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Diagnosing Occult Internal Injury In Children After Motor Vehicle Trauma: Managing The Golden Hour

A not-uncommon scene unfolds in the trauma bay on a Saturday night: EMS brings in a family following a head-on collision between their minivan and an SUV. The driver of the other vehicle was killed at the scene. The driver of this family's vehicle was the father, and although he was restrained and the airbags deployed, his quadrant of the vehicle bore the brunt of the impact and he sustained significant thoracic and lower extremity trauma; he has been taken emergently to the OR and may not survive. The mother, who was in the passenger seat, is less severely hurt. You're working up one of the two children, a six-year-old female who was riding with lap and shoulder restraints but was not in a car seat. She's stable and complains only of hoarseness; she has tenderness on abdominal examination along with an ugly, abraded, ecchymotic contusion of her neck and lower abdomen. The CT scan of her abdomen shows free intraperitoneal fluid, despite a negative FAST exam and no apparent solid organ injury.

"The golden hour" is axiomatic in trauma: 60 minutes from injury to definitive care. Unfortunately, this young patient has a confusing clinical picture that could delay her diagnoses. Does her hoarseness point to an airway injury? What about the seat belt sign? Do the unexplained ascites mandate a laparotomy? Do the death and severe injury of other patients at the scene change your approach? Suddenly, your hour seems to have become a lot shorter.

Even the most cursory look at the pediatric trauma literature will make one fact glaringly clear: trauma is the leading cause of death in the pediatric population, surpassing all natural causes combined. Motor vehicle collisions (MVCs) account for a large proportion of injuries and deaths in children, particularly among ado-

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CME Objectives

Upon completing this article, you should be able to:

1. Describe the epidemiology and pathophysiology of injuries associated with child restraint use and misuse in MVCs.
2. Identify common patterns of injury association in pediatric MVC patients.
3. Determine the most appropriate initial diagnostic test for a given situation.
4. Appropriately triage patients for discharge, admission, or subspecialty consultation.

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lescents.[1] The physiologic, anatomic, and behavioral characteristics of children – and the actions of their caregivers – strongly influence the patterns of injury seen in children involved in MVCs, as do features of the collisions themselves, such as the direction and magnitude of force, the nature of the colliding objects, and the use or nonuse of restraints.

Making the diagnosis of internal injury after blunt trauma can be difficult, and the consequences of missing an injury can be fatal. Controversy exists in the adult literature on how to effectively diagnose head, spine, thoracic, and abdominal injuries after blunt trauma; these uncertainties remain relevant in pediatric practice. How does one best approach isolated free intraperitoneal fluid, for example? How does one balance the risk of radiation and contrast dye exposure with the need to find subtle internal injury? Does focused abdominal ultrasound have a place in pediatric trauma evaluation? How does one identify fractures and dislocations in radiographs of incompletely ossified bones?

This article reviews recent literature on the early management of children following motor vehicle collision, with an eye toward how to direct the diagnostic evaluation in order to minimize missed injuries and optimize definitive patient care. We will discuss the importance of obtaining information about the crash scene in directing the diagnostic evaluation, describe patterns of injury as seen in different crash situations, and review the peculiar anatomic and physiologic characteristics of children as they relate to particular injuries.

Critical Appraisal Of The Literature

The literature review searched Ovid Medline and PubMed for articles related to traffic accidents, blunt trauma, and seat belt use in children and adolescents. The Cochrane Database of Systematic Reviews was consulted, and articles on the use of emergency abdominal ultrasounds, the epidemiology of child booster seats, spinal immobilization, and odontoid fractures were obtained. The review also considered blunt trauma-related guidelines from the Eastern Association for the Surgery of Trauma (EAST). Finally, the federal online National Guideline Clearinghouse was consulted for guidelines related to pediatric blunt trauma. More than 300 articles were identified, more than 150 were reviewed, and citations to 111 are presented here.

There are many more retrospective than prospective studies dealing with pediatric blunt trauma; both types are represented in this review. Furthermore, the trauma literature is weighted toward adult data; series containing adult data were reviewed if no comparable pediatric study was found or if the data set included pediatric and adolescent patients. A significant amount of information exists for common injuries, those associated with seat belts in particular; less ubiquitous but still important injuries are represented in many instances by case reports and reviews of the literature. Case reports were included if they provided a useful insight – the effects of a missed injury, for example, or details about injury pattern from a particular type of collision.

Epidemiology, Etiology, And Pathophysiology

Injury is the leading cause of pediatric deaths and hospitalizations – more than 20,000 pediatric trauma deaths occur annually in the U.S., and another 120,000 children are injured. Motor vehicle collisions are the leading mechanism of fatal injuries in persons less than 20 years of age, with one of every three injury-related deaths among children younger than 12 years of age resulting from an MVC. These injuries are not random and can be studied in a manner analogous to other diseases. Risk factors, environmental causes, host factors, and social factors all figure in to the epidemiology of pediatric trauma.[1-4]

Perhaps the most important risk factor associated with pediatric MVC injury is the lack of use of passenger restraints. Seat belts were introduced in 1960, and since that time, there has been a 45-60% reduction in fatalities and a 50-65% reduction in moderate-to-critical injuries associated with traffic crashes.[5] The proper use of restraints is associated with a significant decrease in the risk of death; one estimate puts the reductions at 71% for infants and 54% for preschoolers, another lists the relative risk (RR) of death for restrained children of all ages compared with nonrestrained as 0.26.[3,6] Restrained child passengers have a markedly reduced risk of overall injury (RR 0.37), head injury (RR 0.18), thoracic injury (RR 0.35), and lower extremity injury (RR 0.26).[6]

Unfortunately, significant numbers of children travel in vehicles either improperly restrained or completely unrestrained. Lower-than-average rates of child restraint use have been associated with lower incomes, advancing age of the child and the driver (particularly among drivers older than 40 years), drivers of nonwhite ethnicity (though this appears to mirror socioeconomic status), and drivers who travel infrequently with young children.[7] Restraint use declines in inverse proportion to age, falling most rapidly after four years of age; by the time children reach school age, data show that only 35% are optimally restrained.[3,8-9] Child car seats are expensive, but programs that provide free or reduced-cost booster seats have been shown to improve rates of use. Furthermore, car seats can be difficult to install correctly; it is estimated that 85% of such seats are not used properly.[10] Cars sold in the U.S. after 2002 are required to have integrated anchoring systems for car seat attachment; however, the vehicle fleet contains a significant number of vehicles manufactured before this requirement.[10-11] Alcohol consumption by drivers is also associated with restraint noncompliance. A review of Federal crash data on pediatric deaths and injuries found restraint rates among children riding with intoxicated drivers to be approximately half those of children transported by sober drivers.[12]

School-age children, particularly between the ages of 5 and 10 years, have the greatest risk of injury – dying more often from MVCs than any other mechanism of unintentional injury – because they are generally too large for infant car seats, yet are too small to effectively use standard seat belts. Booster seats designed for this age group exist and are shown to reduce the risk of injury, yet compliance with booster seat use is low – ranging from 5% to 20%.[6,10-11]

The suboptimally restrained child passenger is exposed not only to the forces of the primary impact, but they also sustain multiple sub-impacts within their vehicle, colliding with vehicular surfaces (dashboard, seats, windshield), with other occupants, or with loose objects propelled by the initial crash. Each of these smaller collisions adds to the patient's injury burden.[4] Failure to use seat belts is associated with ejection from the vehicle; proper restraint reduces the risk of ejection by 95%. Ejection generally occurs through a side window or a door and results in significantly higher rates of head, neck, thoracic, hepatic, and splenic injuries, as well as a mortality rate 2.7 times that of a nonejected passenger.[8,13]

Injury Patterns By Restraint Type – The Seat Belt Syndrome

The introduction of seat belts was associated with a shift in collision injury patterns. Devastating head, neck, and thoracic injuries decreased in prevalence, giving way to abdominal injuries. Restraint-related injuries to children are seen primarily in two situations. First, children who are improperly restrained may be injured rather than protected by their restraint system. A constellation of injuries – classically, abdominal wall contusion, bowel or mesenteric injury, and flexion-distraction fracture of the thoracolumbar spine – known as the "seat belt syndrome" was first described in 1962. Young children have small anterior superior iliac spines and tend to sit forward in the seat, allowing the lap portion of the seat belt to ride up across the abdomen, where their relatively weak abdominal wall cannot protect their viscera.[14,-15] The position of the seat belt over the lower abdomen creates a point of fixation about which the trunk can flex, crushing abdominal organs and vessels between the spine and the seat belt while at the same time allowing forcible distraction of the spine away from the pelvis. In the absence of a shoulder belt, craniocerebral and facial injuries can occur as the head swings forward and strikes other surfaces in the vehicle or the child's lap. Distraction of the thoracolumbar spine disrupts the paraspinal ligaments and produces vertebral body fractures. Two-point, lap-only restraints are more likely than harness restraints or lap-shoulder belts to produce the seat belt syndrome,[16] and toddlers and school-age children are particularly at risk for seat belt injuries. A retrospective review of 17,132 cases of children four to eight years of age showed a 3.5-fold increase in abdominal injuries among seat-belted children compared to children in age-appropriate booster restraints.[14] Another review found a 3.5-fold increase in all injuries among children aged two to five years who were placed in seat belts rather than child booster systems and a 4.2-fold increase in head injuries in this group.[17]

A second unique mechanism of injury in children is exposure to airbags. Approximately half of the vehicles in the U.S. have airbags, which have been linked to more than 260 cases of child death in otherwise nonlethal MVCs. Airbags deploy with a tremendous amount of force – inflating in 0.05 seconds with speeds approaching 250 miles per hour – and small children struck by an inflating airbag may be severely injured or killed. A child in a rear-facing restraint that is struck by an airbag may be driven face-first into the seatback, leading to intracranial injury. A small child in the front seat may sustain high cervical spine injury as they shift forward and toward the bag as the car brakes before collision, where the deploying airbag strikes their face and snaps their head back. Airbags contain chemical propellants that may provoke reactive airway disease or cause irritant injury to the eyes; chemical keratitis has been described following contact with deployed airbags. *(See the November 2006, Volume 3, Number 11,* Pediatric Emergency Medicine Practice *article titled "Ocular Trauma: An Evidence-Based Approach To Evaluation And Management In The ED" for an in-depth review of eye injuries.)* Furthermore, airbags can create a sound pressure of up to 170 decibels in the passenger compartment when they deploy; Kastanioudakis et al described permanent sensorineural hearing loss without other injury following airbag deployment in a low-speed collision.[13,18-21]

Injury Patterns And Collision Factors

The transfer of energy in a collision produces injury patterns that vary predictably by the direction in which the force was applied, by the nature of the objects involved in the collision, and by the patients' seating position within their vehicles.

The direction of impact in a collision influences the amount of energy transmitted to vehicle occupants, the amount of intrusion into the passenger compartment made by the colliding body, and the ability of restraint systems to reduce injury. Lateral collisions are associated with a greater risk of death and the highest injury severity.[22] In a review of children killed in MVCs, t-bone collisions were associated with 40% of all fatalities. In 70% of these situations, the child's seat position was at the point of impact; nearly half of the collisions were deemed "unsurvivable" (i.e., there was complete destruction of the child's seating space).[9] Collision on the patient's side of the vehicle is associated with injury to the thoracic aorta, both from direct impact on the thoracic cage and from the shear effect of the sudden acceleration against the fixed ductus arteriosus, which may contribute to the increased lethality of these crashes.[23] Lateral impacts are associated with an approximately 2.5-fold greater rate of closed head injury than frontal impact; rear impacts are closer to 3-fold. Frontal impacts are associated with injuries to the cerebrovascular arteries, fractures of the thoracolumbar spine, and abdominal injury.[24-26]

The seating position of passengers within the vehicle influences their likelihood of injury. Occupying the rear seat during a collision has been shown in numerous studies to reduce the likelihood of injury or death, with several reports finding nearly a 40% reduction in both risks. Center seat placement, as opposed to either outboard seat, is associated with another 10-20% reduction in the risk of death, presumably by alleviating the danger of airbag-induced injury and by shifting the child away from the point of direct impact in cases of lateral collision.[20,27-29] However, a national database review noted that center-seat position can create an increased risk for seat belt injury of the abdominal viscera, since the only restraint available at this point is a lap belt in many older vehicles.[30]

Finally, the nature of the vehicles involved in the collision can affect injury distribution and severity. As would be expected, collisions with heavier objects at higher speeds tend to produce the greatest injury severity and risk of fatality. Sherwood et al found that collision with an SUV carried the greatest risk of death for child passengers, accounting for one-third of all deaths in the cohort.[9] Such vehicles are not only heavy, their higher bumper can cause greater direct intrusion into the passenger compartment. Riding in a minivan is associated with a 4.58-times greater risk of abdominal injury than riding in a passenger car, possibly as a result of greater interior space within the vehicle which allows the child to more fully and forcefully jackknife their body around their seat belt. Passengers in a pickup truck have a 7.16-fold greater risk of concussion than those in a passenger car; this is because the child's head is more likely to strike a surface within the pickup's relatively small cabin.[26]

Differential Diagnosis

An understanding of the pattern of injuries created by different sets of circumstances – restraint use, age, and speed – can inform the physician as to the differential diagnosis of the MVC trauma patient. The simple mechanical factors of the collision alter the probability of particular injuries; this knowledge can be used to more effectively direct diagnostic efforts. In this section, we will systematically review key considerations to remember during the primary and secondary surveys, paying particular attention to the most common injuries in a given setting and the appropriate level of urgency and priority for particular situations.

General/Systemic

While individual, specific injuries (e.g., open fractures, eviscerations) may be dramatic, remember that trauma is a systemic disease. The stress response to injury is manifest by the release of catecholamines, adrenal cortical hormones, growth hormone, prolactin, anti-diuretic hormone, insulin, and glucagon. Tachycardia, vasoconstriction, hyperglycemia, and cytokine release with increased microvascular permeability and complement activation follow. The stress response, while adaptive to a certain point, can become deleterious if it propagates unchecked. Signs of severe injury reflective of an ongoing physiologic stress can be identified on the initial evaluation. Hypotension is perhaps the easiest to spot and is indicative of blood loss approaching 50% of initial volume. The so-called "triad of death" is particularly ominous and consists of acidosis, hypothermia, and coagulopathy. Acidosis reflects inadequate tissue perfusion; lactate levels that fail to clear with resuscitation portend poorly, with survival rates of less than 15% after 48 hours. Children, with their large surface-to-volume ratio, are particularly susceptible to hypothermia, which potentiates both coagulopathy and acidosis. As core temperature drops below 34.5°C (94°F), capillary leak and coagulopathy worsen, oxygen dissociation from hemoglobin becomes impaired, and cardiac function deteriorates. Patients with core temperatures below 32°C (90°F) approach 100% mortality. Finally, coagulopathy is mainly a function of simple kinetics: as body temperature drops, the esterase reactions involved in the coagulation cascade begin to falter, and the amount of clotting factors and platelets available falls both through consumption provoked by systemic inflammatory mediators and hemodilution resulting from crystalloid resuscitation. Any child with hypotension, acidosis, hypothermia, or coagulopathy is in extremis; rapid control of bleeding, active rewarming, and alleviation of the source of stress are of highest priority in these patients.[31]

Head/Neck/CNS

As previously mentioned, head injury is the chief cause of mortality in children involved in MVCs, and the brain is the organ most frequently injured in these patients.[32] Children have relatively large heads, which magnifies the effect of inertial collision forces on the head; this is exacerbated by the greater amount of head excursion permitted by their weaker neck musculature. Children's skulls are not fully ossified and the bones are thinner than those of adults, providing less protection for the intracranial contents. For these reasons, skull fractures are uncommon in children, and closed head injuries tend to be diffuse rather than focal. The most common discrete intracranial lesion in a child is a subdural hemorrhage. Altered level of consciousness is the best indicator of intracranial injury and warrants imaging. "Impact seizures" may also occur in small children and are not necessarily predictive of severe head trauma.[13,33]

Direct injury to the soft tissues of the child's neck from blunt trauma is rare. Children have relatively short necks, and the large size of the head and the mandible provide some shielding. Pain, swelling, dysphagia, dysphonia, aphonia, or hoarseness in a patient with a mechanism involving a direct blow to the neck or forceful hyperextension may indicate edema in the trachea; the presence of subcutaneous crepitus in this setting is worrisome for tracheal disruption. Establishing a secure airway must be given the highest priority in these patients.[34]

Spinal injuries in children are unusual and are predominantly found in two places: the upper cervical spine and the thoracolumbar spine. There is a biomechanical reason for this – the heavy head transfers a large amount of force to the cervical spine during deceleration – but also a physiologic explanation. Children's spines are incompletely ossified until after three or four years of age, and ligamentous structures in children are lax compared with those of adults. This structural weakness, combined with the child's relatively flat and shallow articulating facets and anteriorly wedged vertebral bodies, further exacerbates the vulnerability of the spinal column. The vertebral column in young children is capable of almost two inches of stretch without disruption, which exceeds the spinal cord's tolerance of a quarter-inch. Thus, significant cord injury can be present without apparent bony spinal injury (a phenomenon known as spinal cord injury without radiologic abnormality, or SCIWORA).[35-36]

While one small study suggested that childhood cervical spine injuries are evenly distributed,[37] most authors report a predominance of upper-level injury. Of spinal injuries in children younger than eight years of age, approximately half to two-thirds occur at C3 or above, with more than half of all spine injuries in children younger than three years of age or occurring at C1 or C2. Most spinal injuries in children are muscular or ligamentous, with actual fractures rare. High-speed collisions are associated with atlanto-occipital dislocations, which are often fatal at the scene; significant acute flexion produces atlantoaxial subluxations, and acute fracture of the C2 vertebral synchondrosis is produced by an acute distracting force (for example, the upward movement of the head away from the fixed body in a child restrained in a car seat). Although more often associated with sports injury, transient quadriparesis – described as a "concussion" of the spinal cord that generally resolves in 24 hours – can be seen in young children after impacts.[35-36,38-39]

Injury to the thoracolumbar spine is a feature of the seat belt syndrome. The Chance fracture is the classic finding: abrupt flexion and distraction of the thoracolumbar junction produces rupture of the posterior ligaments and fractures that travel obliquely through the spinous processes, transverse processes, pedicles, and vertebral body. The Chance fracture is not usually associated with neurologic deficit;[15] 3 of 37 patients with thoracolumbar fracture from MVCs sustained a cord injury in one review.[25] Burst fractures of the thoracic and lumbar vertebrae are also seen in the restrained MVC patient, with a review of 48 patients finding almost equal distribution of burst and Chance fractures. Thoracolumbar spinal fracture of any type is associated with a 68% rate of concomitant intra-abdominal injury.[40] Since spinal injuries are most often seen in the setting of multisystem trauma, they need to be viewed as markers of a significant transfer of force, and children with spinal injuries must receive diligent workup to identify other potential injuries.

Thorax: Cardiovascular And Pulmonary

Thoracic trauma in children carries a 5-14% mortality rate in isolation, increasing to 25% when associated with injuries to the head or abdomen. It accounts for 25% of all pediatric trauma deaths and is the second most common cause of death after head injury.[41] Biomechanically, children have a more flexible thoracic cage than adults; children's anterior ribs can be compressed to meet the spine without breaking, which allows for significant transfer of force to intrathoracic structures without external sign of injury. Children have a small pulmonary functional reserve capacity and will manifest hypoxia more rapidly from lung injury than will adults.[42,43]

Bony thoracic injuries are unusual in children. Rib fractures generally are not seen until adolescence; in small children, they are indicators of significant trauma, with one study showing an overall mortality rate of 42% in children with rib fractures. As with adults, first rib fractures are particularly associated with CNS trauma, clavicular fractures, facial fractures, pelvic fractures, and major vascular trauma. Marked chest trauma can also produce thoracic spine injury, though this is unusual in children.[42]

Blunt trauma to mediastinal structures is rare but devastating. Although a child's mediastinal organs are more mobile and tolerant of acceleration-deceleration than an adult's, they are also less protected from external forces. The heart, great vessels, and trachea can be injured not only directly by being crushed between the sternum and the spine, they can also be damaged through the pressure spike resulting from the precipitous drop in intrathoracic volume that occurs during forceful compression.[42,44]

Cardiac contusion is the most common blunt injury to the heart; cardiac rupture is the most common cause of death from nonpenetrating cardiac injury. Cardiac arrest following blunt thoracic trauma generally reflects profound multisystem trauma – most often severe brain injury – and is rarely survivable. Calkins et al reviewed 25 children who arrested following blunt trauma. Twenty-three died in the emergency department; of these patients, 91% had nonsurvivable brain or spinal cord injury. The two survivors lost their pulses in the trauma bay.[45] Myocardial injury is most typically manifest by dysrhythmias and unexplained hypotension; external signs of thoracic trauma appear in fewer than 30% of patients with cardiac injury. Commotio cordis, an unexplained dysrhythmia that deteriorates into pulselessness and death, is an unusual complication of blunt cardiac injury. Cardiac tamponade may also complicate the picture as a cause of intractable hypotension. Cardiac enzymes may provide a clue to underlying myocardial injury, though their accuracy in this regard is a subject of differing opinions in the literature. Vigilance and clinical suspicion are required in patients with a significant mechanism of injury.[42,46-47]

Nonpenetrating injuries of the hollow structures of the mediastinum are rare. Tracheal disruption has been reported fewer than 70 times in the literature since the 1930s and is believed to result from a forceful blow to the chest, causing a sharp increase in intraluminal pressure against a closed glottis. In children (whose thoracic cages are unable to absorb much of the collision's energy), force is transmitted directly to the alveoli, flooding the bronchial tree with a massive surge of air. The jet-like streams arising from the mainstem bronchi strike with maximum force just superior to the carina where they can dissect through the membranous posterior tracheal wall and possibly shear apart the fibers of the underlying esophagus. Hypoxia despite few signs of external injury with subcutaneous emphysema, pneumothorax, and/or pneumomediastinum are suggestive of a tracheal disruption. This picture, along with worsening hypoxia and gastric distension (sometimes with bubbling in the nasogastric tube) after the initiation of positive pressure ventilation, is suspicious for acute traumatic tracheoesophageal fistula. Persistent air leak or pneumothorax may also point to disruption of a mainstem bronchus with resulting bronchopleural fistula. These injuries are lethal in approximately one-third of patients, usually within one hour of presentation, and must be managed aggressively. Blunt esophageal injury is vanishingly rare but should be considered in cases of chest pain associated with pneumomediastinum, pleural effusion, fever, and sepsis.[42,48-49]

Because of the tremendous amount of force involved, blunt aortic injury almost never occurs in isolation – abdominal, spinal, and head injuries generally travel with it. Death occurs at the scene in up to 90% of these patients, which may account for the rarity of its presentation in the trauma bay.[50-51] MVC is the most common mechanism of blunt thoracic aortic injury in children, and the injury is more common in adolescents than young children – possibly a factor of seating position – with adolescent drivers receiving more steering wheel impacts.[52] Patients who survive to presentation are usually salvageable, with a 50-90% survival rate; though paraplegia complicates recovery in nearly 20% of these children. The initial chest x-ray will be abnormal in 90% of patients; classically, it demonstrates a mediastinum-to-thorax ratio of greater than 25% or apical pleural capping and is often the first diagnostic indication of an aortic or great vessel injury.[42,49]

Lung injuries in children are generally pulmonary contusions which are usually manifest by hypoxia, hypoventilation, and nonanatomic (frequently bilateral) areas of consolidation on chest x-ray. Hemothorax or pneumothorax each complicate about one-third of pulmonary contusions; one-fourth of patients have both. Pneumothorax is often associated with concomitant injury elsewhere; up to two-thirds of patients with pneumothorax have other significant injuries. Tension pneumothorax is life-threatening – leading through a well-known mechanism to respiratory and circulatory collapse – but can be confused with hemorrhagic shock, cardiac tamponade, pulmonary embolus, mainstem intubation, or airway obstruction. Hemothorax, which is frequently associated with rib fractures, is a potential culprit in hypotension given that each hemithorax can hold up to 40% of the child's blood volume.[42,53]

Abdomen

Children have relatively large abdominal organs that are not fully protected by the underdeveloped, thin muscular wall, scant abdominal fat cushion, and flexible, incompletely ossified ribs.[2] Injuries in the abdomen can present a diagnostic challenge to the clinician; signs and symptoms are maddeningly inconstant and vague, distracting injuries erode the reliability of the clinical examination, and the available diagnostic tests are of uncertain accuracy. The specter of missed injury with its attendant preventable morbidity and mortality lends urgency to this confused situation. A rational, systematic, thorough search for injury is the best way to proceed when evaluating the abdomen. Abdominal injuries after MVCs can be conceptually broken into trauma affecting the solid organs, the hollow organs, the abdominal musculature and the diaphragm, and the abdominal vasculature.

Solid organ injury is associated primarily with the force of rapid deceleration.[16] The spleen is the most frequently injured organ in blunt abdominal trauma, followed by the liver. Injury to either organ can produce significant hemorrhage and attendant shock. While injuries to the spleen and liver are generally identified on abdominal CT scan, referred pain to the shoulders – eponymously known as Kehr's sign – can be suggestive of diaphragmatic irritation caused by blood from a lacerated viscus. Injury to the spleen significant enough to ultimately require splenectomy is an indicator of significant mechanism of injury with multisystem trauma; these patients consistently have higher injury severity scores, lower Glasgow Coma Scale (GCS) scores, and significantly greater mortality than patients in whom splenic preservation succeeds. Hepatic injuries also occur in association with multisystem trauma – more than half of the patients in one series had intra-abdominal, head, or thoracic injuries or fractures concomitant with a blunt hepatic laceration.[2,54-55] The kidney is the third most injured abdominal solid organ; it is more often affected by blunt trauma in children than in adults because of the persistence of fetal lobular architecture, the relative paucity of perirenal fat, and the lack of bony ribs for protection. Gross or microscopic hematuria in the setting of blunt abdominal trauma is suspicious for renal injury - though the degree of hematuria does not correlate to the severity of renal injury - and may be absent in the case of avulsion of the renal pelvis or ureter hematuria.[56] Blunt injury to the pancreas is relatively infrequent in the setting of MVC as it tends to require a direct blow to the epigastrium. Its diagnosis is generally suggested by laboratory and CT findings, but it needs to be kept in mind with any patient who has persistent abdominal pain along with unexplained abdominal free fluid on CT.[2] Pancreatic trauma is most often seen in cases of MVC where the child has had inadequate restraints, and it is frequently accompanied by severe systemic injuries; Jacombs et al reviewed 65 cases of children with blunt pancreatic injury and found an associated mortality rate of 33%.[57]

Blunt bowel or mesenteric injury occurs in approximately 1% of patients with blunt abdominal trauma.[58-60] Injury of a hollow viscus poses perhaps the greatest diagnostic challenge in the MVC patient. Physical examination and imaging can be normal despite free leakage of enteric contents into the peritoneum. Patients may not even appear badly hurt; children with blunt bowel injury may have a lower overall injury severity – which correlates to a prolonged time to diagnosis – compared with adults.[61] A high index of suspicion and a thorough (yet rational) workup are therefore crucial.

The compression of viscera between the spine and seat belt can produce a rapid intraluminal pressure spike with blow-out perforation of the bowel, although serosal tears from shear force are more common.[62] Intestinal injury may also be indirect, with ischemia and perforation developing as sequelae to mesenteric vascular disruption. The seat belt sign should raise suspicion of bowel injury: a review of 42 injured patients showed the presence of abdominal ecchymosis to confer a 16-fold greater risk of abdominal injury, while abdominal abrasions carried a 17-fold increase in risk.[63] A prospective study of 390 MVC patients found a seat belt mark to carry a relative risk of 3.2 for intra-abdominal injury and a relative risk of 41 for bowel injury, compared to patients without external signs of injury.[64] A large, retrospective analysis found the presence of abdominal wall bruising to confer a 232.1 relative risk for intra-abdominal injury compared to a patient without a seat belt sign; in the same study, children with no seat belt sign had an intra-abdominal injury rate of 0.06%.[65]

Hollow viscus injuries most commonly involve the small bowel, but injuries to the stomach and colon also need to be considered. Blunt gastric perforation is rare, with an incidence of around 0.5% in one study; MVCs account for most of the cases of this highly morbid injury. Factors associated with gastric perforation include history of a recent meal, impact from the left side, and improper restraint use. Splenic and thoracic injuries are the most common associated pathologies. Blow-out perforation is most likely in the anterior wall along the greater curvature – corresponding to the prediction of the law of Laplace since wall tension will be greatest in the area of greatest radius – while shearing injury occurs at the relatively immobile pylorus.[66] Colonic perforation occurs in 0.3% of cases of blunt abdominal trauma, rarely occurs in isolation (only 5% of cases of colon injury show no other abdominal injury; damage to the liver and spleen are the most common associated injuries), and is associated with longer ICU and hospital stays than small bowel perforation but has similar mortality.[59]

The worst-case version of the seat belt sign is a traumatic hernia; and although the child's abdominal wall is thin and subject to disruption in an MVC, such hernias are rare. At least one case report of evisceration through blunt abdominal wall disruption has been published; and although few traumatic ventral hernias are likely to be this dramatic, most authors advise immediate laparotomy at diagnosis, given the high likelihood of associated intra-abdominal injuries caused by the massive force required to disrupt the abdominal musculature.[67-68]

Traumatic diaphragmatic hernias are more common than ventral hernias, occurring in 1-7% of MVC patients, though they can be difficult to diagnose. Up to two-thirds of diaphragmatic ruptures are missed, with the delay in diagnosis measured in years in some instances. Most of these injuries occur on the left side, in the structurally weak posterolateral aspect of the diaphragm. Nearly all patients will have associated intra-abdominal injuries, most commonly the liver, spleen, or pelvis. The pressure gradient between the peritoneum and thorax encourages visceral herniation into the chest; the stomach is the most common organ to herniate, followed by the colon, small bowel, spleen, and omentum. Respiratory compromise and visceral ischemia can follow. In extremely rare settings, herniation can occur into the pericardium, causing cardiac tamponade. Clinically, these patients may have scaphoid abdomen, chest pain, and unilaterally decreased breath sounds.[42,69-70]

The abdominal aorta and inferior vena cava are rarely injured following blunt abdominal trauma, with slightly more than a dozen cases reported in the pediatric literature. Blunt aortic injury is most likely between the renal artery insertions and the takeoff of the inferior mesenteric artery; interestingly, this corresponds to the anatomic location of the thoracolumbar Chance fractures found in the seat belt syndrome. Choit et al reviewed 12 cases of aortic injury occurring at the level of the spinal fracture, generally at or above the level of L2; hence, the presence of a spinal fracture - particularly associated with alterations of the lower extremity pulses - should raise the suspicion of aortic damage.[71-72] Blunt trauma accounts for 11% of all inferior vena cava injuries, with a 36% prehospital mortality rate and nearly a 60% mortality rate among patients who survive to presentation. No large series have been published on this rare injury in children.[73]

Finally, it is worth bearing in mind that the lower urinary tract and external genitalia may be injured; MVC accounts for 90% of perineal injuries in adolescent females. Mechanical compression of the soft tissues of the perineum against the rigid pelvis or laceration of tissues by fractured pelvic bones are the primary mechanisms. Like bowel injuries, genitourinary injuries may be clinically silent and may produce long-term sequelae such as stricture and fistula. Any sign of perineal or genitourinary trauma – hematoma, hematuria, or perineal swelling or bleeding – demands a thorough investigation.[74]

Prehospital Care

The key relationship of prehospital care to the trauma evaluation of children injured in MVCs is gathering information regarding the collision scene from Emergency Medical Services (EMS) personnel. As has been discussed previously, injury patterns vary depending on the collision setting; other cues from the collision give a sense of the severity of forces involved. At a bare minimum, obtain information on:

1. ***The collision:*** What were the direction and speeds of the vehicles at impact? What was the degree of deformation of the passenger compartment of the patient's vehicle and was there significant intrusion into the passenger's space?
2. ***Seating position:*** Was the patient in the front or rear seat at the time of impact?
3. ***The restraints:*** Were children in age-appropriate child restraint systems, were they using seat belts, or were they unrestrained?
4. ***Ejection:*** Was the child ejected? If so, onto what sort of surface, and how far from the vehicle did they travel?
5. ***Severity:*** Did anyone else at the scene – particularly other passengers in the patient's car – die?
6. ***The patient:*** What was the patient's condition at the scene? Did EMS obtain a Glasgow Coma Scale score for them? Were they awake, talking, interactive? Did they voice specific complaints? Were they able to move all of their extremities?

The information gleaned from this brief conversation can help the clinician establish a mental picture of which injuries to suspect and direct a purposeful, logical workup.

ED Evaluation

Evaluation of the patient proceeds synchronously with resuscitation in the trauma bay following the principles outlined by the American College of Surgeons protocol for Advanced Trauma Life Support, which are well-outlined elsewhere.[75] Briefly, a patent airway must be secured, with endotracheal intubation or surgical control if necessary. Adequate breathing and ventilation must be assured. External hemorrhage needs to be identified and controlled and pulses evaluated in all extremities. Reliable intravenous or intraosseous access must be established and resuscitation fluid administered, labs and radiographs need to be ordered, and the patient must be evaluated with a thorough secondary survey after life-threatening problems have been ruled out or addressed. Although a 2001 Cochrane Review found no randomized, controlled trials showing benefit for spinal immobilization following trauma – and thus could not rule out harm from the practice – standard clinical practice is to provide spine immobilization in the setting of head and neck trauma, loss of consciousness, altered mental status, neck pain, or a cervical seat belt sign.[2,31,35-36,76]

Clearly, some patients presenting in the trauma bay will have only minor injuries, while others will require immediate lifesaving therapy with rapid stabilization en route to emergency operative management. Decision-making in these settings is not difficult. For the vast majority of patients who fall between these extremes, the secondary survey becomes the clinician's chance to identify injuries, preventing missed diagnoses with their attendant morbidity and mortality.

The head and neck must be examined for deformity, lacerations, and contusions. Pupillary response and level of consciousness must be assessed and the GCS score recorded. Anisocoria or other lateralizing neurological deficit are suspicious for focal brain injury and need CT scanning. Signs of spinal injury must be assessed, with attention to neck tenderness or step-off. Neck crepitus is worrisome for perforation of the aerodigestive tract. Cervical hematoma, bruit, thrill, or seat belt sign may indicate vascular injury in the neck.[77-78]

Internal injuries in the thorax and abdomen often have clinical cues that can be picked up in the secondary survey – the Eastern Association for the Surgery of Trauma (EAST) guidelines go so far as to state that careful physical examination is the "most important method" to identify severe internal injuries.[79] Electrocardiographic abnormalities seen in the trauma bay may reflect myocardial injury; while a normal ECG virtually rules out cardiac damage, an abnormal strip necessitates admission with telemetry observation for 24-48 hours, and echocardiography should be considered.[41,80] Hemodynamic instability, tachycardia, and the presence of life-threatening injuries elsewhere all indicate a significantly greater than average risk of intra-abdominal injury for a given patient.[63] Hypotension during initial evaluation is associated with a 4.6-fold increase in the rate of intrathoracic injury and a 5.8-fold increased risk of intra-abdominal pathology. An abnormal thoracic examination – erythema, abrasions, contusions, lacerations, crepitus, tenderness, or auscultatory changes – carries a 3.6-fold increased risk of underlying intrathoracic injury. Abnormal auscultation (although not the easiest sign to identify in a busy trauma bay) is the most predictive finding, with a relative risk of 8.6 for underlying injury. Likewise, abdominal tenderness has been found to have a relative risk for intra-abdominal injury of 5.8, compared with a non-tender patient.[81] The abdominal examination, however, can be unreliable in the trauma setting.[82-83] Although intoxication is less of an issue in the pediatric population than among adults, head injury, altered level of consciousness, other distracting injuries, and an inability to communicate because of age and developmental status all affect the reliability of the clinical assessment. Except in very clear-cut situations with a reliable examination and no physical signs of injury, most cases of blunt thoracoabdominal trauma will be assessed radiologically.

Identification of a seat belt sign on examination merits special consideration. As a marker for large energy transfer, it needs to instill in the clinician a heightened suspicion for underlying internal injury. Cervicothoracic seat belt signs corresponded with a 3% rate of cervicothoracic vascular injury in a prospective study and warrant investigation with either CT or conventional angiography.[78] Intra-abdominal injury rates of 10-15% have been reported for patients with a seat belt mark, compared with 1% of patients sustaining blunt abdominal trauma in general; the relative risk for intra-abdominal injury among patients with a seat belt sign has been reported to be anywhere from 3.2 to 232.1.[60,63-65,84] Thoracic and abdominal seat belt marks are significantly associated with severe underlying injury and the need for operation.[85]

Diagnostic peritoneal lavage, the classic trauma bay screening test for intra-abdominal hemorrhage, is invasive, has a high false-positive rate, and is not frequently used in the pediatric population because of its high rate of complications in children.[86]

Due to their small size and susceptibility to injury, children involved in MVCs are polytrauma patients until proven otherwise.[86] Something to keep in mind during the secondary survey is that particular injuries frequently point to the presence of certain associated injuries. These have been mentioned throughout this review; some considerations are reiterated below:

- ***Abdominal seat belt mark:*** The classic seat belt syndrome includes thoracolumbar fracture/dislocation, bowel or mesenteric injury, and abdominal contusion, sometimes with closed head injury and maxillofacial fractures.[15-16] At least one case of disruption of the inferior vena cava has been described in association with the seat belt sign;[73] likewise, abdominal aortic injury may be more likely in the presence of the seat belt sign.[72]
- ***Cervical spine fracture:*** Associated with orthopedic injuries if superior to C3-C4; maxillofacial injuries if lower.[38]
- ***Clavicular or first rib fracture:*** May be associated with cervical vascular injury.[78]
- ***Diaphragmatic hernia:*** A literature review showed that patients with diaphragm rupture had associated pelvic fractures in 40-55% of cases, splenic injury was seen in 60% of patients, and hepatic injury was found in 24% of patients

with left-sided rupture and 93% of those with right-sided hernia.[70]

- ***Extremity fracture:*** Extremity fracture was present in 57 of 60 patients with blunt vascular injury of the extremity in a small, retrospective review.[87] In a large, perspective review, the presence of a femur fracture was 95% specific for the presence of intra-abdominal injury.[81]
- ***Hip dislocation:*** In a retrospective review of 28 patients sustaining posterior hip dislocation in an MVC, 23 had associated ipsilateral knee injury.[88]
- ***Iliac wing fracture:*** A study of four cases of lap-belt-related iliac wing fracture found two patients with small bowel or colon perforation.[89]
- ***Lower extremity neurologic deficit:*** Although spinal cord injury is far and away the leading concern in these situations, ischemia – either of the limb via local vascular or aortic injury or of the spinal cord from aortic injury – should remain a consideration, particularly in the absence of spinal injury.[72,87,90-91]
- ***Spine fracture (any level):*** Thirty-seven percent of patients will have associated closed head injury.[38]
- ***Thoracolumbar fracture:*** Sixty-eight percent of patients in one study had concomitant bowel or mesenteric injury.[40] Twelve cases of abdominal aortic injuries in association with Chance type lumbar fractures have been described in the literature.[71] Patients with lumbar fractures have a higher-than-normal rate of gastrointestinal and lower extremity orthopedic injuries.[38]

Diagnostic Studies

The laboratory and radiologic workup of the MVC patient must be undertaken in a logical, directed fashion. If a particular study can identify or exclude an injury or if it is necessary as a baseline measurement for tracking further therapy, it may be warranted.[86] In this section, we will discuss how laboratory and imaging data can assist in the search for internal injury.

Laboratory

Although the lab battery drawn during trauma resuscitation varies from institution to institution (from the proverbial "one tube for type and cross" to more comprehensive panels), the complete blood count is a virtually ubiquitous selection. The CBC can provide a sense of the adequacy of the patient's oxygen delivery capacity as measured through hemoglobin concentration; it thus serves to direct resuscitation, determine the need for blood products, and assist in the initial decision to operate immediately. The risk of intra-abdominal injury – including solid or hollow viscera – increased by 11% for each 1% drop in hematocrit in a review by Cotton et al; hematocrit less than 39% in association with elevated transaminases was found to be 88% accurate in predicting intra-abdominal injury.[63] In another review, hematocrit less than 30% was only 14% sensitive but 98% specific for intra-abdominal injury.[81] The white blood cell count may also serve as a proxy indicator of bowel injury; in a review of 46 patients with isolated small bowel injury, 85% of patients had leukocytosis greater than 12,000/mL; though this correlated to a sensitivity of 84.8% and a low specificity at 55.2%.[92]

Several studies have tried to correlate serum chemistries with the presence of intra-abdominal injury. One review evaluated the relationship between clinical findings and transaminase levels and found that an aspartate aminotransferase (AST) level greater than 131 u/L, when seen in the presence of hematocrit less than 39% and abdominal tenderness, was 100% sensitive at detecting intra-abdominal injury; similarly, a normal abdominal exam in the presence of alanine aminotransferase (ALT) level greater than 105 u/L was 100% sensitive. Both groupings were 87% specific and 88% accurate, and each unit increase of ALT correlated to a 2% increase in the risk of intra-abdominal pathology.[63] Another study reported a 17.4-fold increase in the incidence of intra-abdominal injury in patients with an AST level greater than 200 u/L or ALT greater than 125 u/L; this finding was 50% sensitive and 96% specific.[81] Amylase and lipase elevations may indicate bowel or pancreatic injury, though no good data exists on their predictive utility. Jacombs et al studied pediatric pancreatic injuries and found elevated amylase in only half of the patients at admission.[2,57]

Urinalysis may provide insight into injuries of the genitourinary tract. A retrospective study of 110 patients with gross or microscopic hematuria following blunt abdominal trauma found a renal injury rate of 22%, with no injuries found in any patient with fewer than 50 RBCs/high-power field on microscopic analysis.[93]

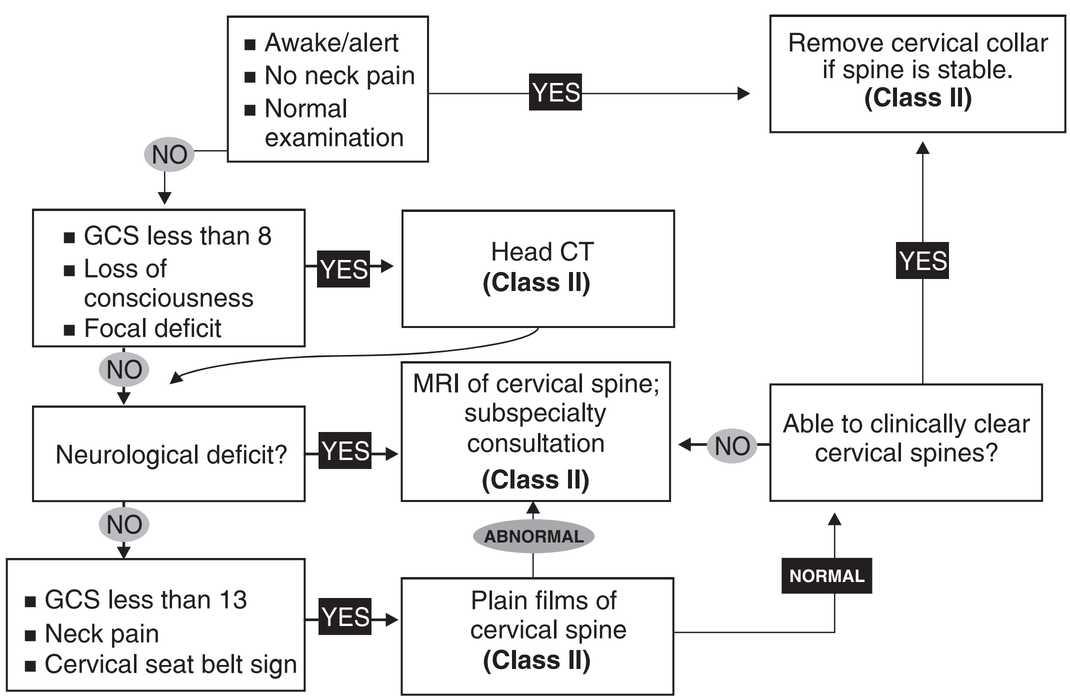
Radiology

The radiologic assessment of the trauma patient must take the mechanism of injury into consideration and must be directed appropriately toward suspected lesions. Each imaging modality has its particular strengths and weaknesses, and to maximize efficacy of the diagnosis, the clinician must select tests appropriately in order to obtain the necessary information for further decision-making.

Evaluation of the thorax with a single anteroposterior chest x-ray is near universal in the trauma setting, although one study found a 30-40% rate of missed plain-film diagnosis in a pediatric trauma population.[43] Pulmonary contusion generally appears as patchy, bilateral, nonanatomic areas of consolidation. A widened mediastinum, particularly in the setting of indistinct aortic knob, apical pleural capping, left pleural effusion, rightward deviation of the nasogastric tube, or depression of the left mainstem bronchus, is concerning for injury to the great vessels and warrants investigation either with helical CT scan of the chest or arch aortography.[42,49] Pneumothorax and hemothorax are readily identifiable on chest film and should be treated in the trauma bay with tube thoracostomy.[42] Pneumomediastinum may suggest rupture of the aerodigestive tract.[48] An elevated left hemidiaphragm may suggest diaphragmatic herniation, as may the classic finding of nasogastric tube in the thorax.[69] Pneumoperitoneum may be seen on the initial x-ray in the setting of bowel perforation but is inconstant – a review of 1300 cases of blunt abdominal trauma found no free air in 80% of patients with gastric rupture – and its absence should not be taken to have diagnostic value.[66]

Plain films are the preferred means of evaluating for spinal fractures. In any patient with a possible cervical spine injury, anteroposterior and lateral films of the cervical spines are mandatory; the occiput through the first thoracic vertebra must be visible for the film to be adequate for interpretation. A Level 2 recommendation from EAST advises CT scan of the cervical spine for any patient with question of injury or for whom adequate plain films cannot be obtained.[94] Caution is necessary in interpreting pedi-

Clinical Pathway: The Evaluation Of Head And Cervical Spine Injuries

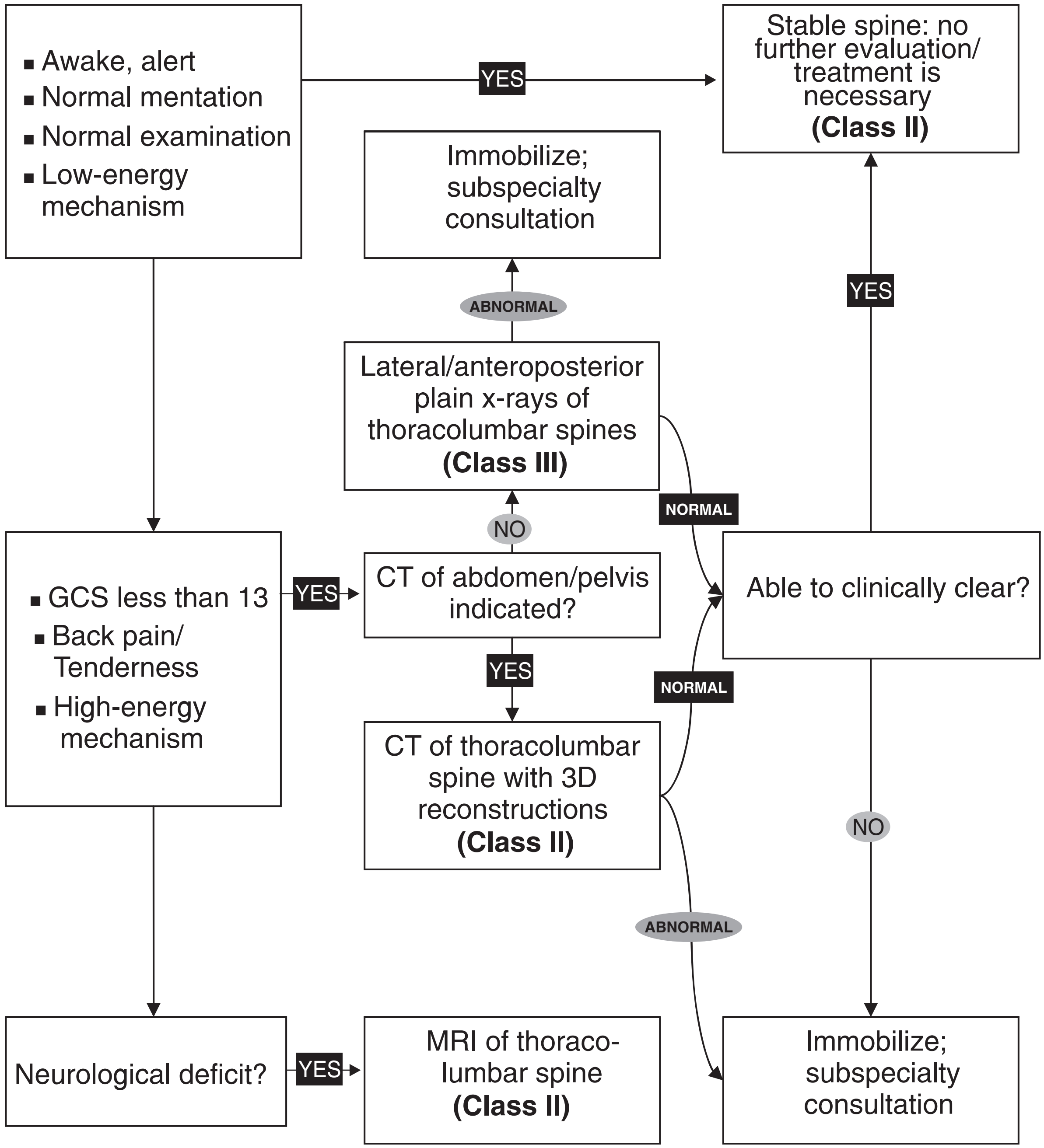


Adapted from Mazzola et al, Marion et al, Diaz et al.

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

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

Clinical Pathway: The Evaluation Of Thoracolumbar Spine Injury After MVC

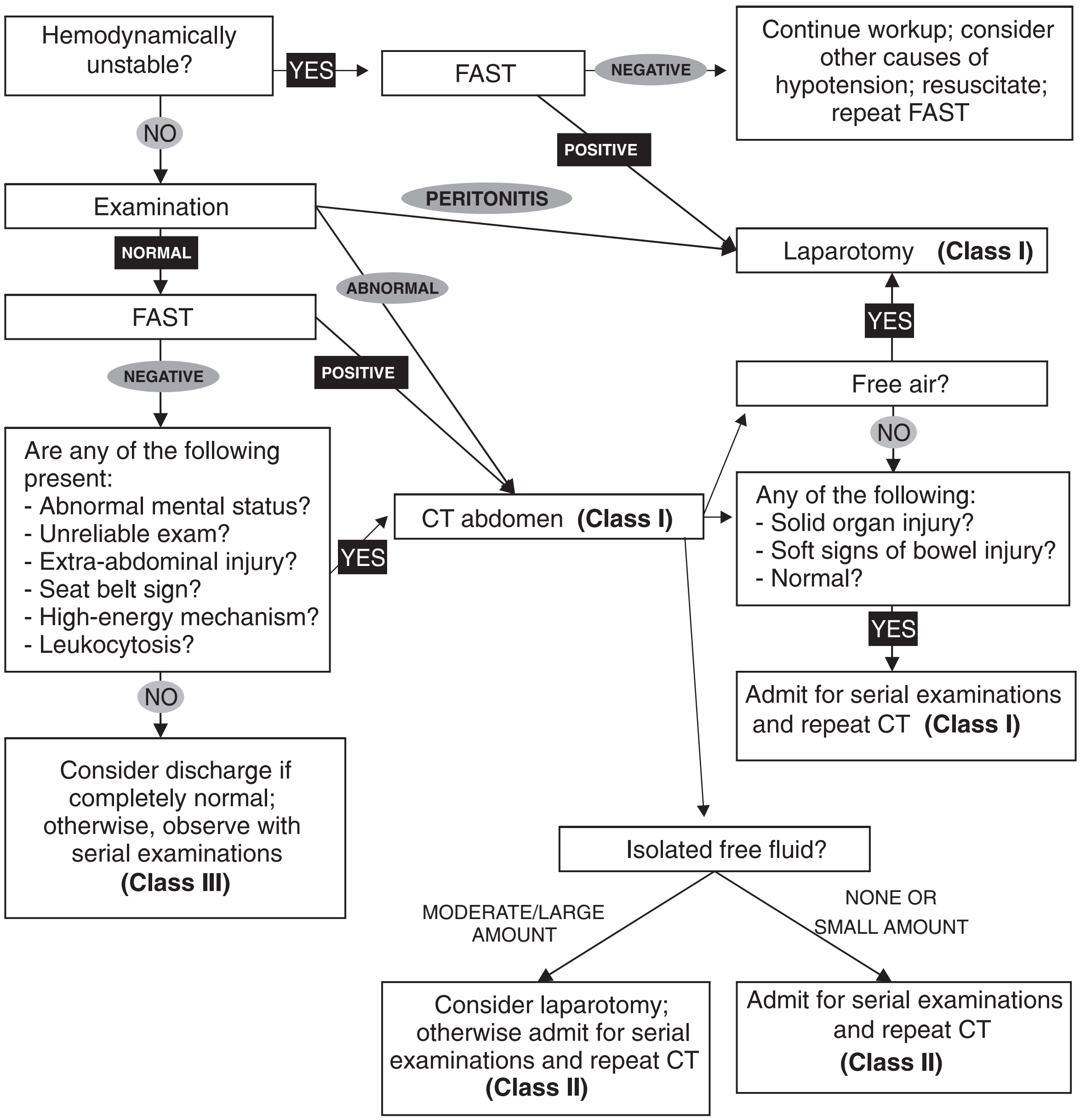


Adapted from Diaz et al, Holmes et al, Bliss et al.

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

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

Clinical Pathway: The Evaluation Of Blunt Abdominal Trauma After MVC



Adapted from Hoff et al, Holmes et al, Hamill et al.

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

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

atric spine films; in children, "pseudosubluxation" of the second cervical vertebra on the third or the third on the fourth is physiologic, with up to 4 mm of anterior step-off within the range of normal. Incomplete odontoid ossification may mimic odontoid fractures.[35] For evaluation of the thoracolumbar spine, a Level 2 EAST guideline suggests that CT scan is superior to plain films in evaluating a patient with altered mental status or distracting injuries, though some data suggest that plain films are more likely to demonstrate the transversely oriented Chance fractures that travel in the plane of CT images and may be lost between CT cuts.[35,95]

In the absence of signs of pelvic fracture, it is questionable whether abdominal/pelvic plain films add much to the initial workup, since most cases of suspected abdominal injury will require a CT scan.[86] CT scanning is the preferred means of screening for intra-abdominal injury, though it is not without its limitations.[63] CT is indicated for any hemodynamically stable patient with blunt abdominal trauma who has an abnormal, equivocal, or unreliable abdominal examination, who has a positive ultrasound for peritoneal fluid, who may be a candidate for nonoperative management of a solid organ injury, or who is at a high risk for intra-abdominal injury (high-energy mechanism of injury, multiple other injuries, neurologic injury).[79] CT is excellent at identifying injuries to the solid organs of the abdomen, assessing the retroperitoneum, and identifying the presence of fluid in the peritoneal cavity. It may indirectly give a sense of the patient's physiologic status; a case report of two patients identified absent renal enhancement on contrast CT of the abdomen – which the investigators termed "black kidney sign" – as a grim prognostic sign following blunt abdominal trauma, indicative of splanchnic vasoconstriction and rapidly decompensating hypovolemic shock.[96]

CT scanning's main weakness is in identifying hollow viscus injury. Pneumoperitoneum is a clear marker for perforation, but the softer signs of bowel wall thickening, mesenteric fat stranding, dilated loops of bowel, hyperintense bowel wall enhancement, and ascites are harder to interpret. The finding of free intraperitoneal fluid without evidence of solid organ laceration is a diagnostic conundrum.[82] Since isolated peritoneal fluid may represent bowel injury, mesenteric injury, or hemoperitoneum from an undetected solid organ injury or pelvic fracture, what is the next step in patients with this finding?

A significant amount of research has gone into evaluating this problem. A four-year, retrospective review evaluated 259 children following blunt abdominal trauma. Of this group, 24 (9%) had isolated free fluid. Of these 24 patients, 13 had sustained an MVC and 11 of this group had a seat belt mark. A total of six patients underwent laparotomy based on these findings; all had small bowel injury. Three more patients had worsening clinical examinations or a repeat CT (demonstrating an increase in volume of ascites) and also underwent therapeutic laparotomy (defined as exploration where an injury requiring repair was identified). Conversely, of patients with a normal CT scan (nearly 60% of the study population), only two required laparotomy because of clinical deterioration. Thus, the study reported a 25% prevalence of small bowel injury among patients with isolated free peritoneal fluid, with increasing prevalence if fluid was present in more than one location or in a large amount; they concluded that admission and serial exams were warranted in all patients with unexplained ascites after trauma.[97] A retrospective review of outcomes among 37 children with isolated intraperitoneal fluid showed an odds ratio of 10.33 for requiring laparotomy if more than a small amount of fluid was present. Of six patients requiring operation, five had abdominal seat belt sign, and four were tender on initial evaluation. No patient with a benign abdominal examination required operation.[98]

One of the largest prospective studies for children looked at more than one thousand patients younger than 16 years of age who were admitted after blunt abdominal trauma. Of this group, 35% were passengers in an MVC. A total of 25 patients went from the trauma bay directly to laparotomy because of clinical indications for operation. Of the 527 patients who received CT scan, 88 (17%) had peritoneal fluid that was unexplained by solid organ injury in 42 (8%). In this subgroup of 42 patients, factors associated with intra-abdominal injury included unreliable exam (25% had injury) or tenderness on exam (29% rate of injury). Abdominal pain was present in 17 patients, none of whom had injury; among the 17 patients who were awake, alert, and nontender, no injuries were identified. This study also found a positive correlation between the amount of fluid and the presence of injury.[99]

These findings corroborate data from the adult population. A large meta-analysis of 10 reports found a 2.8% incidence of isolated free fluid on CT following blunt abdominal trauma. Approximately one-fourth of these patients ultimately required laparotomy; the rate of therapeutic laparotomy was greater in patients with larger amounts of free fluid, while nontender patients with fluid seen on fewer than three CT cuts tended not to have injury.[100] A retrospective piece reviewing 31 patients (including two children) who underwent laparotomy with isolated free fluid as the sole indication found a 94% rate of injury, chiefly of the small bowel and mesentery. Most of these patients were involved in an MVC, and 20% had a seat belt sign. Therefore, isolated free fluid may require laparotomy.[82]

Cost- And Time-Effective Strategies

1. **Keep the workup focused.**
   The golden hour is a time for prioritization and identification of threats to life and limb; the trauma bay is not the place for comprehensive evaluation of every possible injury. Direct studies toward probable injuries first, based on clinical findings and the particulars of the collision.

   Risk management caveat: A thorough tertiary survey within the first 24 hours after admission is a must in any multi-system trauma patient, specifically to identify and address non-lethal but important injuries.

2. **Trust your clinical examination.**
   EAST describes the physical examination as the most important screening test for internal injury. A patient with a benign examination and a low-energy mechanism of injury is unlikely to have serious head, spine, or thoracoabdominal injury.

   Risk management caveat: On the other hand, positive findings – such as abdominal tenderness or ecchymoses – in a patient who looks otherwise well may be harbingers of severe underlying injury and need to be thoroughly investigated.

3. **Know when not to study.**
   Spine clearance may be accomplished without imaging in patients capable of providing a reliable exam, who are nontender, and who were involved in a low-energy MVC. Likewise, a patient with a benign abdominal examination in the setting of hemodynamic stability, absence of distracting injury, and normal mentation may not need further imaging.

4. **Avoid redundant examinations.**
   For example, in the absence of suspected pelvic fracture, pelvic plain films are unnecessary in a patient who will undergo abdominal CT scan; likewise, FAST is a duplication of effort in stable patients who are slated for abdominal CT.

5. **Start with simple and then move to complex studies.**
   Plain films of the spines are an adequate first study to rule out fracture. CT can be reserved for cases where plain films are inadequate or questionable, and MRI should be deferred except for patients who have suspected cord injury or who cannot be clinically cleared.

One modality that may be complementary to CT is Focused Abdominal Ultrasound in Trauma (FAST). FAST is capable of detecting and quantifying free intraperitoneal fluid – in experienced hands, it can identify 200 mL or more of fluid – and is 73-88% sensitive and 98-100% specific. Surgeons, ED physicians, radiologists, and ultrasound technicians can perform FAST with equivalent accuracy.[79] FAST is rapid, easily available, and noninvasive, but the drawbacks are that it is incapable of assessing the retroperitoneum and it cannot distinguish the source of fluid (i.e., blood vs. enteric contents). FAST is less well-studied in children and is believed to have a higher false-negative rate in children than in adults.[2] A significant number (29-44%) of patients with intra-abdominal injury present without hemoperitoneum and are, therefore, FAST-negative. In a review of 23 patients with known bowel or mesenteric injury, 18 patients had a normal FAST, for a false-negative rate of 78%.[60] FAST is likely most effective as an initial screening device – in a hemodynamically unstable patient, a positive scan suggests an abdominal source of bleeding and is an indication for laparotomy,[79] but its poor sensitivity (and thus its inability to rule out injury) proscribes its use as the sole imaging modality for a trauma patient. A Cochrane Review of two randomized, controlled trials and two quasi-randomized trials found an odds ratio of 1.4 in favor of CT scanning compared with abdominal ultrasound for cost-effectiveness, quality of life, and rates of appropriate laparotomy and delayed diagnosis.[101]

Magnetic resonance imaging (MRI) has limited use in the pediatric trauma setting. Its long exposure times make it undesirable for tenuous or critically ill patients, and the associated claustrophobia and need to remain still during scanning make it difficult to use in small children without adding the risks of sedation and airway management. That being said, suspected spinal cord injury is the chief indication for MRI in children, particularly in the setting of SCIWORA. MRI is also useful for the evaluation of the brainstem and for evaluating stability of the cervical spine in patients who cannot be reliably examined.[35-36,42] A literature review found MRI to be 100% accurate in identifying diaphragmatic rupture,[69] and magnetic resonance cholangiography/pancreatography may have some place in identifying pancreaticobiliary injury,[57,102] though these indications may be more germane to the critical care, inpatient setting.

Treatment

As discussed previously, assessment and therapy are essentially simultaneous in the trauma bay setting. The key therapeutic elements of trauma resuscitation are those which correct or stabilize what would otherwise be a rapidly lethal physiologic derangement. This includes, but is not limited to:

- ***Obtaining and securing a stable airway:*** Formal surgical control may be necessary in patients with maxillofacial or anterior neck injuries, particularly in the presence of neck crepitance or evidence of airway disruption; children younger than eight years of age should have needle cricothyroidotomy as a temporizing measure before operative tracheostomy; children older than eight years of age generally have structures large enough for successful standard cricothyroidotomy.[31,34]
- ***Ensuring adequate respiration and ventilation:*** Pneumothoraces or hemothoraces require tube thoracostomy in the trauma bay. Tension pneumothorax must be identified, decompressed with needle thoracostomy, and followed with a chest tube.
- ***Obtaining reliable vascular access:*** Peripheral intravenous lines are ideal, intraosseous lines can be considered in the young child with difficult access, and central venous catheters may be placed for hemodynamic monitoring as well as resuscitation.
- ***Stabilizing the spine:*** Any patient with suspected spine injury requires immobilization until the spines are radiographically and clinically cleared.
- ***Identifying candidates for immediate operation without further workup:*** Two of the more commonly seen situations in the setting of blunt trauma are a hemodynamically unstable patient with a positive FAST[79] or a patient with a hemothorax productive of 15 mL/kg of blood immediately after tube thoracostomy.[42]

Pain control in the trauma bay is an issue which isn't life-threatening but is nonetheless important and often overlooked. A prospective assessment of the pain experience by injured children found that, overall, their pain was undertreated and little was done to assuage their anxieties and fears in the immediate post-injury period. The scene of injury and the ED were identified as the two areas where pain control was the least adequate; suggesting that clinicians should be mindful of the need to provide analgesia as the patient tolerates and the clinical situation dictates during the initial resuscitation.[103]

Special Circumstances

Children with special needs – either cognitive or emotional developmental deficits – may pose a difficult situation during trauma assessment and resuscitation. Developmental delay is a risk factor for missed diagnosis; fractures are the injury most frequently diagnosed late. In the case of a patient with developmental delay (or in a patient who is preverbal or obtunded, for that matter) good attention to the circumstances of the injury – such as the factors discussed in the **Prehospital Care** section on page 9 that should be obtained from EMS and parents or caregivers – will help direct workup toward potential sites of injury.[104-105]

Controversies/Cutting Edge

Family Presence During Resuscitation

A question that has been addressed in the adult literature is whether it is appropriate for family members to be present during heroic measures, including cardiopulmonary resuscitation and trauma resuscitation. While there is a significant amount of anecdotal evidence opposing family presence – primarily opinions of physicians that witnessing such events would be harmful psychologically or that family members will interfere with provision of care – most quantitative data suggests that family members want to be with their loved ones during these moments of crisis, that witnessing the patient's resuscitation (and, often, their death) is emotionally valuable to them and not traumatic, and that family presence does not affect the medical team's ability to care for the patient. What little data there is from resuscitation survivors suggests they appreciate the presence of family members. Physicians tend to be less receptive to the idea of family presence than do nurses and allied health personnel, though there is significant variation between different specialties and regions.[106-107]

In the pediatric setting, attitudes tend to be more permissive as to the inclusion of family members. Pediatric providers in one large survey reported significantly more experiences with family member presence during resuscitation and significantly less sense of discomfort or intimidation because of family presence.[108] A prospective study specifically evaluated resuscitation and invasive procedures in the emergency department and found no cases where care was delayed or compromised; 95% of parents felt their presence helped their child and themselves, and all parents reported they would make the same choice again. Physicians and nurses surveyed were comfortable with family presence; 97% felt the family was not disruptive, 94% felt comfortable with family presence, and 92% felt it had no impact on the outcome. Around 80% of parents and practitioners felt it was the parents' right to be present during resuscitation.[109] A national consensus conference proposed guidelines in 2006 that were endorsed by the American Academy of Pediatrics; their recommendation is to offer family presence during all pediatric procedures and resuscitations providing certain conditions are met (care will not be compromised, the health of the team will not be put in jeopardy, abuse and intoxication are ruled out), preferably with the presence of a staff facilitator to serve as a support person to the family during the resuscitation.[110] Pediatric trauma providers should consider allowing the presence of family members, if feasible, during the initial evaluation of the patient.

Cessation Of Care

Cessation of care in the trauma room itself should be reserved for patients who are clearly nonsalvageable: GCS 3, absent pulse and respiratory effort, no blood pressure, and no electrocardiographic activity. Patients who present after having lost these signs of life in the field rarely survive; patients who lose their vital signs during transport or in the ED have a better chance, though bear in mind that blunt cardiac arrest in the pediatric population is often indicative of a lethal brain injury. As such, prolonged CPR may be indicated only in cases where head injury is not a predominant feature. Emergency department thoracotomy is not indicated for blunt cardiac arrest in children.[31,45]

Disposition

Fortunately, some patients – despite significant mechanisms of injury – will emerge from their traumatic experience unscathed. The key issue for the clinician is identifying these individuals effectively. Discharging patients who do not require inpatient evaluation is a cost-effective use of limited healthcare resources that must be balanced against the potentially disastrous complications of missed injuries. Two areas that have the greatest potential for harm resulting from missed injury, and must receive special consideration before a discharge, are the spine and the abdomen.

Clearing The Spine

If a cervical collar is placed upon a patient – as often happens in the field during extrication and transport – formal clearance of the patient's spine is mandatory before removing the collar. Spinal clearance protocols are well-established in the adult trauma literature: there must be no radiographic evidence of fracture, full neck range of motion, and no midline cervical tenderness in a patient without intoxication, altered level of consciousness, or distracting injury. Since effective patient-provider communication is key to this process, children who can verbally confirm a nontender neck have the most reliable clinical clearance, while the clinical exam is more tenuous in a preverbal child.[35-36]

The EAST guidelines for assessing cervical and thoracolumbar spine injury make the Level 2 recommendation that patients who are awake, have normal mentation, and have no distracting injuries and no neurological deficits have stable spines and need no imaging. A patient who does not meet these criteria or who has a high-energy mechanism of injury should have their cervical spine assessed with the standard three-view plain film series; plain films of the thoracolumbar spines are adequate if no CT scan is otherwise indicated.[94-95] These recommendations are for

Key Points

- A significant number of children ride in vehicles either without restraints or with improper restraints.
- Restraint status, seating position, and physical factors of the collision (speed, nature of the crash partners, direction of impact) predictably affect injury distribution.
- Children involved in MVCs are polytrauma patients until proven otherwise; intrathoracic and intra-abdominal injuries rarely occur in isolation, so don't stop searching after diagnosing the first one.
- Head injury is the leading cause of traumatic death in children after an MVC; thoracic injury is second. Treat these patients with appropriate urgency.
- Significant injuries may occur in the spine, head, thorax, and abdomen without external or radiographic signs of injury; a careful, thorough clinical examination is vital.
- Fractures in the axial skeleton almost always imply serious underlying injury; the absence of fractures does not rule it out.
- Clinical examination must supplement radiologic and laboratory findings in the diagnosis of intra-abdominal injury.
- Consider allowing family presence during resuscitation.

adults; however, they may be appropriate for children older than eight years of age, given that their injury patterns fairly closely to those of adults. Plain films are adequate for assessing the pediatric cervical spine; in children younger than nine years of age, an open-mouth odontoid view is not necessary. Interpretation of these films must bear in mind that children have anteriorly wedged vertebral bodies that may mimic compression fracture, a pseudosubluxation of up to 4 mm (most commonly seen at C2 on C3), a wide interval between the atlas and the dens (up to 4 mm as opposed to 2.5 mm in the older child and adult), and an incompletely fused odontoid that may appear fractured. In children younger than nine years of age who cannot be clinically cleared or who have a deficit, MRI is the preferred next step in imaging as it identifies ligamentous and soft tissue injuries as well as subtle insults to the cord that may have occurred in the absence of fracture. Any neurological deficit or fracture demands subspecialty consultation.[35-36]

Ruling Out Abdominal Injury

In general, patients can be safely discharged with low suspicion of abdominal injury if they have a benign, reliable clinical examination. Given that children rarely have isolated abdominal injury, the lack of other injuries is a reassuring finding. Patients in whom head, spine, chest, and leg injury are excluded have a very low probability of having abdominal injury.[111] Similarly, six clinical findings – hypotension, abdominal tenderness, femur fracture, hematocrit less than 30%, elevated transaminases, and uri-

Risk Management Pitfalls

1. **"There was an obvious femur fracture … I didn't need to get any other imaging."**
   Children's small size and structural vulnerability mean that few will have a major injury in isolation. Don't allow a dramatic or obvious injury to obscure the search for other underlying pathology.

2. **"There were no fractures on the plain films."**
   A child's elastic bones can allow significant internal injury – particularly in the head, chest, and spine – without any signs of obvious external damage.

3. **"It's just a couple of broken ribs."**
   Conversely, the child's pliable bones make any fracture – particularly of the axial skeleton – a marker of significant energy transfer and almost certainly announce the presence of an internal injury.

4. **"He wasn't hypotensive, so I figured he wasn't bleeding."**
   Children can compensate for hemorrhage more effectively than adults and may have no hemodynamic alterations until 30-50% of blood volume has been lost. Subsequent decompensation may be rapid and dramatic.

5. **"Even though she wasn't tender and had no deficits, the lateral c-spine view showed questionable subluxation and what looked like wedged compression fractures, so we called neurosurgery and kept the collar on."**
   The child's cervical spine may have up to 4 mm of antero-posterior subluxation and still be within normal anatomic limits. This pseudosubluxation reduces on flexion and extension. Children's vertebral bodies, at least until ages 9 or 10, are anteriorly wedged physiologically. A radiologist experienced at reading pediatric films should evaluate children's trauma radiographs.

6. **"Most kids ride in car seats; he can't be that badly hurt."**
   Epidemiologic data suggest that child restraint use falls off predictably with age; some studies indicate rates of less than 35% by school age. Children in the grey area between outgrowing their infant car seats and growing into adult seat belts are particularly vulnerable to injury in MVCs.

7. **"The spine is radiologically clear, so we're taking off the c-collar."**
   Spinal cord injury in children may be present without radiologic abnormality of the bony spine (a phenomenon termed SCIWORA). Don't forget that spinal cord injury may also arise as a result of injury to the aorta, either through disruption of cord blood supply or through pressure from an expanding hematoma. An MRI should help differentiate the two lesions and needs to be ordered in any patient with a neurological deficit.

8. **"The abdomen was minimally tender, but FAST was negative so we discharged the patient."**
   Abnormal chest auscultation and abdominal tenderness are worrisome signs for internal injury; don't let an apparently normal chest x-ray, CT scan, or FAST overrule clinical judgment.

9. **"There's a seat belt sign – the patient needs a laparotomy ASAP."**
   Surgical consultation is warranted in these patients; however, only about 10-15% will have surgically correctable intra-abdominal injury. The seat belt sign is, however, an indication for CT scan in a stable patient.

10. **"The family will only get in the way, scare the patient, and faint if we let them into the trauma bay."**
    Although there is a substantial amount of anecdotal data opposing family presence at resuscitation, studies that survey large numbers of parents and providers demonstrate that family presence does not hinder care and can be psychologically comforting to the patient and their family.

nalysis with more than 5 red blood cells/high-power field – are guides to associated intra-abdominal injury. In one review, only 2 of 107 patients with abdominal injury lacked all six findings.[81] A large, prospective trial found no abdominal injuries in patients with a reliable, nontender physical examination,[99] and the absence of abdominal wall bruising indicates a very low likelihood of intra-abdominal injury (a rate of less than 0.1%).[65]

Indications for CT before discharge include:

- Unreliable clinical examination
- Abdominal pain, tenderness, or distension on examination
- Indeterminate FAST
- Negative FAST in the setting of a high-energy mechanism of injury

Patients with a seat belt sign, equivocal physical examination, or positive FAST should also receive CT scans and should be admitted for serial examination. Likewise, patients with evidence of solid organ injury on CT or patients with unexplained free intraperitoneal fluid need to be admitted for observation.[79,81]

Case Conclusion

This young patient's history and physical exam raise several red flags, and you treat her with appropriate urgency. The most immediate potential threat to life is the possibility of airway injury, suggested by the cervical seat belt sign and hoarseness. As she is in no distress and is oxygenating well, you decide to follow this expectantly for the moment, with a low threshold for intubation should her work of breathing increase or stridor develop. You also make a mental note that she needs screening for cervical vascular injury once she is stabilized.

The next major concern is her abdomen. The severity of the collision, the fact that she was inappropriately restrained in adult seat belts, and the presence of unexplained ascites on CT make her clinical findings of tenderness and seat belt sign more ominous. At the very least, she needs admission, serial abdominal examinations, and a repeat CT scan in a few hours. To be on the safe side, you call for a surgical consultation in the trauma bay. When surgery examines her, they find that she now has a rigid, diffusely tender abdomen. The surgical team immediately takes her for laparotomy, where they resect an ischemic section of small bowel that has been avulsed from the mesentery and repair several serosal tears.

Summary

The injury patterns in children following an MVC differ from those of adults for several reasons. First, the anatomic and physiologic characteristics of a child's body – more pliable bones, disproportionally larger head, weaker musculature, larger surface area-to-volume ratio than an adult – make it respond to the traumatic transfer of force differently than that of an adult. Second, passenger restraint systems in vehicles are designed to protect adult occupants, and while they provide some benefit in terms of mortality, they are associated with specific injuries in children. Similarly, children's supplemental restraint systems (booster seats or car seats) can provide protection, but only if properly installed and used – two conditions which are met less frequently than one would expect. Young children are seated in the passenger positions in their vehicles, which changes their relationship to the point of impact and direction of force – and the nature of their injuries – in a collision. Finally, young children, because of their small size and relatively weak structure, are more likely to have multiple injuries than adults for any given traumatic insult.

Knowing these factors and knowing some of the variables of a given collision – speed, direction of impact, other injuries at the scene, method of restraint – can help the clinician remain mindful of injuries that may not be apparent at first glance. Clinical examination is a crucial part of evaluating children after an MVC; decision-making must never hinge on results of imaging and laboratory data alone. Abnormal findings on examination – bruising, tenderness, tachycardia – must never be ignored or dismissed as inconsequential and must all be explained and found benign before a patient can be released. The likelihood of serious occult injury increases with each abnormality uncovered by the workup; the slightly tender abdomen, the seat belt sign, the mild leukocytosis, the unexplained ascites, and the slight anemia are greater than the sum of their parts in hinting at something more sinister beneath the surface. Maintaining a high degree of suspicion for things that may not be obvious is mandatory in preventing missed injuries.

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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, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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111. Brasel KJ, Nirula R. What mechanism justifies abdominal evaluation in motor vehicle crashes? *J Trauma.* 2005;59:1057-1061. **(Review of 56,466 cases in national traffic safety database)**

CME Questions

1. Which age group is most likely to sustain serious injury in a motor vehicle collision, despite the use of restraints?

a. 0-1 years
b. 1-5 years
c. 5-10 years
d. 10-15 years

2. Which collision type is associated with the greatest risk of injury and death?

a. Head-on
b. Lateral (t-bone)
c. Side-swipe
d. Rear-end

3. Thoracic aortic injury occurs most often in which age group?

a. Infants: Because of their car seat buckles
b. Pre-schoolers: Because of airbags
c. School-age children: Because of the seat belt syndrome
d. Teens: Because of steering wheel impact

4. The seat belt syndrome classically consists of which three clinical entities?

a. Abdominal wall contusion, bowel or mesenteric injury, thoracolumbar spinal fracture
b. Abdominal wall hernia, bowel or mesenteric injury, thoracolumbar spinal fracture
c. Abdominal wall ecchymosis, hepatic laceration, thoracolumbar spinal fracture
d. Abdominal wall ecchymosis, bowel or mesenteric injury, aortic transection

5. Lateral impacts are associated with which injury?

a. Hepatic laceration
b. Chance fracture
c. Thoracic aortic disruption
d. Femur fracture

6. The most sensitive initial test for occult thoracic or abdominal injury is:

a. Plain X-ray
b. CT scan
c. FAST
d. Clinical examination

7. A stable patient's chest film shows a wide mediastinum, indistinct aortic knob, and apical capping of the left pleural space. The most appropriate next step would be:

a. ED thoracotomy
b. Admission, with repeat chest x-ray in 24 hours to assure no progression
c. Helical CT of the chest
d. Echocardiogram

8. A teenage boy was an unrestrained driver in a low-speed, head-on collision and has a large bruise from the steering wheel on his chest. His ECG shows frequent PVCs, his troponins are normal, he is pain-free, and his exam is otherwise unremarkable. What is the next appropriate step?

a. Discharge home
b. Admit for 24–48 hours of telemetry observation
c. Cardiology consultation in the ED
d. Admit for cardiac catheterization

9. A patient has a seat belt sign, abdominal tenderness, a normal abdominal CT, and unremarkable labs. What is the appropriate next step?

a. Admit for observation with serial examinations and possible repeat CT
b. Discharge home with instructions to return if pain worsens
c. Discharge home if patient tolerates a meal
d. Exploratory laparoscopy to evaluate occult bowel injury

10. An awake, alert, cooperative 12-year-old arrives in the ED with a cervical collar after a low-speed MVC. Plain films are normal, there is no tenderness on exam, and the patient has full, pain-free range of motion with the neck. What is the next step?

a. CT scan of the cervical spine
b. MRI of the cervical spine
c. Remove cervical collar
d. Re-examine in one hour, remove collar if no change

This article is eligible for trauma CME credits.

Coming In Future Issues

Infectious Upper Airway Emergencies

Blunt Abdominal Trauma

Pulmonary Hypertension

Class Of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

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

Class II
- Safe, acceptable
- Probably useful

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

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

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

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

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

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

Physician CME Information

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

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Date of Original Release: This issue of *Pediatric Emergency Medicine Practice* was published September 1, 2007. **This activity is eligible for CME credit through September 1, 2010.** The latest review of this material was June 4, 2007.

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