Résumé


Objectifs. Évaluer l’intérêt d’une relecture systématique des scanners corps entier dans l’impact thérapeutique de patients polytraumatisés admis au déchocquage.


Résultats. Cette étude a porté sur 105 patients dont 82 hommes (78 %) et 23 femmes (22 %), âgés de 2 à 83 ans. Le niveau à l’admission a été coté niveau III (n = 64), II (n = 30) et I (n = 11). La seconde lecture a identifié 3 lésions non décrites initialement ayant nécessité une modification thérapeutique, à savoir une rupture splénique (n = 1), une fracture du rachis dorsal (n = 1) et un hématome extradural (n = 1), sans conséquence en terme de mortalité. Par ailleurs des erreurs dans l’interprétation initiale ont été identifiées : fractures ostéoarticulaires périphériques (n = 38), lésions thoraciques (n = 36), cérébrale (n = 31), abdominale (n = 28), rachidien (n = 19), face (n = 17), et extravasation de contraste (n = 6).

Conclusion. Devant le nombre important et la gravité de certaines lésions passées inaperçues lors de la première interprétation des scanners corps entier de patients polytraumatisés, nous recommandons une relecture systématique des clichés.

Mots-clés : Scanner, Polytraumatisme, Radiologue, Lecture.


Value of double reading of whole body CT in polytrauma patients

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Abstract

Purpose. To assess the value of standard double reading of whole body CT in the management of polytrauma patients.

Materials and methods. Prospective study between January and July 2005. Two senior radiologists with expertise in trauma imaging, blinded to clinical findings, reviewed 105 initial CT examinations of polytrauma patients. These examinations had initially been interpreted by the on-call radiologist. The second interpretations were performed within 12 hours of admission, and were considered the gold standard.

Results. A total of 105 patients were included with 82 males (78%) and 23 females (22%), aged between 2 and 83 years. The level of admission was graded III (n=64), II (n=30) and I (n=11). The second reading identified 3 lesions that were not initially described, each requiring a change in management, including splenic rupture (n=1), thoracic spine fracture (n=1) and epidural hematoma (n=1), with no unfavorable impact on mortality. Additional errors in the initial interpretation were identified: peripheral fractures (n=58), chest (n=36), brain (n=31), abdominal (n=28), spine (n=19) and maxillofacial (17) lesions and contrast extravasation (n=6).

Conclusion. Based on the large number and severity of some lesions missed at initial interpretation of whole body CT of polytrauma patients, we recommend standard double reading of these examinations.

Key words: CT, Polytrauma, Radiologist, Reading.

Trauma related mortality is a significant concern. Each year, about 150,000 individuals are victim of polytrauma, and about 9,000 will die as a result. Some of the survivors have permanent functional sequelae causing moderate to severe disability. Most polytraumas in France are from motor vehicle accidents (MVA). The fight against this type of trauma has become a public health concern and several measures have been implemented over the last few years to reduce the number of MVA victims. In addition to these preventive measures, improvements must also be achieved in the medical management of these patients, in order to reduce the mortality rate and severity of related sequelae.

In France, the term polytrauma most frequently describes a “severely injured patient with multiple organ injuries with at least one being potentially lethal at short to mid term”. This definition summarizes well the level of difficulties encountered by the medical teams involved in the management of these patients. The urgent context and the multiplicity of organ system involvement complicate the acquisition of a comprehensive work up of all lesions, which may cause some lesions to go undetected at initial evaluation.


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These lesions may have dire consequences with increased mortality and morbidity. Our own clinical experience and data from the literature have lead us to conclude that several lesions remain undetected due to interpretation errors of imaging studies obtained at the time of admission. In our practice, the imaging work up relies heavily on whole body CT. The purpose of this study was to determine if standard double reading of whole body CT examinations would improve the management of polytrauma patients.

Patients and methods

Patients

This study was performed in the surgical emergency and radiology department of the G pavilion of the Hôpital Édouard Herriot in Lyon. In 2005, 421 polytrauma patients were evaluated in the trauma unit, most following MVA. The triage of patients in the trauma unit is based on pre-established protocols that are regularly reviewed to ensure optimal patient care. Prior to their arrival, patients are first evaluated by the SAMU physician and classified into 3 severity groups (I, II and III), according to the classification described by Kienlen and de La Coussaye (1). This allows better and more dedicated management of each individual patient in terms of resuscitation, work-up and medical needs.

Patients in class I are severely injured with serious hemodynamic distress defined as a systolic arterial pressure below 80 mm Hg in spite of good vascular filling and/or neurological distress defined by a Glasgow score below 8 and signs of increased intracranial pressure and/or respiratory distress defined by an oxygen saturation below 90%.

Patients in class II are seriously injured but quite stabilized by intensive care such as massive vascular loading, vasopressors, and oxygenation and/or with Glasgow score below 8 but without signs of increased intracranial pressure.

Patients in class III are stable and are in no distress.

Class I patients are immediately managed in the trauma unit by attending physicians in each of the relevant medical or surgical specialties. The work up is minimized to only detect life threatening injuries without delaying management. It includes a chest radiograph, a radiograph of the pelvis, and an US of the abdomen; echocardiography, transesophageal echocardiography and transcranial Doppler may be added based on clinical findings.

After completion of this work up, and if the patient remains unstable, the patient is directly transferred to the surgical theater or angiography suite for immediate intervention: surgery or arterial embolization. If the patient is relatively stable, a whole body CT is obtained to further characterize the injuries.

The work up of class II patients includes a chest radiograph, a pelvic radiograph, radiographs of injured limbs, and a whole body CT.

The work up of class III patients includes a chest radiograph, a pelvic radiograph, radiographs of injured limbs, and is complemented by an abdominal US or a whole body CT based on the nature of the trauma.

The whole body CT examinations were performed using a multidetector row CT scanner. Our protocol included noncontrast images of the brain followed by postcontrast images of the chest, abdomen and pelvis. The image acquisition was started 25 seconds after initiation of contrast administration at a rate of 3 ml/sec. Coronal, sagittal and/or oblique multiplanar reformatted images along with 3D images were routinely obtained to better evaluate fractures. Whole body CT examinations were routinely interpreted by an attending radiologist and radiology resident. CT images were reviewed on an independent workstation or a PACS station. The report was verbally communicated to the trauma team followed by a written report as soon as possible after completion of the exam.

Study design

This is a prospective study performed between January 1st, 2005 and July 31st, 2005. During this time period, all whole body CT examinations performed on trauma patients (adults, children) from the trauma unit of the G pavilion were systematically reviewed by two senior radiologists with expertise in trauma radiology within 12 hours of acquisition. The reviewers included a senior radiologist with expertise in musculoskeletal and neuroradiology and a senior radiologist with expertise in body imaging. The initial report was made available in all cases. All examinations were reviewed on PACS workstations.

The axial images as well as reformatted images generated per protocol were available in all cases. An itemized review list classifying lesions per organ systems (brain, abdomen-pelvis, chest, active bleeding, spine, bony pelvis, skull, facial bones, and other locations) was used. This expedited the transcription of the report from the second reading.

Data collection

The first and second readings from all examinations were compared and all lesions described on the second reading (gold standard) but not on the first reading were catalogued and analyzed. These lesions were considered as missed on the initial reading. These lesions were further subclassified into three levels of severity (severe, moderate, and minor) based on the Abbreviated Injury Scale (AIS). Severe lesions corresponded to AIS scores 4 and 5, moderate lesions to AIS scores 2 and 3, and minor lesions to AIS score 1. Lesions not addressed in the AIS were distributed into the 3 groups after consensus review by the radiologists and trauma team. Active bleeding, characterized by extravasation of iodinated contrast material on CT, was categorized as a severe lesion if arterial embolization was required.

Results from the double read were provided to the lead trauma physician. When necessary, patient management was modified based on the updated imaging data. The patient population with lesions missed on the first read was compared to the patient population where no lesion was missed based on all recorded data. The interobserver correlation was calculated.

Statistical analysis

A descriptive analysis of the collected data was performed. Quantitative variables were analyzed using the Student t-test or Mann–Whitney test based on their distribution. Qualitative variables were analyzed using the Fisher test or Chi 2 test. A p value<0.05 was considered significant. Interobserver correlation was calculated using the kappa test. A kappa value of 0.60 was selected as the threshold between fair and good correlation.

Results

A total of 105 patients were included in this study, with 78.1% males (n=82). The
mean age was 35.7 years (95% confidence interval [CI]: 31.4-40). The mean age of the pediatric population was 10.6 years (95% CI: 8.9-12.3), and the mean age of the adult population was 43.6 years (95% CI: 39.2-47.9). The mean ISS (injury severity score) was 27.1 (95% CI: 24.3-29.9). The mean Apache II score was 17.4 (95% CI: 15.3-19.5). A total of 10.5% of patients were classified as class I (n=11), 28.6% as class II (n=30) and 60.9% as class III (n=64). A total of 70.5% of patients admitted to the trauma unit were admitted in the hospital for further management (n=74). A total of 12.4% of patients died within the first 28 days after trauma (n=13).

Analysis of missed lesions

1. Number of lesions: Lesions were missed in 75 patients (71.4%) on the initial interpretation of whole body CT examinations. A total of 280 lesions were missed from a total of 765 lesions detected on the second read (36.6%). Of these 280 missed lesions, 31 (11%) were considered severe, 192 (69%) moderate and 57 (20%) minor. Thirty one of 84 (36.9%) severe lesions were initially missed, 192 of 567 (33.9%) moderate lesions were initially missed and 57 of 114 (50%) minor lesions were initially missed.

2. Type of lesions: Missed lesions were distributed as follows based on severity and organ systems (table I):

- severe lesions (n=31):
  - brain: intraparenchymal hematoma (n=7), epidural hematoma (n=1), subdural hematoma (n=2), subfalcine herniation (n=1);
  - facial bones: LeFort type III fracture (n=1);
  - spine: cord compression (n=1);
  - chest: hem mediastinum (n=9), flail chest (n=3);
  - no severe lesion at the abdomen or pelvis, or bony pelvis and no contrast extravasation requiring arterial embolization was missed at the time of initial interpretation.

- moderate lesions (n=192):
  - brain: skull fracture (n=3), intraparenchymal petechial hemorrhage (n=3), cerebral contusion (n=4), subarachnoid hemorrhage (n=2), intraventricular hemorrhage (n=3), cerebral edema (n=10), pneumocephalus (n=2);
  - facial bones: varied fractures of the zygoma, orbits, temporomandibular joints, paranasal sinuses, temporal bones, hyoid bone, and thyroid cartilage (n=14);
  - spine: vertebral body fracture (n=10), occipital condyle fracture (n=1), posterior articular fracture (n=2), pedicle fracture (n=1), transverse process fracture (n=10), spinous process fracture (n=7);
  - chest: fractures of 2 or more ribs (n=13), sternal fracture (n=2), single lobe lung contusion (n=8), hemothorax (n=6), pneumothorax (n=8), pleural effusion (n=2), pericardial effusion (n=1), pneumopericardium (n=1), atrial thrombus (n=1), active bleeding (n=2);
  - abdomen: splenic contusion (n=1), renal contusion (n=3), adrenal contusion (n=3), hemoperitoneum (n=4), intraoperative hematoma (n=6), retroperitoneal hematoma (n=12), pneumoperitoneum (n=1), retropneumoperitoneum (n=1), portal venous gas (n=2), hepatic artery pseudoaneurysm (n=1), active bleeding (n=1);
  - pelvis: acetabular fracture (n=7), inferior pubic ramus fracture (n=4), superior pubic ramus fracture (n=2), parasymphyseal fracture (n=1), articular pelvic fracture (n=1), urethral injury (n=1), sacral fracture (n=4), active bleeding (n=3);
  - limbs: humeral fracture (n=4), clavicle fracture (n=7), scapular fracture (n=4), femoral fracture (n=2), active bleeding (n=1).

- minor lesions (n=57):
  - brain: cephalhema toma (n=5);
  - facial bones: nasal bone fracture (n=3), hemosinus (n=1), foreign body (n=2), orbital emphysema (n=1);
  - spine: foreign body (n=1);
  - chest: rib fracture (n=16); subcutaneous emphysema (n=8), chest wall hematoma (n=1);
  - abdomen: subcutaneous emphysema (n=7), abdominal wall hematoma (n=6), intramuscular hematoma (n=4);
  - pelvis: coccygeal fracture (n=2).

- lesion distribution based on organ systems was as follows:
  - brain: 43 lesions (15.4%);
  - facial bones: 22 lesions (7.9%);
  - spine: 14 lesions (12.1%);
  - chest: 87 lesions (30%);
  - abdomen: 52 lesions (18.6%);
  - pelvis: 24 lesions (8.6%);
  - limbs: 18 lesions (6.4%).

3. Comparison of patient populations: We have compared the population of patients where lesions were missed at initial interpretation with the population of patients where no lesion was missed at initial interpretation, based on collected data. These observations are summarized in table II.

The interobserver agreement was 63.3% (kappa=0.409; 95% CI: 0.35-0.46).

**Table I**

<table>
<thead>
<tr>
<th>Severity /Location</th>
<th>Severe</th>
<th>Moderate</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>11</td>
<td>27</td>
<td>5</td>
<td>43</td>
</tr>
<tr>
<td>Facial bones</td>
<td>1</td>
<td>14</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Spine</td>
<td>1</td>
<td>31</td>
<td>2</td>
<td>34</td>
</tr>
<tr>
<td>Chest</td>
<td>18</td>
<td>44</td>
<td>25</td>
<td>87</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0</td>
<td>36</td>
<td>16</td>
<td>52</td>
</tr>
<tr>
<td>Pelvis</td>
<td>0</td>
<td>22</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Limbs</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>192</td>
<td>57</td>
<td>280</td>
</tr>
</tbody>
</table>

**Discussion**

The management of polytrauma patients may be problematic when injuries are missed at the time of initial evaluation. These missed lesions may have severe functional consequences and may even cause death. A number of strategies were proposed to decrease the number of missed lesions, such as the implementation of pre-established standardized protocols at the time of admission at the trauma room or repeat clinical and paraclinical evaluations. In spite of these efforts, the incidence of missed lesions remains high requiring the implementation of additional measures. A review of the underlying causes for these missed lesions shows that a large portion are due to errors in the initial interpretation of whole body CT examinations. This study was conducted as part of a process to improve the care of our polytrauma patients. The purpose was to...
assess the relevance of a procedure that could reduce the morbidity and mortality in these patients.

We have hypothesized that routine double reading of imaging studies in polytrauma patients would reduce the number of missed lesions. In our department, the imaging work up of polytrauma patients relies heavily on whole body CT. This is why a double reading program was implemented for whole body CT examinations in polytrauma cases. All lesions missed on the initial interpretation were recorded and analyzed to determine the value of this program.

We have observed a high number of lesions that were missed on the initial interpretation with about 280 missed lesions from a total of 765 lesions (fig. 1), including a non-negligible number of severe lesions (11%). About three quarters of patients had at least one lesion that was missed. If the error rate is defined as the proportion of examinations with at least one interpretation error, then, the error rate in our series would be 71.4% with an interobserver agreement of 0.41.

The error rate in the interpretation of imaging studies reported in the literature is much lower, between 0.34-10.6% for radiographs (2, 3) and 1.5-38.7% for CT (4, 5). This may be due to the fact that none of these studies evaluated whole body CT examinations in polytrauma patients. Most studies evaluated standard radiographs (6-11) or CT examinations of specific body parts: brain (4, 5, 12-15), cervico-thoracic and thoracic regions (16, 17), abdomen and abdominopelvic regions (18, 19) or other body parts (20, 21).

One study evaluated whole body CT in a non-trauma patient population and reported a discordance rate of 37% for oncologic patients (22). It may be that the large number of images and the acute clinical context increase the error rate.

Our study design is different from other studies since we have not compared the interpretations from physicians of different qualification (resident versus attending, radiologist versus surgeon, trauma of emergency room physician). In our study, both CT interpretations were performed by senior radiologists. The only difference was that the initial interpretation was contemporaneous to the patient admission and performed by the on-call radiologist of the day whereas the second interpretation was performed by a trauma radiologist. We have not noted any difference in the quality of interpretations between both groups. The error rates on initial interpretation between the radiologists of pavilion G and other radiologists were identical. The large number of missed lesions on the initial interpretations is thus not related to the radiologist’s experience.

Interpretation of a whole body CT represents a considerable amount of work. The urgent and stressful clinical context creates a disruptive work environment that interferes with the radiologist’s ability to concentrate. Also, the patient’s functional prognosis and even survival may depend on the speediness of the interpretation, therefore reducing the amount of time available to the radiologist to generate a report, time that could otherwise be available under different clinical circumstances. Also, a number of CT examinations on polytrauma patients are performed at night, a period when attentiveness and ability to concentrate are reduced.

These considerations probably provide a basis for understanding why a large number of lesions were missed at the time of initial interpretation in our study (fig. 2).

Thirty percent of lesions initially missed on whole body CT were located at the

![](image)

**Fig. 1:** Axial CT images of the abdomen showing (a) a focus of splenic contusion (arrow) and (b) infiltration of the left renal hilum (small arrow). These lesions were missed on the initial interpretation.
chest level, with over 50% of severe lesions initially missed involving the chest (n=18) (table II). Additional time should thus be allocated to the review of chest CT images since the largest proportion of missed lesions, especially severe lesions, involved the chest (fig. 3).

Also, missed lesions were more frequent in adult patients than in younger or pediatric patients (patients in the second population were generally younger than patients in the first population [26.2 versus 39.5 years; p<0.001], with larger number of pediatric patients [40% versus 14.7%; p=0.01]).

A comparison of injury severity between both patient populations demonstrates that severity scores were higher in the patient population with missed lesions (mean ISS of 30.7 versus 18; p<0.001 — mean Apache II score of 19 versus 13.5; p<0.001). The percentage of patients admitted to the intensive care unit was higher in this population (80% versus 46.7%; p=0.0017). On the other hand, there was no significant difference between both groups for the mortality rate at 28 days (p=0.34).

As such, more severely injured patients have more lesions on whole body CT and more of these lesions are missed at the time of initial interpretation. The fact that mortality rates at 28 days are not significantly different eliminates the hypothesis of a causal relation between missed lesion and patient death.

The CT examinations of severely injured patients should be more carefully reviewed, and double reading should be considered.

We have defined all lesions that were described on the second read but not on the initial read as missed lesions. We have viewed the second read as the gold standard. It might have been preferable to obtain a second read from radiologists with expertise in each of the organ systems covered on the whole body CT examinations and compare these to the initial interpretations. However, given the circumstances surrounding the second interpretation, we believe that the second reads obtained in our study are probably very close to the reality compared to the initial interpretations (review by an experienced radiologist, in a calm environment, with possibility to consult with colleagues).

Conclusion

Management of polytrauma patients is complex. Advances have already been achieved with the implementation of standardized protocols, but the incidence of missed injuries remains high. Our results indicate that a large number of injuries are missed at the time of initial interpretation of whole body CT examinations.

As such, double reading of these CT examinations is part of a global process to improve patient management and quality of care. The CT examinations of severely injured patients should be more carefully reviewed since lesions are more frequently missed in this patient population. Finally, additional time should be allocated to the review of chest CT images since the largest proportion of missed lesions, especially severe lesions, involve the chest.

Fig. 3: Axial CT images of the chest with mediastinal (a) and bone (b) windows showing a T7 vertebral fracture (arrow) emphasizing the need for routine multiplanar reconstructions and multi-window image review.

Fig. 2: Axial CT images of the brain showing right frontoparietal hemorrhagic contusions that were missed on the initial interpretation.
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References