal trauma. It is almost always caused by blunt trauma, and often is caused by compression of the pancreas against the lumbar vertebral column.[10]

Of patients with pancreatic injury, children are more likely than adults to have isolated pancreatic injury. In one series of patients with pancreatic injury, 62.5% of children had isolated pancreatic injuries following blunt abdominal trauma, compared with 15.3% of adults.[90] Bicycle handlebar injuries are a particularly common mechanism of pancreatic injury.

Table 3. Grading of Hepatic Injury: American Association for the Surgery of Trauma (AAST) Liver Injury Scale

GRADE 1
Subcapsular hematoma < 1 cm in maximal thickness; capsular avulsion; superficial parenchymal laceration < 1 cm deep; and isolated periportal blood tracking.

GRADE 2
Parenchymal laceration 1-3 cm deep and parenchymal/subcapsular hematomas 1-3 cm thick.

GRADE 3
Parenchymal laceration > 3 cm deep and parenchymal or subcapsular hematoma > 3 cm in diameter.

GRADE 4
Parenchymal/subcapsular hematoma > 10 cm in diameter, lobar destruction, or devascularization.

GRADE 5
Global destruction or devascularization of liver.

GRADE 6
Hepatic avulsion (CT scan grade, not AAST grade).

Reproduced from: Moore EE, Cogbill TH, Jurkovich GJ, et al. Organ injury scaling: Spleen and liver (1994 revision). *J Trauma* 1995;38:323-324, with permission from Lippincott Williams & Wilkins.

Diagnosis. Pancreatic injuries may be difficult to diagnose due to the retroperitoneal location of the pancreas. Clinical signs and laboratory markers may be subtle and require time to evolve, as pancreatic secretions become activated and pancreatic and peripancreatic inflammation begins. Thus, it is prudent to be suspicious for possible pancreatic injury based on mechanism of injury and clinical signs.

Serum amylase and lipase are rarely helpful in the early post-injury period, but can be followed. Abdominal CT scans are the primary imaging modality, but 1) the sensitivity varies widely, ranging from 28 to 85%; 2) they tend to underestimate the severity of pancreatic injury; and 3) the sensitivity for pancreatic ductal injury is particularly low (42.9-54.5%).[91-96]

Management. Nonoperative management of pancreatic injury is being increasingly proposed, and several series have shown that nonoperative management of pancreatic injuries without ductal disruption can result in low morbidity.

However, compared to other solid organ injuries, pancreatic injury is the most likely to fail nonoperative management. Holmes and coworkers' retrospective study of 1818 pediatric patients with solid organ injury showed an overall nonoperative management failure rate of 5%.[97] The failure rates for isolated organ injuries were: kidney 3%, liver 3%, spleen 4%, and pancreas 18%. Of mechanisms of injury, only bicycle accidents demonstrated a significantly increased risk of failing nonoperative management. A summary Abbreviated Injury Scale (AIS) score of greater than 4, isolated pancreatic injury, and more than

one injured organ were significantly associated with nonoperative management failure.[97]

Intestinal Injuries

Small intestine and colon injuries occur less frequently in children than solid organ injuries, but their findings can be more subtle. They should be suspected in any child with significant mechanism of injury, abdominal pain, abdominal tenderness on exam, ecchymoses or contusions, and particularly in children involved in motor vehicle accidents who are found to have seat-belt signs. One should be highly suspicious if the initial exam demonstrates peritonitis or hemodynamic instability (due to mesenteric bleeding).

Three distinct mechanisms of injury have been described: 1) in burst injuries a compressive force ruptures a transiently distended segment of bowel; 2) shear injuries occur when the rapid deceleration of the bowel is resisted by a fixed point such as the ligament of Treitz or terminal ileum; and 3) crush injuries are seen when the bowel is compressed against the spine.

Diagnosis. These injuries are often subtle in their workup as well as in their initial presentation, and the lack of significant findings on routine trauma imaging and laboratory studies does not imply the absence of injury, particularly in the early post-injury period.

FAST scans have low sensitivity for intestinal injuries. Abdominal CT scan with IV contrast is preferred; specific CT scan findings that suggest surgical exploration include evidence of extraluminal air, extraluminal contrast material, or a moderate to large amount of free fluid without evidence of solid-organ injury (seen on 4 or more consecutive CT scan sections).[98]

Management. In hemodynamically stable patients with no clear signs of intestinal injury, diagnosis requires serial exams, serial laboratory tests, and repeat imaging studies. Any child with initial or evolving peritonitis or intestinal injuries on imaging should undergo an exploratory laparotomy.

Renal Injuries

If the posterior abdomen and retroperitoneum are included in the definition of blunt abdominal trauma, then the kidney is the most commonly injured solid organ in pediatrics.[99] Renal injuries should be suspected in any child with significant mechanism of injury, abdominal or flank pain, abdominal or flank tenderness on exam, back ecchymoses or contusions, or posterior rib fractures.

Diagnosis. Urinalyses are frequently obtained in children with abdominal trauma, and both gross and microscopic hematuria have been associated with intraabdominal injury in children. Gross hematuria is defined as being visible to the naked eye. Microscopic hematuria has been defined differently by different authors, as greater than 5 red blood cells per high power field (RBCs/hpf), more than 20 RBCs/hpf, or more than 50 RBCs/hpf.[72,74,99-101]

How well microscopic hematuria predicts renal injury and the amount of workup that is needed in patients with microscopic hematuria remains controversial (partly due to differing definitions of how many red blood cells per high power field constitute microscopic hematuria). In Stein and coworkers' retrospective study of abdominal CT scans in 412 children following abdominal trauma, it was found that all significant renal injuries presented with hematuria (48 had renal injuries documented by abdominal CT; 25 of which had significant injuries and 23 had insignificant renal injuries). Of those with significant renal injuries, 68% (17/25) had microscopic hematuria, and 32% (8/25) had gross hematuria.[102]

In Stalker and colleagues' retrospective chart review of 256 children with blunt abdominal trauma, they found that hematuria has a sensitivity of 33% (35/106) for predicting renal injury. However, they also noted that having a normal blood pressure and less than 50 RBCs/hpf had a negative predictive value of 100%.[101]

Santucci and associates retrospective review of 720 pediatric trauma patients with hematuria found that all patients with significant renal injuries had either gross hematuria, shock, or significant deceleration injury.[103]

Management. Hemodynamically stable children with gross hematuria or other concerning symptoms should undergo an abdominal CT scan with IV contrast to diagnose and grade kidney injuries. It remains controversial whether hemodynamically stable patients with asymptomatic microscopic hematuria need to undergo abdominal CT. In unstable patients, diagnosis should be made at laparotomy.

The standard of care is renal preservation. A recent retrospective study from a single institution's 25-years of experience reported a less than 1% nephrectomy rate.[104]

Conclusion

Abdominal injury in children is a major cause of severe injury and also is the most common cause of initially missed fatal injury in children.[1,2] It usually is caused by blunt injury due to MVC. An understanding of how abdominal injury presents in children as compared to adults, as well as a knowledge of the different patterns of injury can aid in diagnosing pediatric abdominal injury. Although management of many pediatric abdominal injuries is non-operative, use of appropriate imaging modalities to diagnose intraabdominal pathology is essential to the care of these patients.

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CME/CNE Questions

1. Which of the following is true regarding pediatric abdominal trauma?
   A. Mainly due to penetrating trauma
   B. Children with abdominal trauma secondary to abuse are younger than the majority of trauma patients and have more severe injuries
   C. Only 5% of the mortality in abdominal trauma is due to delays in presentation
   D. Penetrating injuries account for 60% of all trauma admissions nationwide

2. Which of the following is true regarding pediatric anatomy?
   A. Pediatric solid abdominal organs are smaller
   B. A compliant rib cage may allow for underlying injury without external evidence of injury
   C. Abdominal wall and internal organs have more fat than adults
   D. The pediatric internal organs are suspended by less elastic structures than adults

3. A child presents with a seatbelt sign. Which of the following is true?
   A. The child may have serious internal injury
   B. The child may have a Chance fracture
   C. The child may have a small bowel injury
   D. All of the above

4. Which of the following is true regarding a child who has a handlebar mark to the abdomen?
   A. The trauma may be considered trivial and initially symptoms may be mild
   B. The mean delay before diagnosis is approximately 23 hours
   C. Traumatic pancreatitis is the most common injury
   D. All of the above

5. CT scan has become a valuable tool in the evaluation of abdominal and pelvic injuries.
   A. True
   B. False

6. Which of the following is *false* regarding the use of ultrasound in a pediatric trauma patient?
   A. FAST is easy, portable, quick, and noninvasive.

CNE/CME Instructions

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

CNE/CME Objectives

Upon completing this program, the participants will be able to:

a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

B. The specificity of FAST for hemoperitoneum in children is 95-100%.
C. In the hemodynamically stable patient the sensitivity of FAST is 100%.
D. The FAST exam does not detect solid organ injuries without free intraperitoneal fluid.

7. The current standard of care for pediatric splenic injury is that the spleen should be preserved whenever possible.
   A. True
   B. False

8. Regarding hepatic injury, which of the following is true?
   A. Hepatic injury is the most common intraabdominal injury following blunt trauma.
   B. In hemodynamically unstable patients, CT scan is the imaging modality of choice.
   C. The majority of children with hepatic injury have low-grade injuries and can be managed nonoperatively.
   D. In unstable patients, CT scan should be performed immediately.

9. Which of the following is true regarding pancreatic injury?
   A. Pancreatic injury is common.
   B. It usually occurs following penetrating injury.
   C. Children are more likely than adults to have isolated pancreatic injury.
   D. Pancreatic injuries are easy to diagnose.

10. FAST scans have a high sensitivity for intestinal injuries.
   A. True
   B. False

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

In Future Issues:

Pitfalls in Trauma Management

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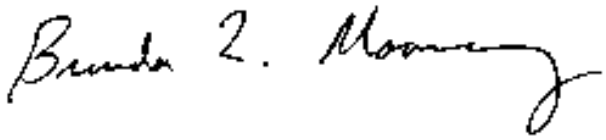

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