Pitfalls in Diagnosis of Blunt Abdominal Trauma

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Abdominal injury is a common indication for hospital admission and diagnostic evaluation in patients who suffer blunt trauma. Blunt abdominal trauma is a leading cause of morbidity and mortality among all age groups but is particularly important in the younger population. Clinical evaluation of the abdomen in the polytraumatized patient is challenging, particularly when the patient's level of consciousness is compromised by head injury, intoxication, or other factors. Following initial evaluation, resuscitation in the trauma room, and, when indicated, focused abdominal with sonography for trauma (FAST) examination, patients with suspected serious abdominal injuries are either taken immediately to the operating room for emergent laparotomy or, more commonly, undergo further diagnostic testing [1, 2]. With the marked decline in the use of peritoneal lavage and with the growing popularity of nonoperative therapy [3], appropriate patient care is usually dependent on an adequately performed and correctly interpreted CT examination by the radiologist [4]. CT imaging is superior to clinical evaluation and peritoneal lavage for diagnosing and classifying intraabdominal injuries [5].

In the setting of blunt abdominal trauma, CT imaging performed with the now widely available multidetector technology is a very robust technique and highly accurate test [6]. However, as with any other imaging procedures, there are multiple pitfalls and causes for error in interpretation that can lead to serious diagnostic mistakes [7]. These pitfalls and errors in interpretation may occur as a result of inadequately performed CT examinations (improper technique); poor image quality resulting from imaging artifacts or patient-related factors, such as extreme body habitus, low cardiac output, or patient motion; anatomic variants that may mimic true injuries; findings associated with significant injuries, which are either physiologic or not caused by the traumatic event (secondary to preexistent conditions); and subtle or uncommon findings that can be easily overlooked if not specifically looked for with a methodical search pattern (true missed injuries).

This chapter will cover some of the most common pitfalls and potential causes for errors that may be encountered when interpreting CT examinations of blunt abdominal trauma. For organizational purposes, these pitfalls and sources of error will be presented based on the potential cause, as listed previously.

CT Technique

At large trauma centers, emergent CT examinations for blunt abdominal trauma are typically performed in a multidetector scanner with thin (1–2.5 mm) axial images. Orthogonal (coronal and sagittal) reformations are recommended for adequate assessment of the spine, diaphragm, and pelvic bones. The use of oral contrast material for blunt abdominal trauma has been abandoned at most large trauma centers [6, 8]; instead, IV contrast material (100–120 mL) is being used and should be administered to all patients. The number of imaging phases acquired, as well as the timing used for each phase, varies between institutions. A portal venous phase, acquired between 60 and 70 seconds after the beginning of contrast injection, is included in most protocols. A common approach includes the addition of delayed phase images, acquired 5–7 minutes after the portal phase. To reduce the total amount of ionizing radiation delivered, it is recommended that these delayed images be acquired selectively in patients with injuries identified or suspected on the portal venous phase images and using a low radiation dose technique [6]. Arterial phase images taken at 25–30 seconds after injection are also often acquired in patients with severe trauma. The decision of how many and which phases to acquire is important, as some misdiagnoses result directly from this technical aspect of the CT examination. With the advent and growing dissemination of multienergy and spectral CT technology, various specific applications for the examination of blunt abdominal trauma are being explored.

Pitfalls Caused by Inadequate Technique or Poor Image Quality

Motion artifact, most commonly originating from inadequate breath-holding during image acquisition is a common source of errors and difficulties in image interpretation. Respiratory motion artifact is a common cause of diagnostic errors in abdominal trauma imaging. Both false-negative and false-positive findings can result from significant patient motion. Although image acquisition times have diminished considerably with the newer generations of CT scanners and devices for patient immobilization are used routinely, patient motion is still difficult or impossible to eliminate, given that under the circumstances of severe trauma patients cannot be expected to obey commands or follow instructions consistently. Thus, patient movement can render a partial or complete examination sub-

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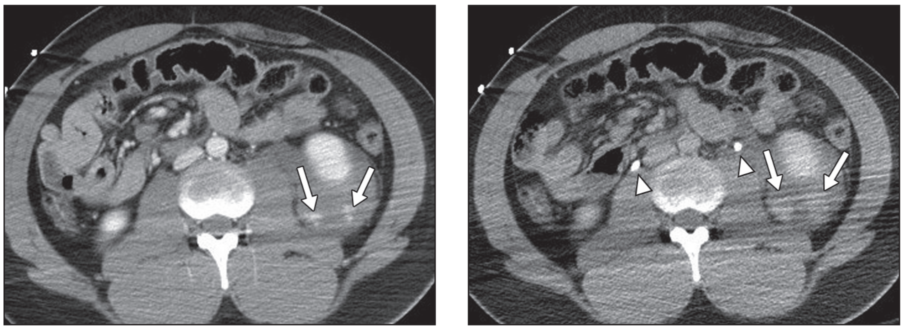

Fig. 1—Importance of delayed images in blunt abdominal trauma.
A, Axial CT image acquired in portal venous phase series shows hematoma around lower pole of left kidney with hyperattenuating foci (*arrows*).
B, Axial CT image acquired in delayed phase at same level as **A** shows growth of hyperattenuating foci (*arrows*), but attenuation is significantly less than that of opacified urine in intact ureters (*arrowheads*). Foci are active extravasation of blood from left kidney while collecting system is intact.

optimal or impossible to evaluate. A careful assessment of the severity of image quality degradation is necessary to decide if the CT examination—or segments of it—should be repeated. The risks of missing an injury obscured by motion artifact should be weighed against the risks of the additional radiation dose or IV contrast material that would be administered to the patient. In general, if any CT sign suggests the presence of abdominal injury, such as free fluid, a repeat scan should be strongly considered.

Respiratory motion artifact can cause an apparent double contour in the surface of the solid organs that can easily be mistaken for a subcapsular hematoma. This is most commonly seen—and is most problematic—in the spleen, where respiratory motion typically causes a gray halo that parallels perfectly the contour of the splenic capsule. True subcapsular hematomas are more commonly crescentic in shape and tend to deform the contour of the spleen. Patient motion can cause apparent displacement of bones and simulate fractures. This is most commonly encountered in the ribs and spine. However, this pitfall can usually be resolved by evaluating the patient's skin surface. Any interruption or step-ladder appearance of the skin confirms that motion is the cause of the pseudofracture appearance on CT.

Streak artifact originating from high-attenuation cortical bone, such as the ribs or the upper extremities if patient condition demands that they be included in the FOV; ECG electrodes or other metallic devices external to the patient; or air–contrast material interfaces, if oral contrast material was administered, can simulate a solid organ laceration [9]. Although this situation is most commonly encountered when evaluating the spleen, it may be more problematic in the pancreas, where any laceration may result in significant morbidity or mortality. Streak artifacts are usually recognizable because they extend beyond the margins of the specific organ. When broad or multiple, streak artifact may cause sufficient image quality as to hide a true parenchymal laceration or contusion. In the spleen, a missed diagnosis of a splenic laceration can result in a delayed rupture [10]. If in doubt, acquiring 5-minute delayed images or even rescanning the area of concern is the best approach to clarify the significance of the potential finding. If radiation dose or readministration of IV contrast material is a concern, a focused sonography or MRI may be considered as options to further evaluate the organ of concern; MR can be particularly useful for evaluation of the pancreas

Proper timing of CT image acquisition, relative to the start of IV contrast injection, is crucial for maximizing the diagnostic potential of the examination and is even more relevant in the era of multidetector scanner technology, where image acquisition times are as short as 3–4 seconds per phase. It is well known that premature scanning—before the peak of the portal venous phase—may result in poor or heterogeneous enhancement of the spleen and unopacified hepatic veins that may be mistaken for parenchymal lacerations. Typically, delayed scans will solve this problem by showing a more homogeneous enhancement of these solid organs. However, true lacerations may be missed by failing to scan at the peak of parenchymal enhancement.

A proper choice of the number of phases to acquire is also important. Delayed-phase CT images serve multiple purposes in the trauma patient. By evaluating the portal venous and delayed phase images side by side, one can improve the sensitivity and specificity of the CT examination. The most common and widely accepted use of delayed images is for determining the integrity of the collecting system in patients with evidence of renal trauma. The addition of delayed images prevents misdiagnosing a urinoma as active extravasation and vice versa (Fig. 1); this differentiation may have therapeutic implications. Another well-established role

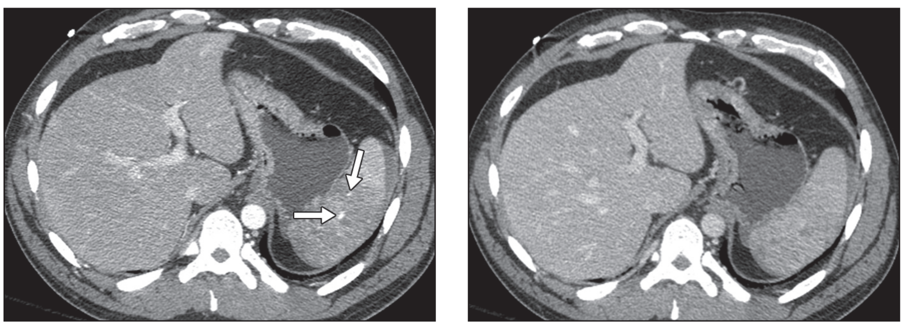

Fig. 2—Splenic vascular lesions seen only in arterial phase.
A and **B,** Axial CT images acquired in arterial phase (**A**) and portal venous phase (**B**). Arterial phase image shows small hyperattenuating foci (*arrows*, **A**) that are not apparent on portal venous phase image (**B**). Hyperattenuating foci are small contained vascular lesions.

of delayed images is in the characterization of intraparenchymal foci of extravascular contrast-enhanced blood seen initially on the arterial or portal venous phases. These may represent contained, or vascular, lesions or areas of true active extravasation. Depending on the clinical and hemodynamic status of the patient, proper characterization of these extravascular foci provides the necessary information for subsequent management: surgical, endovascular (transarterial embolization), or conservative (observation alone). It is also important to note that some foci of extravascular blood are only visible in the early (arterial) phases of image acquisition, particularly in the spleen (Fig. 2). Thus, in the most severely traumatized patients, some major trauma centers now add an arterial phase acquisition to the portal venous phase and reserve the delayed phase for only a small subgroup of patients.

Anatomic Variants and Physiologic Findings That Can Mimic True Injuries

Splenic clefts and lobulations are a very common finding on CT examinations and often are a source of confusion in the trauma patient. Clefts most often appear as well-defined linear low-attenuation areas along the medial aspect of the spleen; however, in some cases, they cannot be distinguished from splenic lacerations, especially if surrounded by blood in the perisplenic space or a subcapsular hematoma. Occasionally, an elongated lateral segment of the left hepatic lobe may wrap around the lateral aspect and upper pole of the spleen, creating an interface that may be mistaken for a splenic laceration. The lack of hemoperitoneum is a clue that can help make the proper diagnosis. In the liver, a focal area of fatty infiltration—most commonly in the vicinity of the falciform ligament and ligamentum venosum—can be confused with a hepatic contusion or laceration.

Anatomic and morphologic variants of the pancreas are common and can easily be misdiagnosed as pancreatic injury on CT. The pancreas often contains multiple lobulations and clefts that may be difficult to differentiate from a glandular laceration in the proper clinical setting. Typical clefts are seen on CT as linear hypoattenuating defects with an orientation that is perpendicular to the long axis of the gland. Although clefts are well-defined and contain fat (Fig. 3), they can be deep—extending to the pancreatic duct and closely mimicking the appearance of true lacerations [11]. Another source of confusion occurs with fatty replacement of the pancreas, a relatively common phenomenon in obese diabetic elderly patients [12]. The distribution of fat in the pancreas is variable and patterns of asymmetric replacement can be misinterpreted as pancreatic contusions. Occasionally, a loop of unopacified duodenum or jejunum may create a well-defined low-attenuation interface with the pancreas, giving the false appearance of a pancreatic laceration. The absence of fluid or stranding in the peripancreatic fat is a reassuring finding suggesting that the pancreas is intact. Conversely, the presence of peripancreatic fluid without any other evidence of pancreatic injury is a nonspecific finding that can be seen in a number of other clinical situations, especially in association with hypovolemic shock (Fig. 4). The pancreas is typically separated from the splenic vein by a thin layer of fat, and fluid in the anterior pararenal space may dissect between the gland and the splenic vein and be detected on CT. Given the significance of pancreatic injuries, the best approach, when faced with a questionable finding, is to perform a repeat CT examination no later than 24–48 hours after admission. This should decrease the number of false-positive diagnoses. MR is an excellent alternative as a problem solver in cases of suspected pancreatic trauma [13, 14]. Lacerations are characteristically hyperintense on T2-weighted images and hypointense on T1-weighted images.

The finding on CT imaging of free intraperitoneal fluid in blunt trauma patients with an absence of identifiable injury causes difficulty in interpretation for both radiologists and trauma surgeons. In female patients of reproductive age, isolated free fluid in the pelvis is likely a physiologic finding that can be explained by ruptured ovarian follicular cysts. In men, the significance of this finding is questionable; the possibility of an occult bowel injury is often raised and the need for a change in patient management considered. In the late 1990s, research suggested that the finding of free intraperitoneal fluid in men the setting of blunt trauma, without an identifiable injury to explain the finding, carried a high risk of an occult bowel and injury and exploratory laparotomy was indicated [15, 16]. More recent data acquired with MDCT technology has led to a more conservative approach, with many of these patients now being admitted for observation without immediate surgical intervention [17]. In a study performed at our institution, we found that approximately 3% of male patients who suffered blunt trauma had small pockets of isolated free fluid with low attenuation (mean, 13.1 HU), of which none was proven to have a surgically important bowel or mesenteric injury [18]. Similar results were reported by Yu et al. [19]. In this setting, the radiologist must carefully evaluate the CT images for findings that could explain the presence of low-attenuation fluid, such as intraperitoneal bladder rupture (urine). A trend for increased incidence of isolated free fluid can be seen in patients who receive higher volumes of fluid resuscitation [18, 19]. It is also hypothesized that advances in CT technology have increased the sensitivity for detecting small amounts of free intraperitoneal fluid (Fig. 5). However, if the attenuation of free blood in the peritoneal cavity is high (< 30–40 HU), the possibility of an occult mesenteric, solid organ, or bowel injury should be strongly considered, as this finding represents true hemoperitoneum. If there is no additional CT finding to suggest presence of a bowel injury, the recommendation is to admit the patient to the hospital for clinical observation and repeat the CT examination 6–8 hours later. At that time, true bowel injuries will likely become apparent either clinically or on CT.

Subtle (but Important) Injuries That Can Easily Be Missed

Some intraabdominal injuries are notable for the difficulty they pose for a precise and timely diagnosis, even in patients benefitting from optimal CT technique and image quality and the most expert radiologists. For example, in a recent study of over 26,000 trauma patients examined with CT over a period of 8 years at 1 institution, the most commonly missed lesion (delay in diagnosis) was a significant bowel or mesenteric injury [20]. Other significant traumatic lesions that pose significant diagnostic challenges on CT include pancreatic and vascular injuries.

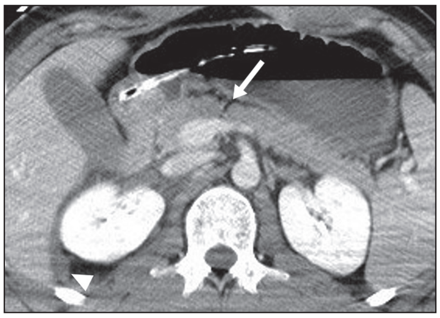

Fig. 3—Pancreatic cleft mimicking laceration. Portal venous phase axial CT image of upper abdomen shows linear defect (*arrow*) at junction of head and body of gland. Morphology and location are consistent with laceration, but presence of fat within defect and absence of peripancreatic fluid confirm it is caused by cleft, not by injury. Note hemoperitoneum in Morison pouch (*arrowhead*).

Fig. 4—Peripancreatic fluid not caused by pancreatic injury. Transverse CT image of patient involved in motorcycle accident who presented with hypovolemic shock caused by severe extremity fractures shows extensive peripancreatic fluid (*solid arrows*). Other signs of hypoperfusion complex are seen in the thickened and hyperenhancing small bowel (*arrowheads*) and flattened inferior vena cava (*open arrow*).

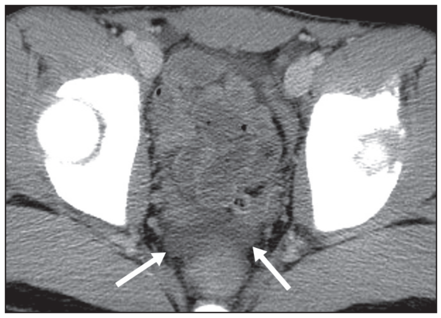

Fig. 5—Free peritoneal fluid in absence of intraabdominal injury. Transverse CT image of male patient who sustained blunt abdominal trauma in motor vehicle accident shows small amount of low-attenuation (9 HU) free fluid in pelvis (*arrows*). CT examination did not show additional findings, and patient recovered without requiring any abdominal intervention.

Bowel and Mesenteric Trauma

The diagnosis of bowel and mesenteric trauma is difficult. Clinically, abdominal pain and guarding from peritoneal irritation are the main manifestations. However, these are signs of established peritonitis and usually indicate that widespread peritoneal contamination has already occurred. Thus, the diagnosis of bowel and mesenteric injuries usually relies on a carefully performed and interpreted CT examination. Free intraperitoneal fluid is a common finding in injuries to the bowel or mesentery [21, 22]. In a retrospective study, Atri et al. [22] demonstrated that the absence of free intraperitoneal fluid practically excludes the presence of a surgically important bowel injury. The significance of finding low-attenuation free fluid in isolation has already been discussed in the preceding section. In the majority of patients with significant (surgically important) bowel injuries, the free peritoneal fluid is higher in attenuation (hemoperitoneum) and is associated with other direct signs of bowel wall trauma, such as focal wall thickening, wall perforation, abnormal wall enhancement, or pneumoperitoneum. Triangular pockets of fluid located in the root of the mesentery are particularly common in patients with proven bowel trauma (Fig. 6). Studies that used different generation of CT scanners report sensitivity that varies between 70% and 95% and specificity that varies between 92% and 100% for the diagnosis of bowel and mesenteric injuries [23, 24]. Thus, all the CT signs are associated with potential false-negative and false-positive interpretations.

Unequivocal localized thickening of a small-bowel loop or segment in the context of blunt trauma is usually an indication of a significant (surgically important) injury, such as a contusion, hematoma, ischemia secondary to mesenteric vascular trauma, or perforation. However, diffuse bowel wall thickening is usually not a result of direct trauma. Instead, the underlying pathophysiology is more likely edema secondary to volume overload or, in the severely traumatized individual with continued bleeding, to profound hypotension with hypoperfusion complex (termed “shock bowel”) where there may be diffusely increased bowel wall

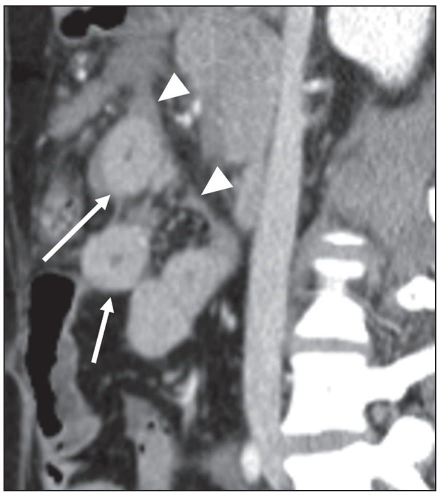

Fig. 6—Mesenteric fluid secondary to bowel injury. Sagittal reformation of CT examination obtained in patient who was involved in car accident shows thickened loops of small bowel (*arrows*) with associated triangular pockets of high-attenuation fluid located between leaves of small bowel mesentery (*arrowheads*). At laparotomy, multiple segments of bowel with contusion and ischemia were found.

Fig. 7—Right diaphragmatic tear. Sagittal reformation of CT image obtained in patient who suffered blunt abdominal trauma shows focal defect in dome of right hemidiaphragm (*arrow*), with associated herniation of intraperitoneal fat into right hemithorax.

enhancement [25] (Fig. 6). When present, other findings characteristic of shock and hypoperfusion complex—such as flat inferior vena cava, increased enhancement of the adrenal glands and bowel, and pancreatic and retroperitoneal edema—are useful to exclude a surgical bowel injury.

Extraluminal gas is a highly suggestive, but not pathognomonic, sign of bowel perforation. The amount of free intraperitoneal gas varies widely and can be massive, filling all peritoneal compartments, or very small, with only a few bubbles noted outside of the bowel lumen. In all blunt trauma patients with any CT finding that could potentially be associated with a hollow viscus injury, images should be reviewed with lung or bone window settings, in addition to the routine soft-tissue settings. This approach improves the ability to detect small extraluminal gas collections. However, many patients with surgically proven perforations do not have any evidence of pneumoperitoneum on CT [23, 24, 26]. A few potential causes of a false-positive finding of pneumoperitoneum should also be considered and ruled out before the diagnosis of bowel perforation is made on the basis of free intraperitoneal gas alone [26]. Causes of pneumoperitoneum without bowel trauma include intraperitoneal rupture of the urinary bladder with an indwelling Foley catheter; massive pneumothorax, especially if there is a coexistent diaphragmatic rupture; barotrauma; benign pneumoperitoneum, as observed in some patients with systemic sclerosis; and the occasional diagnostic peritoneal lavage. Pseudopneumoperitoneum is another potential cause of a false-positive diagnosis of free intraperitoneal gas and bowel rupture. Pseudopneumoperitoneum is air confined between the inner layer of the abdominal wall and the parietal peritoneum, which may be found in patients who suffer injuries to the extraperitoneal segments of the rectum, rib fractures, pneumothorax, or pneumomediastinum, with collections of extraluminal gas accumulating between the deep layers of the abdominal wall and the parietal peritoneum [26]. On CT imaging, the appearance may closely resemble true pneumoperitoneum (Fig. 7). However, most patients with true pneumoperitoneum have collections of gas located deeper in the abdomen, often adjacent to the ruptured viscus, at the porta hepatis or outlining the falciform ligament. If in doubt, delayed images or a decubitus series may help make this distinction.

Pancreatic Trauma

The pancreas may appear normal in up to 40% of imaging studies of patients with confirmed injuries, particularly within 12 hours of the inciting traumatic event [27, 28]. Despite improved image quality with MDCT, inherent imaging pitfalls in assessing pancreatic injury remain. Patients with minimal retroperitoneal fat exhibit decreased contrast between abdominal organs, making subtle defects more difficult to identify. Also, concurrent abdominal viscus injury with hemorrhage can mask a laceration. A laceration can also be obscured by close apposition of the pancreatic fragments [29, 30]. Therefore, if symptoms persist or develop after a seemingly negative admission CT scan, a repeat CT examination or further evaluation with MR are recommended. As the injury evolves, worsening glandular edema or increasing peripancreatic fat stranding or fluid usually uncovers the laceration or contusion.

Major Vascular Injuries

Injuries to major abdominal and pelvic vessels are uncommon highly lethal vascular lesions. Predictably, early death commonly ensues as a result of exsanguinating hemorrhage. Abdominal vascular injuries are associated with extremely rapid rates of blood loss into the peritoneal cavity or retroperitoneal spaces and pose unique challenges for a timely diagnosis and proper therapy. Rapid deceleration from a motor vehicle accident can result in avulsion of major vessels, such as the mesenteric or celiac artery. Another mechanism of injury is related to a direct crush or blow to the major vessels, resulting in an intimal tear with thrombosis or vessel rupture and hemorrhage. Flexion-distraction fractures of the thoracolumbar spine can cause rupture or laceration of the abdominal aorta or inferior vena cava. Diagnosis on CT imaging is obvious when accompanied by a large hematoma or massive hemoperitoneum. In these circumstances, active extravasation of contrast-enhanced blood is an expected finding. More subtle injuries, such as pseudoaneurysms, dissections, intimal flaps, or even thrombosis, may be very difficult to detect and require a proper CT technique—often with a CT angiography phase—and a systematic review of the images by the radiologist [31].

Diaphragmatic Injuries

Injuries of the diaphragm caused by blunt trauma are uncommon. Although multiple CT signs—such as focal discontinuity, focal thickening, intrathoracic herniation of abdominal viscera, dependent viscera sign, collar sign, elevated hemidiaphragm, and combined hemothorax/hemoperitoneum—have been described, sensitivity of CT is suboptimal, and diagnosis remains a challenge [32, 33]. Radiologists interpreting CT images of a trauma patient should diligently evaluate the diaphragm for any direct evidence of injury. With MDCT technology, improved quality of coronal and sagittal reformations—generated routinely as part of the trauma protocols—should lead to an improvement in diagnostic performance for detecting subtle injuries [34] (Fig. 7).

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