Don't Forget the Abdominal Wall: Imaging Spectrum of Abdominal Wall Injuries after Nonpenetrating Trauma[1]

Shanna A. Matalon, MD
Reza Askari, MD
Jonathan D. Gates, MD[2]
Ketan Patel, MD
Aaron D. Sodickson, MD, PhD
Bharti Khurana, MD

Abbreviations: MLL = Morel-Lavallée lesion, RSH = rectus sheath hematoma, TAWH = traumatic abdominal wall hernia

RadioGraphics 2017; 37:1218–1235

https://doi.org/10.1148/rg.2017160098

Content Codes: CT ER GI US

[1]From the Departments of Radiology (S.A.M., A.D.S., B.K.) and Trauma, Burns, and Critical Care (R.A., J.D.G.), Brigham and Women's Hospital, 75 Francis St, Mellins Library, Boston, MA 02115; and Shields Radiology, Brockton, Mass (K.P.). Recipient of a Cum Laude award for an education exhibit at the 2015 RSNA Annual Meeting. Received April 10, 2016; revision requested July 12 and received August 18; accepted September 2. For this journal-based SA-CME activity, the authors, editor, and reviewers have disclosed no relevant relationships. **Address correspondence to** S.A.M. (e-mail: *smatalon@partners.org*).

[2]Current address: Department of Surgery, Hartford Hospital, Hartford, Conn.

SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- List the anatomic areas of relative weakness that are especially susceptible to traumatic injury.
- Recognize common associated injuries in patients with traumatic abdominal wall injury.
- Discuss the frequency, common locations, and imaging findings of TAWH.

See www.rsna.org/education/search/RG.

Abdominal wall injuries occur in nearly one of 10 patients coming to the emergency department after nonpenetrating trauma. Injuries range from minor, such as abdominal wall contusion, to severe, such as abdominal wall rupture with evisceration of abdominal contents. Examples of specific injuries that can be detected at cross-sectional imaging include abdominal muscle strain, tear, or hematoma, including rectus sheath hematoma (RSH); traumatic abdominal wall hernia (TAWH); and Morel-Lavallée lesion (MLL) (closed degloving injury). These injuries are often overlooked clinically because of *(a)* a lack of findings at physical examination or *(b)* distraction by more-severe associated injuries. However, these injuries are important to detect because they are highly associated with potentially grave visceral and vascular injuries, such as aortic injury, and because their detection can lead to the diagnosis of these more clinically important grave traumatic injuries. Failure to make a timely diagnosis can result in delayed complications, such as bowel hernia with potential for obstruction or strangulation, or misdiagnosis of an abdominal wall neoplasm. Groin injuries, such as athletic pubalgia, and inferior costochondral injuries should also be considered in patients with abdominal pain after nonpenetrating trauma, because these conditions may manifest with referred abdominal pain and are often included within the field of view at cross-sectional abdominal imaging. Radiologists must recognize and report acute abdominal wall injuries and their associated intra-abdominal pathologic conditions to allow appropriate and timely treatment.

Introduction

Nonpenetrating trauma accounts for the majority of emergency department visits after unintentional or intentional injury (1). Blunt trauma, such as that resulting from motor vehicle collisions and falls, represents the majority of nonpenetrating trauma, with positional and athletic injuries occurring less commonly. Abdominal wall injuries are found in approximately 9% of patients after blunt trauma (2). The mechanism of injury is *(a)* direct impact with abrupt increase in intra-abdominal pressure or *(b)* shearing forces tangential to the abdominal wall, such as in the setting of motor vehicle collisions. A variety of injury types may occur, including *(a)* abdominal muscle strain, tear, or hematoma, including rectus sheath hematoma (RSH); *(b)* traumatic abdominal wall hernia (TAWH), with lumbar hernias being the most common; and *(c)* Morel-Lavallée lesion (MLL), also known as closed degloving injury (Table 1) (3). Because a substantial impact is required to cause these types of injuries, they are highly associated with graver intra-abdominal visceral and vascular injuries (3,4). Radiologists must be familiar with these abdominal wall injuries

TEACHING POINTS

- Because a substantial impact is required to cause these types of injuries, they are highly associated with graver intra-abdominal visceral and vascular injuries.
- Below the level of the arcuate line of Douglas, the rectus sheath is absent posteriorly, and blood from the RSH may come into direct contact with the peritoneum and cause peritonitis. Misinterpretation of these signs and symptoms may thus lead to a misdiagnosis of an intra-abdominal process, such as ovarian pathologic conditions, appendicitis, hernia, or an abdominal wall neoplasm, and may even result in unnecessary surgery.
- It is important to note that more than 50% of TAWHs are occult at physical examination and are detected only with CT. In the findings of one study of nearly 34 patients with TAWH, only 30% of patients had a hernia evident at physical examination. The posterior location of lumbar hernias, patient pain, and other associated injuries likely all contribute to the low sensitivity of the findings at physical examination for the detection of TAWH. This observation is important, because if TAWHs are undetected or left untreated, as many as 25% of patients may later present with complications such as incarceration or strangulation of hernia contents.
- More than 50% of patients with TAWH have associated injuries, with some investigators reporting an incidence as high as 90%.
- Although most MLLs are identified early after the causative trauma, up to one-third of cases are identified months to years later, often as nonspecific enlarging soft-tissue masses, which explains why these lesions may be confused with neoplasms.

because they often herald more-serious underlying intra-abdominal trauma. Also, failure to diagnose abdominal wall trauma can result in misdiagnosis or delayed complications, which may necessitate a more complicated repair (5–7).

In the radiologic evaluation of abdominal pain after nonpenetrating trauma, additional diagnostic considerations include inguinal disruption, also known as athletic pubalgia, as well as costochondral injuries. Both of these conditions may manifest with referred abdominal pain and are often included within the field of view at cross-sectional imaging of the abdomen (8).

Although blunt injury is more common than penetrating injury, the imaging features of penetrating trauma have been more extensively reviewed in the radiology literature (9–13). For this reason, we focus on the abdominal wall injuries that occur after nonpenetrating trauma, which have not been comprehensively reviewed previously, to our knowledge. First, the anatomy of the abdominal wall is reviewed, followed by discussion and illustration of some of the common and important abdominal wall injuries: *(a)* abdominal wall muscle strains, tears, and hematomas, including RSH; *(b)* TAWH; and *(c)* MLL. For each type of injury, background information, the relevant anatomy, the mechanism of injury, clinical manifestations, imaging features, and typical treatment are reviewed. In addition, inguinal disruption and costochondral injuries are briefly covered.

Table 1: Checklist of Potential Abdominal Wall Injuries

Abdominal wall contusion
Abdominal wall muscle strain, tear, or hematoma
MLL
TAWH
Inguinal disruption (athletic pubalgia)
Costochondral fracture

Anatomy of the Abdominal Wall

The abdominal wall is divided into anterior, lateral, and posterior compartments (14,15). From superficial to deep, the anterior abdominal compartment is composed of skin, superficial subcutaneous fat (also called Camper fascia), deep subcutaneous membranous tissue (also called Scarpa fascia), layers of muscles separated by their investing fascia, a thin layer of extraperitoneal fat, and, finally, the parietal peritoneum (15). The rectus abdominis muscles are two parallel and longitudinally oriented muscles that make up the anterior compartment, which are located just to the right and left of midline, extending from the anteroinferior costal cartilages to the pubis (15). The superior and inferior epigastric vessels run along the posterior border of the rectus abdominis muscles; the superior epigastric artery arises as the terminal branch of the internal thoracic artery, and the inferior epigastric artery arises from the external iliac artery (16).

The lateral compartment is made up of three flat muscles: the external oblique, internal oblique, and transversus abdominis muscles (from superficial to deep). The rectus abdominis muscles are separated from the lateral abdominal musculature by the semilunar line, best known as the site of the spigelian hernia (17–19). The rectus muscles are enclosed by a fascial "sheath," which arises from the aponeuroses of the three lateral abdominal muscles (made up of the external and internal oblique and transversus abdominis muscles). Rectus sheath anatomy undergoes a change at the arcuate line of Douglas, a horizontal or transverse line that lies just below the umbilicus. Above the arcuate line, the rectus abdominis muscle is fully enclosed both anteriorly and posteriorly by the fascial "sheath"; but below the arcuate line, the aponeuroses join to form the sheath only anteriorly, with just a thin posterior lining made up of the transversalis fascia and peritoneum (Fig 1) (20).

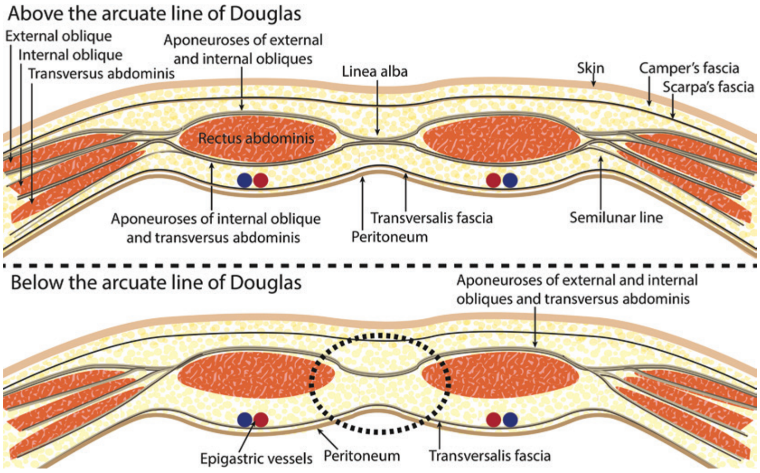


Figure 1. Drawings show axial views of the anatomy of the anterior abdominal wall, with special attention to the rectus sheath above (top) and below (bottom) the arcuate line of Douglas. Below the arcuate line, the aponeuroses of the lateral abdominal wall musculature form only an anterior sheath (dotted oval), with only a thin posterior layer made up of the transversalis fascia and peritoneum.

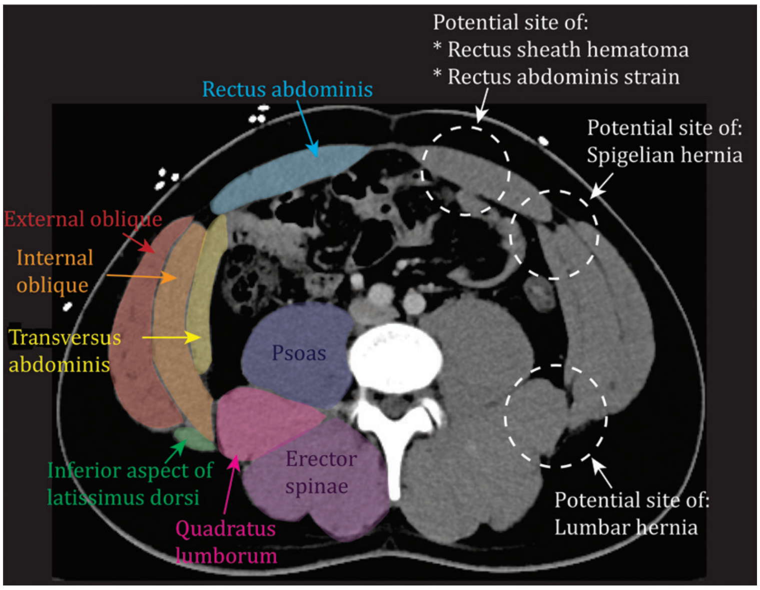


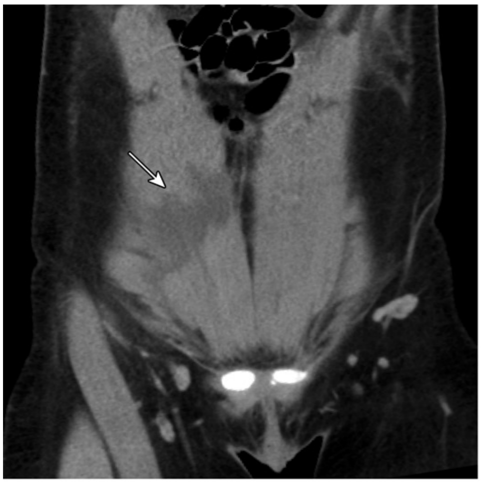
Figure 2. Annotated axial computed tomographic (CT) image shows the anatomy of the abdominal wall and important sites of potential injury (dashed circles) after nonpenetrating trauma to the abdominal wall.

The posterior compartment is made up of the latissimus dorsi, quadratus lumborum, and the erector spinae (paraspinal muscles). These muscles of the posterior compartment are covered by the thoracolumbar fascia, which is divided into anterior, middle, and posterior layers. The transversalis fascia continues posterolaterally as the anterior layer of the thoracolumbar fascia, which lines the anterior surface of the quadratus lumborum (15). The middle thoracolumbar fascia lines the posterior surface of the quadratus lumborum and attaches to the transverse processes of the lumbar spine (15). The posterior compartment is also referred to as the lumbar region and can be further divided into superior and inferior lumbar triangles, which are discussed in more detail in the "Anatomy" section under "Traumatic Abdominal Wall Hernia." Many potential sites of anatomic weakness exist that are especially susceptible to traumatic injury; these sites are discussed in greater detail subsequently in the relevant sections (Fig 2).

Abdominal Wall Muscle Injury

Background

After blunt trauma to the abdomen, most patients present with lower-grade injuries ranging from subcutaneous contusion to abdominal wall hematoma (2). In addition to injuries caused by direct impact, such as in motor vehicle collisions and falls, these injuries can also occur after extreme physical exertion or sports-related injury (such as those in wrestling, soccer, and volleyball) (21–24). Although these injuries are usually identified with a careful history and physical examination, these patients may undergo cross-sectional imaging if concern exists for an intra-abdominal



3.

4.

Figures 3, 4. **(3)** Rectus abdominis strain and tear in a 17-year-old girl after yoga. Coronal CT image shows irregular contour and linear hypoattenuation of the right rectus abdominis muscle (arrow), findings consistent with strain and a high-grade tear. **(4)** Internal oblique strain and tear after an intense abdominal workout in a 20-year-old man with chronic myeloid leukemia and thrombocytopenia. Coronal CT image shows irregular contour and hypoattenuation of the right internal oblique muscle (arrow), findings consistent with muscle strain and tear.

process in the setting of acute abdominal pain. It is imperative that radiologists examine the abdominal wall and recognize these findings so that patients can receive appropriate treatment and avoid unnecessary surgery.

Abdominal wall hematomas most commonly occur within the rectus muscle (also known as RSHs) and less commonly involve the lateral and posterior abdominal wall (25,26). This discussion will focus primarily on RSH, with brief comments on the rest of the abdominal wall.

Anatomy

The anatomy of the anterior abdominal wall is described in detail in the section, "Anatomy of the Abdominal Wall," and can be reviewed by referencing Figure 1.

Mechanism of Injury

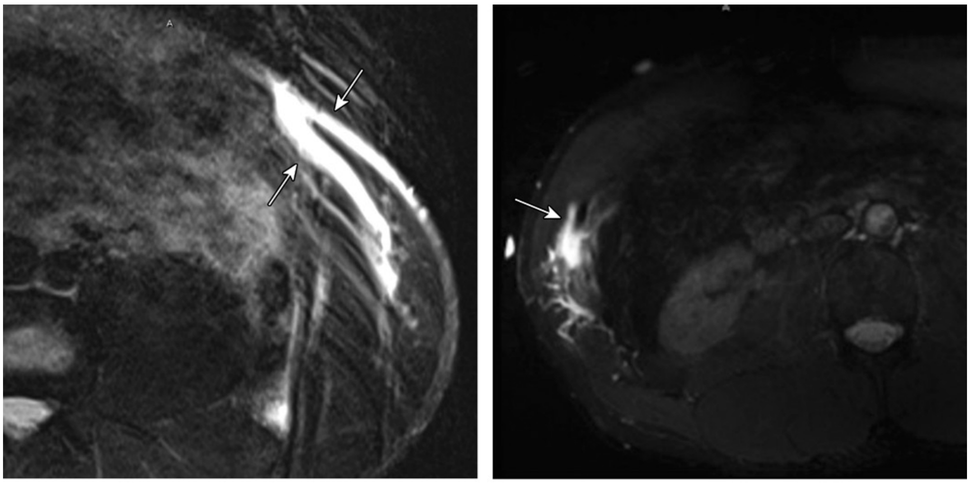
RSH occurs as a result of tearing of the epigastric arteries or damage to intramuscular vessels directly by tearing of the muscle itself (16). Above the arcuate line, the superior epigastric arteries are usually involved; below the arcuate line, the inferior epigastric arteries are most commonly implicated. RSH caused by bleeding from the superior epigastric arteries is more likely to result in self-tamponade because of compression by the circumferential rectus sheath, and RSH caused by bleeding from the inferior epigastric arteries is less constrained by the absent posterior sheath. The most common location is below the level of the umbilicus and thus below the arcuate line of Douglas (20,27). RSH is not exclusively a traumatic injury and may occur spontaneously, secondary to coughing or in the postsurgical setting, most commonly in patients receiving anticoagulant therapy (21,28). In a review of 126 patients with RSH, investigators found that 69% of patients were receiving anticoagulant therapy, with warfarin and unfractionated heparin infusion representing nearly 40% and 32% of cases, respectively (21). In the setting of trauma, an RSH may occur as a result of blunt trauma or twisting injury.

Hematomas occurring in the lateral abdominal wall are classified as slowly growing (oozing from a muscle tear) or rapidly growing (secondary to arterial hemorrhage) (29). When the lateral abdominal wall is involved, the deep circumflex iliac artery is the most likely culprit (25,26).

The abdominal wall musculature can also undergo tear and strain, either as a result of direct blunt trauma or abrupt movement, such as twisting or a rapid change in position (21–24). Twisting injury can occur in athletes or even during regular exercise, especially in patients with predisposing factors such as anticoagulant therapy or coagulopathy (24) (Figs 3–5).

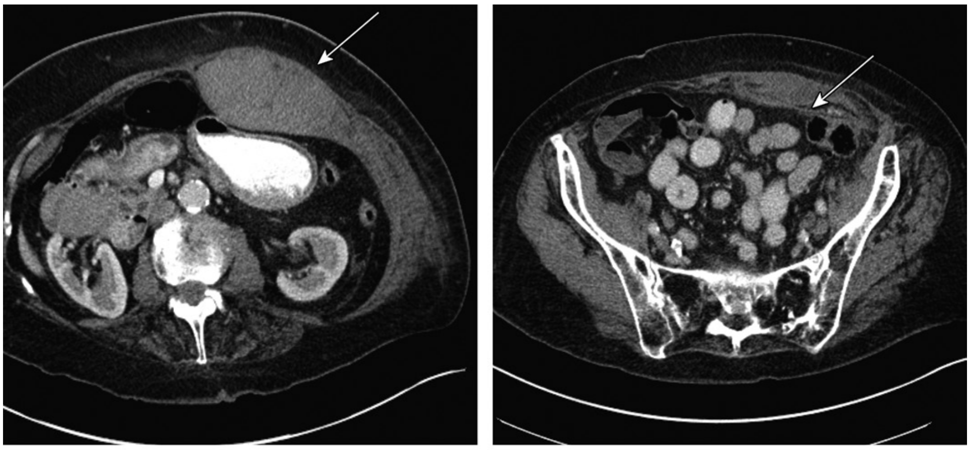
Clinical Manifestations

RSH occurs more commonly in women than in men, with most patients receiving anticoagulant therapy and with warfarin being the most common type (21,30). The most likely symptom at clinical presentation is abdominal pain, followed by an abdominal wall mass and a decreased hematocrit reading (16,20,22,31). A minority of patients present with abdominal wall ecchymosis (21). Below the level of the arcuate line of



a. b.

Figure 5. Magnetic resonance (MR) images of two different athletes who presented with abdominal pain. **(a)** Axial fluid-sensitive MR image shows an external oblique strain and tear (arrows) in a 23-year-old man. **(b)** Axial fluid-sensitive MR image shows an internal oblique strain and tear (arrow) in a 29-year-old man.



a. b.

Figure 6. Shapes of RSHs occurring above and below the arcuate line of Douglas in an 82-year-old woman. **(a)** Axial CT image shows that an RSH above the arcuate line of Douglas tends to be spindle shaped and is supported posteriorly (arrow). **(b)** Axial CT image shows that an RSH below the arcuate line of Douglas is less organized (arrow) because of a lack of substantial posterior fascial support.

Douglas, the rectus sheath is absent posteriorly, and blood from the RSH may come into direct contact with the peritoneum and cause peritonitis. Misinterpretation of these signs and symptoms may thus lead to a misdiagnosis of an intraabdominal process, such as ovarian pathologic conditions, appendicitis, hernia, or an abdominal wall neoplasm, and may even result in unnecessary surgery (21,31–33).

Some of the potential complications of RSH include anemia, hypovolemic shock, muscle necrosis from compartment syndrome, and unnecessary surgery as a result of misdiagnosis (21,34). RSHs are rarely life threatening, although fatalities have been reported (21,35).

Workup and Imaging

Ultrasonography (US), CT, and MR imaging are all able to be used to make this diagnosis of RSH. The shape of the hematoma depends on its location above or below the arcuate line of Douglas; those above the arcuate line tend to appear spindle shaped, and those below appear more spherical because they protrude more posteriorly because of the decreased posterior fascial support (Fig 6) (23). On US images, RSH appears as a hypoechoic or anechoic mass, possibly with areas of internal echoes or septa, depending on the chronicity of the hematoma. No internal Doppler flow should be depicted with spectral, color, or power Doppler assessment. On CT images,

Table 2: RSH Classification System

Type of RSH	Characteristics
Type I	Unilateral intramuscular hematoma with muscle expansion; no dissection along fascial planes
Type II	Type I characteristics plus blood extending between muscle and the transversalis fascia; no blood within the prevesical space
Type III	Type I and II characteristics plus blood in the peritoneum and prevesical space; hematocrit effect

Note.—Adapted, with permission, from reference 20.

the rectus abdominis muscle appears expanded and relatively hyperattenuating, sometimes with a "hematocrit effect" (ie, a fluid-fluid level formed by the layering of heavier elements of blood from the liquid component) if there has been recent bleeding. If bleeding is ongoing, a swirl sign may be seen. Although intravenous contrast material administration is not required for diagnosis of an RSH, active extravasation may be seen if contrast material is administered. As hematomas evolve, CT attenuation values decrease with the breakdown of blood products (14). MR imaging is rarely required for diagnosis, but RSH may be seen incidentally as an abdominal wall mass with T1 and T2 hyperintensity consistent with hemorrhage. Free intraperitoneal or prevesicular fluid or blood may be seen with all modalities, which is suggestive of rupture through the posterior abdominal wall.

In the results of a small study of 13 patients with RSH, CT allowed detection of all cases, but US allowed identification of only 11 of the 13 cases (20). Although the investigators did not discuss the limitations of US, its lower detection rate may be related to variability in user skill and possibly patient body habitus. CT permits the localization, measurement, and evaluation of the extent of hematoma and is likely the most practical modality in the emergency setting because of its availability, speed, and ability to demonstrate other traumatic injuries in the abdomen (20).

Berná et al (20) proposed a classification system that is based on CT findings and subsequent clinical outcome; patients with type I RSH do not require hospitalization, but patients with types II and III usually require hospitalization, with more-involved treatments such as blood transfusion and other procedures (Table 2). By applying this classification system, radiologists may be able to suggest to clinicians which patients may require higher levels of care.

Treatment

Most patients with abdominal wall muscle strain or hematoma can be managed conservatively with pain control therapy and with blood transfusion in the case of hematoma (21). In fact, Berná et al (20) suggested that patients with type I RSHs do not require hospitalization at all. In a small proportion of the patients with RSHs, conservative management fails, and patients require more-invasive treatment; in the results of one of the largest studies of 126 patients with RSH, 8% ultimately required surgical or endovascular management (21). Death is a rare complication of RSH, usually secondary to uncontrolled bleeding and resultant anemia and hypovolemia (21,35).

Traumatic Abdominal Wall Hernia

Background

TAWHs occur in less than 1% of patients presenting to the emergency department after blunt trauma, resulting in a defect of the abdominal wall musculature and fascia, often with herniation of intra-abdominal contents (5,36,37). Motor vehicle collisions cause the majority of TAWHs (38). Although uncommon, TAWHs are important to recognize, not only because failure to diagnose can result in delayed complications such as bowel incarceration and strangulation, but also because TAWHs are highly associated with more-serious intra-abdominal injuries, such as vascular or visceral injuries.

Anatomy

TAWHs do not necessarily occur at the site of blunt impact but instead occur at various points of anatomic weakness of the abdominal musculature (Fig 1). Lumbar hernias are the most common type of TAWH, although TAWHs have been described elsewhere, including just lateral to the semilunar line (spigelian hernia) and, rarely, as transdiaphragmatic intercostal hernias (17–19,39). Lumbar hernias occur within the lumbar region, as defined by the 12th rib superiorly, the iliac crest inferiorly, the paraspinal muscles medially, and the posterior border of the external oblique muscle laterally (38,40). Traumatic lumbar hernias most frequently occur in the inferior lumbar triangle (also called the Petit triangle), an upright triangle seated on the iliac crest (Fig 7) (3,36,38,41). The superior lumbar triangle, or Grynfeltt-Lesshaft triangle, is an inverted triangle

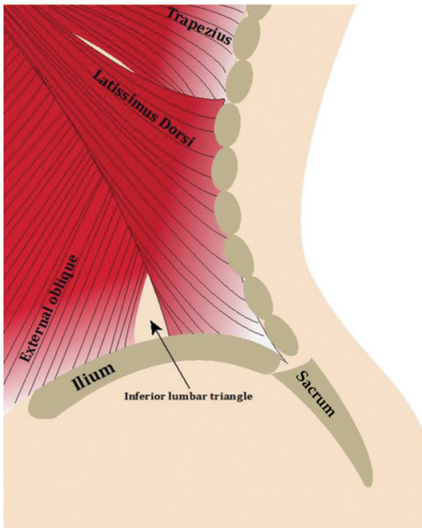


Figure 7. Drawing of an obliquely oriented parasagittal view of the torso shows the location of the inferior lumbar triangle, the most common location of traumatic lumbar herniation.

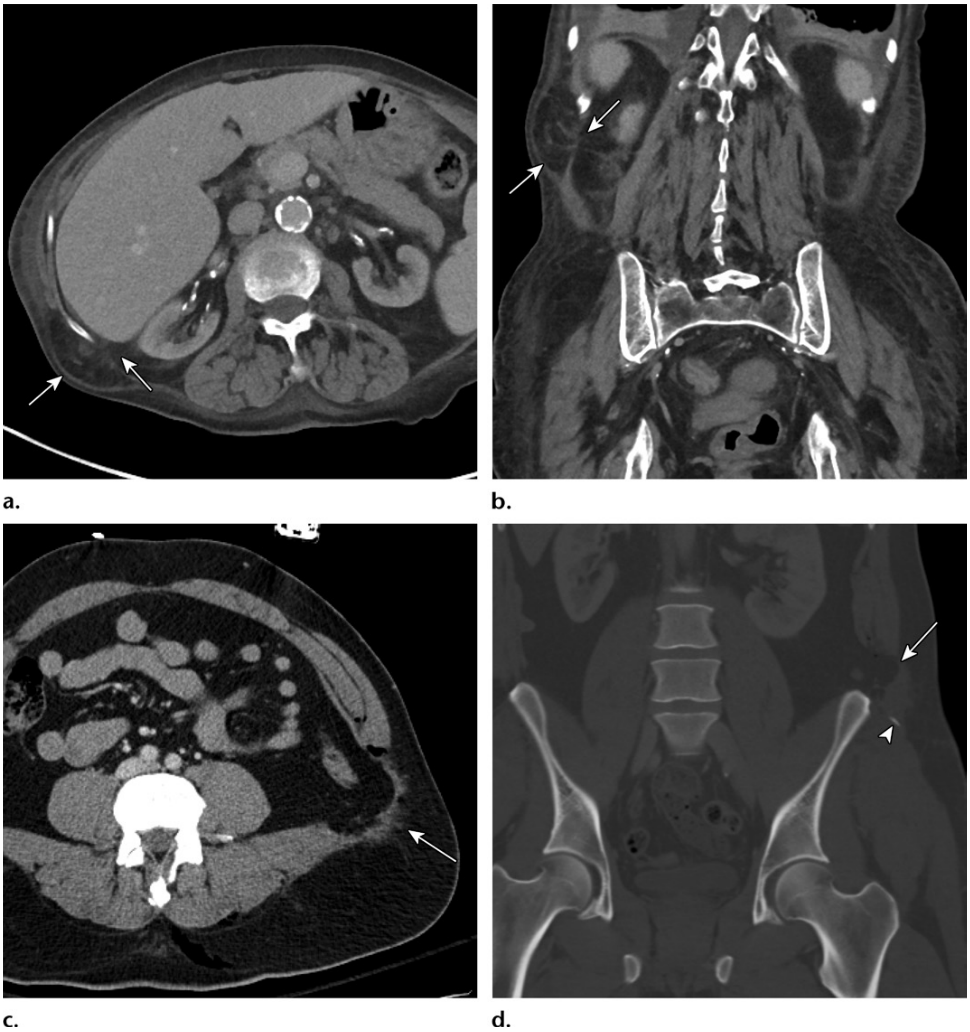


Figure 8. Lumbar triangle hernias in two different patients. **(a, b)** Axial **(a)** and coronal **(b)** CT images show a superior lumbar triangle hernia (arrows) in a 55-year-old man. **(c, d)** Axial **(c)** and coronal **(d)** CT images show an inferior lumbar triangle hernia (arrow) in a 39-year-old man. Note the associated small avulsion injury to the anterior superior iliac spine (arrowhead on **d**).

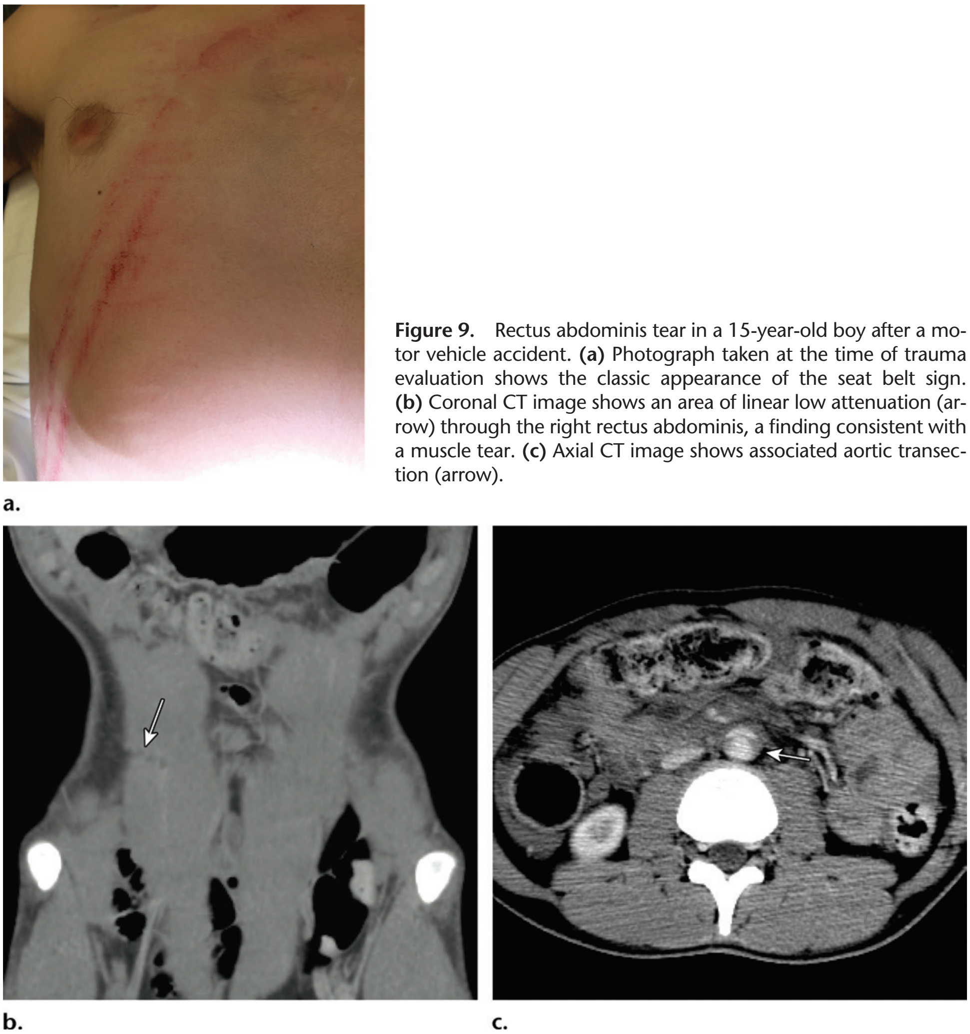


Figure 9. Rectus abdominis tear in a 15-year-old boy after a motor vehicle accident. **(a)** Photograph taken at the time of trauma evaluation shows the classic appearance of the seat belt sign. **(b)** Coronal CT image shows an area of linear low attenuation (arrow) through the right rectus abdominis, a finding consistent with a muscle tear. **(c)** Axial CT image shows associated aortic transection (arrow).

extending down from the 12th rib and is much less commonly involved (41) (Fig 8).

Mechanism of Injury

The mechanism of injury for TAWH is related to sudden deceleration, with shearing of the musculofascial layers and an acute increase in intra-abdominal pressure. The shearing motion is thought to be the mechanism that differentiates this type of blunt injury from that which causes diaphragmatic hernia. Most TAWHs occur in restrained passengers in motor vehicle collisions; TAWHs occur less commonly secondary to a fall from height, a handlebar injury, or a crush injury (38,42). Seat belts likely increase the risk of TAWH, because they result in a direct compressive force between the seat belt and the abdominal cavity (4). The *seat belt syndrome,* a term initially coined in 1962 by Garrett and Braunstein (43), consists of a triad of injuries related to the two-point lap belt, including abdominal wall contusion, hollow viscus injury, and spinal column injury, most commonly a Chance fracture. Seat belts have since been upgraded to a three-point restraint, which results in fewer associated spinal injuries; and thus a new "seat belt lethal triad" has been described, which is made up of TAWH, hollow viscus injury, and abdominal vascular injury (4,41). Although injuries to the abdominal aorta are uncommon, occurring in less than 1% of blunt trauma cases, the mechanism for injury is the same as that causing TAWH; and thus a high index of suspicion should be maintained (44,45).

Clinical Manifestations

At physical examination, there may be focal tenderness and ecchymosis of the abdominal wall, sometimes with a visible bulge. Contusion along the anterior abdominal wall in the distribution of a seat belt (the "seat belt sign") may also be seen, which should increase concern for TAWH and intra-abdominal visceral and vascular injuries, as discussed previously (41) (Fig 9).

It is important to note that more than 50% of TAWHs are occult at physical examination and are detected only with CT (3,36). In the findings of one study of nearly 34 patients with TAWH, only 30% of patients had a hernia evident at physical examination (36). The posterior location of lumbar hernias, patient pain, and other associated injuries likely all contribute to the low sensitivity of the findings at physical examination for the detection of TAWH. This observation is important, because if TAWHs are undetected or left untreated, as many as 25% of patients may later present with complications such as incarceration or strangulation of hernia contents (46,47).

Workup and Imaging

CT is highly sensitive for the detection of TAWH, with some investigators reporting nearly 100% sensitivity (36,38,46). However, in the results of a large meta-analysis of nearly 66 patients, investigators found that diagnosis was delayed in at least 27% of cases, although they did not specify whether the delay was related to a lack of findings at physical examination, nonreporting of CT findings, or other reasons (38). In the results of one study of 32 patients with CT-proven TAWH, investigators found that one TAWH was missed prospectively, with that patient returning to the hospital several months later with a symptomatic hernia (36).

Even if a hernia is identified at physical examination, CT should be performed to further characterize the hernia, including the size of the defect, a description of the contents, and assessment for associated intra-abdominal injuries. CT can also be used to differentiate TAWH from other traumatic injuries, including RSH or abdominal wall abscess, both of which are possible sequelae of trauma and may manifest with a bulge at physical examination.

Netto et al (36) found that most TAWHs had no contents within the hernia sac at the time of examination, suggesting that inflammatory stranding or hemorrhage and a subtle defect in the wall may be the only findings depicted (Fig 10). For TAWHs, the most common contents of the hernia sac are fat, followed by colon and then small bowel (38). It is essential to report any signs of ischemia if there is herniated bowel; eventual incarceration occurs in 25% of cases and strangulation in 10% of cases (48).

The size of the hernia defect is important to report because it is a principal factor in surgical planning. The size of the defect is also a prognostic factor, because hernia defects greater than 4.0 cm are more significantly associated with a higher frequency of bowel and mesenteric injuries ($P < .001$) and an increased number of procedures ($P = .042$), as well as a trend toward a longer stay in the intensive care unit (49).

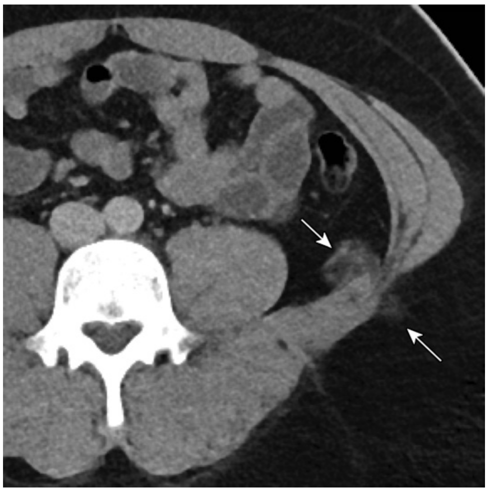


Figure 10. Subtle left-sided inferior lumbar hernia in a 34-year-old man after a motor vehicle collision. Axial CT image shows fat stranding (arrows) on both sides of the abdominal wall at the junction of the lateral abdominal wall musculature and the quadratus lumborum. This finding could easily be missed and has the potential to develop into a larger symptomatic hernia if not identified and treated.

More than 50% of patients with TAWH have associated injuries, with some investigators reporting an incidence as high as 90% (3,36). In the results of one study of 38 patients with TAWH, investigators showed that patients had an average of 2.2 coexistent injuries (3). The most common associated injuries are of the mesentery, bowel, and bones, most commonly pelvic or thoracolumbar fractures (36,37,50) (Fig 11).

Dennis et al (2) reviewed the findings in 140 patients with abdominal wall injury and proposed a grading system in an attempt to characterize the severity of injury on the basis of the CT findings. The grading system ranges from subcutaneous tissue contusion to complete abdominal wall disruption with evisceration. Additional classification systems have been proposed on the basis of the location, the force of injury and hernia size, the mechanism of injury, and the type of accident, although no classification system is widely used at this time (51).

Pearls and Pitfalls

When evaluating the abdominal wall for TAWH, one must take into account possible preexisting conditions and alternative diagnoses that may mimic a TAWH. Given that many traumatic hernias may be missed at the time of the initial trauma, it is possible for a patient with a preexisting TAWH to present for cross-sectional imaging at a later date after a new trauma. Although

a. **b.**

Figure 11. Injuries in a 25-year-old woman after a motor vehicle collision. **(a)** Axial CT image shows a right-sided fat-containing lumbar hernia (arrow) and a subcutaneous contusion (arrowhead). **(b)** Coronal CT image shows an associated pelvic fracture (arrow).

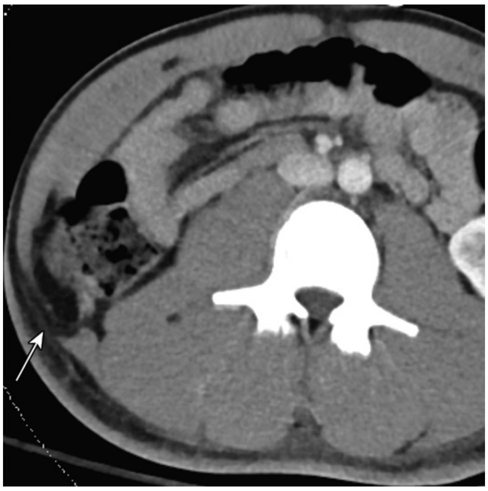


Figure 12. Untreated chronic lumbar hernia in a 27-year-old man after a motorcycle accident. Axial CT image from a whole-body CT examination shows an apparent diastasis of the external oblique from the latissimus dorsi, although without appreciable stranding, a finding suggestive of an old injury (arrow). A review of the patient's medical record disclosed an old stab wound to that area.

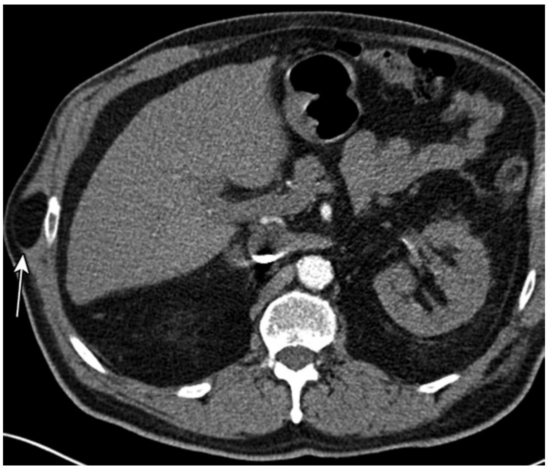


Figure 13. Lipoma in a middle-aged woman. Axial CT image shows an ovoid, well-circumscribed fat lesion (arrow), which is consistent with a lipoma. No surrounding fat stranding or nearby injury, such as a rib fracture, exists to suggest the presence of traumatic herniation.

there are no reported CT findings of TAWH that help to distinguish it from a preexisting hernia (44), experience at our institution suggests that the presence of fat stranding is the most helpful feature to indicate acute trauma (Fig 12). Fat stranding, fluid in the hernia sac, and findings suggestive of compromised bowel (such as wall thickening, hypoenhancement, and vessel engorgement) may be suggestive of acute trauma to either an acute or preexisting hernia (52).

At physical examination during trauma assessment, an abdominal wall lipoma can manifest as a bulge or abnormal contour and may raise concern for a TAWH. Once a TAWH is suspected, cross-sectional imaging with CT is commonly performed and would demonstrate a well-circumscribed fat-attenuation lesion, without associated stranding or adjacent injury (39) (Fig 13).

In most cases, comparison with the images from prior imaging examinations will be helpful in determining the chronicity of an abdominal wall abnormality.

Treatment

Historically, emergent laparotomy was often performed in patients with TAWH, given the high association with intra-abdominal injuries

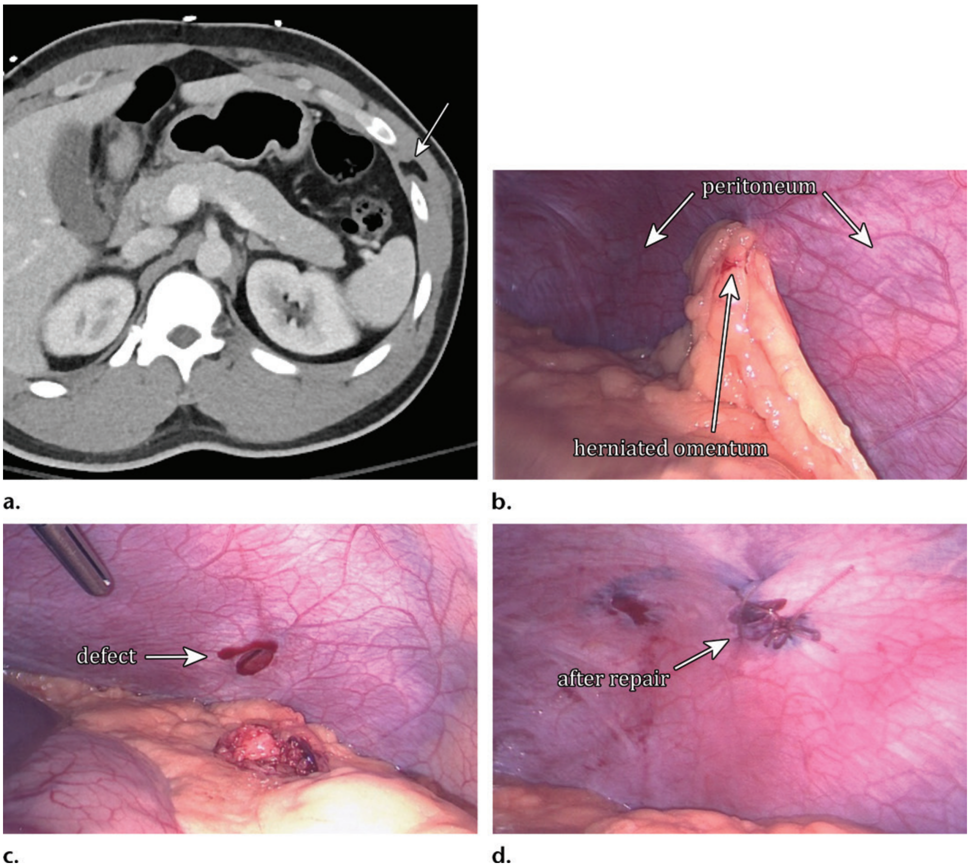


Figure 14. Herniated omentum in a 23-year-old man after a stab wound. **(a)** Axial CT image shows a defect within the left anterolateral lower thoracic or upper abdominal wall, with herniation of omental fat (arrow). **(b–d)** Annotated intraoperative photographs during laparoscopic repair show the omentum herniated through the peritoneal defect **(b)**, the defect after reduction **(c)**, and the postrepair appearance of the peritoneum **(d)**. Although this case resulted from penetrating trauma, the intraoperative photographs well illustrate the surgical anatomy and a simple laparoscopic repair of a small abdominal wall defect.

(48,53). Now, debate is ongoing with regard to the appropriate timing of repair. Support is growing for management of TAWH on the basis of the patient's clinical status and associated injuries. If the patient requires surgery for other trauma-related injuries, simultaneous repair of a TAWH may be considered if the patient's condition remains stable during surgery. Patients with small defects with adequate tissue may undergo tension-free primary closure (Fig 14), possibly with a laparoscopic approach; those patients with larger defects or poor quality of the approximating tissues may require reinforced mesh repairs with a permanent or biologic implant.

Controversy exists about whether to use mesh in the acute setting; although mesh decreases the risk of recurrent hernia, the risk of infection is increased when mesh is used in the emergent setting (36,44,50,51) (Fig 15). Hollow viscus injury remains a contraindication to the use of permanent mesh in the acute setting because of the increased risk of infection, although newer biologic meshes are being used more frequently in these cases, with better success (51).

Although no clear consensus exists about the timing and style of surgical repair, these decisions do depend on several factors, many of which must be accurately reported by the radiologist at the time of the trauma CT examination. These factors include the defect size, the hernia contents, and associated injuries, with special attention to the bowel (Table 3).

Morel-Lavallée Lesion

Background

An MLL is a type of soft-tissue injury that can occur in the setting of blunt trauma or crush injury. Other terms have been used to describe this injury, including *closed internal degloving injury, posttraumatic soft-tissue cyst,* and *chronic expanding hematoma* (54,55). The mechanism of injury is shearing force with disruption of underlying arteries, veins, and lymphatic vessels that results in

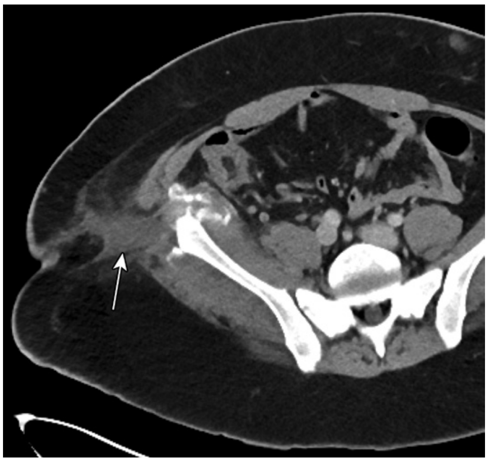


Figure 15. Postoperative complications in a 25-year-old woman who presented with fever and an elevated white blood cell count several months after undergoing emergent repair of a lumbar hernia with mesh. Axial CT image shows stranding and phlegmon (arrow) in the region of the prior right-sided lumbar hernia repair.

Table 3: Important CT Findings of TAWH That May Affect Management

Finding	Surgical Considerations
Small defect	Primary closure may be possible; higher risk of future incarceration or strangulation
Large defect	May require tension-free repair with mesh; lower risk of future incarceration or strangulation
Hernia containing bowel	Risk for future incarceration or strangulation
Other intra-abdominal injuries	Risk of contamination (especially if hollow viscus injury); may need to delay treatment of TAWH until the patient's condition is stabilized

the accumulation of a hemolymphatic collection (54). Depending on the severity of the trauma, the collection can accumulate slowly or quickly, often being detected in an area remote from the site of the traumatic injury and being misinterpreted as a soft-tissue neoplasm (6,7).

Anatomy

An MLL can occur at various sites. In the results of a large meta-analysis, Vanhegan et al (56) found that the most common anatomic location was the greater trochanter and hip (30.4%), followed by the thigh, pelvis, knee, gluteal region, lumbosacral region, abdominal wall, calf, and the head. Areas with mobile superficial tissues and strong fascia are especially susceptible.

Interestingly, in the results of several studies, investigators have found an increased prevalence of MLLs in female subjects, possibly because of a difference in the anatomic distribution of fat, which is often greater within the subcutaneous space relative to the intra-abdominal cavity in women (55,57).

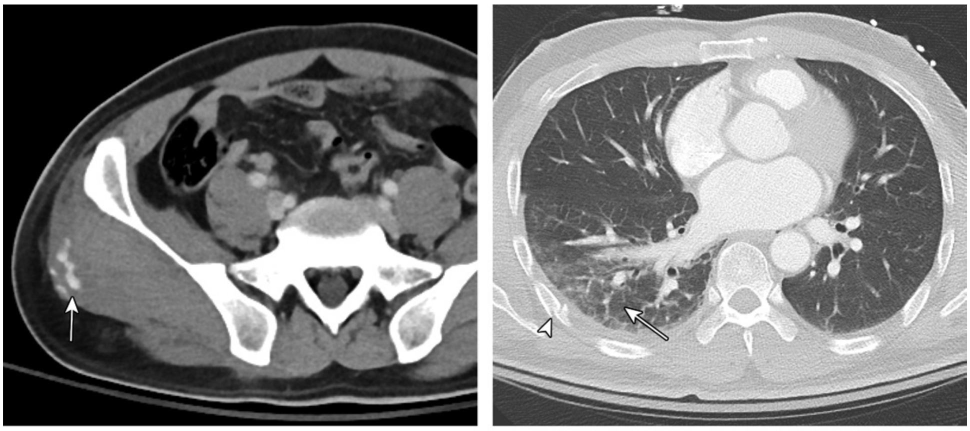
Mechanism of Injury

An MLL results from shearing forces tangential to the fascia that divide the subcutaneous tissues from the underlying fixed fascia, which results in disruption of underlying arteries, veins, and lymphatic vessels. In the case of arterial injury, bleeding may be ongoing after the initial injury (Fig 16). The result is the accumulation of some combination of lymph, blood, debris, and fat (54). Injury to the superficial cutaneous nerves may also occur, with associated loss of sensation (58). Because the fascia remains intact and because the space is relatively hypovascular, it is difficult for the body to resorb the collection, and these collections may enlarge with time (54,55,59,60). As time passes, the collections become predominantly serosanguineous and lymphatic, ultimately developing a peripheral fibrous capsule (55). Once this capsule has formed, the risk for recurrence is increased if surgical treatment is not undertaken (55).

Clinical Manifestations

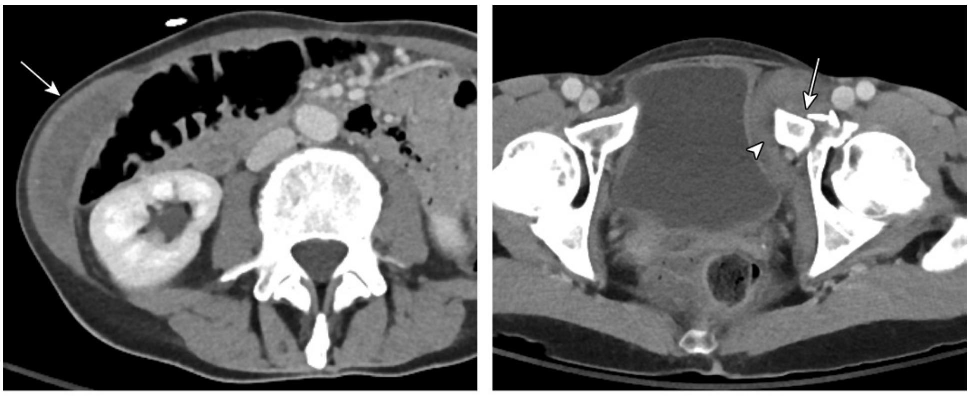
Patients with MLLs generally present with focal pain and swelling, with a fluctuant soft-tissue mass or contour deformity at physical examination (54). Loss of sensation may also be found in the affected region (58).

Although MLLs may be seen in isolation, they are often associated with other traumatic injuries,



a. b.

Figure 16. MLL of the right gluteus medius in a 44-year-old man after a fall down stairs. **(a)** Axial contrast material–enhanced CT image shows low-attenuation expansion of the right gluteus medius muscle, with areas of contrast material extravasation (arrow) indicating active bleeding. This patient ultimately underwent empirical embolization of the right superior gluteal artery, although no active extravasation or pseudoaneurysm was seen at the time of angiography. **(b)** Axial CT image shows that the patient also had a minimally displaced right-sided rib fracture (arrowhead) and a right lower lobe lung contusion (arrow).



a. b.

Figure 17. MLL with associated pelvic fractures in a 62-year-old female pedestrian who was struck by a bus. **(a)** Axial CT image shows a low-attenuation area of expansion (arrow) within the lateral abdominal wall musculature, a finding consistent with an MLL. No active hemorrhage is depicted. **(b)** Axial CT image obtained more inferiorly than **a** shows a left superior pubic ramus fracture (arrow), with an associated pelvic sidewall hematoma (arrowhead).

most commonly pelvic and acetabular fractures (Fig 17) (54,61,62). Although most MLLs are identified early after the causative trauma, up to one-third of cases are identified months to years later, often as nonspecific enlarging soft-tissue masses, which explains why these lesions may be confused with neoplasms (6,7,54).

Workup and Imaging

Although CT is often the first modality used to identify MLLs in the acute setting, MR imaging is considered the modality of choice because of its superior soft-tissue characterization, which can delineate the contents and important features, such as the presence of a capsule (54). An MR imaging protocol should include T1- and T2-weighted sequences, fat-saturated and fluid-sensitive sequences (such as short inversion time inversion recovery), gradient-echo (T2*) sequences, and contrast-enhanced images (63).

Mellado and Bencardino (64) have proposed a classification system made up of six types of MLLs that are classifed on the basis of shape, the presence of a capsule, and MR imaging characteristics. MR imaging appearance varies, depending on the age of the blood: Type I is a simple seroma, which appears hyperintense on T2-weighted MR images and hypointense on T1-weighted MR images. Type II is a subacute hematoma, which appears hyperintense on both T1- and T2-weighted MR images. Type III is a chronic organizing hematoma, which is usually hypointense on T1-weighted MR images and of variable intensity on T2-weighted MR images and can demonstrate internal enhancement from neovascularization and granulation tissue. Type IV is a closed laceration without a capsule. Type V is a pseudonodule. Type VI is a lesion with superimposed infection demonstrating a thick and enhancing capsule (54). Unfortunately, the classification of Mellado and Bencardino (64) has little bearing on treatment and prognosis, making its utility unclear (62). However, it is important for the radiologist to identify the presence of a capsule, because the treatment and the recurrence rate are dependent on this finding (54).

US can also be used to identify and characterize an MLL. MLLs usually appear as fluid collections of varying echogenicity, depending on the stage of evolution, without contained Doppler flow (54). In the acute setting, MLLs tend to be more lobular and heterogeneous, with irregular margins; and with time, MLLs become more fusiform and homogeneous, with smooth margins, (55,62). US is frequently used to monitor these lesions and to guide treatment (61).

Pearls and Pitfalls

Soft-tissue sarcomas and bursitis should be considered in the differential diagnosis of an MLL, especially when the patient presents at a time remote from the occurrence of trauma (6,7,54). For sarcoma, one would expect more-avid internal and peripheral tissue enhancement, which is why the administration of MR contrast material is preferred, if possible. Over the greater trochanter, bursitis is deep to the fascia, and MLL is superficial to it (56).

Treatment

No management is universally accepted for patients with MLLs. Treatment options include monitoring, compression banding, aspiration, sclerotherapy, and surgical evacuation (54). It is important to note that if MLLs are identified in the acute setting, some form of treatment is recommended, because they are prone to becoming chronic, with a potential for superinfection, particularly in patients who have sustained polytrauma (54,55). If the lesion overlies a fracture that requires surgery, prophylactic débridement is recommended. Surgical intervention is also recommended in the setting of infection, open fracture, or severe skin necrosis (54,55). No treatment is typically necessary for chronic asymptomatic lesions, and a watch-and-wait approach is often used (55). More recently, minimally invasive short-term catheter drainage with alcohol sclerodesis has been described in a patient with a symptomatic chronic MLL (65).

If a chronic MLL ultimately requires surgical treatment, it is important that the entire rind, or capsule, around the cavity is excised, to reduce the likelihood of recurrence.

Groin Injury

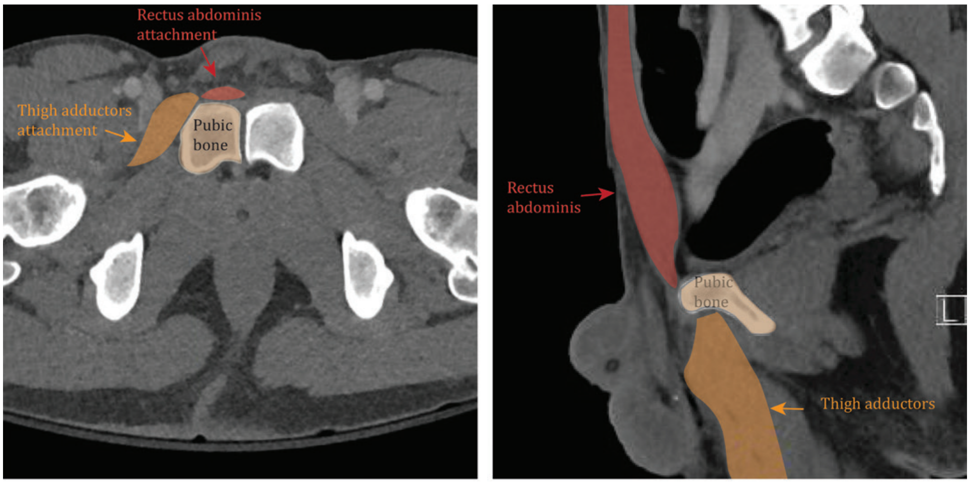
Acute groin pain is especially common in athletes who participate in sports involving kicking or twisting motions, such as American football and soccer (8,66,67). Groin pain may arise from any of the several structures in the inguinal region, including the muscles, tendons, bones, fascial layers, nerves, and joints. Some diagnostic confusion exists in the literature and among clinicians with regard to the terminology applied to various groin injuries, given the complex anatomy and the spectrum of pathologic conditions (67). Although groin injury has traditionally been referred to as a "sportsman hernia," this description is actually a misnomer, because true hernias are quite rare in this population (66). These injuries are now preferentially called "inguinal disruption" or "athletic pubalgia" (8). The most commonly described injuries associated with inguinal disruption, or athletic pubalgia, include a tear of the rectus abdominis aponeurosis at the pubic bone attachment, injury to the hip adductor tendons, and injury to the pubic symphysis itself (66). The rectus abdominis inserts along the superomedial aspect of the pubic bone, and the thigh adductor tendons insert slightly laterally (Fig 18).

Clinically, patients may present with either acute or gradual onset of pain, which may be pinpoint pain to the region of the pubic symphysis or more vague, diffuse pain in the groin, sometimes radiating inferiorly across the inner thigh (8,67).

MR imaging is the preferred imaging technique for the diagnosis of inguinal disruption (8). A typical MR imaging protocol for athletic pubalgia would include three sequences with a large field of view: coronal short inversion time inversion-recovery, coronal T1-weighted, and axial fat-suppressed T2-weighted sequences. In addition, the protocol would include three sequences with a smaller field of view: axial oblique proton-density–weighted, sagittal fat-suppressed T2-weighted, and axial oblique fat-suppressed T2-weighted sequences (axial oblique images are prescribed off the sagittal localizer in parallel to the arcuate line of the pelvis) (68).

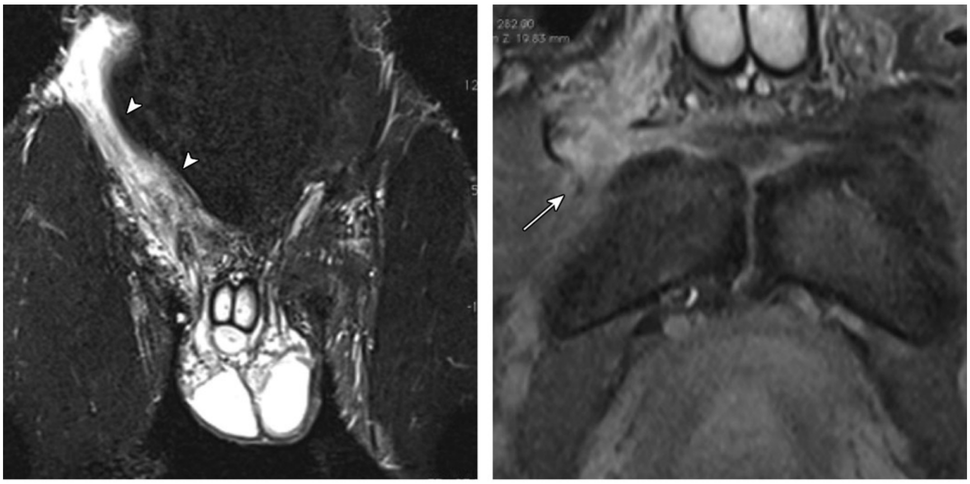
Not only can MR imaging be used to make the diagnosis, but it can also be used to exclude other causes of groin pain, such as osteitis pubis, pelvic bone fractures, inguinal hernia, bursitis, femoroacetabular injury, or even osteoarthritis. As described previously, there are various potential injuries under the heading of inguinal

RadioGraphics



a. **b.**

Figure 18. Anatomy of the pubic symphysis. Annotated axial **(a)** and sagittal **(b)** CT images show the superomedial insertion of the rectus abdominis and the more lateral and inferior insertion of the adductor tendons of the hip. These two insertions are the most common sites of injury in athletic pubalgia.



a. **b.**

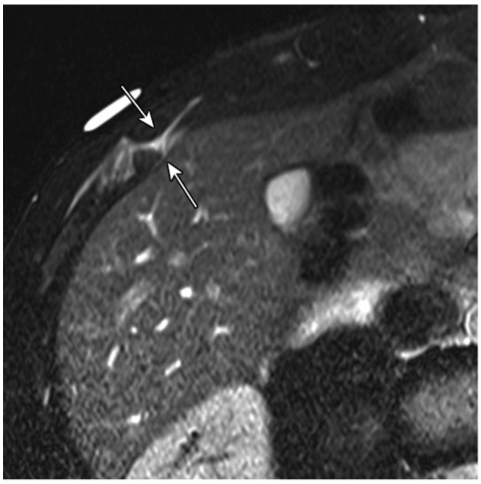
Figure 19. Groin pain caused by a tear of the adductor longus tendon in a 30-year-old man immediately after weight lifting. Coronal **(a)** and axial **(b)** short inversion time inversion-recovery MR images show extensive edema in the right inguinal and parasymphyseal region (arrowheads on **a**) and a torn adductor aponeurosis (arrow on **b**).

disruption, or athletic pubalgia; and, not surprisingly, various imaging patterns may be seen. Zoga et al (66) retrospectively studied the findings at MR imaging and physical examination of 141 patients who were referred for inguinal disruption and found three patterns of injury: *(a)* edema of the pubic symphysis (osteitis pubis), *(b)* edema of the proximal thigh adductor tendons only, and *(c)* tendinous injury to both the pubic insertion of the rectus abdominis and the thigh adductor tendons (Fig 19).

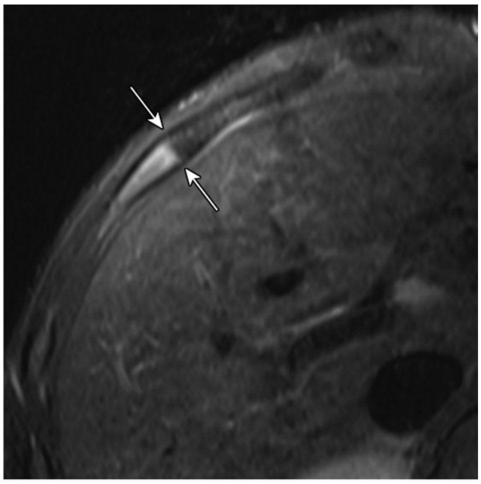
An endometrial implant within the abdominal wall is a rare differential diagnostic consideration that would be readily apparent at cross-sectional imaging (Fig 20) (20). In the results of a study of 141 patients with symptoms thought to represent inguinal disruption, or athletic pubalgia, investigators found that one patient had endometriosis at MR imaging (66).

Accurate diagnosis is important because treatment varies. Osteitis pubis is most commonly treated conservatively with pain control therapy and symphyseal local steroid injection (66). Isolated adductor injuries may also be treated conservatively with rest and physical therapy and also local steroid injection (66,69). Injuries involving the rectus abdominis insertion tend to be treated surgically (66).

Figure 20. Soft-tissue nodule in an adult female patient. Axial CT image shows a soft-tissue nodule with peripheral stranding (arrow), which was later found to be an endometrial implant. Abdominal wall endometriosis can mimic hematoma, hernia, or symptoms of pain secondary to inguinal disruption.



a.



b.

Figure 21. Costochondral rib fracture and abdominal wall musculature strain in a 25-year-old male football player. **(a)** Axial fluid-sensitive fat-suppressed MR image shows fluid interposed within a displaced fracture at the ostochondral junction (arrows). Fluid signal intensity extends down into the abdominal wall musculature. **(b)** Axial fluid-sensitive MR image of a normal costochondral junction (arrows) in a healthy subject is shown for comparison.

Costochondral Rib Injury

Blunt abdominal trauma is often accompanied by injury to the chest wall. Although such an injury is not an abdominal wall injury per se, these patients may present with referred abdominal pain, prompting cross-sectional imaging of the abdomen, at which the most inferior ribs are usually included in the field of view. The radiologist should carefully evaluate the included ribs to assess for traumatic injury. The most common injury to the thorax is rib fracture (70). Rib fractures, especially when accompanied by scapula and sternal fractures, may indicate more-severe underlying thoracic trauma, including hemopneumothorax, pulmonary contusions, cardiac contusions, and aortic or other vascular injury (70). Most rib fractures are detected with radiography; however, radiography is notoriously insensitive for the detection of fractures of the costochondral cartilage, especially if the cartilage is not heavily calcified. When radiographically occult costochondral rib fractures are suspected, CT or US may be performed to improve sensitivity (71,72). Pain may be vague and/or referred to the abdomen, occasionally prompting examination with MR imaging to assess for subtle edema (Fig 21).

Conclusion

The anatomy of the abdominal wall is complex, with several inherent regions of potential anatomic weakness that are prone to nonpenetrating traumatic injury. These injuries are often overlooked either because of the lack of associated findings at physical examination or because of the association of these injuries with other more-distracting intra-abdominal injuries. This fact underscores the need for radiologists to maintain a high index of suspicion for abdominal wall injuries and to actively search for these injuries in patients undergoing cross-sectional imaging after blunt trauma. If an abdominal wall injury is observed, careful review of the vasculature and intra-abdominal organs should be performed to look for associated injuries.

References

1. Centers for Disease Control and Prevention. National hospital ambulatory medical care survey: 2011 emergency department summary tables. Centers for Disease Control and Prevention website. https://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2011_ed_web_tables.pdf. Published 2012. Accessed August 7, 2016.
2. Dennis RW, Marshall A, Deshmukh H, et al. Abdominal wall injuries occurring after blunt trauma: incidence and grading system. Am J Surg 2009;197(3):413–417.
3. Honaker D, Green J. Blunt traumatic abdominal wall hernias: associated injuries and optimal timing and method of repair. J Trauma Acute Care Surg 2014;77(5):701–704.
4. Kulvatunyou N, Albrecht RM, Bender JS, et al. Seatbelt triad: severe abdominal wall disruption, hollow viscus injury, and major vascular injury. Am Surg 2011;77(5):534–538.
5. Belgers HJ, Hulsewé KW, Heeren PA, Hoofwijk AG. Traumatic abdominal wall hernia: delayed presentation in two cases and a review of the literature. Hernia 2005;9(4):388–391.
6. Kalaci A, Karazincir S, Yanat AN. Long-standing Morel-Lavallée lesion of the thigh simulating a neoplasm. Clin Imaging 2007;31(4):287–291.
7. Kumar S, Hasan R, Kadavigere R, Maddukuri SB, Puppala R. Morel-Lavallee lesion (MLL) mimicking a soft tissue neoplasm. J Clin Diagn Res 2015;9(4):TD01–TD02. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4437136/pdf/jcdr-9-TD01.pdf. Published online April 1, 2015.
8. Sheen AJ, Stephenson BM, Lloyd DM, et al. Treatment of the sportsman's groin: British Hernia Society's 2014 position statement based on the Manchester Consensus Conference. Br J Sports Med 2014;48(14):1079–1087.
9. Dreizin D, Munera F. Multidetector CT for penetrating torso trauma: state of the art. Radiology 2015;277(2):338–355.
10. Lozano JD, Munera F, Anderson SW, Soto JA, Menias CO, Caban KM. Penetrating wounds to the torso: evaluation with triple-contrast multidetector CT. RadioGraphics 2013;33(2):341–359.
11. Shanmuganathan K, Mirvis SE, Chiu WC, Killeen KL, Hogan GJ, Scalea TM. Penetrating torso trauma: triple-contrast helical CT in peritoneal violation and organ injury—a prospective study in 200 patients. Radiology 2004;231(3):775–784.
12. Bansal V, Reid CM, Fortlage D, et al. Determining injuries from posterior and flank stab wounds using computed tomography tractography. Am Surg 2014;80(4):403–407.
13. Zeidenberg J, Durso AM, Caban K, Munera F. Imaging of penetrating torso trauma. Semin Roentgenol 2016;51(3):239–255.
14. Goodman P, Balachandran S. CT evaluation of the abdominal wall. Crit Rev Diagn Imaging 1992;33(5):461–493.
15. Moore K, Dalley A. Clinically oriented anatomy. 7th ed. Philadelphia, Pa: Lippincott Williams & Wilkins, 1980; 178–191.
16. Hatjipetrou A, Anyfantakis D, Kastanakis M. Rectus sheath hematoma: a review of the literature. Int J Surg 2015;13:267–271.
17. Aravinda PS, Saha S, Saurabh G, Andley M, Kumar A. Traumatic spigelian hernia: a rare clinical scenario. J Clin Diagn Res 2014;8(5):ND01–ND02. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4080031/pdf/jcdr-8-ND01.pdf. Published online May 15, 2014.
18. Thakur SK, Gupta S, Goel S. Traumatic spigelian hernia due to handlebar injury in a child: a case report and review of literature. Indian J Surg 2013;75(suppl 1):404–406.
19. Gates AA, Desai NS, Sodickson AD, Khurana B, Gates JD. BWH emergency radiology: surgical correlation—traumatic spigelian hernia with right colonic injury. Emerg Radiol 2015;22(6):709–711.
20. Berná JD, Garcia-Medina V, Guirao J, Garcia-Medina J. Rectus sheath hematoma: diagnostic classification by CT. Abdom Imaging 1996;21(1):62–64.
21. Cherry WB, Mueller PS. Rectus sheath hematoma: review of 126 cases at a single institution. Medicine (Baltimore) 2006;85(2):105–110.
22. Fitzgerald JE, Fitzgerald LA, Anderson FE, Acheson AG. The changing nature of rectus sheath haematoma: case series and literature review. Int J Surg 2009;7(2):150–154.
23. Fukuda T, Sakamoto I, Kohzaki S, et al. Spontaneous rectus sheath hematomas: clinical and radiological features. Abdom Imaging 1996;21(1):58–61.
24. Johnson R. Abdominal wall injuries: rectus abdominis strains, oblique strains, rectus sheath hematoma. Curr Sports Med Rep 2006;5(2):99–103.
25. Tai CM, Liu KL, Chen CC, Lin JT, Wang HP. Lateral abdominal wall hematoma due to tear of internal abdominal oblique muscle in a patient under warfarin therapy. Am J Emerg Med 2005;23(7):911–912.
26. Shimodaira M, Kitano T, Kibata M, Shirahata K. An oblique muscle hematoma as a rare cause of severe abdominal pain: a case report. BMC Res Notes 2013;6:18. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3552714/pdf/1756-0500-6-18.pdf. Published online January 18, 2013.
27. Titone C, Lipsius M, Krakauer JS. "Spontaneous" hematoma of the rectus abdominis muscle: critical review of 50 cases with emphasis on early diagnosis and treatment. Surgery 1972;72(4):568–572.
28. Zainea GG, Jordan F. Rectus sheath hematomas: their pathogenesis, diagnosis, and management. Am Surg 1988;54(10):630–633.
29. Dutta S, Sanjay P, Jones ML. Diagnosis and treatment of giant lateral abdominal wall haematoma after blunt trauma: a case report. Cases J 2009;2:9358. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2804729/. Published online December 19, 2009.
30. Scott WW Jr, Fishman EK, Siegelman SS. Anticoagulants and abdominal pain: the role of computed tomography. JAMA 1984;252(15):2053–2056.
31. Klingler PJ, Wetscher G, Glaser K, Tschmelitsch J, Schmid T, Hinder RA. The use of ultrasound to differentiate rectus sheath hematoma from other acute abdominal disorders. Surg Endosc 1999;13(11):1129–1134.
32. Bober SE, Cohen HL, Setzen G, Garenani C. Rectus sheath hematoma simulating penappendiceal abscess. J Ultrasound Med 1992;11(4):179–180.
33. Lohle PN, Puylaert JB, Coerkamp EG, Hermans ET. Nonpalpable rectus sheath hematoma clinically masquerading as appendicitis: US and CT diagnosis. Abdom Imaging 1995;20(2):152–154.
34. Luhmann A, Williams EV. Rectus sheath hematoma: a series of unfortunate events. World J Surg 2006;30(11):2050–2055.
35. Ducatman BS, Ludwig J, Hurt RD. Fatal rectus sheath hematoma. JAMA 1983;249(7):924–925.
36. Netto FA, Hamilton P, Rizoli SB, et al. Traumatic abdominal wall hernia: epidemiology and clinical implications. J Trauma 2006;61(5):1058–1061.
37. Brenneman FD, Boulanger BR, Antonyshyn O. Surgical management of abdominal wall disruption after blunt trauma. J Trauma 1995;39(3):539–544.
38. Burt BM, Afifi HY, Wantz GE, Barie PS. Traumatic lumbar hernia: report of cases and comprehensive review of the literature. J Trauma 2004;57(6):1361–1370.
39. Biswas S, Keddington J. Soft right chest wall swelling simulating lipoma following motor vehicle accident: transdiaphragmatic intercostal hernia—a case report and review of literature. Hernia 2008;12(5):539–543.
40. Cesar D, Valadão M, Murrahe RJ. Grynfelt hernia: case report and literature review. Hernia 2012;16(1):107–111.
41. Kulvatunyou N, Bender JS, Albrecht RM. Traumatic abdominal wall hernia classification [letter]. J Trauma Acute Care Surg 2013;75(3):536.
42. Yan J, Wood J, Bevan C, Cheng W, Wilson G. Traumatic abdominal wall hernia: a case report and literature review. J Pediatr Surg 2011;46(8):1642–1645.

43. Garrett JW, Braunstein PW. The seat belt syndrome. J Trauma 1962;2:220–238.
44. Ballard DH, Kaskas NM, Hamidian Jahromi A, Skweres J, Youssef AM. Abdominal wall hernia and aortic injury secondary to blunt trauma: case report and review of the literature. Int J Surg Case Rep 2014;5(12):1238–1241.
45. Tobler WD, Tan TW, Farber A. Endovascular repair of a blunt abdominal aortic injury. Int J Angiol 2012;21(2):117–120.
46. Hickey NA, Ryan MF, Hamilton PA, Bloom C, Murphy JP, Brenneman F. Computed tomography of traumatic abdominal wall hernia and associated deceleration injuries. Can Assoc Radiol J 2002;53(3):153–159.
47. Mahajna A, Ofer A, Krausz MM. Traumatic abdominal hernia associated with large bowel strangulation: case report and review of the literature. Hernia 2004;8(1):80–82.
48. Esposito TJ, Fedorak I. Traumatic lumbar hernia: case report and literature review. J Trauma 1994;37(1):123–126.
49. Mellnick VM, Raptis C, Lonsford C, Lin M, Schuerer D. Traumatic lumbar hernias: do patient or hernia characteristics predict bowel or mesenteric injury? Emerg Radiol 2014;21(3):239–243.
50. Bender JS, Dennis RW, Albrecht RM. Traumatic flank hernias: acute and chronic management. Am J Surg 2008;195(3):414–417; discussion 417.
51. Liasis L, Tierris I, Lazarioti F, Clark CC, Papaconstantinou HT. Traumatic abdominal wall hernia: is the treatment strategy a real problem? J Trauma Acute Care Surg 2013;74(4):1156–1162.
52. Aguirre DA, Santosa AC, Casola G, Sirlin CB. Abdominal wall hernias: imaging features, complications, and diagnostic pitfalls at multi–detector row CT. RadioGraphics 2005;25(6):1501–1520.
53. Lane CT, Cohen AJ, Cinat ME. Management of traumatic abdominal wall hernia. Am Surg 2003;69(1):73–76.
54. Bonilla-Yoon I, Masih S, Patel DB, et al. The Morel-Lavallée lesion: pathophysiology, clinical presentation, imaging features, and treatment options. Emerg Radiol 2014;21(1):35–43.
55. Greenhill D, Haydel C, Rehman S. Management of the Morel-Lavallée lesion. Orthop Clin North Am 2016;47(1):115–125.
56. Vanhegan IS, Dala-Ali B, Verhelst L, Mallucci P, Haddad FS. The Morel-Lavallée lesion as a rare differential diagnosis for recalcitrant bursitis of the knee: case report and literature review. Case Rep Orthop 2012;2012:593193. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3539348/pdf/CRIM.ORTHOPEDICS2012-593193.pdf. Published online December 20, 2012.
57. Hak DJ, Olson SA, Matta JM. Diagnosis and management of closed internal degloving injuries associated with pelvic and acetabular fractures: the Morel-Lavallée lesion. J Trauma 1997;42(6):1046–1051.
58. Tsur A, Galin A, Kogan L, Loberant N. Morel-Lavallée syndrome after crush injury [in Hebrew]. Harefuah 2006;145(2):111–113, 166.
59. Moriarty JM, Borrero CG, Kavanagh EC. A rare cause of calf swelling: the Morel-Lavallee lesion. Ir J Med Sci 2011;180(1):265–268.
60. Parra JA, Fernandez MA, Encinas B, Rico M. Morel-Lavallée effusions in the thigh. Skeletal Radiol 1997;26(4):239–241.
61. Jalota L, Ukaigwe A, Jain S. Diagnosis and management of closed internal degloving injuries: the Morel-Lavallée lesion. J Emerg Med 2015;49(1):e1–e4. doi:10.1016/j.jemermed.2014.12.084. Published online April 2, 2010.
62. Li H, Zhang F, Lei G. Morel-Lavallee lesion. Chin Med J (Engl) 2014;127(7):1351–1356.
63. Mellado JM, Pérez del Palomar L, Díaz L, Ramos A, Saurí A. Long-standing Morel-Lavallée lesions of the trochanteric region and proximal thigh: MRI features in five patients. AJR Am J Roentgenol 2004;182(5):1289–1294.
64. Mellado JM, Bencardino JT. Morel-Lavallée lesion: review with emphasis on MR imaging. Magn Reson Imaging Clin N Am 2005;13(4):775–782.
65. Isaacson AJ, Stavas JM. Image-guided drainage and sclerodesis of a Morel-Lavallee lesion. J Vasc Interv Radiol 2013;24(4):605–606.
66. Zoga AC, Kavanagh EC, Omar IM, et al. Athletic pubalgia and the "sports hernia": MR imaging findings. Radiology 2008;247(3):797–807.
67. Omar IM, Zoga AC, Kavanagh EC, et al. Athletic pubalgia and "sports hernia": optimal MR imaging technique and findings. RadioGraphics 2008;28(5):1415–1438.
68. Zoga AC, Mullens FE, Meyers WC. The spectrum of MR imaging in athletic pubalgia. Radiol Clin North Am 2010;48(6):1179–1197.
69. Hölmich P, Uhrskou P, Ulnits L, et al. Effectiveness of active physical training as treatment for long-standing adductor-related groin pain in athletes: randomised trial. Lancet 1999;353(9151):439–443.
70. Shorr RM, Crittenden M, Indeck M, Hartunian SL, Rodriguez A. Blunt thoracic trauma: analysis of 515 patients. Ann Surg 1987;206(2):200–205.
71. Malghem J, Vande Berg B, Lecouvet F, Maldague B. Costal cartilage fractures as revealed on CT and sonography. AJR Am J Roentgenol 2001;176(2):429–432.
72. Turk F, Kurt AB, Saglam S. Evaluation by ultrasound of traumatic rib fractures missed by radiography. Emerg Radiol 2010;17(6):473–477.