Errors in Imaging Assessment of Polytrauma Patients

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Although the use of multidetector computed tomography (MDCT) has increased the diagnostic quality by reducing the number of missed diagnoses in polytraumatized patients, errors remain a common phenomenon in emergency room setting. MDCT errors, contributing more commonly to missed or delayed diagnoses in polytrauma patients, are diagnostic errors commonly related to perceptual errors or to nonvisual errors. However, in some cases, misdiagnoses can be attributed to technical and methodological errors leading to incomplete or poor-quality imaging. Knowledge of common patterns of error is the most effective way to avoid future errors. The purpose of this article is to highlight the most frequent types of diagnostic errors in evaluating with MDCT of polytrauma patients.

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Since Roberts1 originally addressed this topic in 1928, the medicolegal implications of radiological practice misdiagnosis has become a very frequently discussed topic. Although, since 1970, the mortality rate that affects polytrauma patients has decreased from 40% to 10%,2 preventable deaths because of human and system errors account for up to 10% of fatalities in patients with otherwise survivable injuries cared for in level I trauma centers.3-5 Despite the use of multidetector computed tomography (MDCT) which has increased diagnostic quality,6 errors remain a common problem in emergency room and radiological practice.

Trauma care, in fact, creates a “perfect storm” for medical errors: unstable patients, incomplete histories, time-critical decisions, concurrent tasks, involvement of many disciplines, and often junior personnel working after-hours in busy emergency departments.4,7

In polytrauma patients, errors may be due to the complexity of the “polytrauma disease” or due to patient’s condition. Polytrauma is a systemic disease and as such can simultaneously affect multiple organs. Therefore, the attention of the radiologist must necessarily be directed to more organ systems because clear histories are often not available.

The technician and radiologist can both perform their jobs in a more efficient and focused manner if they have adequate information,8 however in many cases, blunt polytrauma patients may be hemodynamically unstable, often unconscious and, therefore, not cooperative, with incomplete or absent history. Up to 60% of individuals who have delayed or missed diagnoses have traumatic brain injuries.9,10 Misleading histories cause about 10% of delayed diagnoses11; clinical findings in about 25% of blunt polytrauma patients are equivocal and misleading, and in the setting of loss of consciousness or a head injury, the physical examination is only 60% reliable in detecting an abdominal injury.12,13

Knowledge of the type of trauma (direct, penetrating, or deceleration trauma), its dynamics and its main impact direction, allows one to predict type and site of injuries14,15 and could, therefore, help the radiologist to avoid a missed diagnosis, especially if the type of injury is assessed in relation to patient age. In fact, direct trauma to an elderly person can lead to more serious consequences than those a similar trauma can cause in a child.16

Among delayed diagnoses, about 40% are because of clinical survey oversight: 15% during the primary survey, 25% on secondary survey, and 50% during tertiary survey or re-evaluation. Imaging contributes to these oversights in the secondary and tertiary surveys. Misdiagnoses rates range from 2% to 40% based on how the frequency of error was assessed (trauma registries, retrospective chart review, and retrospective review of all admissions).17

Causes of error in radiology are multifactorial and frequently exist in combination.18,19 In recent years when the role of MDCT in the evaluation of the polytrauma patient has been widely recognized, some authors reported their experiences trying to clarify the different and recurring patterns of diagnostic error and the motivations that led to those errors.20-23
MDCT diagnostic errors contributing more commonly to
the failure or delay in diagnosis of polytrauma patients are
related to perceptual errors or to nonvisual errors, but in
some reports, about 60% of misdiagnoses are attributed to
incomplete imaging or poor-quality imaging.\textsuperscript{2,24} We called
the last type of error “technical and methodological error.”

\section*{Technical and Methodological Errors}

Correct execution of the examination and interpretation of
helpful information provided by contrast-enhanced MDCT
attribute to this imaging modality the role of “Gold Standard”
in major trauma.

The introduction of new equipment, increasingly quick in
“whole-body” scanning, has allowed radiologists to provide
this examination progressively from hemodynamically stable
to semi-unstable to borderline stable patients.

Polytrauma is a systemic disease and as such can simulta-
neously affect more parts of the body. For this reason, a
whole-body MDCT protocol, similar to those reported else-
where in the medical literature,\textsuperscript{25-27} is adopted as a routine
method for scanning blunt multitrauma patients at our insti-
tution. This modality is also useful for identifying vertebral
and pelvic fractures that may be missed on plain-film radiog-
raphy and for identifying associated traumatic lesions to the
brain, chest, or abdomen. Most importantly this modality is
useful for locating the sources of bleeding in vascular lesions,
which should have priority of treatment over skeletal lesions
and often even over parenchymal lesions.\textsuperscript{28}

Some authors have addressed the problem of blunt cere-
brovascular injuries that, although uncommon, are often un-
derdiagnosed among blunt trauma patients.\textsuperscript{29} The notable
morbidity with missed dissections warrants the extension of
contrast material-enhanced MDCT study to the carotid and
vertebral vessels in all polytraumatized patients (Fig. 1).

The application of MDCT technology as well as reducing
the temporal resolution affords important advantages in in-
jury detection and characterization.\textsuperscript{30} Autopic examinations
in polytrauma patients show that the primary cause of death
is severe hemorrhage and severe posttraumatic broncopul-
monary injuries.\textsuperscript{31} Therefore, it has become essential to re-
view diagnostic protocols in the polytrauma patient.\textsuperscript{32}

MDCT technology increases sensitivity in detection of ac-
tive bleeding that can be more promptly detected in the rou-
tine imaging evaluation of the trauma patient.\textsuperscript{33} Active hem-
orrhage is identified in 13%-18% of patients with visceral
injury or pelvic fractures at computed tomography (CT)\textsuperscript{34,35}
and is an important indicator for morbidity and mortality in
polytrauma patients because it denotes significant vessel or
organ injury.\textsuperscript{36} Detection and timely localization of a bleeding
source can improve the efficacy of trauma management,
avoiding delayed or missed diagnoses. Therefore, several au-
thors have addressed the problem of vascular injuries in
polytrauma patients with solid organ (liver, spleen, kidney),
gastrointestinal/mesenteric, and pelvic sources of bleeding.
\textsuperscript{28,30,37-40}

We feel that it is not to identify the extravasation of vascular
contrast medium. Now with the introduction of recent
MDCT equipment, it is essential to characterize its nature,
distinguishing arterial from venous injuries that require dif-
ferring management schemes (Figs. 2 and 3). This is of clinical
importance, as patients with considerable ongoing hemor-
hage do not always present with hemodynamic instability,
and a correct MDCT protocol may aid in the detection of
bleeding that requires direct intervention before hypovole-
mic shock appears.

Furthermore, recent studies have suggested that although
current MDCT imaging protocols are highly sensitive for ac-
tive hemorrhage, up to 25% of contained vascular injuries,
including pseudoaneurysms and arteriovenous fistulae, are not demonstrated on initial evaluation.41

Recognizing arterial from venous bleeding or identifying a contained arterial lesion definitely reduces the possibility of reaching a misdiagnosis or delayed diagnosis, and a correct detection of these can lead to conservative or endovascular treatment, or toward traditional surgery (Fig. 4).

This is possible by performing a correct multiphasic study with a contrast-enhanced arterial and venous phase that allow to decompose the radiologic findings in various phases providing a clear and unequivocal “road map,” which is essential for accurate and timely diagnosis and the most appropriate treatment.

Section thickness should be 0.5-3 mm when evaluating the vasculature in the arterial phase, whereas 3- to 5-mm sections are sufficient for studying the parenchyma of solid organ in venous phase. The amount of a high iodine concentration of contrast agent should be 100-130 mL, administered at high pressure flow rate of 3-5 mL/second. A high iodine concentration of contrast medium (370-400 mgI/mL) can provide better contrast enhancement and image quality than contrast solutions at lower iodine strength.42 Bolus tracking is preferred to the manual technique for timing of

**Figure 2** Value of multiphasic computed tomography (CT) evaluation in the deceleration injury. Multidetector computed tomography (MDCT) of a 40-year-old man with splenic injury after motorcycle accident. (A) Contrast-enhanced CT scan acquired in the arterial phase shows an area of active contrast extravasation (arrow) in the context of a small capsular tear at the posterior margin of the spleen (arrowheads). In portal phase (B), there is no clear evidence of such active bleeding. In this case, the most reliable treatment is selective embolization to prevent the development of ongoing hemorrhage.

**Figure 3** Importance of multiphasic CT evaluation in the management of pelvic vascular injuries. Axial images of venous active bleeding in 83-year-old woman with left ischiopubic branch fracture. In the arterial phase (A), only the fracture of the ischiopubic branch is documented (arrow), whereas, in the venous phase (B), an area of active bleeding at the obturator space is shown (arrow). On this basis, the patient was managed conservatively. Eight hours after, follow-up MDCT axial image (C) demonstrates that active bleeding is no longer detectable (arrow).
Figure 4  Value of multiphasic CT to differentiate and characterize parenchymal vascular injuries. A 26-year-old man after motor vehicle collision. MDCT-axial scans acquired in the portal phase (A-C) show multiple spleen lacerations (arrowheads) associated with hemoperitoneum (thick arrow). The corresponding CT scans in the arterial phase (D-F) show optimal depiction of multiple and contained intrasplenic lesions (pseudoaneurysms, thin arrows). Multiplanar reformation (MPR) coronal image (G) easily describes the extent of lesions (arrows). The patient underwent splenectomy.
the arterial phase, as hemodynamic status may vary significantly among patients.

Multiphasic study protocol should be preceded by an unenhanced thick-section scan. This scan can provide additional information in cases of possible parenchymal lesions permitting to identify the presence of hemoperitoneum or the “sentinel clot” sign, an important clue for locating the bleeding source when other findings of vessel injury are not present, or permitting to emphasize posttraumatic vascular intramural hematoma, especially of the aorta, difficult to evidence in the contrast-enhanced phase (Fig. 5).

In cases of suspected renal or urinary tract injuries, equally important can be a low-dose delayed phase performed 5-20 minutes. This phase is important not only in the dynamics of vascular extravasations (changing in morphology) but also for urinary collecting system trauma (Fig. 6), a large part being treated conservatively or treated by placing a percutaneous drainage catheter with or without ureteral stenting.43

In suspected urinary bladder injuries, active distension of the urinary bladder with diluted contrast material is essential for a high-quality MDCT cystogram that is reliable in excluding a bladder leak.43-45 It is important to avoid false-negative cases to recognize that passive distension of the bladder, using excreted contrast material only, during a routine MDCT study cannot be relied on to diagnose bladder rupture, even with clamping of a urethral catheter,43,46,47 even if the bladder appears to be distended. A minimum of 300-350 mL of diluted contrast media should be instilled into the bladder followed by axial CT imaging of the pelvis.47 Some authors distended the bladder with diluted contrast material before performing routine abdominopelvic CT and reported satisfactory results.44 At our institution, in accordance with other authors, we perform MDCT cystography on a second imaging series after initial routine diagnostic CT of the abdomen and pelvis.48 This technique ensures, by comparison of preand postcystography CT scans, that extraluminal contrast material after CT cystography is indeed from the bladder. If the bladder is filled with contrast material before whole-body CT scan, a possible urine collection could be confused with an active bleeding, for example in traumatic vascular lesions (Fig. 7); in fact, extravasating contrast from lower urological injuries can interfere with the CT assessment for pelvic arterial extravasation, delaying its detection and angiographic embolization.49

Finally, another way to avoid delayed diagnosis is the post-processing tool. Multiplanar reformations (MPRs) are helpful...
in identifying and further characterizing spine or pelvic fractures, diaphragmatic injuries, hematoma site, and areas of active hemorrhage (Fig. 4). MPR may be also helpful to better delineate the site of urinary tract injuries (Fig. 6) or bladder rupture in particular perforations at the dome of the bladder. With the advent of MDCT scanners, image quality has improved because acquisition speeds and slice thicknesses have decreased; isotropic datasets of large territories may be acquired, and reformations provide a real map of the vascular and bone anatomy. In some cases, axial, sagittal, and coronal

**Figure 6** Value of the delayed MDCT acquisition and MPR reconstruction. A 34-year-old man after blunt high-energy trauma. In case of collecting system injuries, the excretory phase is helpful to identify urinary extravasation and differentiate it from active bleeding. Axial image (A) shows a pooling of iodinated urine from the left renal collecting system (arrow). Coronal MPR (B) helps identify in detail the site, amount, and extension of the ureteropelvic junction laceration (arrow).

**Figure 7** Timing of CT cystography in the evaluation of polytrauma. The presence of iodinated urine in the right iliac space, hydrosensitive to the adjacent iliac vessels (A, arrow) may be mistaken as active bleeding if the bladder is filled simultaneously to the injection of intravenous contrast material. (B) However, the disposition of the iodinated fluid along the right psoas (arrows in B and C) and left gluteus maximus muscles (C) helps differentiate urine collection from hemorrhage.
planes help to identify the vessel of origin of active hemorrhage and aid to understand the extent and severity of injury by visualizing the area of active hemorrhage in 3 dimensions. MPR may also add information to accurately classify vessel injury, such as pseudoaneurysm, occlusion, or dissection, suggesting essential information to the interventional radiologist or surgeon.

**Spectrum of Diagnostic Errors**

One of the most commonly recognized types of image interpretation errors is the failure of detection of an abnormality. For instance, one most common causes of error in polytrauma patients is failure to detect fractures, which may account for 41%-80% of diagnostic errors in the emergency department. Missed orthopedic injuries are frequent in the periarticular regions, shoulder girdle, and feet (Fig. 8). Spine injuries constitute approximately 10% of all initially missed diagnoses. These are especially common at the craniocervical junction and cervicothoracic junction. Transverse process fractures may be associated with vertebral body fractures in approximately 10% of cases and may be associated with intra-abdominal injuries in up to 50% of cases.

Compared with extremity fractures, missed liver and spleen injuries contribute 10%-15%. Bowels, either large or small, also contribute to diagnostic errors (approximately 15%-20% of delayed diagnoses). Diaphragmatic injuries, even if uncommon, represent about 5% of all delayed diagnoses. Vascular injuries constitute approximately 5% of delayed diagnoses. Among polytraumatized children, ureteropelvic junction injuries were missed in approximately 50% of cases on initial evaluation. Finally, >80% of patients with a previously unknown first-trimester pregnancy failed to get diagnosed on initial evaluation. Perceptual errors, in
general, can be related to multiple psychophysiological factors, including level of observer alertness or fatigue, duration of the observation task, any distracting factors, conspicuity of the abnormality, and many others.\textsuperscript{60}

Another type of error is wrongly classifying a finding as abnormal. This phenomenon is often because of being over-cautious and is likely more common among radiology trainees and inexperienced radiologists.\textsuperscript{61} False-positive diagnoses may result in unnecessary hospital admission for observation. Patient or respiratory motion can simulate, respectively, apparent bone displacement or apparent double contour in the surface of the solid organs, mimicking, for instance, a subcapsular hematoma (Fig. 9); streak artifacts from bone (arms commonly) can simulate a parenchymal laceration of the solid organs (spleen and liver typically) (Fig. 10). In some cases, splenic clefts may appear very similar to a low-grade laceration (Fig. 11).\textsuperscript{7,62}

Another issue that may affect observer performance is intentional underreading, which is a tendency to interpret abnormality as negative.\textsuperscript{63} Such a phenomenon may occur because of collegial pressure to reduce the number of false-positive interpretations, and thereby, decrease unnecessary workups. Some authors have described this type of error as faulty reasoning.\textsuperscript{64} Another category of error not due to failure to detect an abnormality is to recognize an abnormal finding but assign incorrect etiology. An example of this type of error is shown in Fig. 7. Provenzale et al\textsuperscript{61} classified these last 2 types of error as a misinterpretation error.

Another form of observer error that may contribute to lesions being overlooked is satisfaction of search error: once a

**Figure 10** Streak artifacts mimicking a parenchymal lacerations (arrows). The patient’s arms were located along the body and not extended above the head during whole-body CT scanning, thus producing streak artifacts that can be misinterpreted as a hepatic and/or splenic lacerations. Also, it is important to note that such an arm position during scanning increases the radiation dose exposure.

**Figure 11** Splenic cleft mimicking a laceration. Axial CT image of a 28-year-old man shows hepatic laceration (white arrows) and a hypodense round area in the spleen (black arrow) with well-defined margins and no splenic surrounding hematoma. Parenchymal clefts and lobulations have similar features that can be erroneously be confused with a splenic injury.

**Figure 12** Satisfaction of search. A 37-year-old man run over by a car. Two noncontiguous axial CT scans show a shattered kidney with multiple areas of active bleeding (A, arrowheads) and a hematoma of left adrenal gland (B, arrow). The latter entity was overlooked at the first evaluation. Once such a life-threatening condition has been detected, further pathological issues may be easily overlooked.
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 (Fig. 12).

Another main reason why emergency radiologists are sued is failure to suggest the next appropriate procedure. Radiologists must ensure that their recommendations or suggestions for any additional radiologic procedures are appropriate and will add meaningful information to clarify, confirm, or rule out the initial impression. The American College of Radiology “Practice Guideline for Communication of Diagnostic Imaging Findings” states that “follow-up or additional diagnostic studies to clarify or confirm the impression should be suggested when appropriate.” This is the case, for example, of a polytraumatized patient with an equivocal finding.

Moreover, errors in communication are the fourth most frequent allegations against radiologists in medical malpractice claims. In addition to rendering an official interpretation (a final written report), the radiologist is responsible for communicating findings directly to the referring physician. In emergency radiology, quick diagnosis and treatment are essential factors to improve management or outcome of critically injured patients; therefore, when communication is absent or not documented, the radiologist can risks losing a lawsuit when there are adverse or unexpected clinical outcomes. Documentation should include the date, time, name of the person spoken to, and what was discussed.

Conclusions

Trauma is a systemic evolutive illness, for which it is necessary to have a close clinical-instrumental monitoring. MDCT changed outcome of polytrauma patients, but clinically important diagnostic errors are still relatively common and may lead to misdiagnoses or suboptimal treatment.

A strict collaboration with the trauma team is necessary before and after the execution of MDCT examination. The key elements to avoid errors are represented by the specific basic knowledge, by experience and by the application of a complete and technically correct MDCT protocol. A systematic approach with the use of a checklist to reading wholebody CT for trauma could probably reduce diagnostic errors in inexperienced radiologists.

References
