Trauma Corner – Missed traumatic injuries: A synopsis

S. Peter Stawicki, MD \(^1,2\) and David E. Lindsey, MD \(^1,2\)

\(^1\) Dept of Surgery, Division of Critical Care, Trauma, and Burn, The Ohio State University Medical Center, Columbus, OH, USA
\(^2\) OPUS 12 Foundation, Columbus Chapter, OH, USA

ABSTRACT
The ultimate goal in trauma resuscitation is to promptly identify and treat all injuries. Despite clinical and technological advances in diagnosis and treatment of trauma patients, missed injuries continue to significantly affect modern trauma services. Delayed diagnosis and missed injuries have the potential to exacerbate the severity of the initial insult, and may result in permanent disability or even mortality. Moreover, missed injuries add significantly to length of hospitalization and overall costs of trauma patient care. This article will discuss common themes associated with missed injuries, and will highlight steps that practitioners can take to minimize delays in diagnosis and to reduce the number of missed injuries. This article begins with basic definitions, followed by a discussion of literature pertaining to, and factors associated with, missed injuries. We will then focus on specific mechanisms and injury patterns, as well as the corresponding injury-specific diagnostic and treatment pitfalls that have to be considered in order to avoid missed injuries.

DEFINITIONS
The definitions of missed injury and delay in diagnosis are somewhat arbitrary and vary across institutions and individual trauma care providers. For the purposes of this review, delay in diagnosis occurs when an injury is identified some time after the initial diagnostic phase of resuscitation, but before the injury manifests itself as a clinical problem. Others define it as an injury detected after the initial resuscitation but before discharge from the hospital. Missed injury, on the other hand, occurs when the injury is not diagnosed in a timely fashion, but is discovered after it causes clinical symptoms. Others define a missed injury as one detected after hospital discharge. In both situations, the basic understanding is that the injury would normally have been detected in an awake, alert patient who had the appropriate clinical investigation and diagnostic studies performed.

In hemodynamically unstable patients, the performance of life-saving interventions may take precedence over the secondary trauma survey, which often takes place in the intensive care unit (ICU). This often occurs when the patient is intubated and sedated, limiting the ability to detect injuries. The prudent clinician will perform a complete tertiary trauma exam at such time when the patient is able to fully cooperate in such activity. However, at times this may not be possible. Heavy reliance on non-operative management of traumatic injuries may also be a contributing factor in at least some cases of missed injuries.

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Correspondence to: S. P. Stawicki, MD. Department of Surgery, Division of Critical Care, Trauma, and Burn, Suite 634, 395 West 12 Avenue, Columbus, OH 43210 USA. Email: stanislaw.stawicki@osumc.edu.

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INTRODUCTION
The ultimate goal in trauma resuscitation is to identify and treat all injuries in a timely manner. Despite technological and clinical advances in management of trauma patients, missed injuries continue to adversely affect modern trauma care.\(^1,2,20\) Delayed diagnosis and missed injuries can significantly add to the morbidity of the initial insult, and may result in permanent disability or even mortality. Moreover, missed injuries may contribute to greater length of hospitalization and increased costs of trauma patient care.\(^15\)

This article will discuss common themes associated with missed injuries, and highlight steps that practitioners and trauma teams can take to minimize delays in diagnosis and to reduce the number of missed injuries. We will begin with basic definitions, followed by a discussion of literature pertaining to, and factors associated with, missed injuries. Finally, we will focus on specific mechanisms and patterns of injury, as well as the corresponding injury-specific diagnostic and treatment pitfalls that have to be considered in order to minimize the incidence of missed injuries.

<table>
<thead>
<tr>
<th>Year/Author (Reference)</th>
<th>Number of patients with missed injury</th>
<th>Number (%) patients with missed injury</th>
<th>Number of missed injuries (per patient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973 / Pringle(^22)</td>
<td>160</td>
<td>12 (7.5%)</td>
<td>1.25</td>
</tr>
<tr>
<td>1980 / Chan(^5)</td>
<td>327</td>
<td>39 (12%)</td>
<td>1.26</td>
</tr>
<tr>
<td>1989 / Iorn(^7)</td>
<td>1,006</td>
<td>26 (2.6%)</td>
<td>1.50</td>
</tr>
<tr>
<td>1990 / Enderson(^11)</td>
<td>399</td>
<td>36 (9.0%)</td>
<td>1.14</td>
</tr>
<tr>
<td>1990 / Juhl(^17)</td>
<td>15,806</td>
<td>83 (0.5%)</td>
<td>1.01</td>
</tr>
<tr>
<td>1991 / Lasonen(^9)</td>
<td>340</td>
<td>58 (17%)</td>
<td>2.29</td>
</tr>
<tr>
<td>1991 / Ward(^24)</td>
<td>111</td>
<td>20 (18%)</td>
<td>1.20</td>
</tr>
<tr>
<td>1996 / Kremi(^18)</td>
<td>8,493</td>
<td>51 (6.0%)</td>
<td>1.57</td>
</tr>
<tr>
<td>1996 / Robertson(^24)</td>
<td>3,996</td>
<td>56 (1.4%)</td>
<td>1.25</td>
</tr>
<tr>
<td>1996 / Aaland(^1)</td>
<td>1,873</td>
<td>56 (3.0%)</td>
<td>1.21</td>
</tr>
<tr>
<td>1998 / Janjua(^16)</td>
<td>206</td>
<td>134 (65%)</td>
<td>2.31</td>
</tr>
<tr>
<td>2000 / Buduhan(^7)</td>
<td>567</td>
<td>46 (8.1%)</td>
<td>1.37</td>
</tr>
<tr>
<td>2001 / Guly(^14)</td>
<td>244,442</td>
<td>934 (0.4%)</td>
<td>1.02</td>
</tr>
<tr>
<td>2002 / Houshian(^15)</td>
<td>786</td>
<td>64 (8.1%)</td>
<td>1.34</td>
</tr>
<tr>
<td>2004 / Brooks(^6)</td>
<td>45</td>
<td>10 (22%)</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Table 1. Missed injury – Overall incidence and general characteristics according to 15 largest published literature series.
Table 1

<table>
<thead>
<tr>
<th>Year/Author (Reference)</th>
<th>Missed injury type; Anatomic region (%) patients</th>
<th>Management of missed injuries (where available) &amp; Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990/Enderson (11)</td>
<td>Face (5.6%) Thorax (13.9%) Abdomen (16.7%) Spine (13.9%) Extremities (58.3%)</td>
<td>None of the missed injuries resulted in death. Overall, 7 of 42 (16.7%) injuries required an operation.</td>
</tr>
<tr>
<td>2000/Buduhan (7)</td>
<td>Head (30%) Thorax (19%) Abdomen (1.6%) Spine (7.9%) Extremities (33%)</td>
<td>N/A</td>
</tr>
<tr>
<td>2002/Houshian (15)</td>
<td>Head (3.5%) Face (8.1%) Thorax (17%) Abdomen (16%) Spine (5.8%) Pelvis (8.1%) Extremities (61%)</td>
<td>Operative 67% 57% 27% 79% 0% 14% 14%</td>
</tr>
<tr>
<td>2004/Brooks (6)</td>
<td>Thoracic (8.3%) Abdominal (17%) Orthopedic (75%)</td>
<td>Tube thoracotomy (100%) Nonoperative (100%) Operative (22%)</td>
</tr>
</tbody>
</table>

Table 2. Missed injuries – Anatomic and procedural considerations.

Published reports on missed injuries from major trauma centers describe their incidence in a range of 0.4% to 65%, depending on the patient population, the type of study (retrospective vs prospective), and definition(s) of missed injury versus delay in diagnosis (Table 1). Further, an average number of between 1 and 2.3 missed injuries for each patient with missed injuries was reported. Types of missed injuries also tend to vary between different trauma centers and populations (Table 2). Of note, only a relatively small number of missed injuries require procedural interventions, with most treated non-operatively (Table 2). In one study, approximately 12% of missed injuries were deemed clinically significant, of which 50% were associated with patient mortality.15 In another study, approximately 11% of missed injuries were clinically significant, and 14% of those were associated with mortality.7

Figure 1. The etiology of “missed injury” is multifactorial, and involves the interplay of patient-, provider-, and environment-related factors.

MISSED INJURIES: RELATIONSHIP TO MECHANISM OF TRAUMA

An important diagnostic adjunct in reducing the frequency of missed injuries is the consideration of the mechanism of injury. The reduction of missed injury begins with having a high index of suspicion for specific injuries and injury patterns as suggested by the mechanism of trauma. Understanding constellations of injuries that are frequently seen with specific mechanistic patterns may improve the chance of identifying all potential injuries. Some examples include:

1. Motor vehicle crash. It is imperative to know the exact mechanism of collision and the patient’s position in the vehicle. For example, a passenger seated in the right front seat of a car struck on ipsilateral side would be expected to have the following injuries until proven otherwise: left rib fractures, left hemo-pneumothorax, splenic laceration, left...
renal injury, pelvic fracture, and left femur fracture. Incomplete evaluation of any of these injuries may lead to a missed injury.

2. Falls. It is important to determine the height of fall, whether it was a free fall or an interrupted one, and what surface did the patient impact upon. Patients who free-fall and land on their feet have a constellation of injuries that include calcaneal, tibial and lumbar spine fractures. Those that have interrupted falls may have upper extremity fractures, head, face, and torso trauma.

3. Pedestrian struck. The age and height of the patient, height of the vehicle bumper, as well as the speed and direction of impact of the car are important determinants of injury. Injuries often include lower extremity fractures from the impact with the car, closed head injury from the collision with the windshield, as well as torso and spine injuries from the patient being thrown onto the roadway.

4. Assaults. Assaults often involve the entire body and virtually all anatomic areas are at risk for injury. Special attention should be directed toward any areas of ecchymosis and abrasions. Anticipated injuries include face, neck, head injuries as well as defensive wounds such as upper extremity fractures. Back, flank, and retroperitoneal injuries may occur when the assault victim “rolls up” on the ground or turn in order to protect him/herself during the attack.

5. Gunshot and stab wounds. Determining the type of weapon used is crucial in evaluating penetrating injury, especially in the treatment of gunshot wounds. It is important to determine if there was any associated trauma, such as a fall or subsequent motor vehicle crash. Missed injury in the setting of penetrating trauma can almost always be traced to inability to accurately identify trajectories of all projectiles. Thus, accurate and timely identification of surface wounds and foreign bodies with radiography is critical.

FACTORS CONTRIBUTING TO MISSED INJURY: BLUNT VERSUS PENETRATING MECHANISMS

After discussing general principles and literature-based evidence pertaining to missed injuries, we will focus on the most common factors behind missed injuries in both blunt and penetrating trauma. Our discussion will begin with the most common factors contributing to missed injury associated with blunt mechanisms:

1. Altered mental status. Whenever the patient’s sensorium is diminished, it becomes more difficult to identify injuries because the patient cannot effectively express complaints related to pain and discomfort. Alterations in pain processing may occur with traumatic brain injury, hypoxia, shock, intoxication/substance abuse, and administration of sedation for various reasons (i.e., combative patient).

2. Presence of distracting injury. The pain response can be altered after a major injury and the patient may not be able to process pain from all injuries equally. For example, a metacarpal fracture may not be readily evident with a concurrent presence of an open humerus fracture. Often direct palpation over a specific injury will elicit a pain response. Therefore, comprehensive repetitive physical examinations will often pick up injuries despite the presence of distracting pain.

3. Administration of analgesia and sedation. The contribution of pain medication and sedation to the rate of missed injury is most likely overstated. Pain relief is an important part of the initial care of trauma patients, and analgesia should not be withheld for fear of masking injury. A comprehensive physical exam can be performed quickly before analgesia is administered. With regards to sedation, it likely plays a more significant role in missed injuries than analgesia. In fact, unless specifically indicated, sedatives should be used very scarcely in the setting of acute traumatic injury.

Common causes of missed injury due to penetrating mechanisms include:

1. Misidentification of surface wounds. It is important to quickly and accurately identify all surface wounds following penetrating injury. Patients who arrive obtunded or uncooperative without a clear mechanism of injury should be thoroughly inspected “from head to toes”, looking for any potential penetrating wound. Some injuries, such as stab wounds from an ice pick or pencil, can be very subtle. Areas that often harbor missed surface wounds include the scalp, axilla, perineum, anus, nose and mouth.

2. Pre-existing missile. Patients who have been shot before often have preexisting retained bullets or bullet fragments that make trajectory determination difficult in the context of new gunshot wounding. Identification of a retained bullet on radiographs, for example, does not preclude the possibility that another bullet traversed the patient’s body and exited on the other side. Detailed inspection of the entire patient is still mandatory. All wounds should be clearly marked with paper clips or other radiographic markers in order to identify all potential trajectories.

3. Overwhelming/multiple injuries. It may be difficult to precisely determine projectile trajectories in patients with multiple penetrating wounds, which can contribute to a missed injury. Therefore, after all life-threatening injuries are adequately addressed, a thorough and systematic search for any additional injuries is mandatory in this setting.

4. Altered mental status and the presence of other injuries, including simultaneous penetrating and blunt assault (see paragraphs above pertaining to blunt injury)

REGIONAL CONSIDERATIONS: HEAD AND NECK

Important considerations regarding missed injuries in the anatomic region of head and neck include:

1. Traumatic brain injury (TBI). Significant TBI often presents with loss of consciousness, mental status changes, and associated external trauma such as cephalohematomas or facial injuries. Early computed tomography (CT) of the brain should be considered in all such patients to help prevent missed TBI. Specific patient groups at increased risk for missed brain injury include: (a) Elderly patients – This group of patients may have significant injuries, including intracranial hemorrhage, but often present with
little or no initial symptoms. This is due to a larger extracerebral space secondary to age-related brain atrophy; (b) Patients who are receiving anticoagulants – Those actively taking warfarin, aspirin or other anti-platelet agents (i.e., clopidogrel) may develop significant bleeds following a relatively minor trauma; and (c) Intoxicated patients (drug and/or alcohol abuse) – Substance use may directly mask symptoms of TBI or cause the examiner to attribute mental status changes to the intoxicating substance instead of the TBI.

2. Cervical Spine Injury (CSI). The hallmark of CSI is cervical pain. All patients with blunt trauma are considered to have a CSI until proven otherwise. Declaring the cervical spine clear of injury includes both clinical examination and radiographic testing.

- **The clinical exam** should include palpation of the cervical spine for presence of any point tenderness. If point tenderness is absent, the ability of the patient to range the neck 30 degrees laterally and to perform flexion/extension is tested. If there is no pain elicited from these maneuvers, the cervical spine can be **clinically cleared of injury.** Clearance of the cervical spine by examination alone should not be performed in patients who: (a) Are obtunded or have mental status changes; (b) Are intoxicated; (c) Have significant distracting injuries that blunt pain perception; (d) Have cervical pain at any point during the clinical exam; and (e) Have peripheral neurologic signs or symptoms.

- **Radiographic examination** includes at least a three-view cervical spine series (antero-posterior, lateral, and odontoid views) and must adequately demonstrate C1 to the top of T1, inclusively. Most **missed SCI** occur at C1-C2 high resolution images as part of the head CT to fully evaluate the atlanto-axial complex. Options for adequately imaging C7-T1 include “swimmers view” radiographs, or a cervical spine CT that clearly visualizes C6 to T1. Complete CT of the cervical spine constitutes an excellent option for patients with extensive degenerative disease or body habitus that precludes acquisition of adequate quality plain films of the cervical spine. In fact, CT of the spine has virtually replaced traditional radiography in the evaluation of suspected CSI at many institutions.

- **Ligamentous injury.** Although plain radiography and CT can rule out most skeletal fractures and dislocations, there may still be a ligamentous injury leading to instability of the spine. Acceptable options for ruling out ligamentous injury include: (a) **Flexion/extension radiography** – This modality suggests the presence of ligamentous instability when subluxation is seen with movement of the spine. An experienced practitioner supervises the procedure and the head is carefully flexed and extended until the patient complains of pain or a pre-determined deviation of 30 degrees is reached; (b) If the patient is obtunded or cannot communicate effectively regarding pain sensation, flexion/extension radiographs should not be utilized, and MRI should be considered instead. In addition, if the patient cannot perform full flexion and extension to 30 degrees, the test is very likely to be inadequate; and (c) Magnetic resonance imaging (MRI) can be used to determine whether there is physical disruption and/or inflammation of the ligaments and cord structures. This is an excellent option for obtunded patients or those who cannot cooperate with a flexion extension film. Because acute inflammation eventually resolves, MRI provides highest diagnostic yield during the first 24-72 hours post-injury.

3. Carotid and vertebral arterial injury. Blunt force to the neck may cause occult injury to the carotid artery or vertebral artery. These injuries are often asymptomatic until the patient experiences an acute cerebral vascular accident (CVA). Risk factors for blunt carotid injury include direct force to the neck such as a clothesline injury, rapid torque, flexion or extension of the neck, and compression or crush (i.e., strangulation). Determining which patients should be screened for carotid injury is still controversial, and screening should be based on the overall clinical index of suspicion. Some criteria used for blunt carotid and vertebral artery injury screening include: (a) Seatbelt ecchymosis over the neck after motor vehicle crash; (b) Severe facial and head injuries; (c) severe upper chest injuries; (d) patients with unexplained lateralizing neurologic findings; and (e) Mechanism of hanging, strangulation, or other direct force to the neck.

Screening methods include: (a) **Four-vessel carotid/vertebral angiogram** - The gold standard for diagnosing carotid injuries; (b) **Magnetic resonance angiography (MRA)** - Among alternatives to traditional arteriography, this is the preferred modality, if available; (c) **CT angiography** - This technique is dependent on the technology available at each institution. It has the advantage of acquiring information about all components of the neck (soft tissue, vessels and bones) in one study; and (d) **Duplex Ultrasonography** - This technique has the disadvantage of not being able to visualize the distal most portion of the carotid as the artery enters the skull. This may be the site of injury for torsion type injuries to the vessel.

**REGIONAL CONSIDERATIONS: CHEST**

Important considerations regarding missed injuries in the anatomic region of chest include:

1. **Traumatic aortic injury (TAI).** The screening for TAI is based on both clinical suspicion and chest radiogram findings. The classic signs of traumatic rupture of the aorta such as widened mediastinum, presence of pleural caps and displaced mediastinal structures may be completely absent in approximately 8% of patients with this injury. Patients at high risk for TAI include those who sustained (a) falls from a significant height; (b) front and side impact during high-speed motor vehicle collisions. After establishing the clinical suspicion of TAI, patients at high risk should have a confirmatory study in addition to the chest radiograph. Diagnostic studies important in this setting include: (a) **Aortic angiography**, the gold standard; (b) **High resolution**
chest CT provides excellent visualization of aortic injury, with follow up angiogram subsequently performed at the discretion of the surgeon who may be performing the aortic repair; and (c) Transesophageal echocardiography (TEE) can be performed in the operating room or in the intensive care unit. However, the sensitivity of TEE is not as high as that of an aortogram or CT scan. One must also keep in mind that TEE may not be the optimal study to demonstrate injuries to the ascending aorta and aortic branches (EAST).

2. Pericardial tamponade. Most cases of tamponade present with significant hemodynamic instability. At times, however, there may be slow accumulation of pericardial blood from a blunt injury or a small penetrating injury. Delayed and/or progressive tamponade can be difficult to diagnose, especially in the elderly and patients with pre-existing pericardial effusion (i.e., those with uremia). In general, penetrating injuries with trajectory near the central chest and upper abdomen (the “box” – Figure 2) must always be considered to have involved the pericardium and heart: (a) Mediastinal penetration may occur without associated pneumothorax or hemothorax; (b) Chest wounds on the lateral chest, or in the back, outside the traditional “box” can still reach the pericardium, especially gunshot wounds; (c) The Focused Assessment Sonography for Trauma (FAST) exam is a sensitive and reliable method of ruling out pericardial fluid in experienced hands. Serial exams may be needed to rule out a slow accumulation of fluid. However, FAST may not detect a cardiac injury that has decompressed into the hemithorax; and (d) When the diagnosis is in doubt, additional diagnostic options include formal high quality transthoracic or transesophageal echocardiogram, and operative pericardial window. Chest CT can be used to determine trajectory in hemodynamically stable patients. Some trajectories can be determined to be anatomically away from the heart, helping to rule out pericardial involvement.

Figure 2. Schematic depiction of the “box” – Penetrating injuries in this anatomic area are more likely to involve the heart and great vessels.

3. Esophageal injury is a rare but potentially lethal diagnosis, more often seen with penetrating injury. Suspicion of esophageal injury is increased with: (a) A posterior mediastinal trajectory; (b) Pneumomediastinum or air tracking in the neck; (c) Hematemesis; (d) Free intraperitoneal air; and (e) Straw colored or turbid pleural fluid. Diagnosis of esophageal injury is usually confirmed via: (a) Endoscopy – Flexible endoscopy is most often used unless the surgeon has experience with the rigid technique. The hypopharynx and proximal esophagus are the areas more prone to missing an injury due to poor visualization in this area; (b) Contrast swallow study – This test may be technically difficult to complete in the obtunded or intubated person. Water-soluble contrast is better tolerated when extravasated into the mediastinum but will cause severe pneumonitis if aspirated. Barium is better tolerated after aspiration and has a higher rate of defining a small leak.

BLUNT ABDOMINAL INJURIES

Important considerations regarding missed injuries in the setting of blunt abdominal injury include:

1. Hollow visceral injury (HVI) – Injuries to the small bowel, stomach, and colon belong to some of the more difficult injuries to detect clinically. In addition, the lack of definitive radiographic studies that readily and accurately identify HVI makes them especially prone to delayed diagnosis. Some of the strategies/techniques that may help, but not guarantee, prompt diagnosis of HVI include:

- Abdominal computed tomography (ACT) can be used as a screening test for HVI. A completely negative ACT nearly always rules out HVI. Any of the following findings on ACT are evidence for possible HVI: (a) Free abdominal fluid in the absence of a solid organ injury; (b) Free intraperitoneal air; (c) Mesenteric hematoma, fluid, or edema (streaking); (d) Bowel wall thickening; and/or (e) Extravasation of oral contrast (a very rare finding).

- When the ACT shows evidence of a possible HVI, a confirmatory study is needed. The options include: (a) Exploratory laparotomy – although laparotomy is the gold standard, it is fraught with potential complications and still associated with a small rate of missed HVI; (b) Diagnostic Peritoneal Lavage (DPL) – an invasive test looking specifically for elevation of the white blood cell count, red blood cell count, or evidence for food particles in the peritoneal fluid; (c) Hospital admission with repeated serial physical exams, serial blood count determinations, and documentation of any signs of peritoneal irritation or peritonitis. This requires an awake and alert patient without distracting injuries; and (d) Repeated FAST ultrasonographic examinations 4-6 hours apart – this strategy may reveal new or increasing amount of intraperitoneal fluid, and thus allow for a more prompt diagnosis of HVI.

2. Pancreatic and duodenal injuries. These injuries can be insidious and are difficult to diagnose by abdominal CT
Delay in diagnosis can lead to significant morbidity and mortality.\textsuperscript{25,26} Pancreatic injuries occur following the application of direct force to the epigastrium. Diagnosis relies heavily on high index of clinical suspicion and injury mechanism considerations: (a) The injury can be easily missed on abdominal CT. Any fluid around the pancreas or in the lesser sac should be viewed as evidence of a pancreatic injury; (b) Amylase and lipase values are neither sensitive nor specific for pancreatic injury. If elevated, they require follow-up and/or repeated pancreatic imaging; and (c) Significant sequelae, such as pseudocyst formation, often take days to weeks to present.\textsuperscript{26}

Diagnosis of pancreatic injury can be confirmed by: (a) Exploratory laparotomy – via direct inspection of the pancreas (the gold standard); (b) Endoscopic retrograde cholangiopancreatography (ERCP) – used to identify ductal injury or extravasation consistent with a parenchymal injury; and (c) Magnetic resonance cholangiopancreatography (MRCP) – may better define a pancreatic injury and help determine whether the main duct is involved.

Duodenal injury can include intramural hematomas with or without an intraperitoneal and/or retroperitoneal rupture. Diagnosis is made by imaging or laparotomy (gold standard). Abdominal CT with fine cuts through the duodenum is sensitive for diagnosing duodenal hematomas and ruptures. Ruptures are best seen when the C-loop of the duodenum is filled with contrast. This can be accomplished by administering additional bolus of oral contrast just before the start of the abdominal CT; (b) Hematomas that are initially missed may present as a gastric outlet obstruction, and can be characterized by an upper gastrointestinal (UGI) contrast study; (c) Fluid seen around or behind the duodenum is suspicious for duodenal rupture and should be investigated with laparotomy.

3. **Diaphragmatic injury** can occur with both blunt and penetrating mechanisms. Even small diaphragmatic defects are important to identify since they may enlarge over time and cause herniation of abdominal viscera and subsequent strangulation. Plain radiographs and CT scanning are neither sensitive nor specific for diaphragmatic injury. Radiographic findings that raise the suspicion include the unexplained presence of hollow organs and/or a nasogastric tube in the chest, lower rib fractures with a hemothorax, and significant spleen or liver injuries. Radiographic findings can be masked in patients who are ventilated because the diaphragm can be flattened in the chest. Diagnosis of these injuries is aided by: (a) High degree of clinical suspicion based on trajectory extrapolated from surface wounds and missiles on plain radiography or CT scan; (b) Presence of blood on rectal exam; and (c) The finding of a presacral hematoma during formal operative exploration. Diagnosis of suspected rectal injury is best confirmed by: (a) Rigid sigmoidoscopy – Although the actual injury may not be visualized, blood present past the anal canal provides evidence of rectosigmoid injury and should prompt definitive (operative) treatment; (b) Dissection of the inferior pelvic peritoneum and retrorectal space is encouraged for high rectal injuries. If there is high index of clinical suspicion, performance of a diverting colostomy and presacral drainage is considered to be the definitive management. Rectal washout is controversial and is not currently recommended.

3. **Ureteral injury**. Penetrating injury to the pelvis may cause a rectal injury that is below the peritoneal reflection and thus not readily seen at the time of surgical exploration. Diagnosis of these injuries is aided by: (a) High degree of clinical suspicion based on trajectory extrapolated from surface wounds and missiles on plain radiography or CT scan; (b) Presence of blood on rectal exam; and (c) The finding of a presacral hematoma during formal operative exploration. Diagnosis of suspected rectal injury is best confirmed by: (a) Rigid sigmoidoscopy – Although the actual injury may not be visualized, blood present past the anal canal provides evidence of rectosigmoid injury and should prompt definitive (operative) treatment; (b) Dissection of the inferior pelvic peritoneum and retrorectal space is encouraged for high rectal injuries. If there is high index of clinical suspicion, performance of a diverting colostomy and presacral drainage is considered to be the definitive management. Rectal washout is controversial and is not currently recommended.
Peripheral nerve function should be assessed and documented in every extremity injury. Nerve injury may not be appreciated during the initial evaluation for the same reasons as with other types of injuries, i.e., because of altered mental status and the patient’s inability to adequately co-operate with the physical exam. Regarding these difficult-to-diagnose lesions: (a) Some nerve injuries will not become apparent until the patient participates in physical therapy or more strenuous activity; (b) Fractures of the posterior pelvis, or low spinal column may cause subtle nerve root injury that may become symptomatic only after the initial evaluation; (c) Late complications such as neurogenic bladder are possible with acute pelvic nerve injury associated with pelvic fractures, especially those involving the posterior sacral and sacroiliac joints; (d) Penetrating injury, especially gunshot wounding can cause neuropraxia that manifests as distal paresthesias or anesthesias; and (e) Delayed diagnosis of nerve injuries can cause significant disability and continued requirement for long-term surgical care. Adequate explanation of the injury and its associated long-term prognosis are crucial.

### Table 3. Hard and soft signs associated with peripheral vascular injury.

<table>
<thead>
<tr>
<th>Hard signs of vascular injury</th>
<th>Soft signs of vascular injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent pulses</td>
<td>Hematoma</td>
</tr>
<tr>
<td>Bruit or palpable thrill</td>
<td>History of hemorrhage at the scene of the injury</td>
</tr>
<tr>
<td>Active hemorrhage</td>
<td>Unexplained hypotension</td>
</tr>
<tr>
<td>Expanding hematoma</td>
<td>Peripheral nerve deficit</td>
</tr>
</tbody>
</table>

2. **Vascular injury.** Vascular status should be determined and documented in every extremity injury. In addition to gross palpable pulses, blood pressure discrepancies between corresponding extremities should be fully evaluated and documented as well. **Ankle-brachial index (ABI)** is a ratio of the systolic blood pressure measured in the ipsilateral lower and upper extremity. The normal ratio is one or greater because hydrostatic forces contribute to greater blood pressure in the lower extremities. In general, if the ABI is less than 0.9 in a lower extremity, an angiogram should be performed. At times, patients with pre-existing peripheral arterial disease may need to be considered on a case-by-case basis, mainly due to their abnormal baseline vascular examination and ABI. **Angiogram** is still the gold standard and should be used in all cases of suspected vascular injury or in injuries at high risk (multi level injury, multiple bone and/or bullet fragments, knee dislocation, etc). **Computed tomographic angiography (CTA)** and **magnetic resonance angiography (MRA)** are gaining popularity, and as more evidence emerges regarding their

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S. P. Stawicki and D. E. Lindsey

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approach is beyond the scope of this article, and we refer the reader to other publications for more detail [Stawicki]. Pre-requisites for the utilization of nonoperative approach include hemodynamic stability, good radiographic characterization of penetrating weapon trajectories, the ability to continually examine the patient (necessitates consistently intact mental status), adequate resources available to the surgical team, and the patient not requiring long procedures such as complex orthopedic or cranio-facial reconstructive procedures for associated injuries. Failure of the non-operative approach occurs when injury manifestations become apparent. Failed non-operative management of penetrating trauma is frequently associated with the following: (a) **Missed** hollow visceral injury; (b) Ongoing or new bleeding from a solid organ injury; (c) New onset fever, leukocytosis; or (d) increasing abdominal pain. The diagnosis is usually confirmed upon exploratory laparotomy.

### MUSCULOSKELETAL AND EXTREMITY INJURIES

Important considerations regarding **missed injuries** in the setting of skeletal and extremity involvement:

1. **Bone injuries.** Pain is the most common clinical sign of a fracture. **Missed orthopedic injuries** are therefore often a result of a blunting or inhibition of normal pain signaling pathways. This can occur with traumatic brain injury, sedation, intoxication, or spinal cord injury. Special care is needed to screen patients with blunt pain perception for occult fractures. Adequate anterior-posterior and lateral view imaging of the thoracic and lumbar spine is indicated in trauma patients with high energy blunt mechanisms of injury, particularly following vehicular crashes, falls, and auto-pedestrian collisions. Several series have noted an association between missed thoracolumbar spine injuries and high Injury Severity Score (ISS), low Glasgow Coma Score (GCS), and intoxication.

   The **most frequent sites of missed skeletal injuries are the distal extremities.** Hands and feet may harbor fractures with minimal swelling. Conversely, generalized edema associated with massive resuscitation and systemic inflammation may mask more localized swelling. A fracture that is more proximal in the “weight bearing chain” should warrant further concern. For example, fractures of the femur and tibia on one side should elicit concern about the possibility of an ipsilateral ankle or foot fracture.

   Patients with certain mechanisms of injury should probably undergo “routine” screening for specific orthopedic injury. For example, a fall from a height with lower extremity fractures warrants bilateral imaging of the ankles, knees, and lumbar spine.

   Published series of **missed musculoskeletal injuries** reported a range of between 0.5% to 6% rate of **missed injuries** and noted that 60% of patients with **missed fractures** were identified based upon persistent complaints of pain. Of note, 55% of identified fractures were not imaged at the time of admission and as many as 23% of **missed fractures** were, in retrospect, detectable on admission films.

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diagnostic accuracy, these imaging modalities may rival the traditional angiography. Any vascular lesion is at risk for subsequent occlusion. Therefore, close monitoring of the pulse exam is necessary. If there is any change in the pulse examination, including the presence of hard signs of vascular injury (Table 3), either a follow up angiographic imaging with/without intervention or surgical exploration is warranted.13

3. **Compartment Syndrome** can be easily overlooked in obtunded patients or those without intact pain perception. Any closed extremity injury at risk for increased soft tissue swelling should be monitored closely for the presence of compartment syndrome. Fractures and crush injury to the muscular compartments of the foreleg, thigh, buttock, and forearm are quite common. Serial compartment pressure measurements should be obtained, along with careful clinical re-examinations. Experienced practitioner with high index of clinical suspicion is crucial in this setting. The following patients may benefit from prophylactic fasciotomy to prevent complications associated with compartment syndrome: (a) Those who underwent delayed revascularization of an extremity, generally greater than 4-6 hours following the initial injury; (b) Those with concomitant arterial and venous injuries, especially after major vein ligation (such as with ligation of the popliteal vein); (c) Severe bone fracture in association with significant vascular injury; and (d) Those with crush injury with concomitant rhabdomyolysis; and (e) Those with severe extremity fracture with concomitant shock.

The topic areas of *missed injury* and *delay in diagnosis* are much broader than the scope of this manuscript. Because of this, it was not the author’s intention to discuss every single type and anatomic location of *missed injury*. Rather, the goal of this article is to introduce the reader to certain critical concepts and general principles that are central to the topics of *missed injury* and *delay in diagnosis*.

**CONCLUSIONS**

*Missed injuries* and *delays in diagnosis* continue to pose a significant problem to trauma services around the globe. Although all trauma clinicians should strive to reduce the incidence of *missed* and/or *delayed diagnoses*, it is unlikely that our healthcare systems have the resources necessary to completely eliminate these occurrences. Instead, it is important that clinicians who encounter trauma patients are aware of the epidemiology of *missed injuries* and the clinical pitfalls that contribute to their continued occurrence. It is this knowledge, combined with the astute clinical practitioner that will ultimately contribute to the reduced incidence of these adverse clinical events.

**SELECTED REFERENCES**


