Total-body CT scanning in trauma patients: Benefits and boundaries
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Citation for published version (APA):
GENERAL INTRODUCTION AND OUTLINE OF THE THESIS
GENERAL INTRODUCTION

Trauma is the third cause of death across all age groups (after cardiovascular diseases and cancer), but it is the number one cause in North Americans aged between 1 and 44 years.¹ Every two minutes one European citizen dies of a traumatic injury.² Many others are disabled by accidents or violence. Since most trauma patients are in their working-age years, the economic burden is reflected not only by health care costs, but also in lost productivity. When initial trauma care can be improved, lives might be saved.

The origin of protocollized trauma work-up lies in the late seventies when James K. Styner, an orthopedic surgeon, crashed his plane into rural Nebraska.³ His wife was killed instantly. Three of his four children were severely injured and he was appalled by the abominable care they received in the local hospital. Various medical and nursing groups began to work together to provide a protocol for the management of severely injured patients. The American College of Surgeons modified the set of protocols into the first Advanced Trauma Life Support (ATLS) book, published in 1980.⁴ Currently, the ATLS® course is used worldwide to train doctors in the primary management of trauma victims, whether they are admitted to a rural hospital with limited resources or to an academic level-1 trauma center with a broad range of diagnostic and management possibilities.

In-hospital trauma evaluation

The ATLS® course is based upon the principle ‘treat first what kills first’.⁴ Protocollized clinical examination and diagnostic tests are performed and the trauma patient is managed by a multidisciplinary team of surgeons, anesthesiologists and radiologists. The primary survey consists of an ABCDE approach, an acronym for Airway, Breathing, Circulation, Disability and Exposure. When vital functions are normal or stabilized the secondary survey follows, which consists of a complete head to toe examination supplemented by radiological imaging and other adjuncts. The past decades, there has been a major shift in the trauma care setting. First, specialized care in designated trauma centers has improved trauma outcome.⁵,⁶ Secondly, clinically relevant time intervals are more often used as a quality indicator, although there is no scientific evidence to support the correlation between time intervals and quality of care.⁷-⁹ Lastly, the Computed Tomography (CT) scan has established its crucial role as a supplemental tool to conventional radiologic imaging or even as its replacement during trauma survey.

Conventional radiological imaging and selective CT scanning

Conventional radiological imaging of severely injured patients routinely consists of plain X-rays of the chest and pelvis. Ultrasound of the abdomen is done by Focussed Assessment of Sonography for Trauma (FAST), which is used as a rapid screening tool for the presence of intra-abdominal and intrapericardial fluid.¹⁰¹¹ Since 2009, the Eastern Association for the Surgery of Trauma
(EAST) in the United States, advocates CT scanning of the cervical spine as a replacement for cervical X-rays. The clinical decision to perform imaging of the cervical spine, is based upon the Nexus criteria or Canadian C-spine rules. Recently, the current standard of care for imaging of the thoracolumbar spine (TLS) is also redefined in an EAST guideline and CT scanning is recommended as the screening modality of choice. In general, TLS imaging is performed when there is a clinical suspicion for spine injuries or when there is a trauma mechanism prone to injuries of the thoracolumbar spine (e.g. axial trauma).

Plain X-rays are widely available, have a high specificity for the detection of fractures and are relatively inexpensive. Radiation doses of plain X-rays expressed in milliSievert (mSv) are negligible compared to CT (e.g. a posteroanterior chest X-ray is 0.02mSv and an adult chest CT is 5mSv). However, the sensitivity of plain X-rays for the detection of severe injuries is low. For example, chest X-ray has a sensitivity ranging from 10-45% for the detection of a pneumothorax and about 50% for the detection of rib fractures. The sensitivity of a pelvic X-ray for the detection of significant pelvic fractures varies between 50-70%.

In the past decades, CT scanning is increasingly used in the assessment of trauma patients. Primarily, selective CT scans of certain body regions were performed as a supplement to conventional imaging. CT scanners became faster, more detailed and more available in the trauma care setting. Since the introduction of the multidetector-row technology in the 1990s, CT scanning has been used more often as a replacement for conventional imaging. Image quality was further refined by investigating different patterns of intravenous contrast infusion. Furthermore, it was shown that image quality could be increased by repositioning the patient with his arms raised beside the head.

CT has a high sensitivity for the detection of injuries to most body regions. For example, CT images greatly improve the detection of thoracic injuries and in 20% will reveal more extensive injuries compared with abnormal plain radiographs, necessitating a change of management. CT scanning is also valuable for the diagnosis of abdominal injuries and proved to perfectly identify patients with active bleeding or bowel, mesenteric or pancreatic injuries.

It was shown that the location of the CT scanner in or near the trauma room, as opposed to at the Radiology Department, could also have a beneficial effect on outcome. A higher availability of the CT scanner in the trauma room facilitates its routine use. The Nijmegen trauma research group performed a study to compare routine CT scanning of the chest and abdomen with a selective CT algorithm in severely injured patients. It was shown that with a routinely performed CT scan of the chest, in almost 10 percent of the patients additional injuries were found that led to a change of treatment. For the routine CT scan of the abdomen this percentage was about 6 percent.
Despite its favorable characteristics, CT scanning is still associated with a high radiation dose\textsuperscript{42,43} and might affect health care costs.\textsuperscript{44}

**Total-body CT scanning**

A landmark article on the role of total-body CT (TBCT) scanning in trauma patients was published by Huber-Wagner and colleagues in 2009.\textsuperscript{45} This retrospective analysis of a subset of data (2002-2004) from the German Trauma Registry showed an increase in the probability of survival in patients who received a total-body CT scan (n=1494) compared to those who received no CT scan at all or a selective CT scan (n=3127). The authors conclude that “Total-body CT is recommended as a standard diagnostic method during the early resuscitation phase for patients with polytrauma.” The results may however be confounded by the so called ‘immortal time bias’.\textsuperscript{46} This means that patients that were included in the TBCT cohort, had to survive until the scan was completed. Subsequently, the patients who died before the scan was performed were assigned to the non-TBCT cohort, which might overestimate the number of fatal events in the non-TBCT cohort. Secondly, there were no differences in crude mortality rates found between the TBCT and control group, but CT scanning was associated with a favorable difference between expected and observed deaths. Given the fact that TBCT scanning detects more injuries than a standard imaging strategy, the subsequently increased Injury Severity Score (ISS) and Trauma-ISS (TRISS)\textsuperscript{47} might have artificially increased the survival rate of patients with an apparently poorer probability of survival\textsuperscript{48}.

Several retrospective and prospective studies followed this landmark study, all together assessed in six systematic reviews.\textsuperscript{49-54} In summary, all reviews agreed on a time benefit in favor of TBCT scanning, but no consensus was obtained regarding a possible survival benefit. All systematic reviews concluded their manuscript with saying that solid scientific evidence is needed. Despite the lack of proper scientific evidence, there are more and more trauma centers that use a TBCT scan during trauma survey, either as a supplement to or as a replacement for conventional imaging.\textsuperscript{31,55-57}

With the increased use of CT scanning, incidental (trauma-unrelated) findings are also detected more often. Incidence numbers are found to be around 50\% for either selective or TBCT scanning.\textsuperscript{58-61} In previous studies, indications for a TBCT scan were not clearly described and the clinical consequences of the incidental findings are unclear.\textsuperscript{60,61} Incidental findings might result in increased patients’ anxiety and health care costs in case of additional work-up for abnormalities that ultimately might not affect patients’ health. Therefore, it is useful to know the clinical consequences of the incidental findings in a well-defined study population.

Lastly, several studies have compared radiation doses between pre- and post-total-body CT scan protocol cohorts.\textsuperscript{23,42,43} However, in all these studies the number of polytrauma patients (Injury Severity Score ≥16) was relatively low, while this is the population we are most interested in with regard to radiation dose.\textsuperscript{23,43,62}
OUTLINE OF THE THESIS

The aim of this thesis was to clarify the role of immediate TBCT scanning in severely injured patients, considering its benefits and boundaries. Therefore, this thesis is divided into 8 chapters.

Chapter 1 provides a systematic review of the literature regarding TBCT scanning in trauma patients. Clinical relevant time intervals were assessed, but moreover patient outcome in terms of mortality was described. If time intervals are used to determine quality of care, it is relevant to know how reliable those intervals can be measured.

Chapter 2 contains a study on the topic of clinically relevant time intervals in trauma care in a convenience sample of 100 patients. Subsequently we were interested in which TBCT scanning protocol would suit best for the detection of injuries in trauma patients.

In Chapter 3 we describe a prospective pilot study in which three different TBCT scanning protocols are compared with regard to optimal image quality. Three radiologists independently evaluated protocol quality scores, parenchymal and vascular enhancement and artifacts.

In Chapter 4 a historical cohort of patients who underwent immediate TBCT scanning, without previous conventional imaging, was case-matched with patients who underwent conventional imaging supplemented by selective CT scanning. Groups were compared with regard to thirty-day mortality.

Chapter 5 shows an overview of incidental (eg. trauma-unrelated) findings accompanied by TBCT scanning.

Chapter 6 examines the amount of radiation exposure that polytrauma patients (i.e. ISS≥16) were exposed to before and after the introduction of a dedicated total-body CT scan protocol.

Chapter 7 comprises the study protocol of the Randomized clinical trial of Early Assessment with CT scanning in trauma patients (REACT-2) study. The REACT-2 trial is the first randomized clinical trial on this topic worldwide. Trauma patients are randomized to either conventional imaging with X-rays and FAST, supplemented by a selective CT scan, or to an immediate TBCT scan. In this chapter background, eligible patients and (statistical) methods are described extensively.

Lastly, in Chapter 8 the results of the REACT-2 study are presented. Results regarding the primary outcome measure (in-hospital mortality) are described as well as the most relevant secondary outcome measures (clinically relevant time intervals, radiation dose and cost-utility analysis).
REFERENCES


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