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REVIEW ARTICLE

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Diagnostic errors in polytrauma: a structured review of the recent literature

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Abstract Clinically important diagnostic errors are relatively common among polytrauma patients (2–40%). Errors are not random; they are more frequent in the spine and periarticular appendicular skeleton, especially in hemodynamically unstable patients who require resuscitation or operative intervention before completion of secondary or tertiary clinical survey. Misleading history, distracting findings, and misjudgments all contribute to risks of diagnostic errors.

Keywords Injuries · Multiple · Errors · Diagnostic · Diagnostic error · False-negative reactions · False-positive reactions · Observer variations

Introduction

We present a review of associations (environmental, patient–related, and others) with missed and delayed diagnoses in polytrauma. In particular, we review what lesions are commonly missed, when they are missed, why they are missed, and how such misses can be avoided.

How common are missed injuries?

The frequency of reported "missed diagnoses" depends on how the frequency of error was assessed: based on trauma registries, error rates were approximately 2% [1]; retrospective chart review found approximately 40% [2]; and retrospective review of all admissions revealed missed or delayed diagnoses of approximately 8–10% [1, 3, 4]. Missed injuries can be found in up to 50% of patients who are transferred immediately from the emergency department to either the trauma intensive care unit or the operating room [5].

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What is commonly missed?

In polytrauma patients who died, autopsy findings revealed severe hemorrhage and bronchopneumonia as the most commonly overlooked antemortem diagnoses [6]. Among survivors, patients with delayed diagnoses typically had 1.3 initially missed findings per patient [1, 4, 7–9]. Orthopedic injuries predominate, constituting 75% of missed diagnoses [10], and include fractures of the extremity (approximately half of orthopedic injuries) (Fig. 1). Missed orthopedic injuries are most common in the periarticular regions, shoulder girdle, and feet. Spine injuries constitute approximately 10% of all initially missed diagnoses. These are especially common at the cranio-cervical junction (40–50% of all initially missed spine injuries) and at the cervico-thoracic junction. Among multiply injured patients, recognition of the first fracture increases the likelihood that concurrent injuries will be overlooked.

Compared to extremity fractures, missed visceral injuries to the chest and abdomen are less common, with the liver and the spleen each contributing 10–15%. Bowels, either large or small, also contribute to diagnostic errors (approximately 15–20% of delayed diagnoses). Although diaphragmatic injuries are not particularly common, they represent about 5% of all delayed diagnoses, and a third to half are not diagnosed in the first 24 h [11]. Vascular injuries constitute approximately 5% of delayed diagnoses.

Among polytraumatized children with known skeletal and solid visceral organ injuries, ureteropelvic junction injuries were missed in approximately 50% of cases on initial evaluation [12]. Finally, more than 80% of patients with a previously unknown first-trimester pregnancy failed to get diagnosed on initial evaluation [13].

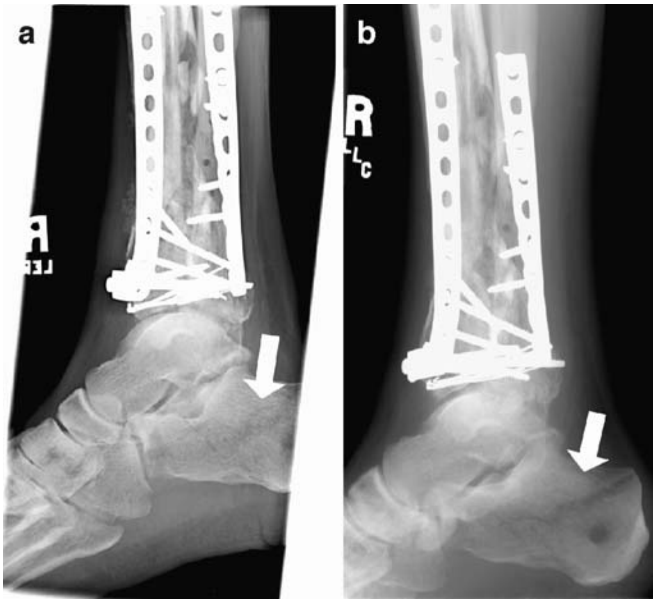

Fig. 1 Missed right calcaneal fracture: satisfaction or truncation of search due to obvious deformity in a 71-year-old man who comes from another state for advice concerning his right pilon fracture and left tibia plateau fracture status after open reduction and internal fixation. Series of right ankle exams performed on May 12, July 26 (**a**), August 9, August 30, October 4, and November 1 (**b**). Nondisplaced calcaneal fracture recognized on November 1, but not on any prior film. The fracture is practically invisible on the May 12 films, but is visible on all the subsequent ones. **a** Lateral conventional radiograph, right ankle. Findings: practically invisible calcaneal fracture (*white arrow*; July 26). **b** Lateral conventional radiograph, right ankle. Findings: a linear lucency within the right calcaneus, extending from the posterior tubercle inferiorly and anteriorly toward the calcaneocuboid joint (findings represent a calcaneal fracture) (November 1)

When are misses made?

Approximately 40% of delayed diagnoses are due to oversight during clinical survey [7, 8], 15% during primary survey (ABCDEs of resuscitation), approximately 25% during secondary survey (traditional history and physical examination), and approximately 50% during tertiary survey (reevaluation). Imaging contributes to oversight during the secondary and tertiary surveys. Not all oversights occur during clinical survey. Forty percent of intra-abdominal delayed diagnoses occur among patients who have previously undergone exploratory celiotomy and result in higher morbidity and mortality in 80 and 15%, respectively [7, 9].

What contributes to misses?

Five patient characteristics are more frequent among individuals who have delayed diagnoses. Misleading histories, such as "found down" and "alcohol on breath," constitute 10% of delayed diagnoses [9] (Fig. 2). Multiple severe injuries or serious and distracting injuries [3, 12] constitute approximately 10% of delayed diagnoses of surgically important intra-abdominal injuries in patients who were initially believed to have nontender abdomen and who had Glasgow coma scores of 15 [14].

Decreased levels of consciousness also increase the risk of missed or delayed diagnoses. Up to 60% of individuals who have delayed or missed diagnoses have traumatic brain injuries [3, 15]. In a similar manner, intoxication has been shown to increase the risk of diagnostic oversight [1]. Hemodynamic instability leading to abbreviated initial evaluation in the emergency department and to triage either to the trauma intensive care unit or to the operating room may be associated with up to 55 and 25% of individuals with delayed and missed diagnoses, respectively [15, 16] (Fig. 3). Multiple injuries in the same extremity increase the likelihood of overlooking a second injury, particularly when there are bulky dressings or splints obscuring less obvious lesions [16].

Failures of diagnosis related to imaging are also well-recognized [4, 16]. Among patients with delayed diagnoses, failure to obtain imagings of regions with signs or symptoms during clinical examination accounts for approximately 15% of delayed diagnoses [9]. Some authors have attributed this failure of clinical examination to less experienced observers. Among patients with delayed or missed diagnoses on which imaging of the involved area has been completed, approximately 60% of errors are thought to have been contributed by either incomplete imaging or poor-quality imaging [7].

Image misinterpretation constitutes 10–30% of delayed or missed diagnoses of injuries [9, 17]. Experience matters; the majority of less experienced observers, compared to those with greater experience (80% correct diagnoses), misinterprets emergency radiographs (<50% correct diagnoses) [18]. One of the most interesting and well-documented risks for imagers is the variant of satisfaction of search. Once a major abnormality has been detected, search time may be truncated on subsequent images; thus, abnormalities are not detected. This is decidedly truncation of search rather than faulty search pattern [19].

How can misses be avoided?

It is estimated that up to 60% of errors can be avoided using validated practices reported in the literature [3]. Repeated use of a standardized checkoff trauma survey form has been shown to reduce clinical oversight error by approximately 35% [15]. On the other hand, 24-h observations of otherwise uninjured patients increased diagnostic findings by only approximately 0.5% [20]. Among patients with chest injuries and delayed or missed diagnoses, pneumothorax was overlooked on initial chest x-ray (when visible in retrospect) in approximately 50%. Diaphragmatic injuries were missed initially in 30–50% of cases. However, chest x-ray was abnormal in approximately 90% and was diagnostic in approximately 30% [11].

Detection of orthopedic injuries can be substantially improved with imaging search patterns directed at areas of recognized clinical abnormalities, resulting in a decrease in delayed or missed diagnoses of approximately 70% in

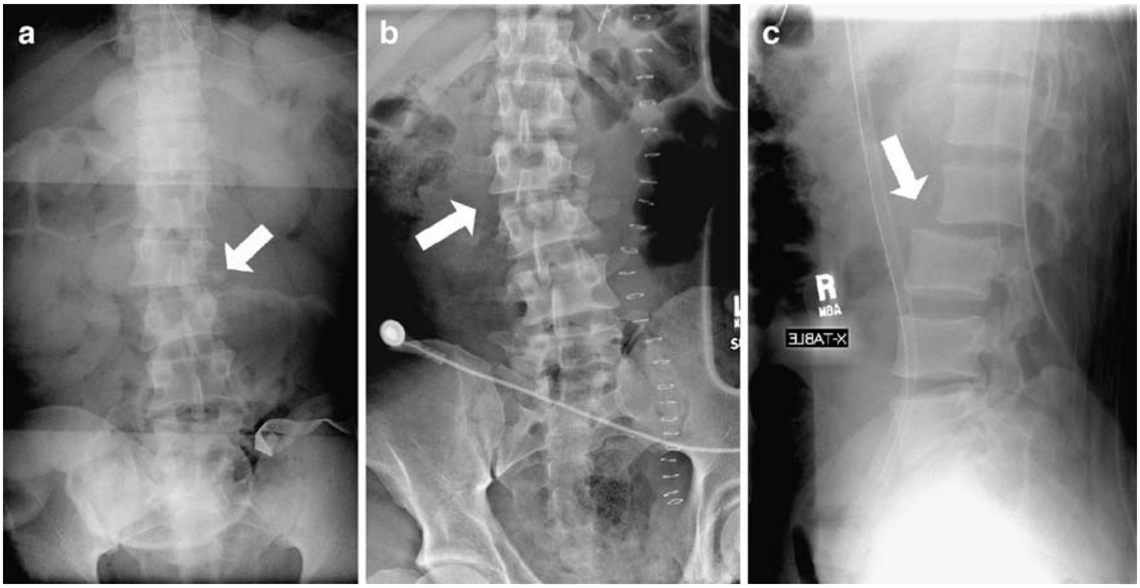

Fig. 2 Misleading history: missed L2–L3 fracture–dislocation in a 24-year-old man "found down." **a** Portable abdomen: missed L2–L3 fracture-dislocation (*white arrows*). **b** Anteroposterior lumbar spine shows a rotation of the body of L2 to the left, with subluxed right L2–L3 facets. **c** Lateral lumbar spine demonstrates L2 retrolisthesis 13 mm on L3, with subluxed facets. True history: the 24-year-old man fell 80 ft from a bridge and sustained polytrauma. Unstable, grossly positive diagnostic peritoneal lavage. Portable abdomen: missed the L2–L3 fracture–dislocation. Emergent laparotomy: diaphragm tear, retroperitoneal hematoma, rectal injury, pelvic fractures, hemopneumothoraces, and others. Secondary survey on the next day (29 h) shows L2–L3 fracture–dislocation

otherwise occult injuries [16]. Recognition of patterns of injuries, the so-called "clinical dyads," improved the recognition of other portions of a combined injury (e.g., Monteggia's fracture-dislocation, displaced ulnar shaft fracture, and radial head dislocation) [21]. Incomplete characterization may also constitute a form of delayed or missed diagnosis. For example, failure to appreciate a transverse portion of a U-type or an H-type sacral fracture may lead to underappreciation of the degree of instability and delay in definitive therapy.

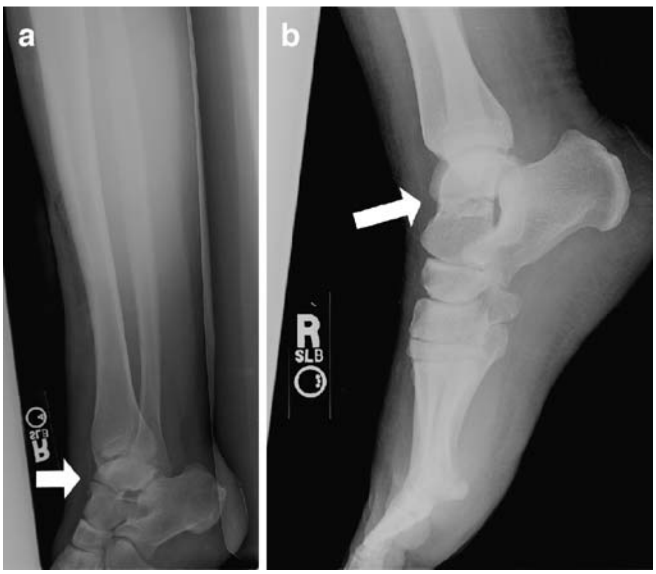

Fig. 3 Emergent laparotomy: associated delay in the diagnosis of right talar neck fracture in a 33-year-old patient with multiple injuries from motor vehicle crash polytrauma. **a** Lateral right tibia-fibula: missed right talar neck fracture (*white arrow*). **b** Lateral right foot (19 h later): fracture to the right talar neck (*white arrow*)

Use of appropriate imaging techniques can substantially decrease the risk of missed or delayed diagnoses. Magnetic resonance, computed tomography (CT), or scintigraphy can increase fracture detection in up to 25% of otherwise occult injuries. In particular, the use of whole-body bone scintigraphy is particularly useful among brain-injured and pediatric polytrauma patients [22].

CT is particularly useful in "low-volume" trauma centers (less than 500 polytrauma cases per year), in lieu of diagnostic peritoneal lavage or focused abdominal sonography for trauma [23]. Helical CTs of the cervical spine, chest, and abdomen improve the detection of otherwise occult injuries. It is estimated that conventional radiography, compared to helical CT of the cervical spine, misses 40–60% of injuries, especially at the craniocervical junction [24–26]. Helical CT of the thorax more reliably detects hemothoraces and pneumothoraces, contusions and lacerations, and diaphragmatic injuries. Moreover, among patients who have chest injuries graded as Abbreviated Injury Scale >2, earlier treatments are associated with a reduction in acute respiratory distress syndrome (8 vs 20%) and mortality (10 vs 21%) [27].

Appropriate performance of examination is important. For example, when routinely using multidetector CT of the abdomen with slice thicknesses of 5–7 mm to evaluate hemodynamically stable victims of blunt force trauma, CT will detect bowel or mesenteric injury with a prevalence of approximately 0.6–1.5%, a specificity of >99%, and a false-negative rate of approximately 15% [28]. Demonstration of active contrast extravasation is facilitated by an intravenous contrast volume and a contrast rate of >100 ml and >2.5 ml/s, respectively. This is important as extravasation is a good predictor of the need for intervention [29].

Similar to the "clinical dyads" noted above, recognition of associations can improve the recognition of otherwise occult injuries. For example, among patients with chest injuries, an unexplained hemodynamic compromise 12–14 h postinjury strongly suggests cardiac injury, and echocardiography will thus be diagnostic in almost all cases [30]. In a similar manner, recognition of a diaphragmatic injury is important as associated intra-abdominal injuries are present in approximately 80% of cases.

In evaluating abdominal CT, a search for so-called "packages," which include lateral, midline, and pelvic packages, should be performed [31]. "Lateral packages" represent the combination of ipsilateral solid intraperitoneal organ injury (e.g., liver or spleen) and adjacent injuries to the kidney, duodenum, or pancreas. These are often seen with ipsilateral inferior rib and extremity fractures and with lateral compression pelvic ring fractures. The "midline package," which is commonly associated with anteroposterior pelvic ring disruption, includes injury to the left lobe of the liver, stomach, pancreas, and great vessels, as well as injury to the small and large bowels. "Pelvic packages" include the association of retroperitoneal blood with injuries to the lower genitourinary system. Abdominal wall hematomas, particularly those of the anterior abdominal wall superior to the anterior superior iliac spine, are radiographic equivalents of lap belt signs and have a strong association with intra-abdominal injuries, especially bowel injuries.

The location of retroperitoneal hematomas can aid in the recognition of otherwise occult injuries. Compared to lateral perinephric hematomas, medial hematomas are more commonly related to vascular or renal pedicle injuries [32]. Midline retroperitoneal hematomas are worrisome for injuries to the root of the mesentery, including adjacent great vessels [33]. Finally, the combination of pelvic ring and other appendicular skeletal fractures increases the risk of concurrent head and abdominal injuries, especially in children [34].

Recognizing the increased risk of thoracolumbar spine fractures among patients who have been triaged either to the operating room or to the trauma intensive care unit from the emergency department for resuscitation can reduce diagnostic error rate. It is among this group that 75% of delayed diagnoses in thoracolumbar spine injuries, including both contiguous and noncontiguous injuries, occur [35].

Thoracolumbar fractures are missed more often among patients who have recognized intra-abdominal injury, especially those with abdominal wall ecchymosis, and contribute to diagnostic error by up to 45%. The frequency of missed spine injuries seems to be highest among those with concordant injuries to the hollow viscus, followed, in order, by injuries to the mesentery, solid organs, and great vessels [36]. Transverse process fractures, of which only 60% are identifiable with conventional radiography, may be associated with fractures of the vertebral body in approximately 10% of cases [37]. Moreover, transverse process fractures may be associated with intra-abdominal injuries in up to 50% of cases [38].

In the appendicular skeleton, recognition of multiple fractures that are tied to mechanism can be helpful. For example, the spectrum of the so-called dashboard injury includes posterior fracture-dislocation at the hip and midshaft femur, knee dislocations, and regional fractures (patella and tibial plateau fractures). Among dashboard-injured femurs, multiple femur fractures occur in about 10%; in 90% of these, the second fracture is in the intracapsular portion of the proximal femur.

In a similar fashion, motor vehicle crashes with floor pan intrusion into occupant space are associated with at least one fracture in 75% of cases and are commonly associated with multiple lower extremity fractures.

One of the most important mechanisms for systematic reduction of error is a formal review of diagnostic "errors." These group reviews may serve as forums for developing protocol worksheets for clinical surveys and for focusing on topics and individuals for education [5].

In summary, reduction of errors in polytrauma is the trauma team's responsibility, not the sole responsibility of any one of its members. The key elements in improving patient outcome are: use of protocol-driven survey forms, use of clinical prediction rules to guide whom and how to image, optimal use of the right technology, directed search in secondary and tertiary surveys focused on clinical examination, and formal search for patterns of missed diagnoses.

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