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Author:

John Kahler, MD, FAAEM, Clinical Assistant Professor, Department of Emergency Medicine, University of Michigan Hospital and Health Systems, Ann Arbor.

Peer Reviewer:

Steven M. Winograd, MD, FACEP, St. Barnabas Hospital, Clinical Assistant Professor, Emergency Medicine, New York College of Osteopathic Medicine, Old Westbury, NY.

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AHC Media

Winter Sports Injuries

Whether we like it or not, winter is just around the corner. With it comes an entire set of emergency presentations. In addition to influenza, which we have covered several times in the past, cold exposure and icy roads and sidewalks bring an increased number of patients into our EDs, especially in the Northeast.

This paper reviews the most common injuries related to winter sports. Over the past decades, there has been an increase in the variety of winter sports, as well as increased participation by individuals at all levels of fitness. There have also been some improvements made that reduce injuries. For example, breakaway ski boots have reduced the number of tibia and ankle fractures. With some sports becoming more dangerous with jumps and aerial moves, helmets are beginning to be more common, but sadly not fast enough.

This review should help you get through this winter season and perhaps offer some advice for your patients, your family, and yourself.

— Sandra M. Schneider, MD, Editor

Introduction

With the growing participation in winter sports, emergency physicians (EPs) can anticipate a rise in the number of patients seen who are injured while participating in these sports. In addition, older individuals are more likely to continue participation in the sports they love, often attempting the same level of performance that they had decades before. Knowledge of basic fundamentals of these sports, as well as their unique injury patterns, can help the EP anticipate injuries. This ultimately can lead to timely diagnosis and treatment and help avoid missing injuries that might otherwise be overlooked. As with any physician-patient encounter, opportunities may exist for intervention that may help prevent future injuries.

Northern climates have sports that are unique to their environment due to snowfall and ice formation. Some of these sports, such as ice hockey, began as games played on frozen lakes, but now are enjoyed year round and in indoor ice rinks in southern climates such as Florida, Texas, and Arizona. Even indoor skiing and tubing sites are being created and used year round. Thus, the geography of some winter sports is evolving. Given the different environments in which these sports are played, injury patterns are often unique to the specific sport. With the high number of winter sports participants and the ease at which travel around the world occurs, physicians anywhere should be aware of the inherent dangers and injury profiles of these sports.

Many winter sports involve competition at all levels, from the local pick-up hockey games to the Olympic Games. Some of these sports have been around for hundreds of years, such as sledding and skiing, whereas others are relatively new, such as snowboarding. All have seen a growth interest and, thus, development of newer and often safer equipment. It is important to note that some of these sports are still evolving; therefore, injury patterns referenced now are likely changing with time. Examples of this include the increased participation in acrobat skiing that involves aerial maneuvers, back-country snowboarding, and faster snowmobiles. This review is focused more on the recreational

Executive Summary

- While downhill skiing and snowboarding look similar, the injuries associated with each are different. Ski injuries are most often of the knee or the ulnar collateral ligament. Snowboarding is associated with upper extremity injuries. Head injuries occur in both sports.
- Alcohol plays an important role in increasing the number of injuries seen in winter sports. It is most often seen in males involved in aggressive sports such as snowmobiling.
- Skier's thumb is an acute rupture of the ulnar collateral ligament. Patients present with pain at the insertion of the ligament, as well as pain upon pinching the thumb and index finger together. Many patients, but not all, will demonstrate lateral laxity when stressed. Patients should be splinted and receive orthopedic evaluation as an outpatient.
- Open fractures should receive prompt assessment and care. Where there is distal ischemia, reduction may be attempted prior to imaging. Otherwise, the wound should be covered, antibiotics started, and X-rays obtained. Patients should have an orthopedic evaluation in the ED.

sporting activities of the public at large as opposed to the elite athlete, and is meant to be a general review. Many excellent reviews of the specific injuries exist that can be referenced for more detailed information.

Downhill Skiing

Downhill skiing is one of the most popular winter sports worldwide, with more than 200 million participants and growing.[1,2] Snow skiing has been around for many years and has its roots back as far as about 5000 BC in Russia, where the oldest wooden skis were found, and Scandinavia in 2000 BC, where it was primarily a method of transportation.[3,4] It is a sport that is challenging and physically demanding. Downhill skiing generally involves being transported to elevation on a chairlift, then descending down a slope that is either groomed or packed snow or natural powder. The skier wears rigid plastic boots that are attached to the skis by bindings that release when undesirable forces are placed on them, such as occurs when one loses control and crashes. Lightweight ski poles are often held in each hand to help with movement on flatter terrain and sometimes with turning. Helmets traditionally haven't been worn, but their use is becoming more routine. Given the high speeds involved and skill needed, serious injuries occur at a surprisingly low rate. According to the National Ski Areas Association (NSAA) data, serious injuries occur one per one million skier/snowboarder visits. The 2011-2012 season saw 54 fatalities and 510 serious injuries in the United States. Injuries in general have dropped over the years to about two to three per 1000 skier-days.[2] The reason is unclear, but it is generally thought that better equipment such as bindings may play a part. Injuries from skiing occur most commonly from ground level falls, but also commonly occur from collisions and falls from chair lifts.[1,5]

Knee sprains are the most common injury in skiers, making up nearly one-third of total injuries in adults.[2,6,7] The medial collateral ligament (MCL) and anterior cruciate ligament (ACL) are involved in most cases. Traditionally, skiing was associated with a high incidence of mid-shaft tibia-fibula fractures, but this injury has declined in incidence significantly as ACL injuries have increased. It is generally believed that releasable bindings are the main reason for this trend. The rise in ACL injuries may also represent better recognition in light of MRI, arthroscopy, and the general availability of reparative techniques now widely used. Emergency evaluation of knee injuries should include a physical examination. As with all extremity injuries, evaluation of distal motor, sensory, and vascular function is important. Injury to the anterior cruciate ligament is assessed with a Lachman test or the pivot shift test. The Lachman test is done with the patient supine and knee bent. The examiner pulls on the upper calf and looks for excessive movement of the joint. At times, it is necessary to compare the two sides. The pivot shift test is done with the knee extended. The examiner twists the knee while pushing on the foot. There are good videos on YouTube for those unfamiliar with the exam. Both the Lachman and pivot shift test are positive when there is a complete tear of the ligament and, therefore, joint instability. In cases of acute injury, the test may be negative due to muscle spasm. As the test can be painful in an acute injury, aggressive technique is not indicated, as a patient with an ACL tear will be stable in a knee immobilizer.

The diagnosis of an MCL tear will have tenderness over the insertion of the ligament. Testing involves applying vagus and varus stress to the knee. Patients should receive X-rays to rule out a fracture, and a knee immobilizer along with orthopedic follow up. Many ACL injuries will ultimately require operative repair.[8] Some MCL tears can be managed conservatively.

Approximately one-third of downhill skiing injuries involve the upper extremity, mainly the shoulder and ulnar collateral ligament in the thumb (commonly referred to as gamekeeper's or skier's thumb).[2] A wide range of shoulder injuries occur, as listed in Table 1. Evaluation of shoulder injuries initially should involve a careful physical exam assessing for any neuro-vascular

Table 1: Shoulder Injuries

More Common	Less Common
• Acromioclavicular separation • Clavicle fractures • Rotator cuff injury • Glenohumeral instability	• Greater tuberosity fractures • Proximal humerus fractures • Scapula-clavicular separations • Acromion fractures • Biceps tendon strains • Biceps tendon dislocation • Glenoid fractures • Humeral head fractures • Trapezius strains

Table 2: Head Injury Patterns

Occipital 31%
Frontal 29%
Diffuse 23%
Temporal 14%
Parietal 3%

compromise, deformities, or any loss of range of motion (ROM). X-ray imaging is commonly needed and, aside from glenohumeral dislocations, most injuries can be treated with a sling, analgesics, passive ROM exercises, and close follow up. Patients must be educated as to the importance of keeping the shoulder mobile, even early in treatment, to avoid the devastating "frozen shoulder" or adhesive capsulitis that can evolve with immobilization.[9] This is particularly true in older patients.

Sprain or strain of the ulnar collateral ligament (UCL) of the metacarpophalangeal joint of the thumb is the most common upper extremity injury, making up almost 10% of overall injuries.[2] It is generally believed that this injury occurs in high frequency due to the use of ski poles. When a skier falls on an outstretched open hand with the pole in the palm, undue forces are placed on that joint. It is theorized that the straps that wrap around the wrist increase the likelihood of injury by not allowing the poles to fall away from the skier's body during a crash. Therefore, current recommendations favor the use of ski poles without wrist straps. Patients present with pain at the site of insertion of the ulnar collateral ligament as well as pain with pinching the thumb and index finger. Some recommend X-rays prior to stressing the ligament, as it can potentially displace a nondisplaced fracture. Lateral laxity of greater than 35 degrees or more than 15 degrees when compared to the other side suggests a complete tear. However, lateral laxity is not always present shortly after an acute injury due to swelling and muscle contraction. Therefore, all patients with suspected skier's thumb should have a splint applied and be referred to an orthopedist within one week.

Head injuries are commonly seen in the downhill ski population. They are the leading cause of death in ski accidents and the leading diagnosis requiring admission of child and adolescent skiers.[1,5,10] Helmet usage is increasing and is done on a voluntary basis. Although controversy does exist, wearing a helmet has been shown to reduce the risk of head injuries.[1] Head injuries occur primarily from falls on the slopes, but collisions with other skiers and snowboarders run a close second.[1] Evaluation of the patient with a skiing-related head injury involves a careful neurologic assessment and appropriate spinal precautions. Although there are no specific guidelines for the care of skiers with a concussion, guidelines for other athletes should apply. These guidelines are reviewed later in this paper.

Spinal injuries occur much less often in skiers as opposed to snowboarders, but this gap may be closing due to the increase in skiers involved in aerial maneuvers such as jumps.[2]

Multisystem trauma is not often seen in downhill skiing, but when it dose occur, it should be managed in a standard fashion. There is growing concern that multisystem trauma may become more of a problem with the increasing popularity of backcountry or out-of-bounds skiing and ski jumping.

Snowboarding

Snowboarding is one of the fastest growing winter sports and has only been mainstream for the past few decades. Modern snowboarding was developed in the 1960s and, thus, was a fairly recent addition to the Olympic Games in 1998.[11] The number of U.S. snowboarders was estimated to increase from 4.3 million in 2000 to nearly 6.1 million in 2010, with the largest cohort ages 12-24.[12,13] The number of recorded U.S. fatalities in the 2009-2010 season was 13 (12 male/1 female).[12,13] Most snowboarding is done at standard ski resorts, with the majority of ski resorts allowing both traditional skiing and snowboarding. There are some ski resorts that do not allow snowboarding.

Snowboarding is performed by descending down an incline on a board with both feet secured to the board by bindings. Since both feet are secured to the same object, the movement patterns differ and, thus, the injury patterns seen are different. Another major difference from skiing is that the bindings on the snowboards are mostly non-releasable, as opposed to skis, which are meant to release if enough torque is placed on them.

In contrast with alpine skiing, snowboarding is associated with more upper extremity injuries (most commonly wrist injuries), shoulder

Table 3: Cross-country Skiing Injuries

Overuse	Trauma
• Medial-tibial stress syndrome • Achilles tendon problems • Low back pain • Stress fracture (metatarsal, sesamoid bone)	• Ankle sprain and fracture • Muscle ruptures • Knee ligament sprains • Shoulder dislocation • Acromial separation • Rotator cuff tear • Ulnar collateral thumb sprain* • Hip fracture *most common upper extremity injury

Figure: CT of Subdural Hematoma

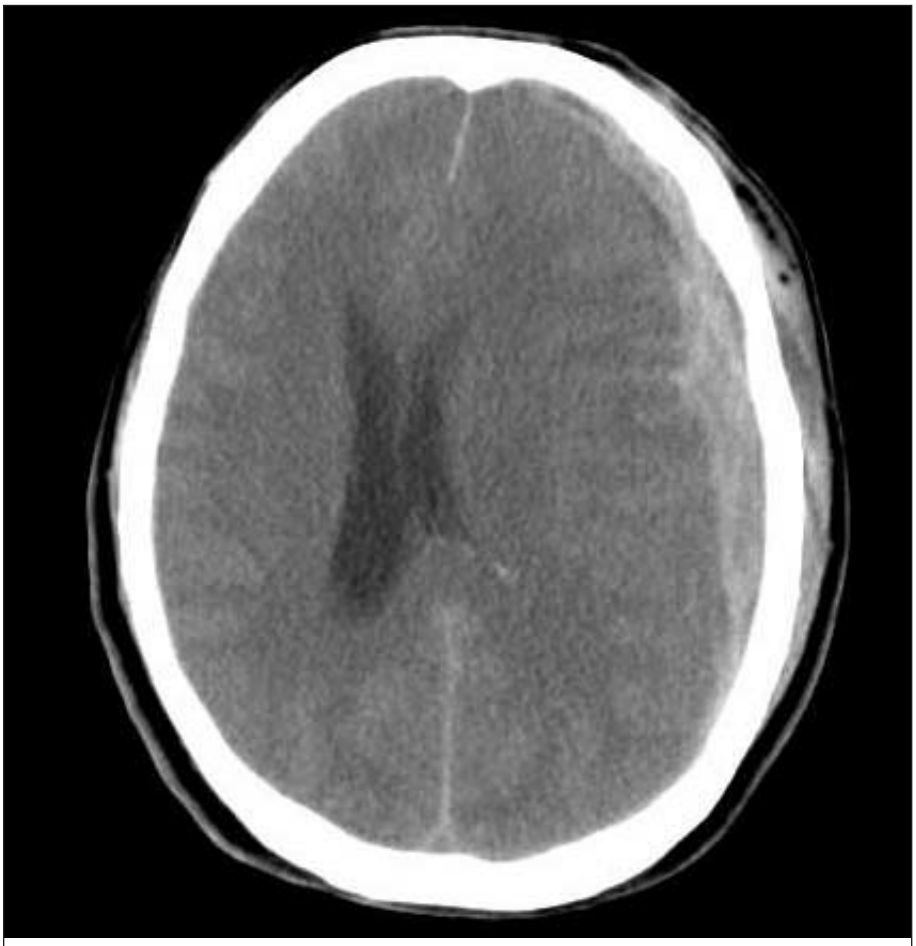

Image used with permission from: Werman HA, Brogan M, Falcone R. Radiologic evaluation of head trauma: Identifying the spectrum of injuries. *Trauma Reports* July 2006.

injuries, ankle injuries, spinal injuries, and head injuries.[14-18] (*See Table 1.*) Head injuries make up nearly one-quarter of snowboarding injuries and are more likely to be seen in male participants. Head injuries account for nearly one-half of the snowboarding injury transfers to trauma centers.[1,3] Most of these head injuries occur from loss of the board edge and falling on mild to moderate slopes.[1] Snowboarders are more likely to suffer from intracranial hemorrhage requiring craniotomy than skiers, and more frequently require longer rehabilitation and ongoing care. Interestingly, snowboarders are more likely to sustain a subdural hematoma as compared to skiers, who are more likely to have a skull fracture.[1] (*See Figure for a CT image of subdural hematoma.*) Fortunately, most head injuries seen are mild, and the most common diagnosis is concussion. Table 2 shows the incidence of injury to various regions of the brain.[19] A growing use of helmets has been associated with a decrease in the number of head injuries and may change some of these patterns of injury.[20,21]

A variety of upper extremity injuries/shoulder injuries occur with snowboarding as with skiing.[22] (*See Table 1.*) Injury patterns have changed slightly over time, with an increase in clavicle fractures seen, along with a decrease in medial collateral ligament (MCL) and ankle injuries in snowboarders.[15] The major mechanism of injury in snowboarding is falling forward, with torsion of the body coming in second.[16] This explains why the upper extremity sustains most of the trauma. There are data to suggest that wrist protectors may aid in the prevention of wrist injuries, especially in beginners who are much more prone to wrist injury.[14]

Wrist injuries should be assessed by determining neurovascular status and using X-ray imaging when indicated. The most common fracture is the distal radius (Colles' fracture), which in many cases requires closed reduction to properly align. If displaced, reduction can be performed with or without conscious sedation and/or the use of a hematoma block. Several excellent reviews exist regarding safe and effective sedation in the emergency department.[23-25] A splint is then applied and orthopedic referral suggested.

Clavicle fractures, for the most part, are non-operative and are usually managed in a sling. Clavicular straps that once were popular are not commonly used, as they may impinge on nerves and are unnecessary for alignment. Clavicle fractures

Table 4: Concussion Signs and Symptoms

Signs Observed by Medical Staff	Symptoms Reported by Athlete
• Appears dazed or slurred • Confused about assignment • Forgets sports plays • Unsure of game, score, or opponent • Moves clumsily • Answers questions slowly • Loses consciousness transiently • Shows behavior or personality changes • Can't recall events prior to impact • Can't recall events after impact	• Headache or "pressure" in head • Nausea • Balance problems or dizziness • Double or fuzzy vision • Sensitivity to light • Sensitivity to noise • Feeling sluggish or slowed • Feeling foggy or groggy • Does not "feel right"

have a fairly high incidence of malunion, especially the distal third of the clavicle, but function is usually preserved and surgery is usually unnecessary.[26] The physical exam should focus on ruling out a brachial plexus injury from bone fragments, performing a vascular assessment of the upper extremity, and assuring adequate lung sounds bilaterally. The most vital aspect of management of clavicle fractures is to educate the patient that mobility of the shoulder is vital and must be maintained. This is usually done in the acute phase by having patients perform pendulum exercises. A resulting frozen shoulder from adhesive capsulitis is a devastating outcome for those patients who keep the shoulder immobile for too long.

Snowboarding lends itself to the more frequent use of terrain parks, which are separate areas of alpine ski resorts that have above the ground metal rails, jumps, and half pipes. Snowboarding in these areas often involves aerial maneuvers, which are associated with an increased risk of head, spine, and abdominal injury and tend to be more serious injuries.[18,27] As a result of this greater frequency of abdominal injuries, splenic injuries are seen more often in snowboarders, with a male preponderance.[28] Thus, the clinician should inquire as to whether the injury occurred in a terrain park or involved any aerial maneuvers. If so, a level of suspicion should focus the clinical evaluation on occult intra-abdominal injury, such as splenic laceration and spinal injury. Given the high incidence of head injuries and the possible concurrent alcohol use, a low threshold for imaging should exist, along with appropriate spinal precautions. Intra-abdominal injuries are best excluded by contrast-enhanced computerized tomography (CT) of the abdomen and pelvis; however, a quick ultrasound of the abdomen (FAST) can help determine the presence or absence of free fluid in the abdomen.

There is a growing interest and participation in snowboarding and skiing in the back country. Paralleling this trend is a rise in the number of deaths from snow avalanche.[3] Death from avalanche usually results from asphyxiation, and the snowboard may predispose participants to a higher risk of death when avalanche occurs, since the bindings don't release. This makes it harder for the victim to dig out when buried and for others to extract the snowboarder from under the snow. This form of boarding exposes people to more risk of environmental hazards, such as hypothermia, frostbite, avalanche, and falling into crevasses. Standard mountaineering skills are warranted. Back-country skiing should be reserved for those with intermediate to expert snowboarding skills, mountaineering experience, those using appropriate equipment, and those who are physically fit. It should not be done alone. Otherwise, they place themselves in a higher-risk situation.

Cross-country Skiing

Cross-country skiing (also referred to as ski touring) is a type of Nordic skiing in which the skier uses slender skis and poles to move across snow-covered terrain that is fairly flat. As a form of Nordic skiing, only the toe of the boot, and not the heel, is fixed to the ski. Other forms of Nordic skiing include ski jumping, telemark skiing, and biathlon. Cross-country skiing is most popular in Scandinavia and Canada, with some participation in the United States and Europe.

Injury data are scarce pertaining to cross-country skiing since it often takes place in non-designated areas and is not as regionalized like downhill skiing, where clinics and local hospitals will concentrate the injuries for data collection. This form of skiing at the recreational level and competitive level is considered an endurance sport and, thus, is fraught with mostly overuse injuries (75%) vs. acute trauma (25%).[29] Of the traumatic injuries seen, most occur on downhill terrain and involve the lower extremity.[30] There are a variety of injuries seen, but good data don't exist as to the specific incidence of each. (*See Table 3.*) The most common overuse injuries occur in the shoulder and upper torso.[31] The most common traumatic injuries are MCL and ulnar collateral ligament (UCL) thumb sprains.[32] The latter are usually the result of a fall while the skier is holding ski poles.

There are two major techniques to cross-country skiing: classic and skating. The classic technique involves more of a shuffling or gliding forward on one ski, while the skating technique involves more of a lateral push off similar to skating. There has been no significant difference in injury pattern found between the two techniques.[33] Prevention strategies should focus on strength

Table 5: Grading of Open Fractures

Grade	Characteristics
I	Small, < 1 cm, clean wound
II	Larger, > 1 cm, clean wound without extensive soft-tissue damage
III	Extensive tissue laceration, damage, or loss, or segmental fracture; fractures that have been open for > 8 hours

training and conditioning, proper technique, and letting go of the poles when falling. Use of poles without wrist straps is recommended, as it is for downhill skiing to prevent UCL injuries.

Ice Skating

There is a paucity of literature regarding injuries during ice skating. Ice skating is enjoyed as a recreational activity as well as a competitive venue. In most settings, skaters do not wear protective equipment.[34] As one would guess, collisions with the ice are a major source of injury. This is in contrast to ice hockey, in which players are heavily padded and, thus, don't sustain many injuries due to impact with the ice surface. Injuries occur more often in beginning skaters,[35] with fractures and lacerations of the hand quite common.[36] Falls on the outstretched hand or onto the elbow are common, with the associated fractures to the wrist and elbows. Skate blades are particularly sharp, especially for more serious skaters, and can cause significant lacerations. In one case seen by the editor, the blade penetrated the anus, leading to an extensive rectal laceration. As with many other sports, alcohol tends to increase the risk of injury.[37]

Another common injury is a fracture of the coccyx. The diagnosis is generally made clinically, as imaging is difficult and high radiation levels are needed. Finding a fracture does little to alter the treatment or prognosis. Open fractures are rare but should be ruled out with an appropriate rectal examination. Most pharmacies carry donut pillows, which are designed to keep weight off the coccyx. Analgesics and time are needed. Some patients will find stool softeners to be beneficial.

Figure skaters who train regularly are more skilled and, thus, prone to overuse injuries vs. traumatic injuries.[38,39] Stress fractures are not uncommon injuries in figure skaters.[38]

Ice Hockey

Ice hockey is a team sport in which skaters use sticks to move a hard rubber puck around the ice surface while attempting to put it in the opponent's net. It is a fast-paced sport that is played around the world, but is most popular in Canada, the United States, and Europe. The International Ice Hockey Federation has 52 full members (countries in which field teams in international competition). It is the official winter sport of Canada and dates back to the first official recorded game in Montreal in 1875.[40] Originally played on frozen ponds, lakes, and rivers, it has evolved into a worldwide sport for which many countries field Olympic teams. Like other winter sports, involvement in ice hockey grew over the past decade, with more than 500,000 players registered in the United States and more than 600,000 registered in Canada for 2012-2013. These statistics don't take into account kids who play on ponds, lakes, and parks and doesn't include the thousands of adults who play in various leagues throughout the United States and Canada.

Ice hockey is primarily played in indoor ice arenas where the field of ice is surrounded by boards. However, the boards also provide another obstacle with which players can collide and become injured. Injuries from ice hockey are the result of trauma (80%) and overuse (20%).[41] Injuries can occur in a number of different ways. Most commonly, injuries occur during body checking, in which a defensive player attempts to gain possession of the puck by a body-to-body collision intended to separate the puck carrier from the puck.[42] These collisions create injury more commonly in open ice than when a player is checked into the boards.[43] Defensive players have been shown to have a slightly higher rate of injury.[44] After body checking, injuries occur commonly from contact with the sticks or pucks. Common injuries to the upper extremity include scaphoid fractures, UCL injury, and acromioclavicular joint sprains and dislocations.[41] In contrast, soft-tissue injuries predominate in the lower extremity, such as thigh contusions, adductor hip strains, and MCL injuries.[41]

Controversy exists as to the optimal age to begin body checking in ice hockey. In the United States, body checking used to begin around age 11-12 (peewee level), compared to Quebec where body checking begins at age 13-14 (bantam level). Recently, body checking in the younger players was found to be associated with a three-fold increase in game-related injuries.[45] This has prompted USA hockey to change the age of body checking to the bantam level (ages 13-14). This move seems intuitive to many, but proponents of early body checking argue that if physical contact is allowed from the beginning, kids will learn to skate with more awareness and will better protect themselves. Injuries due to physical contact occur at a much greater frequency the first year or two after the introduction of body checking, but these spikes in injury incidence then decline after players get used to this style of hockey.[46]

Concussions are some of the more common injuries in ice hockey and, therefore, assessment and management as well as return to play are vital skills. Signs and symptoms of concussion are listed in Table 4

and typically are most severe during the first 24-48 hours, and then slowly abate over the following days to weeks.[47] Players diagnosed with a concussion should be removed from play (including non-contact practice) until a full evaluation is performed. Depending on the severity of symptoms, a player may require brain imaging if there is a loss of consciousness, abnormal neurologic exam, or other concerns for intracranial hemorrhage. In most cases, imaging is not necessary. Rest with as little stimulation as possible is optimal. Some athletes with ongoing symptoms should be referred for neuropsychological testing (NP), which is often more sensitive for detecting brain dysfunction from concussion than the physician's clinical exam. Most players, however, can be managed without NP testing.[48]

The CDC has published information for general use by clinicians, which includes a pocket card. Recognition of concussion is often easier than making return-to-play decisions. It is not uncommon for hockey players who have sustained a concussion to present to the emergency department for evaluation and foremost on their mind is "When can I play again?" Return-to-play decisions should be made by a physician who has been trained in the evaluation and management of concussions.[48] Generally, return to play is a graduated stepwise process in which first the activity level is increased to see if any recurrence of symptoms occurs. If so, the patient goes back to the beginning and must undergo another period of rest.[48]

Dental injuries are common, particularly in athletes who do not wear mouth guards. While well-fitting mouth guards can be custom fitted by a dentist, there is no evidence that these prevent injury better than less expensive store-bought devices. Helmets with face shields also prevent dental and facial injuries, once far more common in the sport.

Injury patterns at the youth level differ from those at the high school, college, and adult elite levels. At an elite level, most injuries occur during competition as opposed to practice.[44] Youth hockey players are much more likely to experience concussion or various soft-tissue contusions, as opposed to older athletes who are more likely to have sprains or ligamentous injury.[45] In addition, the preseason practice injury rate was found to be greater than twice that of regular season practices.[43] Most of these injuries include various contusions, strains, and sprains from body-to-body contact, with the most common serious injury being medial collateral ligament (MCL) tear.[44]

Snowmobiling

Snowmobiling is a popular sport that involves operating a motorized sled on snow and ice surfaces. It is enjoyed by more than two million people in North America and accounts for approximately 14,000 injuries and 200 deaths annually.[49] Snowmobiling often involves high speeds, sometimes in excess of 100 mph, on natural terrain; thus, multisystem trauma and head injuries are a leading cause of morbidity and mortality.[50] Head injuries are the leading cause of death in snowmobiling accidents in both adults and pediatric populations.[50-52] Snowmobiling injuries are, for the most part, due to human error, and male gender and alcohol consumption have been found to be the biggest risk factors.[51,53] Interestingly, only 15% of snowmobile accidents occur on groomed, designated trails where roughly 80% of riding occurs.[1] That is to say that most injuries occur while riding on ungroomed trails and on roadways. Several risk factors have been identified, with the most common being poor lighting conditions, which explains why riding groomed trails is associated with safer snowmobile operation.[50] Other risk factors include alcohol consumption and excessive speed.[50] Snowmobiling is enjoyed by a wide age range, including older children. In children, the most common injury is to the head, followed by the extremities, with head injury being the most common cause of death.[54] Despite this, helmet laws are often non-existent or do not pertain to private property in many states.[55] Perhaps the most alarming statistic is the finding that only 35% of riders who were fatally injured were wearing a helmet.[56]

Given the likelihood of high-speed injuries with snowmobiling, emergency physicians should become very familiar with ATLS and the management of the multisystem trauma patient. Many snowmobile accidents involve multisystem trauma and concurrent alcohol intoxication. This requires a high index of suspicion for occult injuries.

For high-speed crashes or those involving intoxicated patients, a CT scan of the chest, abdomen, and pelvis may be indicated, even if the physical exam is equivocal or if the patient is altered. For isolated fractures not involving high-speed crashes, CT is not necessary. Displaced and open fractures require urgent attention with an initial assessment of neurovascular status. If intact, then reduction can usually wait for X-ray imaging. However, where there is vascular insufficiency distal to the injury, reduction can be attempted prior to X-rays, especially if imaging will be delayed. Open fractures should have minimal exposure. They should be quickly irrigated if obvious contamination is evident and covered with a sterile dressing. Intravenous antibiotics are indicated prophylactically. Open fractures are graded as shown in Table 5, which has implications for treatment.

Clearly the above information suggests that preventative strategies can target high-risk behaviors such as drinking alcohol and operating a snowmobile in unfamiliar territory after dark. Also, programs aimed at improving helmet compliance may yield better injury statistics.

Sledding

Winter snow sledding is a sport that is enjoyed in northern climates by people of all ages, but most commonly children and adolescents. Sledding is most commonly defined as travelling downhill on snow with some sort of sled, which can range from the elaborate flexible flyer to

an improvised sled such as a cafeteria tray. The activity is performed in a seated or lying position, either head first or feet first. Sledding is done in both the recreational and competitive venue (bobsledding, luge, skeleton). The activity is enjoyed in rough natural environments as well as structured park environments designed specifically for this activity.

The injury patterns can vary slightly depending on the environment in which the activity is done. In more rural, natural environments, collisions are more likely to occur with structures such as trees and rocks and are less likely with other sledders. In contrast, public sledding parks often have higher volumes of sledders, and collisions with other sleds and with pedestrians are more likely.

Sleds come in a variety of different forms and vary in complexity from simple sheets of plastic to higher-tech sleds made of wood and metal with maneuvering capability. Sleds can be single-person vehicles such as saucers or multi-person toboggans.

One review found that there were an estimated 57,000 ED visits in the United States during the 2001-2002 winter for sledding-related injuries.[57] Sledding speeds, even in recreational areas, can be significant. In one study in Rochester, NY, the average maximum speed attained during a run was 19 mph, with the highest recorded as 25 mph. Plastic tube devices were the fastest. In this study, no individual was observed wearing a helmet.[58] Although sledding is enjoyed by multiple age ranges, most injuries occur in the 5- to 14-year-old age range, and are the result of falls or collisions.[57] The body part injured has also varied depending on the age, with children younger than age 9 most likely to experience head and neck injuries. Older children (7-18 years) were more likely to sustain an extremity injury.[59] Sledding accidents that lead to injury are most commonly from a collision with a stationary object.[59]

Opportunities exist for injury prevention, given that more than 50% of injuries were of the head and neck region, but less than 5% of sledders wore helmets.[59] Injury prevention can also be focused on sled construction and the development of safe obstruction-free sledding hills.

Special Considerations in the Older Adult

The aging Baby Boomer generation is participating in athletic activities in large numbers. Despite increased fitness of this group, age-related effects need to be addressed. Older adults are more susceptible to hypothermia and dehydration. They are less likely to drink when dehydrated, as their thirst response may be blunted or they may be taking diuretics. Even with exercise and calcium/vitamin D replacement, bones weaken with age, making fractures more common.

Physicians can intervene by helping advise patients as to proper attire for winter sports. Layering of clothing is vital, with the base layers not made of cotton but instead with synthetic fibers that wick moisture away from the body. The next layer should be an insulating layer that helps maintain core temperature. The current trend is to wear a separate outer shell made of a breathable, water- and wind-resistant material such as Gore-Tex. This way, if temperatures rise, then the insulating layer can be removed, leaving just the base layer and outer shell. Also, hydration during outdoor winter sports can be easily maintained using various products such as camelbacks, small lightweight backpacks that are hydration compatible, or waist-mounted water bottles.

Perhaps most importantly, head injuries can be more serious. A large number of older adults are anticoagulated, most often for atrial fibrillation. In addition, with age the brain shrinks, with increased tension to the bridging veins. Relatively minor injuries can cause bleeding in these patients. Because there is "extra space" between the brain and skull, symptoms may be less evident or may be delayed. Many providers have a lower threshold for ordering a CT scan in these patients compared to younger adults. Because there is a small risk of delayed bleeding in anticoagulated patients, some providers observe these patients for six hours, repeating the CT scan at that time. It has been shown that patients on clopidogrel have a higher incidence of intracranial hemorrhage after head injury when compared to those on warfarin.[59] However, those on warfarin are more likely to have a delayed hemorrhage, albeit this is rare.[60]

Summary

With millions of people involved in winter sports, injuries presenting to emergency departments in northern climates have become a common occurrence. Certain injury patterns exist for each winter sport, which can be useful to the clinician when assessing an injured winter athlete. Musculoskeletal injuries predominate, with extremity injuries and head injuries the most common. Multisystem trauma does occur due to high speeds involved in some winter sports, such as extreme skiing, snowboarding, and snowmobiling. Thus, emergency physicians should have training and systems in place to stabilize and manage these patients. EPs should be familiar with Advanced Trauma Life Support (ATLS) principles in order to optimize outcomes. Opportunities exist for preventative public health measures and interventions by physicians that can reduce these injuries.

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Emergency Medicine Reports

CME Objectives

Upon completion of this educational activity, participants should be able to:

- recognize specific conditions in patients presenting to the emergency department;
- apply state-of-the-art diagnostic and therapeutic techniques to patients with the particular medical problems discussed in the publication;
- discuss the differential diagnosis of the particular medical problems discussed in the publication;
- explain both the likely and rare complications that may be associated with the particular medical problems discussed in the publication.

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Physician CME Questions

1. Which of the following have been identified as a common risk factor for snowmobile injuries?
   A. poor lighting conditions
   B. alcohol usage
   C. excessive speeds
   D. A, B, and C
   E. none of the above

2. Which of the following statements regarding cross-country skiing is *not true*?
   A. Ulnar collateral sprain is the most common upper extremity injury seen.
   B. Overuse injuries occur at a greater frequency than traumatic injuries.
   C. Skating technique is associated with a higher incidence of overuse injuries.
   D. Medial-tibial stress syndrome is a common overuse injury seen in cross-country skiers.

3. An 18-year-old skier falls 20 feet off a chair lift and is brought to the ED with what appears to be an open tibia fracture. Which of the following statements is true regarding optimal treatment?
   A. If the fracture is non-displaced and the wound clean and small, a sterile dressing should be applied, the leg immobilized in a splint, and outpatient orthopedic follow up should be arranged.
   B. IV antibiotics should be given empirically in the emergency department.
   C. Reduction of a displaced fracture should never be attempted without X-ray imaging to evaluate and confirm the fracture.
   D. Because the tibia is a large bone, CT scan of the abdomen should be performed even if there is no abdominal tenderness.

4. Which of the following statements regarding downhill skiing is true?
   A. Knee sprains are the most common downhill ski injury.
   B. The leading cause of death in ski accidents is abdominal trauma from impact with a stationary object.
   C. The use of ski helmets has not been shown to decrease head injuries.

D. Shoulder dislocations should be immobilized for 2-3 weeks to prevent re-dislocation.

5. Which of the following statements is true regarding snowboarding?
   A. The introduction of quick-release bindings has reduced the number of lower-extremity injuries.
   B. Snowboarding pre-dates skiing, as it is a natural extension of sledding.
   C. Snowboarding has been implicated as a major cause of collisions with skiers.
   D. The incidence of death from avalanche has been increasing in snowboarders.

6. A 5-year-old child is brought to the emergency department after sustaining a sledding accident. Which of the following is true regarding sledding accidents?
   A. Sledding accidents are usually minor and are rarely seen in the ED.
   B. The head and neck are the most frequently injured body parts in this age group.
   C. Going off jumps is the most common mechanism of injury in sledding.
   D. Parks with designated sledding areas have the highest incidence of sledding injuries due to crowded conditions.

7. Injury during ice hockey games occurs mostly from getting hit by another player's stick or the puck.
   A. true
   B. false

8. A 17-year-old high school hockey player is brought to the ED for evaluation of a concussion sustained that night in a hockey game. He did not lose consciousness, but reports ongoing mild headache, slight dizziness, and nausea. He is neurologically intact. The most appropriate management includes which of the following?
   A. Order a CT scan of the brain and admit for monitoring.
   B. Order a CT scan of the brain and discharge cleared to play if the scan is negative.
   C. Discharge home with follow-up sports medicine evaluation and instructions for no further hockey until re-evaluated.
   D. Discharge home with neurosurgery referral.

9. It is recommended that skiers use poles without wrist straps.
   A. true
   B. false

10. Stress fractures are rare in competitive figure skaters.
   A. true
   B. false

In Future Issues

Treatment of Shock Using Vasopressors

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Winter Sports Injuries

Shoulder Injuries

More Common	Less Common
• Acromioclavicular separation • Clavicle fractures • Rotator cuff injury • Glenohumeral instability	• Greater tuberosity fractures • Proximal humerus fractures • Scapula-clavicular separations • Acromion fractures • Biceps tendon strains • Biceps tendon dislocation • Glenoid fractures • Humeral head fractures • Trapezius strains

Head Injury Patterns

Occipital 31%
Frontal 29%
Diffuse 23%
Temporal 14%
Parietal 3%

Cross-country Skiing Injuries

Overuse	Trauma
• Medial-tibial stress syndrome • Achilles tendon problems • Low back pain • Stress fracture (metatarsal, sesamoid bone)	• Ankle sprain and fracture • Muscle ruptures • Knee ligament sprains • Shoulder dislocation • Acromial separation • Rotator cuff tear • Ulnar collateral thumb sprain* • Hip fracture *most common upper extremity injury

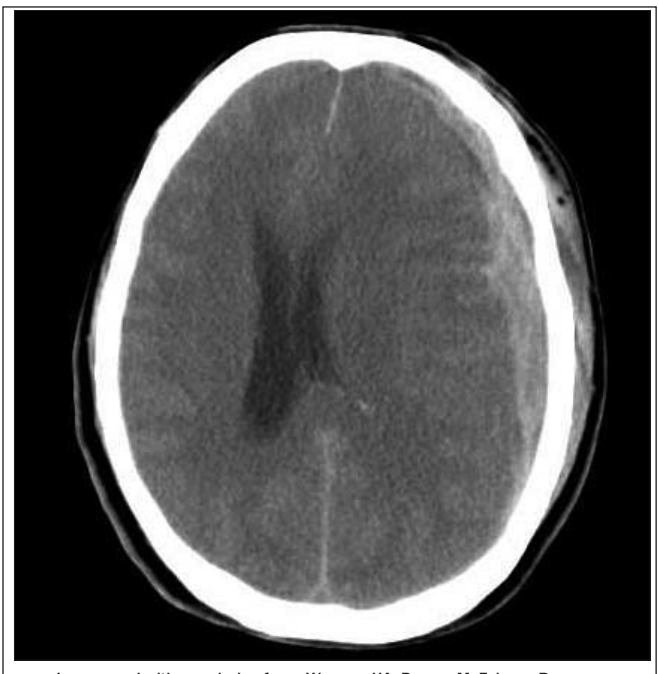
Concussion Signs and Symptoms

Signs Observed by Medical Staff	Symptoms Reported by Athlete
• Appears dazed or slurred • Confused about assignment • Forgets sports plays • Unsure of game, score, or opponent • Moves clumsily • Answers questions slowly • Loses consciousness transiently • Shows behavior or personality changes • Can't recall events prior to impact • Can't recall events after impact	• Headache or "pressure" in head • Nausea • Balance problems or dizziness • Double or fuzzy vision • Sensitivity to light • Sensitivity to noise • Feeling sluggish or slowed • Feeling foggy or groggy • Does not "feel right"

Grading of Open Fractures

Grade	Characteristics
I	Small, < 1 cm, clean wound
II	Larger, > 1 cm, clean wound without extensive soft-tissue damage
III	Extensive tissue laceration, damage, or loss, or segmental fracture; fractures that have been open for > 8 hours

CT of Subdural Hematoma



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Trauma Reports

PRACTICAL, EVIDENCE-BASED REVIEWS IN TRAUMA CARE

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Authors:

Terrence Curran, MD, Trauma, Critical Care, General Surgery, Morristown Memorial Hospital, Morristown, NJ.

Young Hwan Chun, MD, Surgical Resident, Morristown Memorial Hospital, Morristown, NJ.

Peer Reviewer:

Dennis Hanlon, MD, FAAEM, Vice Chairman, Operations, Allegheny General Hospital, Department of Emergency Medicine, Associate Professor of Emergency Medicine, Pittsburgh, PA.

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Blunt Abdominal Trauma in Pediatrics

Pediatric abdominal trauma is common, with delays in diagnosis and treatment resulting in an increased rate of complications. Advances in technology have made evaluation of intra-abdominal injuries increasingly less invasive, but clinical diagnosis and an appropriate level of suspicion are still the most important variables in management. The authors review common intra-abdominal injuries and the current standard for diagnostic evaluation and management.

— Ann M. Dietrich, MD, Editor

Introduction

Trauma is the number one cause of death in the pediatric age group.[1,2] Blunt trauma is much more common than penetrating trauma and can present a serious challenge to care providers.

Blunt abdominal trauma accounts for the large majority of abdominal injuries in the pediatric population. Blunt abdominal trauma far outnumbers penetrating abdominal trauma,[3] and the mechanisms of injury vary among the different age groups. Motor vehicle-related injuries, whether as vehicle occupants, bicyclists, or pedestrians, are the most common cause of pediatric blunt abdominal trauma.[4] Child abuse is the leading cause of homicide in infants and may occur secondary to blunt abdominal injury. Other mechanisms of blunt abdominal trauma include falls, sports, and recreation-related injuries.

There are specific injury mechanisms that should lead the practitioner to suspect the presence of intra-abdominal injury,[5] such as a handlebar injury (*see Figure 1*) to the upper abdomen and seat belt signs from a motor vehicle accident.

Management of intra-abdominal injury has undergone a major shift to non-operative management during the past decade. This shift to non-operative management has been possible due to the ability to accurately evaluate the abdomen and pelvis with computed tomography (CT) scan and ultrasound. Although most blunt injuries can be successfully managed non-operatively, the decision not to operate must be a thoughtful and rational decision. Early involvement of a surgeon experienced in the management of traumatic abdominal injuries in children is considered imperative.[7]

Pathophysiology

It must be remembered that children are not small adults. They have a unique anatomy, a different physiologic reserve, and a more pliant skeleton. As a result of unique anatomy and physiology, the injury patterns in children are different.[8]

Children's intra-abdominal organs are more closely situated to each other, and the likelihood of multiple organs being injured is higher in pediatric blunt abdominal trauma. There is also less protective adipose tissue, connective tissue, and muscle mass. This results in the force of the blow transmitting more energy to internal organs and increasing the chance of intra-abdominal injury.[9,10]

Executive Summary

- There are specific injury mechanisms that should lead the practitioner to suspect the presence of intra-abdominal injury, such as a handlebar injury to the upper abdomen and seat belt signs from a motor vehicle accident.
- It must be remembered that a negative FAST exam alone does not exclude hemoperitoneum or intra-abdominal injury, and repeated assessment is warranted to ascertain a change in the patient's clinical condition.
- Since most solid organ injuries do not require surgical intervention, a positive DPL has limited clinical significance in the management of solid organ injuries.
- One study shows that children with no evidence of abdominal wall trauma, no abdominal tenderness, a GCS greater than or equal to 14, no vomiting, no thoracic wall trauma, and normal breath sounds are at very low risk of an intra-abdominal injury and do not require CT scan to exclude injury.
- The spleen is the most commonly injured organ in pediatric abdominal trauma. Non-operative management has become standard practice.

The skeleton of a child is not completely calcified, which allows it to be more pliable. The consequence is that a child's skeleton absorbs less energy from the trauma, and underlying organs may be injured even in the absence of bony injury. Alternatively, when there are bony injuries, this suggests that a great amount of force was applied, and the suspicion of intra-abdominal injury should be high.

Initial Management

The initial evaluation of any trauma patient is vital to a successful outcome. Every trauma patient, including pediatric patients of all ages, must be initially managed according to the principles of Advanced Trauma Life Support (ATLS).[11]

A primary survey needs to be completed without delay to identify immediately life-threatening injuries.[12] The primary survey consists of an assessment of the airway to ensure that it is open to allow the travel of air into and out of the lungs without any hindrance.[13]

Vital signs in children vary according to age group, and the practitioner should be familiar with the range of normal vital signs in children. (*See Table 1.*)

Hypoxia is the most common cause of cardiac arrest in children, and bradycardia in children is a sign of hypoxia. Any child who cannot maintain his or her own airway, including those with severe head injury, significant hypovolemia, or in whom an operation is likely necessary, must be intubated.[15]

Spontaneous, effortless breathing should occur. A quick way to assess airway patency is to engage the patient in a conversation, and if patient is able to speak without difficulty, then the airway is likely intact. If there are clear breath sounds with easy flow of air, you can move on to checking for circulation.

Circulation is evaluated to ensure that there is no life-threatening bleeding. External bleeding is easily detected and controlled with manual compression. Internal bleeding may be more difficult to detect, but close attention to the patient's vital signs and physical appearance can help in detecting occult bleeding. A child who is exhibiting signs of hypovolemia should alert the practitioner to the possibility of internal injuries and the need for resuscitation, as well as an investigation to find the source of bleeding.[16]

Finally, the primary survey should be completed with a quick neurologic examination, including Glasgow Coma Scale (GCS), and the patient must be disrobed from head to toe to allow for a complete and unhindered examination. Cover the child with warm blankets to prevent hypothermia once a thorough examination is complete.[17]

Adjuncts to the primary survey may include a chest X-ray, a pelvic X-ray, and the Focused Abdominal Sonography for Trauma (FAST) exam.

Figure 1. Handlebar Injury[6]

Chest X-ray

The chest X-ray in pediatric trauma is a valuable tool to identify conditions such as rib fractures, pneumothorax, hemothorax, and the rare aortic injury. It also serves as a screening tool to determine which patients need further imaging with a CT of the chest. A completely normal chest X-ray is associated with a reduced risk of having a significant

Table 1. Vital Functions[14]

Age	Weight (kg)	Heart Rate (beats/min)	Blood Pressure (mmHg)	Respiratory Rate (breaths/min)	Urinary Output (mL/kg/hr)
0-12 months	0-10	< 160	> 60	< 60	2.0
1-2 years	10-14	< 150	> 70	< 40	1.5
3-5 years	14-18	< 140	> 75	< 35	1.0
6-12 years	18-36	< 120	> 80	< 30	1.0
> 13 years	36-70	< 100	> 90	< 30	0.5

thoracic injury and may allow the practitioner to safely avoid a CT of the chest.[18]

Routine pelvic X-rays in pediatric trauma patients are not necessary. A screening tool from the University of Michigan level 1 pediatric trauma center accurately predicts the absence of a pelvic fracture.[19] (*See Table 2.*)

FAST Exam

The FAST exam has added a method to quickly evaluate a patient with possible abdominal injuries in the trauma bay. While FAST does not replace a CT scan in the evaluation of abdominal trauma, it can aid in the decision to perform a CT scan or go to the operating room.

A positive FAST in a hemodynamically unstable patient who is not responding to resuscitation is an indication to go to the operating room. A positive FAST in a hemodynamically stable patient should spur further evaluation with a CT scan.

A negative FAST exam in combination with a benign physical exam and normal levels of ALT/AST, amylase, and lipase can decrease the likelihood of a CT scan being necessary.[21,22] However, it must be remembered that a negative FAST exam alone does not exclude hemoperitoneum or intra-abdominal injury,[23] and repeated assessment is warranted to assess for a change in the patient's clinical condition.

Secondary Survey

A secondary survey follows the primary survey once the practitioner is confident there is no immediate life-threatening injury and the patient's vital signs are normal or responding appropriately to resuscitation.[24]

The secondary survey consists of a complete medical history, including medications, surgical history, last meal, and allergies. Additional tests in the secondary survey may include further radiographic imaging, such as a CT scan or additional X-rays and lab work.

In the evaluation of blunt abdominal trauma, a CBC, CMP, hepatic function panel, amylase, and lipase should be sent. Laboratory studies are sent to assist in the evaluation of the patient with blunt abdominal trauma based on organ system. Serial laboratory values are generally more helpful than any single value, but ALT and AST values greater than 250 U/L warrant further evaluation.

CT SCAN

CT scanning is the imaging study of choice for blunt abdominal trauma in children, but there is a downside to CT scans.[25] Although CT is able to identify and evaluate intra-abdominal organ injury with great accuracy,[26] children should not be unnecessarily or reflexively exposed to the radiation from a CT scan.[27]

Hemodynamically unstable patients do not belong in the CT scan under any circumstances. A trauma patient who is hemodynamically unstable belongs in the operating room if he or she is not responding to resuscitation.

While CT scans are being increasingly used to assess for traumatic injuries,[28] there is concern for the eventual development of malignancy related to the radiation exposure from even one CT scan. One study shows that children with no evidence of abdominal wall trauma, no abdominal tenderness, a GCS greater than or equal to 14, no vomiting, no thoracic wall trauma, and normal breath sounds are at very low risk of an intra-abdominal injury and do not require CT scan to exclude injury.[29]

CT is beneficial when assessment must be made of an intubated trauma patient.[30] Use of oral contrast is not indicated in a trauma setting. It leads to a delay in diagnosis and is a potential aspiration risk.

Diagnostic Peritoneal Lavage

Diagnostic peritoneal lavage (DPL) is rarely indicated in evaluation of pediatric trauma and, if performed, must be done by a surgeon. It has been largely replaced by the FAST exam. Because most solid organ injuries do not require surgical intervention, a positive DPL has limited clinical significance in the management of solid organ injuries.[31] DPL does have the highest sensitivity in detection of bowel injury. The presence of bile, food particles, and amylase activity can be used to diagnose small bowel perforation.

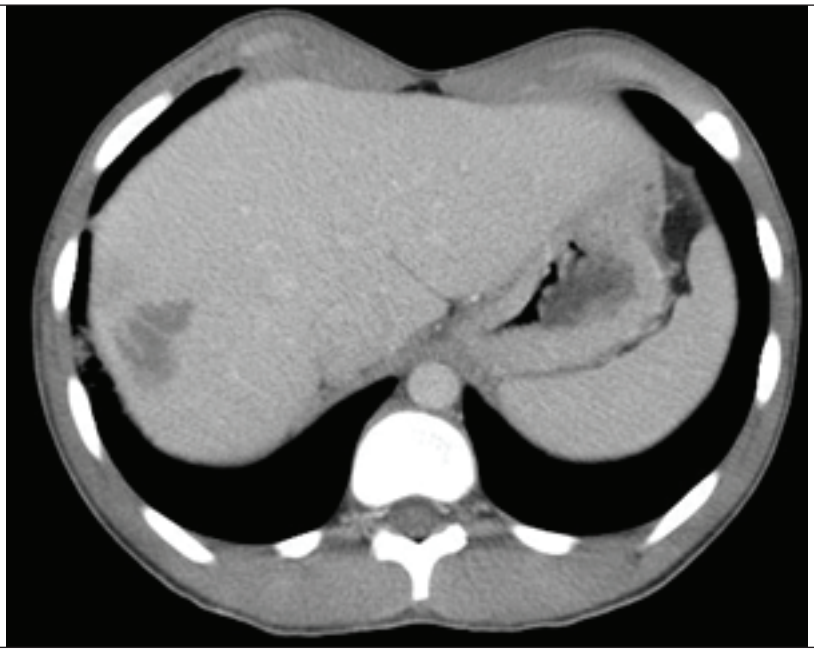
Diagnostic Laparoscopy

Diagnostic laparoscopy can be both diagnostic and therapeutic in

Table 2. Risk Factors Predictive of Pelvic Fracture[20]

High-risk Clinical Findings
• GCS < 14
• Positive urinalysis
• Pelvic tenderness
• Pelvic laceration
• Pelvic abrasion
• Abdominal pain/tenderness
• Femur fracture
High-risk Mechanism of Injury
• Unrestrained motor vehicle crash
• Motor vehicle crash with ejection
• Motor vehicle crash rollover
• Pedestrian struck by motor vehicle
• Bicyclist struck by motor vehicle

Figure 2. Liver Laceration with Blush



cases of bowel injury.[32] Some trauma surgeons contend that a diagnostic laparoscopy is appropriate in the scenario of suspicion for a bowel injury instead of DPL because of the lower morbidity associated with diagnostic laparoscopy. It is also the test of choice for suspected diaphragmatic injury, although this is rare in pediatric trauma patients.

Resuscitation

The goal of initial resuscitation is to normalize vital signs and to maintain perfusion of vital organs.[33] One pitfall to be aware of in pediatric trauma patients is that they are able to maintain a normal blood pressure despite significant volume loss. The initial physiologic response to blood loss will be tachycardia. Hypotension in children indicates a significant hypovolemia. (*See Table 3.*)

The initial bolus of intravenous fluid should be 20 mL/kg of a crystalloid solution, such as normal saline or lactated Ringers. If there is no response, a second bolus should be given. If hemodynamic instability remains, a third bolus of 20 mL/kg of a crystalloid solution can be given, but at this point there should be a consideration for using packed red blood cells.[35,36] Transfusion protocols vary and are dependent on institution-based protocols.

Continuous monitoring of the patient response to the fluid boluses is imperative. Patients are characterized as either responders, non-responders, or transient responders.

Responders will have improved vital signs, a clearer mental status, return of normal skin color, increased perfusion of the extremities as indicated by peripheral pulses, and increased warmth of the skin.

Non-responders are those patients whose hemodynamic status does not respond to crystalloid or blood products. These patients must receive ongoing resuscitation and be taken to the operating room for control of hemorrhage.[37]

Hemodynamic instability should not delay surgical intervention because ongoing hypotension that is unresponsive to resuscitation increases mortality and morbidity. Prompt control of injuries is necessary.

Transient responders show preliminary improvement of their hemodynamic status, but the status worsens again over time. This likely indicates ongoing bleeding and requires ongoing resuscitation and consideration of surgical intervention. It is also possible that additional resuscitation will stabilize a patient and avoid the need for an operation.

Liver Injury

The liver accounts for nearly one-third of injured organs in pediatric blunt abdominal trauma, and

Table 3. Physiologic Response to Blood Loss[34]

System	< 30% blood loss	30-45% blood loss	> 45% blood loss
Cardiovascular	Increased heart rate, weak thready peripheral pulses, normal blood pressure (80-90 + 2 × age in years), normal pulse pressure	Markedly increased heart rate, thready central pulses, absent peripheral pulses, low normal systolic blood pressures (70-80 + 2 × age in years), narrowed pulse pressure	Tachycardia followed by bradycardia, very weak or absent central pulses, absent peripheral pulses, hypotension (< 70 + 2 × age in years), narrowed pulse pressure (or undetectable diastolic blood pressure)
Central nervous system	Anxious, irritable, confused	Lethargic, dulled response to pain	Comatose
Skin	Cool, mottled, prolonged capillary refill	Cyanotic, markedly increased capillary refill	Pale and cold
Urine output	Low to very low	Minimal	None

most injuries are managed non-operatively as long as the patient remains hemodynamically stable and does not have other injuries (i.e., a bowel injury) that require operative intervention.

Liver injury should be suspected in patients with trauma to the right upper quadrant and those complaining of right upper quadrant pain. Severe liver trauma can cause significant internal bleeding that may need operative intervention. Patients with suspected liver injury who are unstable and not responding to resuscitation need to go to the operating room. These injuries have a high mortality, even with surgical intervention.

An active blush on CT scan may be successfully managed by embolization, but there is still debate over the safety of angioembolization in children.[38] (*See Figure 2.*)

Non-operative management according to APSA guidelines have been successful in guiding care. They suggest bed rest equal to the grade of the injury plus one day, but protocols vary by institution. There are data to suggest an accelerated protocol of one night of bed rest for grade I and II injuries, and two nights for grade III or higher can be used without harm.[39]

Figure 3. Splenic Injury

Splenic Injury

The spleen is the most commonly injured organ in pediatric abdominal trauma. Non-operative management has become standard practice and achieves a high success rate.[40] Splenic preservation should be achieved whenever possible to avoid post-splenectomy infection, which has a high mortality rate, and splenectomy has been shown to increase risk of infection and death.[41,42]

Splenic injury should be suspected in children with direct trauma to the left side, associated rib fractures, and left upper quadrant tenderness. CT

Table 4. Spleen Injury Scale (1994 Revision)[49]

Grade*	Injury Type	Description of Injury
I	Hematoma	Subcapsular, < 10% surface area
	Laceration	Capsular tear, < 1 cm parenchymal depth
II	Hematoma	Subcapsular, 10%-50% surface area Intraparenchymal, < 5 cm in diameter
	Laceration	Capsular tear, 1-3 cm parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular, > 50% surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma > 5 cm or expanding
	Laceration	> 3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (> 25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury with devascularized spleen

*Advance one grade for multiple injuries up to grade III.

scan is the standard imaging study to diagnose and grade a splenic injury. (*See Figure 3.*) CT also guides management of injuries, and a finding of blush on CT scan seems to increase the rate of operation and correlate with hemodynamic instability.[43] However, even most of the patients with blush still can be managed successfully with non-operative management.[44,45]

Splenic angioembolization (SAE) can be used when the CT scan suggests ongoing bleeding, as long as the patient is hemodynamically stable. (*See Figure 4.*)

The decision to operate on a patient with a splenic injury is best based on hemodynamic stability, ongoing blood loss, and responsiveness to non-operative methods rather than grade of injury.

Observation with bed rest, serial physical examinations, and frequent hematocrit checks for management of splenic laceration according to APSA guidelines have been shown to be effective.[46,47] Stylianos proposes that only grade IV injuries or above (*see Table 4*) should be observed in the intensive care unit (ICU) for one day, and that no follow-up imaging is indicated. Activity restriction should be based on grade of injury.[48]

Injury to the Intestine

Detection of bowel injury poses a challenge to the clinician. Bowel injury is not always evident at initial presentation and may have a delayed presentation secondary to perforation. Mesenteric tears can cause associated bowel to become ischemic and present with perforation even days after the initial trauma. (*See Figure 5.*)

Intestinal injury should be considered with any patient who has suffered trauma to the abdomen, has any abdominal tenderness, or has visible abdominal wall ecchymosis. In particular, a seat belt sign should raise a clinician's suspicion for a bowel injury.[50] CT findings of extraluminal air, free intraperitoneal fluid, bowel wall thickening, bowel wall enhancement, bowel dilatation, and fat stranding should raise the clinician's suspicion of a bowel injury and perforation. Although CT scan is very useful in diagnosing injuries, the findings on CT scan must be interpreted in the clinical context. Serial clinical examination is the gold standard for diagnosis of intestinal injury.[51]

Rapid deceleration, as in the case of a restrained passenger in a motor vehicle crash, can cause injury to the bowel near a point of fixation (i.e., ligament of Treitz, terminal ileum, and rectosigmoid region).

Initial and subsequent serial abdominal exams are more critical to the diagnosis of bowel injury than any imaging modality.[52] If there is a perforation, early or late, an awake patient will have abdominal pain and signs of peritonitis due to the contents of the bowel irritating the peritoneum.

If a bowel injury is suspected, surgical consultation is mandatory.

Duodenal Injury

Duodenal injury is a specific type of injury to the intestines with unique characteristics. Due to the location of the duodenum in the protected retroperitoneum, duodenal injury is rare. Additionally, duodenal injuries may be associated with other injuries that can distract the clinician from making the diagnosis. There are reports that isolated duodenal injury is highly associated with child abuse.[53] Therefore, the clinician's suspicion of child abuse should rise when presented with a patient with isolated duodenal injury, as well as a history of trauma that does not correlate with the injuries.

Diagnosis of duodenal injury is difficult, but when suspicion for a duodenal injury exists, early CT scan with oral contrast will help make

the diagnosis.[54] Duodenal injuries can be categorized into different grades based on size of hematoma or perforation/laceration.

A duodenal hematoma is managed non-operatively, and perforation is managed with an operation.[55] Non-operative management of hematoma is bowel rest with no oral intake and total parenteral nutrition. Resolution of the hematoma normally requires 1-3 weeks of observation and nutrition provided with TPN.

There are multiple operative managements of duodenal lacerations, and surgical consultation must be obtained in cases of duodenal perforation. All surgical treatments include drainage of the area. A variety of methods exist to bypass and repair the injury.[56] However, each institution has a low number of experiences with operative duodenal injuries per year, and a definite best method of repair is not established.

Pancreatic Injury

Pancreatic injuries are rare in pediatric blunt abdominal trauma, with an estimated range from 3% to 12%. Detecting this rare injury requires a high degree of suspicion based on the mechanism of injury and early CT scan (*see Figure 6*) to prevent a delay in diagnosis and subsequent complications, such as infection.[57]

Pancreatic injury occurs most commonly from force applied to the abdomen that results in compression of the abdomen against the vertebra and crushes the pancreas in between two structures, such as a classic handlebar injury to the mid upper abdomen. The signs and symptoms are vague, which often leads to a delay in diagnosis.

The initial serum amylase may be normal, even with complete transection of the duct. A CT scan with IV contrast and serial measurements of amylase are helpful in making the diagnosis. If injury is still suspected, ERCP can provide early evaluation and the possibility of intervention with pancreatic injuries.

Treatment of pancreatic injury is not well defined, secondary to the rarity of this injury. Proponents of non-operative management point to safe management of pancreatic injury with no morbidity.[58,59] The development of pseudocysts is

Figure 4. Angioembolization of Grade V Splenic Laceration

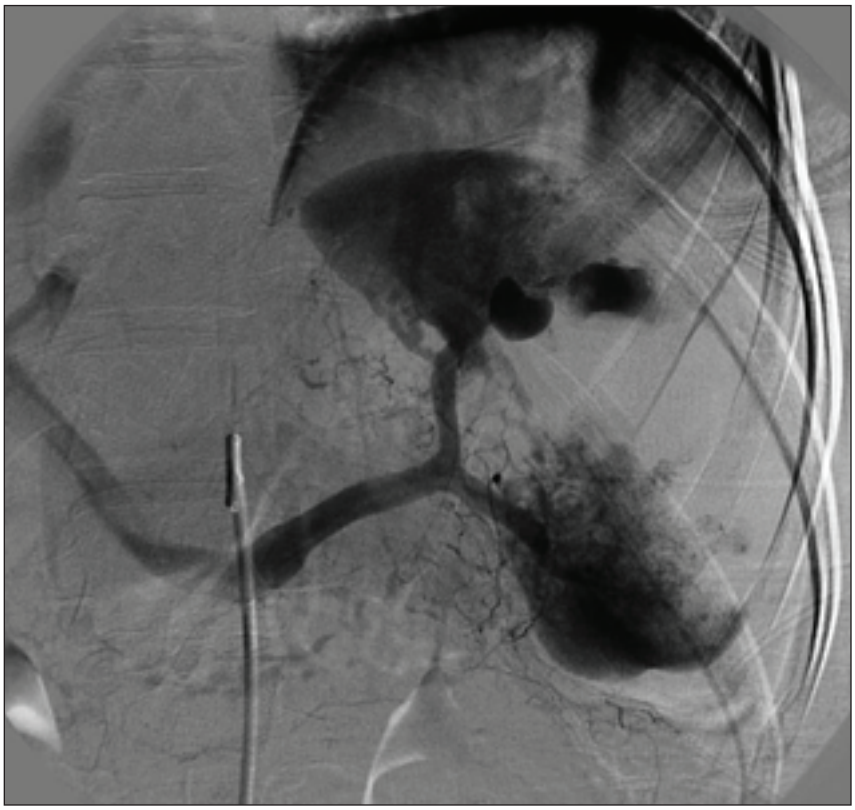
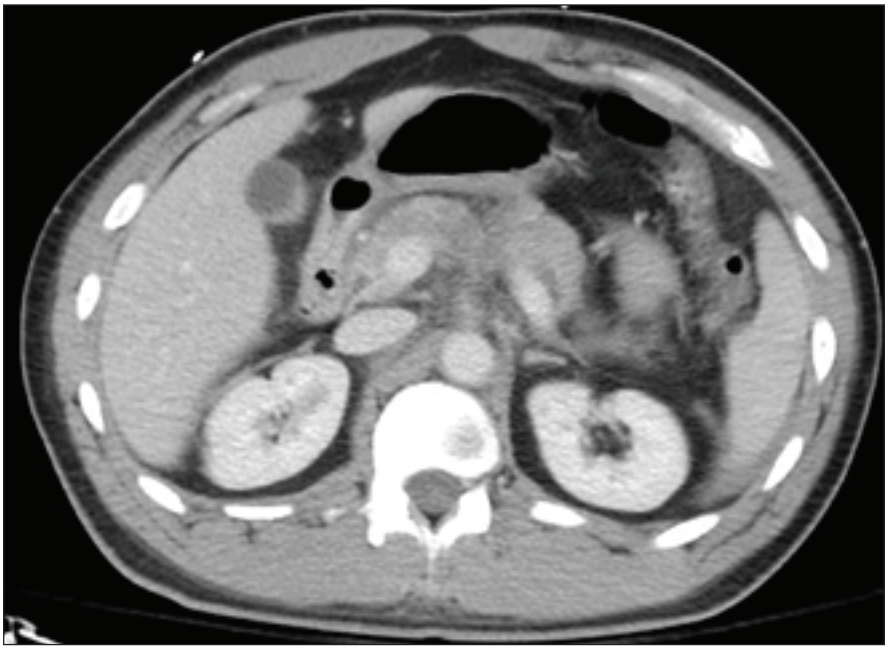


Figure 5. Bowel Injury Found on CT: Dilated Bowel with Surrounding Induration

Figure 6. Pancreatic Injury



expected in this patient population and can be managed with percutaneous drainage.[60] Proponents of early intervention quote a higher rate of TPN dependency and an increase in complications with non-operative management.[61]

Higher-grade pancreatic injuries can be managed with ERCP. Laparoscopic pancreatectomies of the distal pancreas, when indicated, are possible.

Renal Trauma

The majority of cases of renal injury result from motor vehicle crashes, falls, and sports-related trauma.[63] Like the other solid organ injuries from blunt abdominal trauma, renal injuries in a hemodynamically stable patient can be managed non-operatively.[64]

Renal injury should be suspected in patients with gross hematuria or microscopic hematuria with associated hypotension. Other findings associated with renal trauma include flank tenderness, a flank or abdominal mass, and ecchymosis of the flank.

In a hemodynamically stable patient, a CT scan with IV contrast should be obtained to grade the injury. Management should be based on the grade of the injury. Grade 1 to 3 injuries can be almost universally managed non-operatively. Grade 4 or 5 injuries can be selectively managed non-operatively if the patient is hemodynamically stable and has no associated abdominal injuries that require surgery.[65,66]

As long as the patient remains hemodynamically stable, bed rest and observation are indicated. If there is an active bleed seen on CT scan and the patient is hemodynamically stable, angiographic embolization can be used. Surgical intervention should be undertaken for hemodynamic instability or persistent blood loss requiring ongoing transfusions.[67]

If the patient is unstable, the operating room is the safest place. Prior to performing a nephrectomy on the injured kidney, the surgical team should ensure that the patient has two kidneys.

Aortic Injury

Blunt abdominal trauma causing abdominal aortic injury is exceedingly rare in the pediatric population. Since 1966, there have been only 17 reports in the literature of pediatric trauma patients with aortic injury from blunt trauma.[68]

Chance fractures associated with seat belts from motor vehicle crashes are a common mechanism.[69] Other mechanisms include child abuse, horseback riding, and handlebar injuries from bicycle crashes.

The symptoms of abdominal aortic injury include nonspecific complaints of abdominal and back pain, as well as specific findings such as loss of distal pulses, pulsatile abdominal mass, abdominal bruit, and paraplegia.[70]

Diagnosis can be made with a CT scan, and treatment normally includes open operative repair. Endovascular techniques have been reported for thoracic aortic injuries in children, but disadvantages, such as stent migration as the patient grows, must be considered.

Child Abuse

Abdominal trauma is the second leading cause of abusive trauma mortality.[71] The true incidence of abusive abdominal trauma is difficult to determine, but child abuse should be considered when a child presents with abdominal trauma and a discordant story. Risk factors include poverty, male gender, young age, previous unexplained or repetitive injuries, an adult male other than the father in the home, and children with physical and developmental delays.[72]

While any organ may be injured from abuse, the liver and the bowel are the most common, and injuries to multiple organs are not uncommon. Toddlers aged 2 to 4 years of age are the most likely to suffer abusive injuries, but infants and older children, including adolescents, are at risk, too.

A high level of suspicion should be maintained in children whose history and pattern of injuries do not correlate. Social work consults and referral to child protective services for investigation should be considered in suspected cases.

Summary

Adherence to the principles of ATLS is imperative in managing

pediatric trauma effectively. A delay in diagnosis and treatment leads to an increased rate of complications. Advances in technology have made evaluation of intra-abdominal injuries increasingly less invasive, but clinical acumen and a high degree of suspicion is still the most important aspect of management.

The majority of blunt abdominal injuries to solid organs can be managed non-operatively, but surgical consultation should be obtained prior to committing this course of treatment. Serial examination and re-evaluation is mandatory while treating any injury non-operatively. Hollow organ injuries, such as bowel injuries, require operative intervention and should not be treated non-operatively.

The care of pediatric patients with blunt abdominal trauma can be challenging. Adhering to the principles of trauma resuscitation according the ATLS will help clinicians to recognize injuries early and lead to proper treatment. Transfer to institutions well versed in the care of pediatric patients should be considered, especially for those with multisystem trauma.[73]

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CNE/CME Objectives

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

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

CNE/CME Instructions

HERE ARE THE STEPS YOU NEED TO TAKE TO EARN CREDIT FOR THIS ACTIVITY:

1. Read and study the activity, using the provided references for further research.

2. Log on to **www.cmecity.com** to take a post-test; tests can be taken after each issue or collectively at the end of the semester. *First-time users will have to register on the site using the 8-digit subscriber number printed on their mailing label, invoice, or renewal notice.*

3. Pass the online tests with a score of 100%; you will be allowed to answer the questions as many times as needed to achieve a score of 100%.

4. After successfully completing the last test of the semester, your browser will be automatically directed to the activity evaluation form, which you will submit online.

5. **Once the completed evaluation is received, a credit letter will be e-mailed to you instantly.** You will no longer have to wait to receive your credit letter.

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CME/CNE Questions

1. Blunt trauma can be caused by which of the following?
   A. motor vehicle crashes
   B. bicycle accidents
   C. child abuse
   D. sports injuries
   E. all of the above

2. The initial management of a pediatric trauma should be guided by the principles of:
   A. Advanced Trauma Life Support
   B. patient comfort
   C. parental concerns
   D. individual hospital protocol

3. Which of the following is the most common cause of cardiac arrest in children?
   A. blunt thoracic trauma
   B. hypoxia
   C. severe head injury
   D. blunt abdominal trauma

4. Which of the following factors is/are predictive of pelvic fracture?
   A. pelvic tenderness
   B. motor vehicle crash with ejection
   C. abdominal tenderness
   D. positive urinalysis
   E. all of the above

5. Which of the following is true of the FAST exam?
   A. It replaces the need for a CT scan.
   B. It can help in deciding if a patient needs further evaluation with a CT scan.
   C. It definitively excludes intra-abdominal injury.
   D. It should not be repeated if a patient's condition worsens.

6. The goal of the initial resuscitation is:
   A. to normalize vital signs and maintain perfusion of vital organs
   B. to normalize laboratory values
   C. to prevent fluid overload
   D. to allow a hemodynamically unstable patient to go to CT scan

7. Which of the following is true of patients with a grade 3 splenic injury?
   A. They must be taken to the operating room immediately, even if hemodynamically stable.
   B. They should be placed on bed rest and undergo continuous hemodynamic monitoring and serial CBC monitoring.
   C. They may be safely discharged home.
   D. They must be monitored with serial CT scans.

8. Which of the following is true regarding pancreatic injury in children?
   A. It is extremely common.
   B. It can be easily diagnosed with a single amylase level.
   C. CT scan with IV contrast and serial measurement of amylase are helpful in making the diagnosis.
   D. ERCP is not able to provide either evaluation or intervention of pancreatic injuries.

9. Risk factors for child abuse include which of the following?
   A. poverty
   B. male gender
   C. young age
   D. adult male in the home other than the child's father
   E. all of the above

10. In evaluating pediatric patients with suspected blunt abdominal trauma, which of the following is true?
   A. CT scans should be used liberally without concern for sequelae.
   B. CT scan is the study of choice to detect solid organ injury.
   C. Ultrasound can definitively exclude intra-abdominal injury.
   D. Physical exam has no role in evaluating the patient.

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Interim Editorial Director: Lee Landenberger

Executive Editor: Shelly Morrow Mark

Managing Editor: Leslie Hamlin

POSTMASTER: Send address changes to Trauma Reports,
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Subscriber Information

Customer Service: 1-800-688-2421

Customer Service E-Mail:
customerservice@ahcmedia.com

Editorial E-Mail:
shelly.mark@ahcmedia.com

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