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Clinical Study

Early and Rapid Diagnosis with Multislice CT Reduces Lethality in Trauma Patients Requiring Intensive Care: Findings of a Prospective Study

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Objective. The objective of this study was to investigate if short diagnostic times by MSCT have an influence on lethal outcomes. *Methods*. In three different patient populations, hospital mortality was examined. Group 1: retrospective data derived from conventional diagnostic methods in the trauma room between 2002 and 2003; group 2: data from the same centre taken prospectively between 2004 and 2010 after modification of the trauma room algorithm; group 3: a reference population from the TraumaRegister DGU (TR-DGU) from 2004 to 2010. Injury severity was determined using the ISS and lethality was predicted on the basis of the RISC. *Results*. At the singular centre, data from 943 polytraumatised patients requiring intensive care between 2002 and 2010 were examined. With the new trauma room algorithm, lethality was likewise significantly lower (9.1% versus 15%; $P < 0.05$) compared to the population from 2002 to 2003, with a comparable ISS (28.5 versus 30.2). The ISS (28.5) was comparable with the TR-DGU (24.9) population and lethality was significantly lower. *Conclusion*. Early diagnostic approaches using MSCT during the first minutes of trauma room treatment, as an integral part of a stringently timed, highly structured concept, have been found to reduce lethality as compared to the TR-DGU and our own retrospective historical data. This trial is registered with DRKS00005055; TR-DGU-Projekt-ID: 2009-005.

1. Introduction

Recent studies have demonstrated that the majority of deaths occurring in patients within 24 hours after suffering critical injuries can be attributed to bleeding and traumatic brain injury (TBI) [1]. Bleeding is the most common cause of death during the first three hours; for example, severe TBI is the leading cause in the subsequent hours [2]. In order to counter such causes of death therapeutically, a rapid diagnostic approach is essential. A current study in USA has revealed that at a level 1 trauma centre, critical injuries were overlooked in 21% and less critical injuries in 33% of the patients who had died [3]. This underlines the importance of undertaking thorough diagnostic imaging procedures as quickly as possible. Moving on from previous bimodal concepts that employed projection radiography and computed tomography, we have developed a treatment concept that involves only early multislice whole-body CT in the trauma room. The combination of multidetector row CT and table feed offered by modern CT equipment on the one hand permits excellent z-axis resolution with slices of 1 mm thick and on the other hand allows scans of up to 1.80 m in length to be performed. In light of this, it is possible to perform full scans from the parietal regions to the symphysis pubis within a maximum of 90 seconds, as well as taking additional images of the lower extremities.

The fact that early and systematic deployment of CT in the trauma room can clearly shorten the times spent in the trauma room was demonstrated in our earlier study [4]. Other studies have also demonstrated the beneficial effect of digital radiodiagnostic methods [5], especially CT [6–8], with a view to reducing trauma room times. Recent data from the TraumaRegister DGU of the German Trauma Society (DGU) have identified whole-body CT as an independent predictor for improved outcomes [9]. Having established a clear time reduction with the help of CT, our aim was to investigate whether initial diagnostic assessments using whole-body CT—by securing the vital functions prior to taking any further action—elicit a reduction in lethality.

2. Patients and Methods

2.1. Patients. Three patient groups were studied as part of this project. Groups 1 and 2 entailed trauma patients of any age admitted to our trauma centre between 2002 and 2010 as primary and secondary cases requiring intensive care for at least 24 hours following admission. Patients arriving at the hospital after reanimation, or those dying in the trauma room or operating room, were also included in the study. Only those patients who had an Injury Severity Score (ISS) of at least 16 points were considered. These patients were divided into two groups: (1) those between 2002 and 2003 undergoing conventional trauma room radiography, and (2) those between 2004 and 2010 after a modified trauma room algorithm had been introduced. The data for the first group were derived retrospectively from the patient files, and those for the second group were recorded prospectively.

For comparison, the same inclusion criteria were applied to a third group of patients who had been treated between 2004–2010 at other German national trauma centres and were documented in the TraumaRegister DGU (TR-DGU) of the German Trauma Society (DGU).

2.2. Methods. By integrating multislice CT (MSCT) equipment into the trauma room of our hospital and by developing a CT-orientated trauma room algorithm at the end of 2003, the treatment processes in the trauma room were fundamentally transformed. Even before performing time-consuming, stabilising measures, diagnostic CT procedures are undertaken after screening for life-threatening A, B, and C problems, by applying the algorithm described in Figure 1, whilst continuing the therapy initiated beforehand by the emergency doctor.

The following procedure was followed as defined by the new algorithm; wherever possible, the following should be done prior to the patient's arrival (phase *ZERO*): trauma team alerted, CT as well as trauma room equipment prepared (e.g., radiocontrast pump, level one rapid transfusion system), and, if not yet available, surgical resources organised.

During phase *ONE*, the patient is admitted to the emergency suite by the anaesthetic team and trauma surgeon, as the trauma team leader. The overall status of the patient is assessed on the basis of the available information concerning the nature of the trauma, injuries suspected by the emergency doctor, the vital parameters recorded at the trauma site, and an initial clinical examination. In the trauma room, the trauma surgeon checks the patient's body without removing any of the clothing. The patient is then placed on the transfer board, which is situated on the CT table. The patient is positioned feet first, with his arms by his sides. Any further repositioning of the patient ensues on the transfer board until surgery takes place or intensive care is initiated. The trauma surgeon will decide, on the basis of the information obtained and an initial, brief clinical examination, whether a CT scan as far as the symphysis pubis will suffice or whether a full CT of the whole body, from skull to soles of the feet, will be necessary. The procedures undertaken in the trauma room are consistent with the Advanced Trauma Life Support (ATLS) programme, whereby the anaesthetist is responsible for points A (airway), B (breathing), and C (circulation), whilst the trauma surgeon concentrates on D (disability) and E (exposure/environment). Obvious problems with A, B, or C, such as tense pneumothorax, respiratory insufficiency, or immediately controllable external bleeding, can be treated straight away and further stabilising measures are initially waived.

During the subsequent phase *TWO*, radiocontrast CT is performed using a maximum time-optimised CT protocol to guarantee extremely short examination times. This paper will not go into more detail concerning the specifics of the protocol, however.

Subsequent to diagnostic imaging, phase *THREE* entails further measures such as stabilisation of the patient, insertion of invasive access ports, and laboratory tests including preparation of blood products, Whilst the patient is being stabilised and receiving anaesthesiological support, the trauma surgeon, radiologist, and further specialists (e.g., neurosurgery and visceral surgery) will assess the injury pattern on the basis of the clinical information obtained and perform an initial physical examination and CT scans. Further treatment plans are devised and initiated.

By phase *FOUR*, trauma room treatment is complete and the patient is transferred to the operating room if there is an urgent need for surgery or, if this is not necessary, to the intensive care unit for continuation of treatment.

Treatment is administered on the basis of the given algorithm in the following situations: patients having suffered high-speed trauma, those found unconscious at the trauma site, those arriving at the hospital after being intubated and ventilated by the emergency doctor, and those whose initial clinical examination suggests critical injuries with a suspected ISS $\geq$ 16. Since the hospital has three potential trauma rooms (two with integrated CT, namely, one 32 and one 16-detector row scanner, and one conventional TR), patients not fulfilling the aforementioned criteria are treated in accordance with the conventional Nast-Kolb structured concept [10, 11]. Patients arriving with an incomplete initial diagnosis or findings indicative of dynamics likewise undergo whole-body CT.

The described practice has been in use since 2004.

2.3. Data Analysis. The following data were analysed during this study: patient's age, sex, injury severity based on

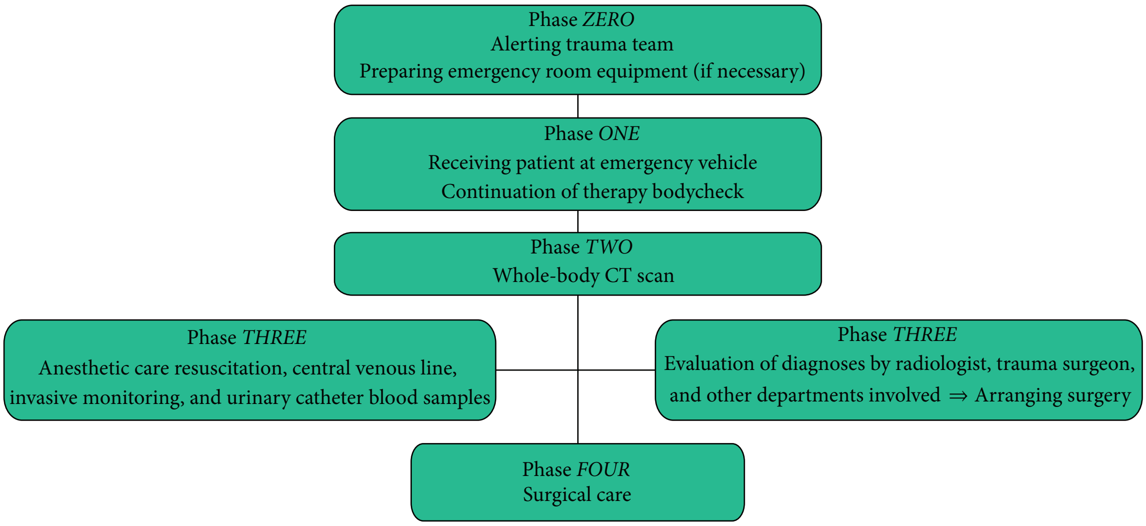

Figure 1: Trauma room algorithm at Bergmannstrost Trauma Centre [4].

the Injury Severity Score (ISS) and observed lethality (hospital death), and early lethality in the first 24 hours after trauma. Furthermore, the lethality prognosis was determined using the Revised Injury Severity Classification (RISC) [12]. Direct comparison of mortality rates would be misleading, due to varying injury severity, and so mortality rates were standardized according to patients' prognoses. This was done by dividing the actual mortality rate (as a percentage) by the expected mortality rate (prognosis as a percentage) to give the standardized mortality rate (SMR). To permit comparison of the timings and processes, the preclinical treatment period and trauma room time were included in the analysis.

As a first approach, the data obtained from the patient population between 2002 and 2003 who had been treated in line with the trauma room algorithm of Nast-Kolb et al. [10] were compared against the data from the years 2004 to 2010 in which the MSCT-based algorithm had been used. As a second step, data from patients directly admitted from the trauma scene to our hospital from 2004 onwards were compared against those patients directly admitted from the trauma scene to a level one trauma centre from the TR-DGU.

Statistical comparisons of the frequencies and percentages were conducted using the chi-squared test, and due to the normal distribution of the groups measurements, they were compared using the Student's t-test. The level of significance was taken as $P < 0.05$. The analysis was performed using the statistical programme SPSS version 18.0 (IBM, Armonk, NY, USA). The study was registered in the German Clinical Trails Register with the trail registration number DRKS00005055 and in the TraumaRegister DGU with the project ID 2009-005.

3. Results

During the entire study period, data were recorded from 943 patients at our centre, amongst whom male patients clearly predominated at 76% (n = 719). The mean age of the patients was 43 years.

Table 1: General data of the two trauma cohorts from Bergmannstrost Hospital.

	Bergmannstrost	
	2002-2003	2004–2010
Patient number	266	677
Age	41.9	43.3
Male	74.4%	77%
ISS	30.2	28.5

Table 2: Comparison of mean times (trauma room/preclinical) of the two trauma cohorts at Bergmannstrost Hospital.

	Bergmannstrost	
	2002-2003	2004–2010
Preclinical time in min.	82	81
Ø ER time in min.	87*	40
ER time for emergency op.	41*	20
ER time for early op.	87*	39
ER time for ICU transfer	90*	41

ER: trauma room; *significant differences ($P < 0.05$).

3.1. Former Trauma Room Management (2002 to 2003). Between 2002 and 2003, 266 trauma patients received intensive care, 31.6% of whom had been referred from other hospitals. The mean age of the patients was 41.9 (SD 19.3) years, and the mean ISS was 30.2 (SD 14.8) points. 74.4% (n = 198) of the patients were males, and 25.6% (n = 68) were females (Table 1).

Preclinical treatment lasted a mean of 82 minutes and the trauma room time 87 minutes (Table 2).

Of the 266 patients, 40 died (15.0%), early lethality amounted to 5.2% (n = 14), and the RISC-predicted lethality

Table 3: Prognosis and lethality compared between the two trauma cohorts from Bergmannstrost Hospital including transferred patients.

	Bergmannstrost	
	2002-2003	2004–2010
Lethality	15%*	9.1%
Early lethality	5.2%*	3.7%
RISC prognosis	17.2%	19%
SMR	0.87	0.48

*$P < 0.05$.

was 17.2% (Table 3), resulting in a standardized mortality ratio (SMR) of 0.87.

3.2. Prospective Documentation. During the observation period of 2004 to 2010, 677 critically injured patients requiring intensive care received treatment, 38% ($n = 261$) of whom had been referred from other hospitals. Of these patients, 77% ($n = 521$) were males, and the mean age was 43.3 (SD 19.9) years. The mean injury severity of the patients in line with the ISS was 28.5 (SD 15.9) (Table 1).

Preclinical treatment lasted a mean of 81 minutes and the trauma room time 40 minutes (Table 2).

Of the 677 patients, 62 died, corresponding to a lethality of 9.1%. Early lethality amounted to 3.7% ($n = 25$). Lethality in this population was predicted as 19% (SD 27.1) by the RISC, resulting in an SMR of 0.48. Table 3 shows the results of the two trauma cohorts from 2002 to 2003 and from 2004 to 2010 with regard to lethality and RISC prognosis.

3.3. Bergmannstrost Hospital versus Traumaregister DGU Level 1 Trauma Centres. The results from trauma patients admitted directly from the trauma scene to our hospital between 2004 and 2010 were compared with those patients admitted directly from the trauma scene to level one trauma centres of the TR-DGU.

Of the 677 critically injured patients requiring intensive care, 416 were admitted directly from the trauma scene. Of the 416 patients, 46 (including 8 patients admitted under ongoing CPR) died. The RISC was 19.4% and lethality 11% ($n = 46$), resulting in an SMR of 0.57 (Table 4).

The comparison group ($n = 17.533$) of the TR-DGU (level one trauma centres, admitted directly from the trauma scene, ISS ≥ 16) had the following characteristics: mean age 41.9 years, 72.3% male, mean ISS 29.2, lethality 20%, RISC prognosis 22.4%, and SMR 0.89.

Table 5 lists the injury pattern of the patients treated between 2004 and 2010 compared to the TR-DGU, whereby only the relevant injuries are stated with an Abbreviated Injury Scale (AIS) severity of ≥3. It is evident that the pattern of injuries is very similar.

4. Discussion

In 1983, Trunkey [13] introduced the trimodal distribution concept of trauma deaths'; more recent works question such trimodal distribution [1, 14]. Irrespective of this, roughly 50% of trauma patients die during the first hour after trauma, a factor that underlines the “golden hour” concept developed by Cowley [15] in the 1970s. This concept claims that it can be vital to a patient's survival to stabilise the circulation and to counteract a shock within the first hour after severe trauma [15]. Most trauma patients die during the first hour from bleeding or severe TBI [1]. Trauma centres can demonstrate their greatest potential here, namely, saving patients from imminent death. According to the TraumaRegister DGU Annual Report of 2011, the average trauma patient in Germany only reaches the hospital after 72 minutes, meaning that the golden hour has already been greatly exceeded [16]. Hence, in addition to reducing the prehospital period and rapidly transferring the patient to a suitable trauma centre, it is important to keep an eye on the deaths occurring in the subsequent hours.

Table 4: Prognosis and lethality compared between Bergmannstrost Hospital versus TraumaRegister DGU group (Only patients admitted directly from trauma scene).

	Bergmannstrost 2004–2010	TR-DGU 2004–2010
Lethality	11%*	19.6%
Early lethality	3.7%*	9%
RISC prognosis	19.4%	22.4%
SMR	0.57	0.89

*$P < 0.05$.

Table 5: Patterns of injuries at Bergmannstrost Hospital (only patients admitted directly from trauma scene) versus TraumaRegister DGU group (level 1 centres, admitted directly from trauma scene).

Localisation of injury	Bergmannstrost 2004–2010	TR-DGU 2004–2010
Head	58.9%	59.3%
Chest	60.4%	57.0%
Abdomen	23.2%	19.7%
Extremities	40.2%	35.5%*

*$P < 0.05$.

To treat the two causes of death that are the most common in the first 24 hours (bleeding and TBI), expedited diagnostic evaluation is essential. External bleeding can of course be diagnosed at first sight and is usually easily treated with appropriate compression. Internal bleeding or the treatable consequences of severe TBI (e.g., EDH, SDH, etc.) are not usually detectable at first sight and therefore require rapid diagnostic imaging and, as a consequence, appropriate therapy for circumventing any potential lethal outcome. MSCT combined with intravenous contrast agent is an excellent method, also for identifying smaller venous, arterial haemorrhages or bleeding of the parenchymal organs. Corresponding studies have revealed, for instance, that 64-detector row MSCT is in fact superior to digital subtraction angiography (DSA) in identifying bleeding in bodily cavities [17, 18]. A 16-detector row CT has been shown to diagnose bleeding in trauma patients with an equal degree of certainty as the previous criterion standard, namely, DSA [19]. For many years, CT has been the established imaging method for TBI.

A current study in USA has revealed that at a level 1 trauma centre with conventional ER diagnostic equipment, critical injuries were overlooked in 21% and less critical injuries in 33% of the patients who had died [3]. This underlines the importance of rapid and thorough diagnostic procedures that need to be undertaken during the very first minutes of a patient's presence in the trauma room. This can only succeed if the MSCT is located in the trauma room and is deployed as a diagnostic method prior to performing time-consuming, stabilising measures. In the opinion of the authors, a thorough diagnostic investigation of the critically injured patient prior to performing elaborate stabilising measures should be an integral component of a stringent, structured trauma room concept managed by an experienced team. This is perfectly justifiable in light of the now short examination times promised by MSCT. It is not MSCT alone, but its integration into a smoothly functioning trauma management system and appropriate intensive care expertise that are the key to successful trauma care.

The fact that the time spent on diagnostic and trauma room procedures can be curtailed by the early deployment of MSCT has now been demonstrated by a number of studies [4, 7, 8]. The use of whole-body CT is also an independent predictor for improved outcomes, as was demonstrated for the first time by Huber-Wagner et al. [9] in a retrospective study using TR-DGU data. The presented data reveal a correlation, namely, that the systematic and early use of MSCT as part of a structured, efficient trauma room concept decreased the lethality in a historic reference population as well as when compared to the TR-DGU. Hutter et al. obtained similar findings [20], having likewise established a reduction in lethality.

It must be noted that the information in the TR-DGU has not been adjusted to account for the equipment used at each of the contributing hospitals. The data summarised in the TR-DGU have been collated using diverse systems and submitted by centres providing different levels of care (local, regional, and national trauma centres). Hence, a comparison with the TR-DGU must prove positive, as does the comparison for the majority of the hospitals taking part. To circumvent such an issue, we extracted data only from patients in the TR-DGU on primary care (ISS > 16) who received treatment at a national level 1 trauma centre. By the way, it must be mentioned that some of the level 1 trauma centres use a similar approach [21] and this may cause some bias. Moreover, almost 68% of the TR-DGU patients from the year 2010 had undergone whole-body CT. Nonetheless, the results that we obtained were significantly better than those in the TR, suggesting indirectly that the described procedure can be viewed as effective. Irrespective of this, the SMR (the value indicating the ratio of predicted/anticipated lethality to lethality actually observed) achieved in the studied patient population can be used to demonstrate that the described procedure is effective. Hence, the mean SMR of the top 10 trauma centres of the TR-DGU between 2004 and 2007, when applying the RISC as a prognostic score, was 0.58 [22]. This confirms our own findings.

There is no certain explanation for the reduction in lethality achieved by the concept we have proposed when considering the diagnoses available early on; yet some conclusions can be drawn from the clear reduction in early lethality as compared to the TR-DGU. If examining the TR-DGU data related to the time elapsing between arrival of the patient and discontinuing diagnostic procedures in the trauma room due to the need for an emergency intervention, then the period amounts to 40 minutes [16]. This is a time range within which the patients at our hospital have completed the diagnostic process and left the trauma room fitted with all the requisite invasive ports for transferral to (early) surgery or intensive care. It is here where we believe our proposed concept is of tremendous benefit. Care is provided to patients whose injuries and issues have been identified. When considering the time factor alone, the trauma room algorithm that we prefer means that patients are already on their way to early surgery or intensive care at the point which in the TR-DGU corresponds to "end of the trauma room phase." Using our concept, the diagnostic imaging procedures are always available in the trauma room in less than 15 minutes after admission, with the advantage that targeted treatment can be introduced early on.

One point repeatedly raised by critics of whole-body CT is the level of radiation to which the patient is exposed. It has been demonstrated that the use of whole-body CT, compared to conventional diagnostic methods (X-ray, ultrasound, and organ-specific CT scans), at best entails no increase in exposure, and at worst a threefold higher exposure to radiation [23]. Multislice CT is occasionally referred to as a "dose trap" [24], though this should be refuted. Multislice systems offer a diverse range of techniques for dose reduction. Moreover, the quantum efficiency of today's solid-state detectors is up to 60% more effective than earlier machines. A national multislice CT survey in Germany revealed that on introducing the multislice CT technique, there was no increase in the collective radiation exposure level [25]. In clinical terms, it can be confirmed that when treating critically injured patients, saving their lives is paramount. The statistical risk of dying from radiation-induced cancer following exposure to a certain level of radiation is a secondary consideration.

Nevertheless, every effort must be made to minimise the radiation exposure from MSCT as defined by the ALARA principle (as low as reasonably achievable). Useful ways of reducing the dose of radiation are as follows: using the linear laser to centrally position the patient in the gantry and protecting the testicles of young boys [26]; elevating the arms may also be useful [27].

4.1. Limitations. This study is naturally limited by certain factors. It was a single-centre study, the results of which cannot simply be applied to other centres. The comparison entailed a historical population from our own hospital and it cannot be ruled out that, in addition to the modified and curtailed trauma room procedure, there may be further factors that could have had a positive impact on the reduction in lethality. In general, the approach—whether surgical (damage control) or intensive care—was not modified; yet since 2005, an alternative solution for infusion has been in use: Ringer's lactate solution used to date has been replaced by Ringer's acetate solution. It is not certain whether this may have contributed to the reduction in lethality.

The comparison against the figures of the TR-DGU also reveals certain weaknesses, since the patient population that we examined included only those patients requiring intensive care or patients who died in the trauma room or operating room. It is also impossible to rule out that other intensive care strategies affect a decrease in lethality compared to the TR-DGU. Potential lethality-related differences in the intensive care procedures would most likely become apparent in terms of lethality after 24 hours or more. With a mortality of approximately 7.4%, the values are almost identical to those of the TR-DGU. Hence, the lower rate of lethality overall in the studied population is mainly attributable to a drop in early lethality.

In addition to hospitals providing maximum or specialised care, those delivering basic and standard care also contribute to the TraumaRegister DGU. The fact that there is a difference in trauma lethality between the individual care levels has been demonstrated by various studies [22, 28, 29]. As mentioned above, therefore, the lethality in the TraumaRegister can possibly be expected to be higher. Whole-body CT is also finding increasing use in the patients of the TR, though at different times. In the period in question, almost 60% of critically injured patients in the TR underwent whole-body CT [16].

In spite of the listed limitations and a very conservative interpretation of the presented findings, the authors have yet to identify a prospective study that has demonstrated a decrease in lethality when undertaking thorough diagnostic imaging with MSCT as early as possible as part of a structured and efficient trauma room management programme, prior to carrying out any time-consuming, invasive procedures.

5. Conclusion

Early, rapid, and extensive, whole-body MSCT diagnosis after screening for life-threatening A, B, and C problems as part of the procedures described herein has been found to correlate with reduced lethality as compared with a historical population at our hospital and with the TR-DGU. The early use of MSCT, namely, in the first few minutes of trauma room treatment, appears to be wise in light of such information. It would permit full advantage to be taken of such rapid diagnostic methods. Further studies are needed in order to confirm the positive results on a multicentre scale.

Conflict of Interests

The authors declare no conflict of interests.

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