Radiological findings during trauma workup in a cohort of 1,124 level-1 trauma patients

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Submitted
ABSTRACT

Background
During the initial assessment of patients with potential severe injuries, radiological examinations are performed in order to rapidly diagnose clinically relevant injuries. Previous studies have shown that performing these examinations routinely is not always necessary and that trauma patients are exposed to substantial radiation doses. The aim of this study was to assess the amount and findings of radiological examinations during the initial assessment of trauma patients, and to determine the radiation doses to which these patients are exposed to.

Methods
We analyzed the 1,124 patients included in a randomized trial. All radiological examinations during the initial assessment (i.e. primary and secondary survey) were assessed. The examination results were categorized as positive findings (i.e. (suspicion for) traumatic injury) and normal findings. The effective radiation doses for the examinations were calculated separately for each patient.

Results
Eight hundred and three patients were male (71%), median age was 38 years and 1,079 patients sustained blunt trauma (96%). In total, during initial assessment, almost 3,900 X-rays were performed, of which 25.4% showed positive findings. FAST of the abdomen was performed in 989 patients (88%), with positive findings in 10.6%. Additional CT-scanning of specific body regions was performed 1,890 times in 813 patients (72.1%), of which approximately 43.4% revealed positive findings. Hemodynamically and neurologically stable patients showed more normal findings on the radiographic studies than unstable patients. The mean radiation doses for the total population was 8.46 mSv (± 7.7) and for polytraumatized patients (ISS ≥16) 14.3 mSv (±9.5).

Conclusion
Radiological diagnostics during initial assessment of trauma patients show a relatively high rate of normal findings in our trauma system. The radiation doses to which trauma patients are exposed is considerable. Considering that the majority of the injured patients are hemodynamically stable and alert, we suggest more selective use of X-ray and CT-scanning.
INTRODUCTION

Nowadays, in the Netherlands and most other Western countries trauma patients with (potential) severe injuries are transported to designated trauma centers. After arriving at the hospital, these patients are assessed by a specialized trauma team according to the ATLS guidelines. The guidelines include standard radiological examinations. Due to prehospital overtriage, a considerable amount of these radiological examinations do not show any injury at all. As previous studies have shown that this overuse of facilities leads to increased costs. In addition, trauma patients are exposed to significant radiation doses from diagnostic imaging, resulting in an excess risk of cancer. This (albeit small) individual risk may become a greater public health issue since more and more Computed Tomography (CT) examinations are performed. Especially, patients with musculoskeletal injuries, severely injured patients and patients with prolonged hospital stay are at an increased risk of excessive radiation exposure. Several studies have concluded that the overuse of initial diagnostics during primary survey is still high, leading to unnecessary costs and health risks. To our knowledge, no earlier study has described the diagnostics during the initial assessment of (potential) severely injured patients, combined with positive finding rates and the radiation exposure of these examinations.

The aim of this study was to describe the amount and findings of all radiological examinations during initial assessment of adult level 1 trauma patients. Secondly, the radiation exposure of these diagnostic examinations was determined.

PATIENTS AND METHODS

Study setting

The VU University Medical Centre (VUmc) and the Academic Medical Centre (AMC) are two of the 11 designated Level-1 trauma centers in the Netherlands which are both located in Amsterdam. Together with the surrounding affiliated hospitals they are responsible for the trauma care of the 2.7 million inhabitants in this region. Approximately 700 trauma patients are presented in the trauma resuscitation room (TR) of each trauma center per year, of which roughly 25% are polytraumatized patients (Injury Severity Score (ISS) ≥ 16).

In general, in both hospitals patients with (potential) severe injuries undergo standard X-rays (i.e. chest, pelvis and cervical spine (CS)) and/or Focused Assessment with Sonography for Trauma (FAST) of the abdomen. In addition, selective CT-scan examination is performed where necessary (i.e. abnormal findings during physical examination).

The trauma resuscitation rooms in both centers are fully equipped for assessing and treating injuries of (potentially) severely injured patients, including overhead X-ray equipment and mobile ultrasound equipment. During the study, the VUmc had a 64-slide CT scanner installed at the radiology department. During the study a moveable 4-slice CT scanner was located in the TR in the AMC.

Study design

This study was conducted as part of the prospective Randomized study on Early Assessment by CT scanning in Trauma Patients (REACT-trial; registered as ISRCTN5332315). The aim of the REACT trial was to assess the effects of a setting with a CT scanner available in the trauma
resuscitating room with a standard setting with a scanner located at the radiology department. Adult patients were included for the REACT trial between November 2005 and November 2007.

For the present study data on patient, injury and initial assessment characteristics were extracted from the REACT trial database.

Information concerning demographic characteristics (sex, age), mechanism of injury, initial Glasgow Coma Scale (GCS) and Systolic Blood Pressure (SBP), frequency of initial radiological examinations (X-rays, FAST and additional CT scans), Injury Severity Score (ISS) and 1-year mortality were analyzed for each patient. Radiological findings were compared between stable and unstable patients. Stable patients were defined as having a SBP above 89mmHg and having a maximal GCS during admission.

All radiological examinations (including X-rays and CT-scans of different body regions) during primary and secondary survey were assessed. The examination results were categorized as 1. positive findings (traumatic injury), 2. normal findings and 3. incomplete or not evaluable results.

The effective doses for X-ray examinations was described according to the study of Mettler and colleagues. In particular, the effective doses for a chest X-ray was equal to 0.02 mSv, for the C5 0.2 mSv, for the thoracolumbar spine 2.5 mSv, for the pelvis 0.6 mSv and for each extremity 0.001 mSv.

In our study, effective dose calculations were performed using the ImPACT Dosimetry Calculator (www.impactscan.org).

Continuous variables were described as mean with ranges or as median with interquartile ranges (P25 – P75). Categorical variables were described as percentages. Statistical analysis was performed using the SPSS software package (SPSS 17.0 for Windows; SPSS, Chicago, IL, USA).

Both institutional ethical boards evaluated the REACT study protocol and declared that the need for informed consent was waived.

RESULTS

In the REACT trial 1,124 trauma patients presented in the TR of both level-1 trauma centers were included for analysis. Table 1 shows the baseline characteristics of the study population.

The median ISS was 6 (2-14). Two hundred and sixty five (24%) concerned polytrauma patients (ISS≥16) and 121 patients (11%) had sustained severe traumatic brain injury (TBI). During initial assessment, almost 3,900 X-rays were performed for the total population. Nine hundred

<table>
<thead>
<tr>
<th>Table 1. Demographics of study population</th>
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<tbody>
<tr>
<td>Included patients</td>
</tr>
<tr>
<td>Male (%)</td>
</tr>
<tr>
<td>Median age in years (P25 – P75)</td>
</tr>
<tr>
<td>Blunt trauma (%)</td>
</tr>
<tr>
<td>CT scan during primary survey (%)</td>
</tr>
<tr>
<td>Median ISS (P25 – P75)</td>
</tr>
<tr>
<td>Patients with missed injuries (%)</td>
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<tr>
<td>1-year mortality (%)</td>
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</table>
and eighty nine patients (88%) underwent a FAST of the abdomen in the TR. Additional CT scans were totally performed 1,890 times for 813 patients (72.1%). In total, positive findings were found in 850 (25.4%) X-ray examinations, in 63 (10.6%) FAST examinations of the abdomen and in 821 (43.4%) CT scans (Table 2).

<table>
<thead>
<tr>
<th>Examination</th>
<th>Total</th>
<th>Injury detected</th>
<th>No injury detected</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray</td>
<td>3,879</td>
<td>850</td>
<td>2,893 (74.6%)</td>
</tr>
<tr>
<td>X - Chest</td>
<td>1,109</td>
<td>253</td>
<td>854 (77%)</td>
</tr>
<tr>
<td>X - Pelvis</td>
<td>957</td>
<td>117</td>
<td>838 (87.6%)</td>
</tr>
<tr>
<td>X - C-spine</td>
<td>819</td>
<td>65</td>
<td>622 (75.9%)</td>
</tr>
<tr>
<td>X - Extremity</td>
<td>501</td>
<td>278</td>
<td>223 (44.5%)</td>
</tr>
<tr>
<td>X - Thor/Lumbar Spine</td>
<td>493</td>
<td>137</td>
<td>356 (72.2%)</td>
</tr>
<tr>
<td>Abdominal Ultrasound</td>
<td>989</td>
<td>63</td>
<td>884 (89.4%)</td>
</tr>
<tr>
<td>CT Brain</td>
<td>623</td>
<td>281</td>
<td>342 (54.9%)</td>
</tr>
<tr>
<td>CT Face</td>
<td>95</td>
<td>63</td>
<td>32 (33.7%)</td>
</tr>
<tr>
<td>CT C-spine</td>
<td>618</td>
<td>109</td>
<td>509 (82.4%)</td>
</tr>
<tr>
<td>CT Thoracic spine</td>
<td>125</td>
<td>53</td>
<td>72 (57.6%)</td>
</tr>
<tr>
<td>CT Lumbar spine</td>
<td>89</td>
<td>48</td>
<td>41 (46.1%)</td>
</tr>
<tr>
<td>CT Chest</td>
<td>127</td>
<td>101</td>
<td>26 (20.5%)</td>
</tr>
<tr>
<td>CT Abdomen</td>
<td>115</td>
<td>77</td>
<td>38 (33%)</td>
</tr>
<tr>
<td>CT Pelvis</td>
<td>42</td>
<td>39</td>
<td>3 (71%)</td>
</tr>
<tr>
<td>CT Extremity</td>
<td>56</td>
<td>50</td>
<td>6 (10.7%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,758</strong></td>
<td><strong>1,734</strong></td>
<td><strong>4,846 (71.7%)</strong></td>
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</tbody>
</table>

Figure 1 depicts the performed radiographic studies with their findings, classified according to age. As the age increases, a trend of an increasing positive findings rate is seen. The same effect is shown in Figure 2, were the studies are categorized according to the ISS. As the ISS is increasing, the normal finding rate decreases.

The effective doses of both CT scanners (64- and 4-slide) were calculated for each body region as depicted in figure 3. The mean radiation exposure for the total study population was 8.46mSv (± 7.7), ranging from 0mSv to 40mSv and for the polytrauma patient population 14.3mSv (± 9.5) (Figure 4). The lowest doses concerned the CT-scan of the face (0.3 and 0.6 mSv), the highest for the CT-scan of the pelvis (8.4 and 11mSv).

The comparison of the radiological examinations in stable and unstable patients is shown in Table 3. Stable patients showed more studies with normal findings and less studies with positive findings, compared to unstable patients.

**DISCUSSION**

This study shows a high rate of normal radiological findings during the initial assessment of a large cohort of trauma patients in two European level 1 trauma centers. To our knowledge,
Figure 1. Summary of primary diagnostics positive for injury classified according to age.

Figure 2. Summary of primary diagnostics positive for injury classified according to the Injury Severity Score.

The effective doses of both CT scanners (64- and 4-slide) were calculated for each body region as depicted in figure 3. The mean radiation exposure for the total study population was 8.46mSv (± 7.7), ranging from 0mSv to 40mSv and for the polytrauma patient population 14.3mSv (± 9.5) (Figure 4). The lowest doses concerned the CT-scan of the face (0.3 and 0.6 mSv), the highest for the CT-scan of the pelvis (8.4 and 11mSv).
Figure 3. Radiation exposure and positive finding rate in CT-scan diagnostics per body region.
Table 3. Comparison of primary diagnostics in the 1,124 trauma patients between stable and unstable patients

<table>
<thead>
<tr>
<th>Examination</th>
<th>Stable (n=769)</th>
<th>Unstable (n=355)</th>
</tr>
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<tbody>
<tr>
<td>X-ray with injury</td>
<td>444 (16.7%)</td>
<td>406 (33.3%)</td>
</tr>
<tr>
<td>Abdominal Ultrasound with injury</td>
<td>30 (4.4%)</td>
<td>33 (10.8%)</td>
</tr>
<tr>
<td>CT-scan with injury</td>
<td>357 (35.5%)</td>
<td>465 (52.7%)</td>
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</table>

Stable: SBP > 89 mmHg and GCS = 15; Unstable: SBP ≤ 89 mmHg and / or GCS ≤ 15

Figure 4. Radiation exposure correlated to the Injury Severity Score

Figure 4 shows the radiation exposure correlated to the Injury Severity Score (ISS). The radiation exposure increases with the ISS, indicating a higher exposure for patients with higher ISS scores.

This is one of the largest patient cohorts, assessing the frequency and findings of primary radiological examinations, in relation to the radiation exposure in trauma patients.

The majority of the patients in this study (73%), received full diagnostic trauma series, including x-rays of the chest, CS, pelvis and FAST of the abdomen. A well known problem in our trauma system is however prehospital overtriage, resulting in unnecessary transportation of trauma patients to the TR of level 1 trauma centers. A previous study showed that one third of these patients are discharged from the hospital after TR assessment due to not having any injuries. The question is therefore: Should all trauma patients who are presented at the TR receive full diagnostic trauma series?

As we showed, almost 72% of all radiological studies resulted in normal findings. In general, the risk of missing (potential) life-threatening injuries is considered more important than the
small risk for cancer from radiological examinations. However, unnecessary studies should be avoided and therefore, the indication for radiological examinations should be taken for every patient separately into consideration. Especially unnecessary CT scans should be avoided as much as possible, due to the significant costs and radiation exposure.\(^{3,4}\)

More diagnostics does not necessarily mean less missed injuries.\(^5,7\) Inaba et al\(^7\) conducted a study in which initial radiological diagnostics during two different periods (2002 and 2007) were compared. They concluded that there was a significant increase in the use of CT and plain radiographs in the management of the injured patient resulting in a significantly higher radiation exposure with no improvements in diagnosis of missed injuries, mortality, or length of hospital stay.\(^7\) Similar studies, concentrated only on advanced radiology (CT and/or MRI scanning) concluded the same, showing that the use of these diagnostics have been multiplied in the course of years, resulting in an increased risk of adverse effects from CT scan examinations in trauma patients.\(^8,13\)

Early CT scanning is becoming more and more the common screening tool. CT scanning also leads to findings of which the clinical significance is questionable. We found traumatic injuries in more than the half of all conducted CT-scans (56.6%). Previous prospective studies assessing the amount of radiation to which trauma patients are exposed to showed that trauma patients receive high radiation doses due to radiological examinations during their stay in the hospital. The mean radiation exposure ranges in the literature between 0.68 mSv and 106 mSv.\(^3,7,13,15\) In the present study the mean radiation doses to which patients were exposed to was 8.46 mSv. It concerns though a heterogenic group of trauma patients (ISS range 0-75) for whom the dose was only calculated during primary assessment and not for the complete hospital stay. Polytrauma patients (ISS≥16) had the highest positive finding rate for injuries during initial assessment, but also the highest radiation exposure, reaching in some patients almost 40 mSv which is considerable.

The ATLS guidelines recommend performing routine pelvic x-rays in all patients after blunt torso trauma.\(^16\) Its sensitivity and cost-effectiveness have been shown to be low.\(^17,18,19\) However, in the present study more than 85% of the population received pelvic x-rays, revealing injury in only 117 patients (12.2%). A meta-analysis by Sauerland and colleagues\(^17\) showed that a thorough clinical assessment is sufficiently reliable enough (sensitivity and specificity of 90%) to rule out pelvic fractures in blunt trauma patients. They described seven anatomical criteria that are reliable enough to rule out any relevant pelvic fracture. Also the initial chest X-ray continues to be recommended by the ATLS.\(^16\) Our results show that chest injury was found in 23% of all patients who underwent x-ray’s of the chest. Wisbach and colleagues\(^20\) concluded in their study that chest x-rays during initial assessment do not add decision-making information to cases of hemodynamically stable patients who do not require intubation and who have normal physical examination of the chest. They showed that chest X-ray in stable trauma patients with a normal physical examination appears to be unnecessary in their initial evaluation, recommending to limit its use only for clear clinical indications.\(^20\) Chest CT is even more a point of discussion, being nowadays one of the most overutilized diagnostics in advanced imaging techniques. This because of the risk of missing life-threatening injuries such as blunt aortic injury, even when the chest X-ray shows normal findings. Plural and colleagues\(^14\) showed that despite the liberal use of chest CT, there had not been an increase in the overall diagnosis of (life-threatening) injuries that needed emergency intervention. Brink et al identified significant independent predictors of injuries on chest CT in high-energy blunt trauma patients, having a sensitivity of 95%.\(^25\)
A well-known phenomenon in daily practice is fear of failure to identify CS injury, which leads to extremely liberal use of radiography in patients with blunt trauma and possible neck injury. Many trauma systems successfully use the NEXUS criteria and the Canadian C-Spine rule as the gold standard for clearing the CS in stable trauma patients, showing both a high sensitivity for detecting CS injury and thereby reducing unnecessary radiological examinations. In the present study, the normal finding rate in the stable patients group was high (x-ray: 81.2% / CT-scan 51.8%). Another problem which frequently occurs are the incomplete or inevaluable results of the CS x-rays, resulting in additional CT scanning to exclude potential injury. In this study, a CS X-ray was performed in 819 (72.9%) patients. One hundred and thirty two (16.1%) of these patients showed incomplete or inevaluable results, receiving additional CT-scanning. As Saltzherr et al. suggested in their study, in patients who are at high-risk for having CS injury (i.e. having clavicular and/or rib fractures), primary CT scanning of the CS should be considered.

In contrast to the other body regions, physical examination of the abdomen in blunt trauma is subjective and often yields equivocal results. In the present study, almost 90% of all performed FAST examinations revealed no abnormalities. An earlier study found an incidence of equivocal physical examination of 45% in severely injured trauma patients and 84% in patients with fractures of the lower ribs. FAST is a rule-in triage tool, not a true diagnostic tool. However, outcome data on its true contribution to patient management remain unsatisfactory. The inability of FAST to diagnose injury, together with the improved availability of high quality CT scanning, has led to an increasing preference to send patients with potential intra-abdominal injury directly to the CT scan. Thus, we found that 66% of all abdominal CT scans resulted in a positive finding. Natarajan and colleagues showed in their study though that in the setting of the unstable patients in which time is of the essence, FAST is a bedside investigation that can be used before deciding on whether emergency intervention is needed. Moreover, it is performed relatively quickly and does not expose the patient to any doses of radiation.

The results of this study demonstrate that amount of normal findings during primary radiological assessment of level 1 trauma patients is considerable. However, it has been shown that with the use of strict (mostly clinical) criteria it is possible to limit the amount of unnecessary examinations in early trauma care. The need for plain radiography of the spine and pelvis can be assessed by accurately performing physical examination. Possible injuries to the abdomen are more difficult to exclude and therefore primary CT scanning of this region is advised. Based on the present study we propose a diagnostic strategy in our system, including clinical criteria as described in the literature, for the assessment of trauma patients to safely reduce inappropriate radiological studies. Future research on selective performing radiological examinations in trauma patients is therefore mandatory.

**CONCLUSION**

Primary radiological diagnostics during initial assessment of level 1 trauma patients are associated with a relatively high rate of overuse. This study shows that the radiation doses to which trauma patients are exposed are considerable. Considering that the majority of the injured patients who are presented in the TR are hemodynamically stable and alert, careful clinical examination should be performed to rule out injury followed by selective X-rays and CT-scanning.
REFERENCES