Total-body CT scanning in trauma patients: Benefits and boundaries
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SYSTEMATIC REVIEW AND META-ANALYSIS OF IMMEDIATE TOTAL-BODY COMPUTED TOMOGRAPHY COMPARED WITH SELECTIVE RADIOLOGICAL IMAGING OF INJURED PATIENTS

JC Sierink, TP Saltzherr, JB Reitsma, OM van Delden, JSK Luitse, JC Goslings

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ABSTRACT

Objective The aim of this review was to assess the value of immediate total-body computed tomography (CT) during the primary survey of injured patients compared with conventional radiographic imaging supplemented with selective CT.

Methods A systematic search of the literature was performed in MEDLINE, Embase, Web of Science and Cochrane Library databases. Reports were eligible if they contained original data comparing immediate total-body CT with conventional imaging supplemented with selective CT in injured patients. The main outcomes of interest were overall mortality and time in the emergency room (ER).

Results Four studies were included describing a total of 5470 patients; one study provided 4621 patients (84.5 percent). All four studies were non-randomized cohort studies with retrospective data collection. Mortality was reported in three studies. Absolute mortality rates differed substantially between studies, but within studies mortality rates were comparable between immediate total-body CT and conventional imaging strategies (pooled odds ratio 0.91, 95 percent confidence interval 0.79 to 1.05). Time in the ER was described in three studies. In two it was significantly shorter in patients who underwent immediate total-body CT: 70 vs. 104 min ($P = 0.025$) and 47 vs. 82 min ($P < 0.001$) respectively.

Conclusion This review showed differences in time in the ER in favour of immediate total-body CT during the primary trauma survey compared with conventional radiographic imaging supplemented with selective CT. There were no differences in mortality. The substantial reduction in time in the ER is a promising feature of immediate total-body CT, but well designed and larger randomized studies are needed to see how this will translate into clinical outcomes.
INTRODUCTION

The initial diagnostic evaluation of injured patients is frequently based on Advanced Trauma Life Support (ATLS®) principles, including a fast and priority-based physical examination as well as screening radiographs supplemented with selective computed tomography (CT). Since the introduction of spiral CT in the early 1990s, CT scanning has become more important in trauma care.

The introduction of multi-detector-CT (MDCT) scanners made total body CT (TBCT) technically feasible and its high diagnostic accuracy makes it an attractive diagnostic tool for the initial radiographic imaging of trauma patients. Furthermore, the amount of scanning time needed to obtain a TBCT appears to be acceptable. An increasing number of trauma centers encourages the use of immediate TBCT in the diagnostic phase of primary trauma care. The number of time-consuming transfers (and associated dangers) will be decreased with the use of immediate total-body CT. Furthermore, rapid total-body CT in an environment that enables resuscitation may streamline clinical pathways. Whether the advantages of such scanning justify the higher radiation dose given remains controversial. The most important remaining question is whether the use of immediate TBCT improves survival.

The primary aim of this systematic review was to assess whether immediate TBCT scanning during primary survey is associated with a lower mortality than conventional imaging supplemented with CT scanning. The second goal was to determine its effect on the time in the emergency room (ER).

MATERIALS AND METHODS

The guidelines for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were followed.

In- and exclusion criteria
Studies comparing immediate total-body CT during the primary survey of injured patients with conventional imaging and selective CT in a control group were included. Methods of analysis and inclusion criteria were specified in advance. Both randomized and observational studies were included. Only studies with a mainly adult study population were included (defined as median age of the study group above 16 years). Case reports, reviews, editorials, meeting abstracts and theses were excluded. Publications in a language other than English or German were also excluded.
Outcome
The main outcome of interest was overall mortality rate. The secondary outcome measure was time spent in the ER. Missed injury rates, complications and total length of hospital stay were also analyzed.

Search strategy
The MEDLINE, Embase Web of Science and Cochrane Library databases were searched for articles published between 1947 and November 2010 (cut-off date 1 November 2010). The search terms consisted of [(‘fbct’ or ‘tbct’ or ‘whole body ct’ or ‘total body ct’ or ‘full body ct’)] OR [(‘whole body’ or ‘full body’ or ‘total body’) AND [(‘ct’ and ‘scan*’ or ‘tomograph*’ or ‘ct scan’)]. These terms were combined with the following terms: [(‘trauma’ or ‘injur*’ or ‘shock*’ or ‘emergen*’)].

In addition, reference lists of each eligible article and reviews selected for abstract screening were scanned for additional references. The last search was performed in October 2010 and was conducted with the help of a clinical librarian.

Study selection
Two reviewers independently assessed titles or abstracts of all studies identified by the initial search and excluded irrelevant studies. The full text of potentially relevant studies was obtained. Then full-text articles were assessed to determine whether they met the inclusion criteria for this review. Any discrepancies in inclusion were resolved by discussion between the reviewers. If necessary, an independent third reviewer was consulted.

Data extraction and methodological quality
Two reviewers extracted the following data from each included paper on a data extraction sheet: publication year, sample size, language in which the paper was written, study design, patient characteristics, type of intervention and outcomes. Disagreements were resolved by discussion between the two reviewers; if no agreement could be reached, a third reviewer made the final decision. Furthermore, the corresponding author of an original study was contacted if the reported data were unclear or incomplete.

The methodological quality of the studies was described using the Newcastle–Ottawa Scale, designed for assessing the quality of non-randomized studies in meta-analyses. It scores potential sources of bias and variation in cohort studies regarding selection, comparability and outcome.23
**Statistical analysis**

Patient characteristics, mortality rates and time in the ER for each included study were summarized using descriptive statistics. For mortality, data were extracted to calculate the odds ratio and its standard error for each study. Random-effects meta-analysis of the logit-transformed proportion of mortality was done using the NLMIXED procedure (non-linear mixed model) (SAS® version 9.2; SAS Institute, Cary, North Carolina, USA).

**RESULTS**

**Search strategy and selection**

The computerized search resulted in 796 titles from the MEDLINE database, 396 titles from the EMBASE database, 382 from the Web of Science database and 11 titles from the Cochrane database. Following application of inclusion and exclusion criteria, eight full-text articles were reviewed (Figure 1). The cross-reference search added one additional paper, giving a total of 9 articles for full-text review.\(^6,13,15,20,24-28\) Five of these were found to be irrelevant to this systematic review (three made a comparison between single-pass TBCT and multi-detector TBCT; two had irrelevant outcomes).\(^6,13,15,20,24\) Therefore, the remaining four studies were included.\(^25-28\)

**Figure 1** Flow chart for the review.

Abbreviations: CT, computed tomography; MDCT, multidetector CT.
These studies all had a non-randomized cohort design with retrospective data collection. They reported on mortality as well as time in the ER, mortality and time to the operating room, mortality alone and time in the ER alone. Huber-Wagner and colleagues were contacted and provided additional information on time in the ER. Wurmb and co-investigators provided their raw data with mean ISS scores.

The included studies scored 6 or more (maximum 8) on the Newcastle-Ottawa scale. All studies achieved the maximum amount of points regarding the ‘selection’ category. Comparability of the cohorts was not always assured because three of the studies did not adjust for possible confounders in the analysis. Outcome was generally recorded well, although most of the studies made no comments regarding the follow-up time. Furthermore, all included studies lacked randomization, a power calculation, long-term mortality reports and quality-of-life data. None of the studies was excluded because of poor methodological quality. The level of evidence was 2b according to the Oxford Level of Evidence scale.

Data extraction
The four studies described a total of 5470 patients. One series, with a population of 4621, provided 84.5 percent of the total number of patients. The median sample size of the other three studies was 318. The study characteristics are summarized in Table 1. All reports provided data on the comparison between injured patients analyzed by immediate total-body CT and a control group that had conventional imaging supplemented with CT.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Country</th>
<th>Study design</th>
<th>Newcastle-Ottawa scale</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huber-Wagner</td>
<td>2009</td>
<td>Germany, Austria and Switzerland</td>
<td>Non-randomized cohort</td>
<td>7 of 8</td>
<td>4621</td>
</tr>
<tr>
<td>Weninger</td>
<td>2007</td>
<td>Austria</td>
<td>Non-randomized cohort</td>
<td>7 of 8</td>
<td>370</td>
</tr>
<tr>
<td>Wurmb</td>
<td>2009</td>
<td>Germany</td>
<td>Non-randomized cohort</td>
<td>6 of 8</td>
<td>161</td>
</tr>
<tr>
<td>Wurmb</td>
<td>2011</td>
<td>Germany</td>
<td>Non-randomized cohort</td>
<td>7 of 8</td>
<td>318</td>
</tr>
</tbody>
</table>

Total-body CT was performed with MDCT scanners, and comprised unenhanced imaging of the head followed by contrast-enhanced CT of the chest, abdomen and pelvis. The scanner was located in the ER in three studies, whereas information on its location was not available in one report. In three studies a 16-slice MDCT instrument was used; one multicenter study provided no information about the scanners. The scanning protocols for CT, when described,
varied regarding the slice thickness, which ranged from 0.75 to 5 mm for the head and neck, and from 1 to 5 mm for the torso. Detailed information on rotation time, table speed and delay after injection of contrast material was not described routinely. Variations were also seen in the workflow; some centers performed focussed assessment with sonography for trauma (FAST) in hemodynamically unstable patients to examine the abdomen for the presence of free fluid before starting total-body CT. Conventional evaluation strategies were not described routinely in each study, but in general consisted of plain X-ray of the chest, cervical spine and pelvis, a check of the abdomen by FAST and, finally, selective CT when necessary.
Table 2 Patient demographics

<table>
<thead>
<tr>
<th>Reference</th>
<th>N</th>
<th>Trauma mechanism</th>
<th>Mean age (years)</th>
<th>Median ISS (points)</th>
<th>P-value</th>
<th>Total-body CT</th>
<th>P-value</th>
<th>Conventional imaging</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huber-Wagner²⁵</td>
<td>4621</td>
<td>blunt</td>
<td>42.5</td>
<td>42.7</td>
<td>0.85</td>
<td>32.4*</td>
<td>&lt;0.001</td>
<td>28.4*</td>
<td></td>
</tr>
<tr>
<td>Weninger²⁶</td>
<td>370</td>
<td>blunt</td>
<td>43.5</td>
<td>40.7</td>
<td>ns</td>
<td>26.6*</td>
<td>ns</td>
<td>27.6*</td>
<td>ns</td>
</tr>
<tr>
<td>Wurmb²⁷</td>
<td>161</td>
<td>blunt</td>
<td>39</td>
<td>36</td>
<td>ns</td>
<td>24</td>
<td>ns</td>
<td>22</td>
<td>ns</td>
</tr>
<tr>
<td>Wurmb²⁸</td>
<td>318</td>
<td>blunt and penetrating</td>
<td>38</td>
<td>38</td>
<td>ns</td>
<td>27</td>
<td>0.001</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ISS, Injury Severity Score; NS, not significant. *Values are mean. Conventional imaging comprised conventional imaging strategies supplemented with selective computed tomography (CT).
Table 2 shows the demographics of the study groups. Three studies included only patients with blunt trauma\textsuperscript{25-27}, and one also included patients with penetrating trauma.\textsuperscript{28} The mean age varied from 36 to 44 years, and did not differ significantly between the total-body CT and control groups in any of the studies. In two studies, the Injury Severity Score (ISS) was comparable between the two groups\textsuperscript{26,27}, whereas in the other two series patients who received immediate total-body CT had a significantly higher ISS.\textsuperscript{25,28} One study included only patients who underwent emergency surgery immediately after trauma resuscitation and diagnosis in the trauma room.\textsuperscript{28}

Data on outcome are summarized in Table 3. Mortality was reported in three studies.\textsuperscript{25,26,28} Huber-Wagner and colleagues\textsuperscript{25} described an overall mortality rate of 20.5 percent among patients who had total-body CT versus 22.1 percent in the group evaluated with conventional imaging strategies (P = 0.21). Weninger et al.\textsuperscript{26} reported similar in-hospital mortality rates in the two groups (16.2 versus 16.8 percent), and Wurmb et al.\textsuperscript{28} found no significant difference in 30-day mortality rates (8.6 versus 9.0 percent). The absolute mortality rates varied widely between studies. Within studies, however, mortality rates were comparable between immediate total-body CT and conventional imaging strategies (pooled odds ratio 0.91, 95 percent confidence interval 0.79 to 1.05) (Figure 2). The result was the same when patients with an ISS of 0–15 in one study\textsuperscript{28} were excluded (pooled odds ratio 0.91, 0.78 to 1.05).\textsuperscript{25,26,28}

Table 3 Outcomes

<table>
<thead>
<tr>
<th>Reference</th>
<th>Median time in ER (min)</th>
<th>Overall mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total-body CT</td>
<td>Conventional imaging</td>
</tr>
<tr>
<td>Huber-Wagner\textsuperscript{25}</td>
<td>70* (tER)</td>
<td>78* (tER)</td>
</tr>
<tr>
<td>Weninger\textsuperscript{26}</td>
<td>70 (tER)</td>
<td>104 (tER)</td>
</tr>
<tr>
<td>Wurmb\textsuperscript{27}</td>
<td>47 (tER)</td>
<td>82 (tER)</td>
</tr>
<tr>
<td>Wurmb\textsuperscript{28}</td>
<td>105 (tOR)</td>
<td>120 (tOR)</td>
</tr>
</tbody>
</table>

Abbreviations: Total-body CT, total body computed tomography; Conventional imaging, conventional imaging strategies supplemented with selective CT; tER, time in the emergency room; tOR, time to the operating room; ISS, injury severity score; na, not available; ns, not significant. * mean, ‡ P-value not mentioned, † in-hospital mortality rate, • 30-day mortality rate

Time in the ER was registered in three studies.\textsuperscript{25-27} Huber-Wagner and colleagues (personal communication) reported no difference between the total-body CT and conventional imaging groups (70 versus 78 min respectively), whereas time in the ER was significantly shorter in the immediate total-body CT group in the studies by Weninger et al.\textsuperscript{26} (70 versus 104 min; P = 0.025) and Wurmb and co-workers\textsuperscript{27} (47 versus 82 min; P < 0.001). One study reported time
to the operating room, which was significantly shorter among patients who had total-body CT (105 versus 120 min; P < 0.050).28

None of the included studies described missed injury or complication rates. Total length of hospital stay was described in two studies. Huber-Wagner and colleagues31 reported a mean hospital stay of 28.2 days in the total-body CT group versus 25.0 days in the conventional group (P = 0.002), whereas Weninger and co-workers26 reported 29.0 and 32.5 days respectively (P = 0.046).

**Figure 2** Meta-analysis of overall mortality.

A random-effects model was used. Odds ratios are shown with 95 percent confidence intervals on a logarithmic scale. * No mortality data reported.

**DISCUSSION**

Mortality rates did not differ between patients who were evaluated with immediate total-body CT and those who had conventional imaging supplemented by selective CT. However, the studies differed markedly in their absolute mortality rates and the meta-analysis was dominated by one large study.25 Time in the ER, registered in three studies, was significantly shorter in patients who underwent immediate total-body CT in two studies and showed a non-significant difference in favor of this approach in the third report. Missed injury and complication rates were not described in the included studies. Although two studies described a significant difference in length of hospital stay between the groups, these results were inconclusive.

All reviewed studies had a retrospective non-randomized design. Because of their retrospective nature, they showed associations rather than causalities. Characteristics of included injured patients, especially ISS, determined prognosis and this could have caused selection bias. Wurmb and colleagues27,28, for example, included patients with an ISS of 0–15, which probably accounted for the lower mortality rates in their studies compared with the other series. However, reanalysis of the original data from Wurmb et al.27,28, after exclusion of patients with an ISS of 0–15, showed a mean ISS and trends in outcome variables comparable with those of the other studies (data not shown).
Differences in time in the ER between the two groups may have depended on factors other than the one under study. Selection bias among patients subjected to total-body CT and CT protocols (arm-raising before contrast-enhanced CT of the torso is time-consuming) may have affected the measured time intervals. The experience of the trauma team, imaging interpretation by the radiologist and different institutional levels may also have played a role. The indications for CT were well defined in most reports, but in one study the indications were chosen by each participating hospital and were not mentioned separately.25

Overall, the smaller number of cohort studies identified, the small sample sizes (with the exception of one study) and the many differences in study protocols and methods hampered interpretation of the results. Several studies reported data on time factors related to the use of immediate total-body CT, but fewer studies compared the effects of immediate total-body CT versus conventional imaging supplemented with selective CT. Even less is known about the effects on survival.

Injured patients are exposed to significant radiation doses during diagnostic imaging with total-body CT.21 The effective radiation dose is assumed to be 10–20 mSv for one examination.30 However, conventional imaging protocols supplemented with CT account for significant radiation doses as well31, and so the burden in terms of radiation dose of immediate total-body CT remains controversial.15;20;21

Although immediate total-body CT has proved to be highly accurate in detecting a range of significant injuries3;4;6-9;14;32, its effect on clinical outcome remains unclear. Some studies have suggested a trend towards lower mortality when immediate total-body CT is used. In the large study by Huber-Wagner and colleagues25 the patients in the total-body CT group had a significantly higher ISS than those in the control group. Despite this unfavorable prognostic characteristic, mortality rates were comparable with those among less severely injured patients who underwent conventional imaging. However, it is uncertain whether this was a consequence of use of the total-body scan. Furthermore, the same study reported a significant increase in probability of survival for patients who had immediate total-body CT compared with those who underwent non-total-body CT.25 Hilbert and co-workers18 described a decrease in mortality rate from 15 to 8.6 percent after introduction of a clinical algorithm using immediate total-body CT in the clinical care of seriously injured patients. Whether this was due to the scan or to the clinical care algorithm, and whether the study groups were comparable, remains unclear.

Larger and higher-quality studies are needed to further examine the potential role and value of immediate total-body CT in the primary trauma survey.33 Future studies should randomize patients with comparable prognosis to either immediate total-body CT in the trauma room or conventional imaging supplemented with selective CT. It is crucial to select patients who will benefit the most from immediate total-body CT. Outcomes of interest are (24-h or in-
hospital) mortality, several clinical relevant time intervals, missed injuries, complication rates, radiation exposure during the hospital stay and cost-effectiveness of the intervention in both cohorts. For the CT protocol, use of a MDCT scanner is mandatory and availability of multiplanar reconstructions is strongly recommended. The direct evaluation and structured reporting of images by the radiologist should be guaranteed. To equalize study protocols and increase the study population, a multicenter and international study design is preferable.

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