



Thoracoabdominal Injuries

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Intrathoracic and Intra-abdominal Injuries

A soccer player sustains trauma to his abdomen in a collision with an opponent. The player is taken out of the game, only to return within 2 min feeling little ill effect. He is noted to be coughing but is able to continue. After the game, he is complaining of left upper quadrant abdominal pain. The athletic trainer relates that the player has had a recent upper respiratory tract infection.

Did the player sustain a splenic rupture because of underlying splenomegaly, caused by infectious mononucleosis, or is this an abdominal wall hematoma or muscle strain? Alternatively, could the coughing be indicative of an intrathoracic injury, such as a pneumothorax?

This scene illustrates the difficulties involved in diagnosing injuries to the chest and abdomen. Unless there is a low threshold to pursue investigation, athletes may suffer serious consequences. Injuries to the chest and abdomen are often more subtle in presentation than other injuries, such

as an acute ligament rupture. Thoracoabdominal injuries are uncommon, and catastrophic events can occur if an intra-abdominal or intrathoracic injury is unrecognized. Awareness of the organs that can be injured, and how such injuries may present, is the best defense against missing potentially life-threatening thoracic and abdominal trauma [1].

Anatomy

The thorax contains the heart, the great vessels, and the lungs. The lungs are surrounded by two layers of pleurae protected by the ribs and the thoracic musculature. The diaphragm divides the thoracic and peritoneal cavities with a variable position throughout respiration [2]. The expulsive motion of the diaphragm can raise the right crus to the level of the fourth anterior costal cartilage. Importantly, the abdominal contents may be raised well into the chest and exposed to chest wall trauma.

The peritoneal cavity contains solid organs, such as the liver, spleen, and pancreas, plus hollow viscous organs, including the stomach and the small and large intestines. Also in this area are the lower ribs, the abdominal wall musculature, vascular structures, the bladder, and retroperitoneal organs and spaces.

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Clinical Evaluation

Thoracic Injury

Athletes with a thoracic injury may present with chest wall pain and, often, shortness of breath. Inspection for ecchymosis can also be helpful with intrathoracic injuries incurred in sport. Pulmonary auscultation is essential for assessment for lung pathology. Cardiac auscultation may be indicated for myocardial contusion or arrhythmias. Further examination may include palpation for tenderness over a suspected rib fracture.

Abdominal Injury

Athletes can present with an immediate onset of pain or a more insidious onset [1]. Athletes who have a history of a high-risk mechanism, such as a rapid deceleration or high-energy impact, or who have continuous, persisting abdominal pain should be examined.

Physical exam should begin with the measurement of vital signs, which may be normal or reflect a state of shock. Inspection for ecchymosis and tenderness on abdominal palpation helps detect the potentially affected organ. Abdominal wall muscular contusion can be difficult to distinguish from intra-abdominal injury. Contusions are usually only tender over the area of sustained injury, and pain may be evident with contraction of the underlying muscle. Conversely, intra-abdominal injuries may elicit tenderness from various angles of palpation.

Among athletes with significant abdominal trauma, 50% will have a negative initial exam, so reexamination can be crucial. One estimate is that 20% of patients with an acute hemoperitoneum have an initial benign abdominal exam [3].

Liver or spleen injuries can bleed, causing intra-abdominal irritation and pain. Pain is often mild, without palpable tenderness. Injuries to hollow viscera and the pancreas cause peritonitis, often resulting in severe pain. Initially, this is localized to the site of injury. Peritoneal signs, such as referred tenderness and loss of bowel

sounds, are found with progression of intra-abdominal injury. Auscultation for bowel sounds can be misleading, as the presence of bowel sounds does not exclude injury. Walking or coughing can also precipitate pain. Retroperitoneal injuries may occur without peritoneal signs when there is minor trauma. Hematuria is often the only clinical manifestation of renal trauma.

Coexisting Injuries

It has been well recognized that lower chest wall trauma places the upper abdominal organs at risk for injury. Most commonly, a blow to the lower left chest wall can result in an injury to the spleen [1]. Conversely, several case reports exist in the literature of abdominal impact resulting in an intrathoracic injury, such as a pneumothorax. One such report by Roberts [4] described an ice hockey player who was checked into the boards and sustained an impact over his left lower ribs. Initial concern for a splenic injury proved unfounded, and he was allowed to return to the game. However, he was too uncomfortable to continue, and assessment afterward revealed a 15% pneumothorax on chest x-ray. Hence, pulmonary injury from abdominal trauma can occur without disruption of the diaphragm. Diaphragm rupture is uncommon but is usually left sided (70–90%), as the liver appears to protect the right side.

Diagnostic Assessment

Laboratory investigations, including serial determination of hematocrit, diagnostic imaging, and diagnostic peritoneal lavage (DPL), can be performed in a hospital setting. DPL has become less commonly performed with the increased availability of diagnostic ultrasound and computed tomography (CT). A chest x-ray is usually indicated. An erect view is helpful to exclude air under the diaphragm, suggesting bowel perforation.

An emerging imaging modality for chest and abdominal trauma is diagnostic ultrasound,

which has useful applications in the evaluation of thoracic trauma and may be a better diagnostic tool than supine x-ray for pneumothoraces and lung contusions [5–7].

Abdominal CT scan after blunt trauma has 67% sensitivity in its ability to predict the need for surgery in a pediatric population [8]. The negative predictive value was 98.7% in the same study. A combination of clinical exam and CT scan did not miss any significant injuries. Serial examination may be performed in a hospital setting. CT scan alone may miss clinically significant injuries.

CT is the best choice for imaging solid organs such as the liver and spleen [9] and remains the gold standard in evaluating blunt abdominal trauma in hemodynamically stable patients [10–13] though diagnostic ultrasound has advantages. While ultrasonography is not as sensitive for intra-abdominal trauma, does not provide as much anatomic detail, does not allow for injury grading [14], and remains operator dependent, it does have a role, for instance, in the hemodynamically unstable patient [15, 16]. Hoffman et al. described a sensitivity of 85% and a specificity of 99% in detecting intra-abdominal injuries [16], while Berkoff suggests sensitivity of 60% (95% CI 49–70) [17]. Ultrasound visualizes free intraperitoneal fluid well, though it may not identify the injured organ [18]. Conditions identified on ultrasound in unstable patients will eventually require CT to identify the injury and to guide management [18]. The use of abdominal ultrasound for evaluation of unstable patients has been described by the term “focused assessment with sonography for trauma” (FAST) [19]. The FAST examination aims to recognize peritoneal fluid/blood, which typically arises from a solid organ injury. A hypotensive athlete who has suffered abdominal trauma with a positive finding on a FAST examination has a higher likelihood of operative management [17, 19–26].

Treatment

Field treatment for shock, before and during transfer to a trauma center, is essential when

shock is detected. Intravenous access with a large-bore cannula should be established at two sites with rapid infusion of 0.9% saline, rather than dextrose-containing fluids.

Current surgical goals are for organ salvage and repair, rather than removal of injured intra-abdominal organs. Indications for removal revolve around uncontrolled bleeding, particularly when associated with coagulopathy. In such circumstances, the risks of surgery are outweighed by the benefit of achieving hemostatic control, with a low likelihood of control being achieved any other way. Once stabilized, discharge with home observation is often practical. However, caution is required regarding delayed rupture of the spleen at 7–10 days.

Thoracic Injuries

Thoracic injuries generally result from rapid deceleration or high-energy impacts, which occur most frequently in high-speed, high-energy contact sports, such as bicycling, skiing, football, hockey, and boxing [15]. Statistically, adolescents have a higher incidence of penetrating thoracic trauma relative to younger children, who have higher rates of blunt thoracic trauma [27]. Road traffic accidents and pedestrian injuries have been reported as the leading cause of thoracic injuries, with sports-related injuries occurring much less frequently [28]. However, evolution of “extreme sports” may increase the potential for high-energy impacts and may be especially dangerous in the setting of remoteness from immediate medical attention. In one study, 6.1% of injured snowboarders sustained chest trauma, whereas only 2.7% of skiers had similar injuries [29].

Lung Injuries

Pneumothorax

This is the most common intrathoracic injury after blunt thoracic trauma [30]. Among all children who sustain high-energy thoracic trauma, approximately one quarter to one third will

develop a pneumothorax [31, 32]. Pneumothorax related to sporting activity or injury is relatively uncommon. Spontaneous occurrences have been reported in a number of sports such as soccer [33] and weight lifting [34]. Pneumothorax as a result of blunt trauma during sports generally involves deceleration of the athlete's thorax against a moving or a stationary object, as has been reported in skiing and snowboarding [35], bicycling [36], football, and ice hockey [37].

Tension pneumothorax occurs in 1–2% of patients with a spontaneous pneumothorax [38]. Pneumothorax results from the loss of air from the lung into the pleural space. If no mass effect is caused by this air, the injury is referred to as a simple pneumothorax. However, if the loss of air into the pleural space continues, tension can result with concomitant shift of the mediastinum away from the side of the pneumothorax. Such a tension pneumothorax requires immediate decompression with a needle into the chest cavity and, optimally, by a tube thoracostomy. If this is not done, the continued pressure and mediastinal shift will lead to respiratory compromise by inhibition of airflow into the working lung and to cardiac compromise by a reduction in venous return to the heart.

Pneumothorax, whether simple or tension, can occur spontaneously from rupture of a bleb, from a sudden compressive force to the chest with a resulting rupture of the lung parenchyma, or from a displaced rib fracture that penetrates the lung. Both simple and tension pneumothoraces are associated with tachypnea, dyspnea, and sudden chest pain, though these findings may be quite subtle with a simple pneumothorax. Of those with spontaneous pneumothorax, up to 87% will present with chest pain and 43% with shortness of breath [39].

On examination, a simple pneumothorax may present with a small shift of the mediastinal structures to the side of the pneumothorax, whereas tension pneumothorax is associated with a shift to the opposite side. Physical examination may also demonstrate decreased breath sounds on auscultation and hyperresonance to percussion on the side of the lesion. Tension pneumothorax is also asso-

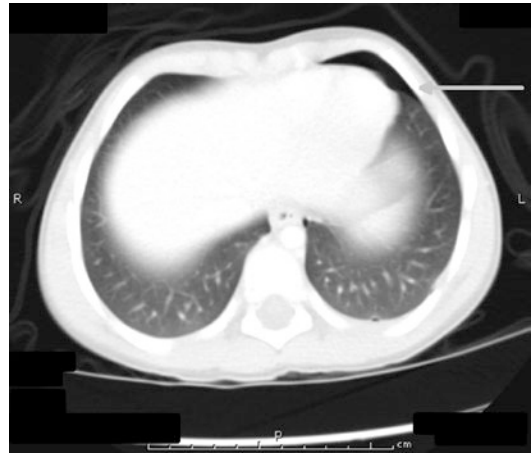


Fig. 7.1 Left pneumothorax. Courtesy of David Mooney, MD, Children's Hospital, Boston, MA

ciated with tachycardia, neck vein distension, and hypotension.

The diagnosis is confirmed by chest x-ray, but as noted previously, tension pneumothorax should not await chest x-ray for treatment. Figure 7.1 illustrates a CT of a left pneumothorax which remains the gold standard for diagnosis. Ultrasound has gained increased interest given its growing availability, feasibility, and lack of radiation exposure, of particular importance in the pediatric population. Though investigation is ongoing, studies have suggested improved sensitivity and comparable specificity of ultrasound compared to supine chest x-ray for detecting pneumothorax [40, 41]. One study demonstrated that prehospital critical care providers were able to learn the techniques, correctly diagnose, and retain the skills needed to identify sonographic signs suggestive of a pneumothorax [42], a practice that could be applied by appropriately trained sports medicine physicians [17].

Tube thoracostomy and suction at -20 cm H_2O are all that is required for the treatment of most pneumothoraces. Thoracoscopic talc pleurodesis has been shown to be an effective intervention in recurrent or persistent spontaneous pneumothoraces [43]. The athlete can resume normal activity within a few days of discharge or as other injuries allow. Occasionally, a small, simple pneumothorax of 20% or less can be treated without tube thoracostomy if the patient is asymptomatic

and has no other injuries. This approach requires careful observation and repeat chest x-ray to document stability. Regardless of treatment type, recurrence rates of primary spontaneous pneumothorax are reportedly high in children, up to 54% [44]. Return to physical activity should be delayed until complete resolution of the pneumothorax [45]. Symptoms of primary spontaneous pneumothorax often resolve within 24 h, even prior to resolution of the pneumothorax [46]. Therefore, return to play should be determined on a case-by-case basis. Current guidelines recommend avoidance of air travel within 2–3 weeks following a pneumothorax, due to concern that a volume of air trapped in the pleural cavity may expand and develop into a tension pneumothorax in the lower cabin pressure of a commercial airplane in flight [47].

Pulmonary Contusion

Pulmonary contusion is a bruise of the lung associated with hemorrhage and edema into the lung parenchyma [15]. It can result from a sudden deceleration in which the lung strikes the chest wall, from a concussive blow to the chest that compresses the lung or from a displaced rib fracture [30]. Children appear prone to this injury in the absence of a rib fracture because of the compressive nature of the rib cage [31]. As a result, the force of impact is transmitted to the lungs, rather than being absorbed by the ribs, which may not fracture. It is important to identify pulmonary contusion, as some patients will go on to develop pneumonia or acute respiratory distress syndrome (ARDS).

Patients present with cough, hemoptysis, and dyspnea. Exam shows diminished breath sounds, crackles, or both. Chest x-ray findings vary from fluffy, patchy infiltrates to consolidation and are diagnostic in 85–97% of patients [48, 49]. The extent of pulmonary contusion on CT scan can help to predict the risk of developing ARDS [50]; however, the role of CT in the pediatric patient with chest trauma remains controversial [51]. Ultrasound is emerging as an alternative diagnostic tool in thoracic trauma and may be a useful alternative to CT for assessment of the extent of pulmonary contusion [7].

Fluid intake should be minimized, if possible, to reduce pulmonary edema. Supportive ventilation is necessary in severe instances. Pulmonary contusion after athletic injury is usually self-limited, without long-term sequelae. Once resolved, an athlete can resume training but should do so gradually, because exercise tolerance and pulmonary reserve will be reduced.

Hemothorax

Hemothorax may result from injury to the lung parenchyma or any of the intrathoracic vessels that may be lacerated by a traumatic rib fracture. In the setting of trauma, a pneumothorax may accompany this hemorrhage, causing a hemothorax. Clinically relevant hemothoraces occur in 14% of children sustaining blunt-force chest injury [31]. Blood in the thorax is often asymptomatic, unless the volume is large. In this instance, hemothorax can present similarly to tension pneumothorax, with decreased breath sounds and hypotension. Dullness to percussion is noted over the area of pooled blood. Treatment involves supporting ventilation and circulation with intravenous fluids and then placing a chest tube once transferred to an appropriate setting.

Cardiac Injuries

Comotio Cordis

Comotio cordis is a cause of sudden cardiac arrest resulting from blunt, nonpenetrating trauma to the precordium. It is often of apparently low energy and results in cardiac arrhythmias in the absence of any structural injury to the heart or surrounding tissues [52]. The epidemiology of commotio cordis has been studied in the United States over the last several decades with the use of a commotio cordis injury registry, first described by Maron et al. in 1995 [52–55]. Most cases occur in teenage males, with a mean age of 15 years, and it has been speculated that the more compliant chest cage of younger athletes may make them more susceptible to these impacts. Over half of reported commotio cordis events occur during organized competitive sports, with the remainder occurring during practice or daily

activities. The majority of blows resulting in commotio cordis are the result of a small projectile impacting the chest, such as a baseball, lacrosse ball, or hockey puck, while the rest are from bodily contact [56].

Animal models have been developed that suggest a specific and rare combination of circumstances is required to produce commotio cordis [57–59]. An impact must occur directly over the precordium, with a small enough surface area to transmit all of the energy from the collision to the heart [52, 59]. If this occurs exactly at the time of ventricular repolarization, just before the peak of the T wave, there is a 10–20 ms period of susceptibility that can result in ventricular fibrillation [54, 57–60]. In animal models, when a blow occurs outside this time, other arrhythmias may result, including heart block or bundle branch blocks [57].

Commotio cordis had previously been thought to have a high fatality rate with a low likelihood of reversal, despite the lack of structural injury [52, 53]. However, with increasing awareness and availability of automated external defibrillators (AEDs) at sporting events and in the community, the percentage of patients who survive commotio cordis has increased from 10 to 15% before 2000 to greater than 50% during the period from 2006 to 2012. Predictors of survival are prompt defibrillation and occurrence in a competitive event (during which rapid response and AED availability are more likely) [56].

Protective equipment such as chest guards and softer “safety balls” have been used to try to prevent blunt cardiac trauma, but evidence that such equipment prevents commotio cordis is lacking [61]. The most recent registry report at the time of this writing indicated that almost 40% of commotio cordis victims were wearing chest protectors at the time of the event, suggesting that current equipment may not offer sufficient protection [56]. In some cases this may be due to incomplete coverage of the precordium, or migration of equipment during movement [52, 54], but commercially available chest wall protectors failed to prevent ventricular fibrillation in an animal model of commotio cordis despite complete coverage of the cardiac silhouette [62].

For survivors of commotio cordis, a comprehensive cardiac work-up is necessary to rule out structural defects, conduction abnormalities, or other cardiac diseases that could have led to arrhythmia or arrest. Return-to-play decisions depend on the presence of underlying cardiac disease and should occur in consultation with a cardiologist. Some experts suggest avoiding return to sports with risk of chest impact after a commotio cordis event, at least until an older age [55].

Cardiac Contusion and Other Blunt Cardiac Injuries

In the setting of thoracic trauma, structural injuries to the myocardium must be considered. Such injuries may range in severity from contusion to free wall or septal wall rupture, valvular injury, and coronary artery or great vessel injury [63, 64]. Cardiac contusion (also referred to as contusio cordis) may result from a direct blow to the chest or from a rapid deceleration of the heart, causing it to strike the rib-sternum complex. Most injuries occur to the right ventricle, due to its proximity to the anterior chest wall. It has been reported in contact sports [65–67] but is more common in high-speed events such as motor vehicle accidents.

If blunt cardiac trauma is suspected due to mechanism or associated injuries, patients should be referred for further diagnostic testing. The use of cardiac enzymes for diagnosis and prognosis of cardiac contusion has been a topic of debate in the literature [68–73] and is complicated by the fact that there is no agreed-upon gold standard for comparison. Creatine kinase (CK) and creatine kinase-myocardial band (CKMB) have not shown diagnostic utility [68]; however, the combination of a normal cardiac troponin and normal electrocardiogram (EKG) is predictive of the absence of clinically significant cardiac trauma [70–72]. Most experts recommend obtaining an EKG and cardiac troponin if cardiac trauma is suspected, and further evaluation such as echocardiography should be obtained if the results are abnormal. Patients with EKG abnormalities or elevated troponin should be monitored for 24–48 h, as most dysrhythmias will occur during the first 24–48-h period after injury [64, 69, 70, 74, 75].

In the absence of EKG or troponin abnormalities, asymptomatic patients can resume normal activities as other injuries allow.

Chest Wall Injuries

Rib Fractures

Acute Rib Fractures

Rib fractures are considered the most common serious injury of the chest wall [76, 77]. Children are more vulnerable to intrathoracic injuries than adults, even in the absence of rib fracture, because of the increased elasticity and flexibility of their thoracic cage, which allows energy to be transmitted to the intrathoracic structures [78]. A fracture of the rib in a pediatric patient is more likely to be associated with other more significant injuries than in adults [79] and should increase clinical suspicion of other intrathoracic or intra-abdominal trauma.

Rib fractures can be divided into upper zone (first four ribs), midzone (ribs 5–8), and lower zone fractures (ribs 9–12) [80]. The most commonly fractured ribs from direct impact in any age group are the midzone ribs [77]. Fractures of the upper zone or lower zone ribs, multiple fractures, and flail segments are less likely to be isolated injuries than other patterns of rib fractures and may result in injury to surrounding structures [76, 80]. Acute traumatic impact fractures of the first and second rib are often associated with neck trauma and vascular injuries, as well as pneumothorax, lung laceration, and hemothorax. Direct impact fractures of the lower ribs may injure the kidneys, liver, or spleen. Splenic trauma has been reported in up to 20% of left lower rib fractures and acute liver trauma in up to 10% of right lower rib fractures [77]. Fractures of the first rib and the floating rib are generally thought to be more common in sports [76]. Isolated fractures of the first rib were initially described primarily as stress fractures or overuse injuries in athletes or physical laborers [81–83], though more are being reported in contact sports participants.

First rib fractures in sports may also occur from indirect trauma as a result of forceful

opposing muscle contraction [83] and have been reported in tennis players, surfers, windsurfers, rowers, dancers, gymnasts, and basketball players [84–90]. Fractures from indirect trauma occur with hyperabduction of the arm and falling on an outstretched arm, as well as sudden muscle contraction [83, 84, 91, 92]. The intercostal muscles and serratus anterior pull inferiorly, while the scalene muscles pull superiorly. The anterior scalene muscle produces bending forces at the subclavian sulcus, which is the usual fracture site [93].

Floating lower rib fractures may also occur with indirect trauma [76]. They are caused by avulsion of the attachments of the external oblique muscles and latissimus dorsi muscles with sudden contraction [76]. These types of fractures have been reported in baseball players and batters [76, 94].

The diagnosis of acute rib fractures is often indicated by a history of a traumatic event. The pain may initially be diffuse and gradually localize over the affected rib. Direct palpation, deep inspiration, coughing, twisting, or flexion to the side may exacerbate the pain. If there is accompanying lung or pleural injury, there may be subcutaneous emphysema. While these findings should prompt evaluation for rib fracture, clinical examination alone is not sensitive for detecting many rib fractures [95]. First rib injury may be particularly challenging, as palpation of the first rib is difficult.

A chest x-ray is often sufficient to establish the diagnosis and exclude other diagnoses, such as a pneumothorax or hemothorax. Dedicated rib series are more sensitive than conventional chest x-ray for detection of rib fracture, though their utility in minor chest trauma is debated [96, 97]. Patients with significant chest trauma should be referred to the emergency department for evaluation with a CT scan, which can also assess for associated intrathoracic and intra-abdominal injuries. An emerging diagnostic modality in the assessment of acute rib fracture is thoracic ultrasound. Some early studies suggest that ultrasound is effective and may be more accurate than x-ray in detecting rib fractures in the acute setting [95, 98–100]. Ultrasound is also useful and potentially more accurate than x-ray in the assessment of other injuries associ-

ated with rib fractures, including pneumothorax and pulmonary contusion [5–7].

The majority of rib fractures heal with rest. The goal of therapy for uncomplicated rib fractures is pain relief, improvement of ventilation, prevention of worsening injury, and a safe return to sport. Pain is usually controlled with oral analgesics. Ice may also be used. Deep breathing should be encouraged to prevent atelectasis. Taping is controversial and may lead to increased splinting, pulmonary complications, and atelectasis. Activities should be modified until symptoms resolve, and training should be resumed gradually. Return to play should only be considered in patients whose symptoms resolve and who have minimal pain with palpation.

Rib Stress Fractures

Stress fractures are relatively uncommon in the ribs as compared to the lower extremities, but they have been described in youth and adult athletes [101–103]. Most published information on rib stress fractures is in the form of case reports, with such reports indicating that these injuries occur predominantly in the first rib or in the middle ribs [102, 104].

First rib stress fractures have been reported mostly in overhead sports such as baseball, basketball, tennis, and weight lifting [81–83, 89, 104–106], as well as in surfers, swimmers, and dancers [84, 85, 107]. Unlike with acute traumatic first rib fractures, isolated first rib stress fractures are infrequently associated with other significant injuries of the vasculature or the lung (Fig. 7.2) [93].

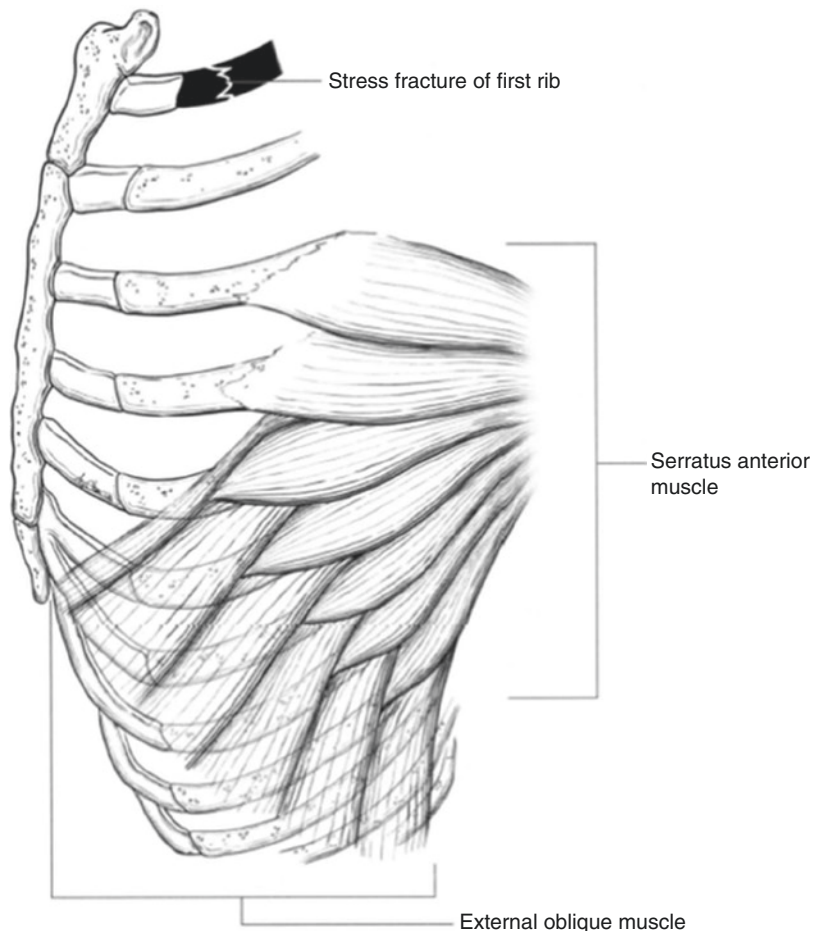


Fig. 7.2 First rib stress fracture

Stress fractures of the middle to lower ribs are reported mostly in patients who engage in swinging or pulling activities such as golf and rowing [104, 108–111]. Etiological factors associated with these sorts of fractures include improper technique, equipment problems, and lack of flexibility and strength [108, 111, 112]. Onset of symptoms is often preceded by an increase or change in physical activity or training [113]. Stress fractures of the ribs in rowers are postulated to be caused by excessive action of the serratus anterior muscle [114].

An athlete with a rib stress fracture typically presents with insidious onset of pain, either in the scapular region in the setting of a first rib fracture or with lateral, posterior, or anterior chest pain in the case of middle rib injury [93, 111]. Diagnosis is often delayed due to the nonspecific symptoms, which may be misdiagnosed initially as a muscle strain [102, 109].

In a study by Lord et al., plain radiographs revealed stress fractures in 16 cases of 19 rib fractures performed 2 weeks after the injury [109]. However, plain radiographs may initially be negative with stress fractures prior to callus formation, and diagnosis typically requires a triple-phase bone scan [101–103]. CT scans and magnetic resonance imaging (MRI) may also be useful for definitive diagnosis [115]. Rest from sport is suggested for a period of 4–6 weeks, though there is little evidence regarding the best approach to return to sport [116, 117]. Delayed union and nonunion are the most common complications of first rib stress fractures in throwing athletes. In patients with recalcitrant pain, referral to an orthopedic surgeon may be necessary [90].

Slipping Rib Syndrome

Slipping rib syndrome (also referred to variably in the literature as rib-tip syndrome, clicking rib syndrome, or rib pain syndrome) was first described in the early twentieth century and is characterized by an abnormal movement of the lower ribs resulting in intercostal nerve impingement and pain. This diagnosis has remained somewhat elusive, in part due to variation in definitions within the literature. Scott and Scott described the more inclusive “painful rib syndrome” as the clinical presentation

of pain in the lower chest or abdomen, a tender spot on the lower costal margin, and reproduction of pain by pressing that spot [118]. Slipping rib syndrome may also mimic abdominal pathology, due to its common presentation with upper abdominal pain [119]. The condition typically involves the eighth, ninth, and tenth ribs. These ribs are attached to each other by fibrous tissue in adults and by cartilaginous tissue in children. It is believed that when these connections are weakened or ruptured by trauma, the ribs can slip and impinge on the intercostal nerve, producing pain [120]. Rib-tip syndrome is usually unilateral; however, it may be bilateral [118, 121]. This condition particularly affects running, vigorous arm exercise, arm abduction, and swimming [101]. It has been reported more frequently in adults but nevertheless is a cause of rib and upper abdominal pain in adolescent and collegiate athletes [122–124].

Pain is often localized to the upper abdomen, epigastrium, or inferior costal regions. Some patients report a slipping movement of the ribs or a popping sensation. Pain may vary from mild to severe and often is reproduced by movement [118]. Symptoms can often be reproduced upon clinical examination by hooking the fingers under the inferior rib and pulling anteriorly, referred to as the “hooking maneuver” [125]. A positive test reproduces the patient’s pain and results in a click. Direct tenderness over the cartilage is another frequent finding. The diagnosis is clinical, and diagnostic imaging is generally not helpful, although it may exclude other conditions. Intercostal nerve blocks may be useful in establishing the diagnosis. Ultrasound has been described in adult patients as a means to observe cartilage subluxation during movement [126].

No definitive consensus exists as to the best management for slipping rib syndrome [127]. Conservative management for mild cases includes reassurance and avoidance of aggravating motions. Some patients have reported favorable outcomes with single or multiple local anesthetic nerve blocks [119, 128], and corticosteroids added to an injection may be beneficial. Surgical excision of costal cartilage for recalcitrant cases has demonstrated efficacy in both adults and children [120, 122, 129, 130].

Costosternal Syndromes (Costochondritis)

A variety of diagnostic terms have been used in this group of syndromes, including costochondritis, costosternal syndrome, and anterior chest wall syndrome. Costochondritis is a common cause of atraumatic chest pain in children and adolescents and is characterized by pain and tenderness of the costochondral junction without swelling [131]. This condition may account for 9–22% of cases of pediatric chest pain [132, 133]. The sites most typically involved are the second through fifth ribs [131]. Costochondritis may be preceded by an upper respiratory infection or by exercise that stresses the upper body, and symptoms may persist for several months [134].

Diagnosis of costochondritis is clinical, based on a history of chest pain and by exclusion of other etiologies [134]. Anterior chest wall tenderness may be localized to one or more costochondral junctions, and movement of the arm on the ipsilateral side may also reproduce the pain [131, 134].

The course is usually self-limited, and most patients recover spontaneously from the condition. Anti-inflammatory agents, ice, muscle relaxants, and injection of lidocaine (with or without corticosteroid) have been used in selected cases [134, 135]. Stretching exercises may also be of benefit [136]. Patients should be reassured of the benign course of this condition and can continue to participate in sports as tolerated.

Sternal Fractures

Sternal stress fractures have been reported in golfers, weight lifters, and wrestlers [101, 137, 138]. Acute traumatic sternal fractures are frequently seen in association with deceleration injuries and/or direct blows to the chest in adults, though a case series in children suggested that more minor blunt trauma may be a common mechanism in this age group [139]. Isolated sternal fractures from direct impact do not pose significant risk to the athlete. Injuries to the sternum have traditionally led to a search for associated cardiac, great vessel, and pulmonary injuries caused by the anatomic proximity of these struc-

tures, but associated morbidity with these injuries is low. Studies in both Europe and the United States have shown the mortality associated with isolated sternal fractures to be less than 1%, and the incidence of associated blunt cardiac injury to be low [140–142]. Nevertheless, it is important that one carefully assess the pediatric patient who presents with a sternal fracture for symptoms of other potentially associated injuries. These include pneumothorax, pulmonary contusion, and cardiac contusion.

Sternal fractures are often better seen on lateral sternal x-rays than on standard anterior-posterior (AP) chest films, because most of these fractures are oriented transversely. Standard radiographs can also be challenging to interpret in pediatric patients, due to the variable pattern of ossification centers in the sternum [139, 143]. In cases in which a fracture is questionable, CT scans are more sensitive but may not improve detection of clinically significant sternal fractures [144]. Ultrasound is a promising diagnostic tool for sternal fracture, with recent reports suggesting better accuracy than traditional radiographs [145, 146]. If intrathoracic trauma is suspected in the setting of a sternal fracture, further imaging and assessment are warranted. Otherwise asymptomatic pediatric patients with isolated sternal fracture can be safely discharged home [139].

Scapular Fractures

Scapular fractures represent less than 1% of all skeletal injuries and 5% of shoulder fractures [147, 148]. It is uncommon for scapula fractures to occur in isolation [149], and presence of a scapula fracture should prompt consideration of other thoracic injuries [150]. Fractures of the scapula are rare in athletes, with the majority of reported cases occurring in football players [147, 148, 151]. Injuries occur during tackling, when the shoulder is in abduction and the scapula is pulled away from the chest wall where it is unable to dissipate direct force.

There are eight types of scapular fractures. They are classified by anatomic location: body, glenoid rim, glenoid fossa, anatomic and surgical neck, acromion, spine, and coracoid process. The

Table 7.1 Sports-related abdominal trauma

Intra-abdominal pathology	Abdominal wall contusions	Splenic ruptures	Ruptured jejunum	Pancreatic injury	Renal injuries
No. of patients	11	4	1	1	7

Source: Ref. [152]. Reprinted with permission from Elsevier

majority of scapular fractures are body fractures [151]. Approximately 10% of fractures occur in the acromion, coracoid, and spine [115].

A scapular fracture may present with symptoms that are similar to a rotator cuff injury [151]. Cain and Hamilton reported that rotator cuff injuries were initially suspected in half of football players who were diagnosed with scapular fractures [147]. Clinical examination reveals weakness with abduction and external rotation of the shoulder. Pain and weakness in the shoulder region are exacerbated with movement. Localized tenderness, swelling, and hematoma formation over the fracture site may also be present.

Scapula fractures are often not seen on standard scapula x-rays (AP, lateral, and axillary views). In one study, 43 out of 100 scapular fractures were missed on initial radiographs [149]. Therefore, specialized views such as the scapula Y, CT, or MRI may be necessary.

Treatment of nondisplaced scapular fractures is usually conservative and involves rest from sports and physical therapy. The application of ice is recommended for the first 48 h. A sling may also be used for immobilization, along with early range of motion exercises for 2–4 weeks. Rehabilitation should then focus on strengthening, and full return to sport may take several months [151]. In severe cases, surgical fixation should be considered.

Abdominal Injuries

Ten percent of all abdominal injuries have been reported to result from sports-related trauma [152]. Football [153, 154], rugby [155], soccer [156–158], and wrestling [159] are the most common contact sports for abdominal trauma. Noncontact sports, such as downhill skiing [160–163], water skiing [164], and horseback



Fig. 7.3 Duodenal injury from a bicycle fall. Courtesy of David Mooney, MD, Children's Hospital, Boston, MA

riding [153, 165], result in high-speed deceleration mechanisms and may result in very serious injuries.

A retrospective cohort study of Swedish children by Bergqvist et al. [153, 166], involving 348 injuries over 30 years, revealed 7.1% of abdominal trauma was sports related (Table 7.1). Sports involved were ice hockey (eight cases), skiing (six cases), soccer (five cases), pole vaulting (one case), and gymnastics (one case).

The same study contrasted recreational cycling with organized sport and found 12% of abdominal trauma in children was related to this pastime. In addition to the pathologies detailed in Table 7.1, there were liver injuries, a mesenteric rupture, muscle lacerations, a stomach rupture, and colon injuries with cycling. Ballham [167] showed that bicycle injuries had a higher injury severity index than other sports. Pediatric bicycle injury data from Puranik [168] of 211 children under 15 years old revealed 9% had internal organ injuries. The handlebar imprint can sometimes be seen along the upper edge of the abdomen (Fig. 7.3) [169]. Bicycles [170–172] and other types of sports-related vehicular use may

result in the same patterns of abdominal injury that are seen in automobile accidents.

Splenic Injury

Injuries to the spleen can result from a direct force to the abdomen, especially the left upper quadrant, and from a sudden deceleration when the hilum is torn or by displacement of lower left rib fractures. Any of these mechanisms are possible in high-speed or contact sports.

The mechanism of splenic injury was explored in a study of downhill skiers [173]. In high-velocity or high-impact collisions, e.g., with a tree, a chairlift pole, or a snow fence, multiple trauma was always present (fractures or damage to multiple organs). Skiers were unable to move at the scene, and splenectomy resulted in five out of six cases (83%). With low-velocity or low-impact collisions, often just a single organ was involved. Such injuries resulted from falls on ski trails, on moguls, or on tree stumps or rocks. Presentation in these cases was often delayed for hours, while the individual continued skiing. Splenectomy was necessary in 5 of 12 cases (42%).

Machida et al. [29] found a significantly higher abdominal injury rate in snowboarders compared to skiers. Injuries to the kidney, liver, and spleen were seen in both. In snowboarders, riding mistakes after jumping and subsequent falls were responsible for 31.6% of the abdominal traumas. Skiers were more likely to have a collision as the mechanism for their abdominal injury.

Physical exam is neither sensitive nor specific for splenic injury. Therefore, patients with a concerning mechanism or pain should undergo diagnostic imaging. The most important determinant of nonoperative management of splenic rupture is hemodynamic stability, including hematocrit. Nonoperative management of splenic injuries consists of careful hemodynamic monitoring, frequent physical and laboratory examination, and, most importantly, strict bed rest. Given a stable course, a CT scan should be repeated after 5–7 days and should show stabilization or improvement of the injury. Rest and avoidance

of contact sports are recommended for up to 4 months after injury. This is determined largely by the severity of the injury seen on CT and its resolution. Nonoperative splenic management seems to be more successful in children (90%) than in adults (70%) [174].

Epstein-Barr Virus, Infectious Mononucleosis, and Splenomegaly

By age 30, 90% of the population has been exposed to the Epstein-Barr virus, which causes infectious mononucleosis [175]. This may frequently be unrecognized, particularly in children. From 1 to 3% of college students are affected each year [176]. The peak incidence is in 15–24-year-olds.

A study using physical exam alone reported splenomegaly in 8% of patients with infectious mononucleosis [177]. In comparison, a study utilizing ultrasonography demonstrated that 100% of patients with infectious mononucleosis had an enlarged spleen; physical examination detected the abnormality in less than 20% of the same cases [178]. These studies indicate that physical exam alone is an insensitive tool to diagnose splenomegaly in the setting of infectious mononucleosis.

During bouts of mononucleosis, spleen length increases by 33% and peaks between 2 and 4 weeks from onset of symptoms [178]. Comparison with normative anthropomorphic measurements with ultrasound should be used to guide recommendations for return to sport after infectious mononucleosis [179–181].

Infectious mononucleosis causes the splenic architecture to become distorted, making the spleen susceptible to rupture from any increased abdominal pressure, even from sneezing or coughing. Splenic rupture in infectious mononucleosis occurs in 0.1–0.2% of cases, with the highest estimate being 0.5% [182]. The timing of this complication is predictable, being noted in the first 3 weeks of the illness. Splenic rupture is unusual beyond 3 weeks from the onset of symptoms (headache, sore throat, and fever). The prodromal period is not considered when determining the onset of the illness.

Splenic rupture is associated with abdominal pain, left shoulder pain (Kehr's sign), or periscapular pain. Left upper quadrant abdominal tenderness may or may not be accompanied by peritoneal signs, such as generalized tenderness, guarding, and rebound tenderness. Indicators of hypovolemia, such as tachycardia and hypotension, are worrisome signs. This complication fortunately is often not fatal. Splenectomy is necessary in some instances, although nonoperative management is often successful [183]. Treatment should be individualized. There is no evidence to suggest corticosteroids reduce spleen size or shorten the duration of the illness [184].

The appropriate time to allow an athlete with infectious mononucleosis to resume his or her activity is determined by the duration of symptoms, as well as the presence of splenomegaly and risk of splenic rupture. There is concern that contact trauma may precipitate splenic rupture. In a 1976 survey of college team physicians, the respondents identified 22 cases of splenic rupture. At the time of the trauma, 41% of these were diagnosed with infectious mononucleosis. Seventeen of the student athletes were participating in football [185]. Most splenic ruptures in the setting of infectious mononucleosis, however, are spontaneous, not the result of contact.

Return-to-play recommendations in the literature have been varied [186]. To protect the enlarged spleen, which should probably be assumed to be present in all cases [184], all strenuous activity should be avoided for the first 21 days. At this point the athlete may start a graded aerobic program, avoiding contact, if the athlete is asymptomatic, afebrile, and does not have a palpable spleen. At 4 weeks, if the signs are equivocal or the athlete is at high risk for collision, an imaging study such as ultrasound should be considered [187]. It should also be noted that normal spleen size has been directly correlated with athlete size; hence, a large athlete with an appropriately sized spleen may be mistakenly diagnosed with splenomegaly if the splenic volume/body mass is not considered [180, 188].

Hepatic Injury

With the evolution of CT scanning, recognition of minor liver injuries has been enhanced. Although the spleen was previously asserted to be the most commonly injured intra-abdominal organ, the incidence of liver injuries may be similar [189]. This is not surprising considering the large size, soft substance, and unprotected position of the liver. Injury can result from a direct blow, especially to the right upper quadrant, a sudden deceleration, or by displacement of right lower rib fractures. Hepatomegaly results in an increased risk of injury, not only because of the increased size but also because an enlarged liver is softer than normal. Therefore, hepatomegaly is a contraindication to high-speed or contact sports.

The mechanism of injury, especially for lower rib fractures, is much more important than the physical exam to suggest a possible liver injury. Right upper quadrant abdominal tenderness, an abrasion/contusion over the right upper abdomen, right shoulder pain, or hemodynamic instability may be present. A CT scan is warranted with any appropriate mechanism. The typical appearance of a liver laceration is illustrated in Fig. 7.4. Unstable patients should have an immediate laparotomy. However, even high-grade injuries can be managed nonoperatively despite an imposing CT appearance, if the patient is hemodynamically stable.

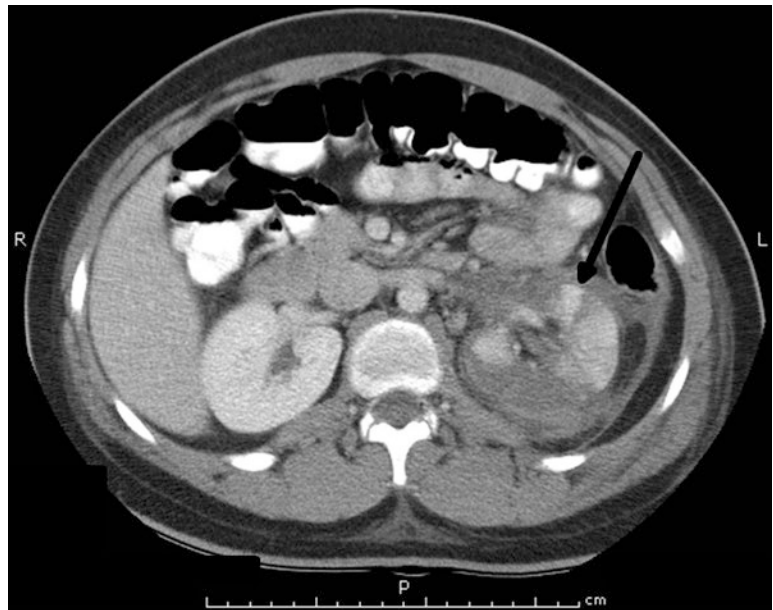
Renal Injury

The kidney is the most commonly injured intra-abdominal organ in some sports, such as rugby. Renal injuries may be relatively asymptomatic, even with repeated blows, such as in boxers, or they may result in renal contusions causing microscopic or gross hematuria. Occult hematuria without radiographic evidence of injury is extremely common in several sports. It is present in 25% of boxers [164], college football players [190], and distance runners [191]. Kidney trauma from a direct blow is particularly common in football and rugby. Twenty-five percent of renal

Fig. 7.4 Hepatic injury. Courtesy of David Mooney, MD, Children's Hospital, Boston, MA



Fig. 7.5 Left kidney injury. Courtesy of David Mooney, MD, Children's Hospital, Boston, MA



injuries and 40% of renal pedicle injuries do not demonstrate hematuria [192]. An injury to the kidney is shown by CT in Fig. 7.5.

Gross hematuria should be evaluated in the hospital. Nonoperative management is appropriate as long as the athlete is not in shock, there is no expanding hematoma, and no free extravasation of urine seen on intravenous contrast CT. Complete healing is essential before

return to sports. Most renal injuries heal within 6–8 weeks. Microscopic hematuria may persist for 3–4 weeks after injury.

Younger patients require special attention, as renal injury is more common than splenic or hepatic injury. Up to 30% of renal trauma in children is related to sport. This may be caused by a proportionally larger kidney size or a lack of musculoskeletal protection [8].

Pancreas

The pancreas is injured in 1–2% of abdominal trauma. A forceful blow to the upper abdomen is the most common mechanism of injury [155, 158]. For instance, a bicycle fall where the handlebar twists and “spears” the child may be the presenting history [1, 169]. As with other internal organs, there are often minimal obvious physical signs of damage. Patients can develop nausea, vomiting, and abdominal pain up to 48 h later. Typically, the pain radiates to the back. CT is the most useful imaging modality.

Bowel Injury

Bowel injury is infrequent and most commonly occurs as a result of a forceful blow to a small area over the small intestine. Physical findings may be limited. An erect chest x-ray may reveal air beneath the diaphragm, although CT is the most sensitive diagnostic imaging modality.

Groin Pain and Injuries

This is one of the more difficult problems to diagnose in athletes, especially if chronic. Soccer, hockey, hurdling, and skiing are sports where groin injuries are especially common [193]. The etiology is most commonly soft tissue injury, contusion or hematoma, and muscle-tendon strain. However, consideration of inguinal hernia, bursitis, and nerve entrapment is warranted.

Additionally, there is evidence evolving in the literature regarding the sportsman’s hernia [194]. This is a tear in the transversalis fascia in the posterior inguinal floor that Hackney [195] describes as an “incipient direct inguinal hernia.” The mechanism of injury is aggressive abduction in specific athletic situations, such as cutting maneuvers. Sportsman’s hernias are particularly common in sports such as soccer and hockey, where athletes frequently change direction at high speed [195–197]. The sportsman’s hernia is resistant to conservative therapy, and symptoms will recur after a period of rest. The key physical

exam finding is tenderness at the pubic tubercle. This injury does not typically show up on routine imaging. Surgical repair of the inguinal floor will return approximately 90% of patients to full activity without pain [194].

Prevention

Thoracoabdominal trauma is uncommon in pediatric athletes. Certain injuries may be preventable. Sport-specific safety equipment should be worn to minimize the risk of injury. For instance, chest barriers and safety balls in baseball may have decreased (though not eradicated) the risk of commotio cordis [52]. An AED should be present at venues.

Conditioning is also important. Appropriate core strength, including the entire trunk, will maximize protection in contact sports and minimize overuse stress in noncontact sports. Attention to proper sports technique can also minimize the possibility of overuse.

Return-to-Play Guidelines

Onsite return-to-play decisions should be based on pain resolution, unless a minor abdominal wall injury is considered likely. Vital signs should be normal and peritoneal signs absent. Further, players should be able to exercise without an increase in symptoms.

Athletes who have sustained a solid organ contusion require a normal CT scan 2–3 weeks before being allowed to return to practice. Lacerations and subcapsular hematomas require longer periods of recovery because of the greater architectural damage sustained; hence, a prolonged period of healing is necessary. If an organ has to be removed, full tissue postoperative healing takes 6–24 weeks. Strenuous activity should therefore be postponed for 6–8 weeks and contact sports for 12–24 weeks, although advice varies by surgeon.

Rib injuries should be considered on a case-by-case basis, but return to sport is usually possible in 4–8 weeks. Tullos and Erwin

described a baseball pitcher who was asymptomatic with a first rib injury at 3 weeks and was able to return to pitching with a pain-free nonunion [94]. The athlete with a sternal fracture can return to play when he/she can compete in a pain-free manner. If the patient engages in contact sports, a flank jacket or other similar device can be used to protect the injury.

Clinical Pearls

- It is essential, when assessing an athlete who has sustained trauma to the thorax or abdomen, to maintain a high level of suspicion for internal injury.
- There may be no external sign initially, and serial physical examinations are crucial.
- If a significant injury is suspected, the athlete should be transferred to a setting where CT imaging and advanced medical care are available.
- Rib fractures may be traumatic from direct impact or secondary to acute muscle contraction. They may also occur as a stress injury.
- Fractures of the first four ribs or the last two ribs, multiple fractures, and flail segments may result in injury to surrounding structures.
- Scapular fractures are unusual in sports and are often missed initially.

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