Structural and Process Data on Radiological Imaging in the Treatment of Severely Injured Patients – Results of a Survey of Level I and II Trauma Centers in Germany

Struktur- und Prozessdaten zur radiologischen Bildgebung bei Behandlung schwerstverletzter Patienten – Ergebnisse einer Befragung überregionaler und regionaler TraumaZentren in Deutschland

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ABSTRACT

Purpose Systematic data collection regarding the integration of radiology as well as structural and process characteristics of radiological diagnostics of severely injured patients in Germany using a structured questionnaire.

Materials and Methods Personal contact with all certified Level I and Level II Trauma Centers in Germany. Data on infrastructure, composition of the trauma room team, equipment, and data on the organization/performance of primary major trauma diagnostics were collected.

Results With a participation rate of 46.9 % (n = 151) of all German trauma centers (N = 322), a solid database is available. There were highly significant differences in the structural characteristics incl. CT equipment between the level I and II centers: In 63.8 % of the level II centers, the CT unit was located more than 50 m away from the trauma room (34.2 % in the level I centers). A radiologist was part of the trauma room team in 59.5 % of level II centers (level I 88.1 %). Additionally, highly significant differences were found comparing 24-h provision of other radiologic examinations and interven-

tions, such as MRI (level II 44.9 %, level I 92.8 %) and angiography (level II 69.2 %, level I 97.1 %).

Conclusion Heterogeneous structural and process characteristics of the diagnosis of severely injured patients in Germany were revealed, with highly significant differences between level I and level II centers.

Key Points:

- This is the first study on the diagnostic reality of radiology in severely injured patients in Germany. Despite a high level of standardization, significant differences were observed.

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ZUSAMMENFASSUNG

Ziel Systematische Datenerhebung der Integration der Radiologie sowie von Struktur- und Prozessmerkmalen der primären Diagnostik von schwerstverletzten Patienten in Deutschland.

Material und Methoden Persönliche Kontaktaufnahme mit allen zertifizierten überregionalen (ÜTZ) und regionalen TraumaZentren (RTZ) in Deutschland. Daten zur Infrastruktur, Zusammensetzung des Schockraumteams, Gerätedaten der CT-Scanner und Daten zur Organisation/Durchführung der primären Schwerstverletztendiagnostik wurden mit strukturiertem Fragebogen erfasst.

Ergebnisse Bei einer Teilnehmerquote von 46,9 % (n = 151) aller deutschen TraumaZentren (N = 322) liegt eine solide Datenbasis vor. Bei den Strukturmerkmalen incl. CT-Ausstattung gab es zwischen ÜTZ und RTZ teilweise hochsignifikante Unterschiede: Bei RTZ lag das CT-Gerät in 63,8 % über 50 m vom Schockraum entfernt (ÜTZ 34,2 %). Bei traumatologischen Schockraumaktivierungen war ein Radiologe in 59,5 % der RTZ anwesend (ÜTZ 88,1 %). Ebenfalls hochsignifikant waren die Ergebnisse beim Vergleich der 24-h-Vorhaltung weiterer radiologischer Untersuchungen und Interventionen wie etwa Magnetresonanztomografie (RTZ 44,9 %, ÜTZ 92,8 %) und Angiografie (RTZ 69,2 %, ÜTZ 97,1 %).

Schlussfolgerung Es zeigten sich heterogene Struktur- und Prozessmerkmale der Diagnostik schwerstverletzter Patienten in Deutschland mit hochsignifikanten Unterschieden zwischen ÜTZ und RZT.

Introduction

In spite of significant advancements regarding prevention, diagnosis, and treatment, polytrauma continues to be associated with a high mortality rate. The WHO refers to a “Global Burden of Disease” [1]. In Germany, severe injury has been the main cause of death in people under the age of 40 in spite of a steady decrease in the number of traffic accident deaths [2, 3]. The creation of the TraumaRegisters DGU (Trauma Registry of the German Trauma Society) in 1993, the publication of the first White Book on Medical Care of the Severely Injured in 2006, and the publication of the first S3 Guideline on the Treatment of Polytrauma/Severe Injuries in 2011 were milestones in the improvement of the care of severely injured patients in Germany [4–7]. The certification of trauma centers as level I, level II, and level III centers and the creation of TraumaNetzwerken DGU (Trauma Networks of the German Trauma Society) resulted in lasting improvement of the quality of care [8]. Level I trauma centers represent the highest level of trauma care in Germany. Level II trauma centers represent the second highest level of care. The first and second versions of the White Book on Medical Care of the Severely Injured recommend primary admission at either a level I or level II trauma center. If this cannot be performed in a timely manner, admitting patients to a level III trauma center, which is usually a standard care facility, must be considered [4, 9].

Since the introduction of the first multidetector CT scanners in the clinical routine, traumatologists in Germany have increasingly used whole-body CT as the basis for determining treatment for severely injured patients [10]. In 2019, the cases of almost 30 000 severely injured patients were documented in the TraumaRegister DGU, with approximately 80 % of those patients having undergone whole-body CT in the trauma room phase [6].

According to the current literature, both hemodynamically stable as well as unstable severely injured patients benefit from whole-body CT and have a significantly better survival rate [11, 12]. Therefore, in Germany, whole-body CT can be considered the gold standard in emergency diagnostics in the case of severely injured patients [13]. There seems to be significant heterogeneity regarding infrastructure, the organizational and logistical integration of radiology for the diagnosis and treatment of polytrauma, and radiological examination options beyond CT in German hospitals.

To analyze the actual availability of methods and the workflow of radiology in the primary care of severely injured patients at German hospitals, we conducted a comprehensive nationwide survey of participating hospitals. We evaluated the content and logistics of radiological examinations of severely injured patients at hospitals in Germany.

The goal of the study was to examine the integration of radiology in the care of severely injured patients. The performance of ultrasound examinations, CT, MRI, and angiography examinations and interventions was evaluated based on the results of the survey. In addition, the actual status of the available CT equipment was analyzed. Finally, we determined how the evaluated hospitals typically handle radiology reporting and workflow as part of trauma room management.

Since all examined hospitals are part of the trauma network initiative of the German Trauma Society, homogeneous structure and

process characteristics were to be expected. The goal of this study was to test this hypothesis and identify any relevant deviations.

Materials and Methods

The ethics committee approved the present survey (University Hospital Regensburg, no. 17–668–101).

In interdisciplinary consensus, the members of the German Trauma Society and the German Radiological Society created a survey to gather comprehensive information with direct and indirect connection to whole-body CT. The survey (complete survey provided as supplement) included 142 items from the following categories:

- Contact data and level of the trauma center (4 items)
- CT equipment data, infrastructure, trauma room management (23 items)
- Protocol design, patient positioning, scan settings, contrast agent (72 items)
- Image reconstruction (27 items)
- Reporting, follow-up, further diagnostic and treatment options (16 items)

Data was collected between 7/1/2017 and 12/31/2017. All certified level I (n = 110) and level II (n = 212) trauma centers in Germany were identified (TraumaNetzwerk DGU, www.traumanetzwerk-dgu.de). Due to the requirements of the White Book on Medical Care of the Severely Injured and the preclinical selection of target hospitals, the number of severely injured patients admitted on a primary basis to level III trauma centers is low (on average 11 per hospital per year). According to the TraumaRegister annual report, 2647 (6.6 %) severely injured patients (ISS ≥ 16) received primary treatment at a level III trauma center, while 37 516 (93.4 %) were treated at level II and III trauma centers in 2020. Therefore, this study focuses on examinations performed at level I and II trauma centers.

The personalized study design allowed every participating hospital to respond to only one survey: The responsible chief radiologist of each identified hospital was first contacted personally via e-mail or telephone. During initial contact, permission to collect data was obtained and personal contact to employees was established for the further detailed processing of the survey. The employees appointed by the chief of radiology then answered the survey with additional telephone support provided by the principal investigator as needed.

The results of the paper and pencil surveys were transferred by the study center to IBM SPSS Statistics for Windows 23 (IBM Corp., Armonk, N.Y., USA) for further evaluation. Missing data were not taken into consideration in the percentages but were displayed as "missing data" in the tables. Free text entries were grouped.

The frequency over all participating hospitals was then calculated and a subgroup analysis according to level I and level II trauma center was performed.

The Pearson's chi-squared test was used for all nominal variables to calculate the significance of the differences between level I and level II trauma centers.

A value of $p < 0.05$ was considered significant and a value of $p < 0.001$ was considered highly significant.

Results

46.9 % (n = 151) of the 322 identified trauma centers participated in the study (▶ **Table 1**). A participation rate of 63.6 % among level I trauma centers and 38.2 % among level II trauma centers was achieved.

Structural characteristics

Distance of the CT scanner from the trauma room

In 50.0 % of the hospitals (34.3 % of level I trauma centers; 63.8 % of level II trauma centers, $p < 0.001$), the distance from the trauma room to the CT scanner was more than 50 m (▶ **Table 1**). The distances were up to 150 m in some hospitals, and the CT scanner was on a separate floor in 3 hospitals. The CT scanner was located in the room next to the trauma room in 37.3 % of the hospitals and in the trauma room in 12.7 % (22.9 % of level I trauma centers, 3.7 % of level II trauma centers, $p < 0.001$). Statistically, the distances between the trauma room and the CT scanner in level II trauma centers were highly significantly greater (▶ **Table 1**).

Data about the CT scanner

The majority of the hospitals included in the study used a CT scanner manufactured by Siemens Healthcare GmbH (61.3 %) followed by Phillips Healthcare, Canon Medical System GmbH (formerly Toshiba), and GE Healthcare GmbH (▶ **Table 1**). There was no statistically significant difference between the levels of care with respect to manufacturer or number of detector rows. The number of detector rows ranged from 4 to 512. The hospital with a 4-slice CT scanner was in the process of a new acquisition during the study. Most hospitals had 64- and 128-slice CT scanners. 95.7 % of the level I trauma centers and 53.8 % of the level II trauma centers had a second backup CT scanner ($p < 0.001$). Most backup scanners were 16-slice scanners (with 64- and 128-slice scanners being used as the primary units). The backup scanners at level I trauma centers had a significantly higher number of detector rows (▶ **Table 1**).

Process characteristics

Examination procedure and reporting

98.7 % of the hospitals specified that their CT scanners were available 24 hours a day 7 days a week (▶ **Table 2**).

A lead time of up to 30 minutes was needed in 15.0 % of the hospitals. 6.8 % of the level I trauma centers and 22.1 % of the level II trauma centers required lead time. The average lead time was 12.3 minutes. The difference between level I and level II trauma centers was statistically significant.

Trauma room team composition

The trauma room team included a radiologist in 72.6 % of participating hospitals (▶ **Table 2**). No radiologist was present in the trauma room in 20.5 % of the hospitals and the presence of a radi-

▶ **Table 1** Summary of survey data on structural features of whole-body CT.

	Total (n/%)	Level I trauma center (n/%)	Level II trauma center (n/%)	p-value
Contacted hospitals	322	110	212	
Participating hospitals	151/46.9 %	70/63.6 %	81/38.2 %	
Structural characteristics				
Location of CT scanner				< 0.001
In the trauma room	19/12.7 %	16/22.9 %	3/3.7 %	
Directly next to the trauma room	56/37.3 %	30/42.9 %	26/32.5 %	
Farther away from the trauma room	75/50.0 %	24/34.2 %	51/63.8 %	
Missing data	*1*	*0*	*1*	
Manufacturer of CT scanner				0.105
Siemens Healthineers	92/61.3 %	47/67.1 %	45/56.3 %	
Philips Healthcare	28/18.7 %	11/15.7 %	17/21.2 %	
Toshiba or Canon	17/11.3 %	4/5.7 %	13/16.2 %	
GE	13/8.7 %	8/11.4 %	5/6.3 %	
Missing data	*1*	*0*	*1*	
Number of detector rows				0.279
4	1/0.7 %	1/1.4 %	0/0 %	
16	24/16.0 %	9/12.9 %	15/18.8 %	
20	5/3.3 %	2/2.9 %	3/3.8 %	
32	8/5.3 %	4/5.7 %	4/5.0 %	
40	5/3.3 %	2/2.9 %	3/3.8 %	
64	54/36.0 %	22/31.4 %	32/40.0 %	
80	6/4.0 %	1/1.4 %	5/6.3 %	
128	30/20.0 %	18/25.7 %	12/15.0 %	
192	1/0.7 %	1/1.4 %	0/0 %	
256	12/8.0 %	8/11.4 %	4/5.0 %	
320	1/0.7 %	0/0 %	1/1.3 %	
384	2/1.3 %	2/2.9 %	0/0 %	
512	1/0.7 %	0/0 %	1/1.3 %	
Missing data	*1*	*0*	*1*	
Backup concept (second CT scanner)				< 0.001
Present	110/73.3 %	67/95.7 %	43/53.8 %	
Not present	40/26.7 %	3/4.3 %	37/46.3 %	
Missing data	*1*	*0*	*1*	

Missing data: Number of unanswered items of the questionnaire.

ologist was variable ("as needed") in 6.8 %. Radiologists were present in the trauma room in level I trauma centers highly significantly more frequently than in level II trauma centers (88.1 % vs. 59.5 %).

eFAST prior to whole-body CT

93.8 % of the hospitals performed eFAST (extended Focused Assessment with Sonography for Trauma) after admission of a patient to the trauma room (▶ **Table 2**). eFAST was performed by trauma surgery in 35.0 % of all evaluated trauma centers and by radiology in 27.0 %. There was a statistically significant difference between level I and level II trauma centers. eFAST was performed by radiologists statistically significantly more frequently at level I trauma centers (34.9 %) than at level II trauma centers (20.3 %). In contrast, ultrasound was performed more frequently by trauma surgeons (36.5 %) in level II trauma centers.

▶ **Table 2** Process quality, performance, and reporting.

	Total (n/%)	Level I trauma center (n/%)	Level II trauma center (n/%)	p-value
Participating hospitals	151/46.9 %	70/63.6 %	81/38.2 %	
Process characteristics				
CT availability				0.125
Continuous availability 24/7	147/98.7 %	67/97.1 %	80/100 %	
Limited availability	2/1.3 %	2/2.9 %	0/0 %	
Missing data	*2*	*1*	*1*	
Lead time needed				< 0.016
No	108/85.0 %	55/93.2 %	53/77.9 %	
Yes	19/15.0 %	4/6.8 %	15/22.1 %	
Missing data	*24*	*11*	*13*	
Team composition – radiology present in the trauma room				< 0.001
Yes	106/72.6 %	59/88.1 %	47/59.5 %	
No	30/20.5 %	8/11.9 %	22/27.8 %	
Variable/depending on need	10/6.8 %	0/0 %	10/12.7 %	
Missing data	*5*	*3*	*2*	
eFAST performed				0.357
Yes	137/93.8 %	62/91.2 %	75/96.2 %	
No	8/5.5 %	5/7.4 %	3/3.8 %	
Frequently	1/0.7 %	1/1.5 %	0/0 %	
Missing data	*5*	*2*	*3*	
eFAST performed by				0.022
Radiology	37/27.0 %	22/34.9 %	15/20.3 %	
Trauma surgery	48/35.0 %	21/33.3 %	27/36.5 %	
General surgery	20/14.6 %	12/19.0 %	8/10.8 %	
Internal medicine	5/3.6 %	2/3.2 %	3/4.1 %	
Other	1/0.7 %	1/1.6 %	0/0 %	
Variable	26/19.0 %	5/7.9 %	21/28.4 %	
Missing data	*14*	*7*	*7*	
When CT was performed				0.808
Within 20 minutes	52/35.6 %	26/38.2 %	26/33.3 %	
After the first trauma room phase	89/61.0 %	40/58.8 %	49/62.8 %	
Situation-dependent	5/3.4 %	2/3.0 %	3/3.9 %	
Missing data	*5*	*2*	*3*	
Primary reporting during the day				0.063
Resident	58/40.6 %	34/51.5 %	24/31.2 %	
Board-certified radiologist	26/18.2 %	8/12.1 %	18/23.4 %	
Resident or board-certified radiologist	46/32.2 %	21/31.8 %	25/32.5 %	
Consultant	5/3.5 %	1/1.5 %	4/5.2 %	
Not known	8/5.6 %	2/3.0 %	6/7.8 %	
Missing data	*8*	*4*	*4*	
Primary reporting at night				< 0.001
Resident	60/42.0 %	35/53.0 %	25/32.5 %	
Board-certified radiologist	19/13.3 %	5/7.6 %	14/18.2 %	

▶ **Table 2** (Continuation)

	Total (n/%)	Level I trauma center (n/%)	Level II trauma center (n/%)	p-value
Resident or board-certified radiologist	40/28.0 %	24/36.4 %	16/20.8 %	
Consultant	2/1.4 %	0/0 %	2/2.6 %	
Teleradiology	17/11.9 %	0/0 %	17/22.1 %	
Not known	5/3.5 %	2/3.0 %	3/3.9 %	
Missing data	*8*	*4*	*4*	
Structured reporting				0.408
Yes	85/63.9 %	43/69.4 %	42/59.2 %	
No	42/31.6 %	16/25.8 %	26/36.6 %	
Variable	6/4.5 %	3/4.8 %	3/4.2 %	
Missing data	*18*	*8*	*10*	

Missing data: Number of unanswered items of the questionnaire.

When is CT performed

35.6 % of the hospitals stated that they always perform CT first within the first 20 minutes of patient admission. It is standard procedure at the majority of the hospitals (61.0 %) to perform whole-body CT after the first trauma room phase (primary survey). The procedure is determined based on the situation at 3.4 % of the hospitals. There was no statistical difference between level I and level II trauma centers.

Whole-body CT reporting

All final findings were validated by a board-certified radiologist/consultant. During regular hours, on-site initial reporting for whole-body CT was most frequently (40.6 %) primarily performed by residents (▶ **Table 2**). Initial diagnosis was made by a resident or board-certified radiologist depending on availability in 32.2 % of the hospitals, while primary reporting was only performed by a board-certified radiologist or consultant in 21.7 % of the hospitals (▶ **Table 2**, column 1). There was no statistically significant difference between level I and level II trauma centers. "Resident or board-certified radiologist" was additionally offered as a possible answer due to the clinical routine and response to the survey.

In principle, the situation was similar for initial reporting at night and on weekends, with reporting being performed primarily by residents in 42.0 % of cases, residents or board-certified radiologists depending on availability in 28.0 % of cases, and by consultants or board-certified radiologists in 14.7 % of cases. The differences between level I and level II trauma centers were statistically highly significant. Primary reporting was performed by a resident in 53.0 % of cases at level I trauma centers and only in 32.5 % of cases at level II trauma centers. Initial reporting was performed significantly more frequently by a consultant or board-certified radiologist at level II trauma centers (20.8 %) than at level I trauma centers (7.6 %). There was a major difference between level I and level II trauma centers with respect to the use of teleradiology, which was performed exclusively at level II trauma centers (11.9 %) and was not part of the clinical routine at the level I trauma centers.

Availability of additional radiological diagnostics and treatment

67.3 % of the hospitals stated that magnetic resonance imaging is always available (▶ **Table 3**). The average lead time was 26.5 minutes. The difference regarding the availability of MRI between level I trauma centers (92.8 %) and level II trauma centers (44.9 %) was statistically highly significant.

Diagnostic angiography was available at all times in 82.2 % of all participating hospitals with an average lead time of 32 minutes. The maximum lead time for interventions was 60 minutes. Angiographic interventions were available any time of day in 71.0 % of the hospitals. The difference between level I (89.6 %) and level II (55.1 %) trauma centers was also highly significant here. In addition, interventional angiography was possible depending on staffing ("usually") in 7.5 % of the level I trauma centers and 10.3 % of the level II trauma centers (▶ **Table 3**).

Discussion

To our knowledge, this is the first study systematically evaluating the integration of radiology as well as the structural and process characteristics of radiological diagnostics of severely injured patients in Germany.

The participation rate of 46.9 % of the 322 identified level I and level II trauma centers (TraumaNetzwerk DGU) resulted in a solid database with representative results.

▶ **Table 3** Advanced radiological examinations and intervention options.

	Total (n/%)	Level I trauma center (n/%)	Level II trauma center (n/%)	p-value
Participating hospitals	151/46.9 %	70/63.6 %	81/38.2 %	
MRI				< 0.001
Continuous availability	99/67.3 %	64/92.8 %	35/44.9 %	
No continuous availability	48/32.7 %	5/7.2 %	43/55.1 %	
Missing data	*4*	*1*	*3*	
Diagnostic angiography – 24/7				< 0.001
Yes	120/82.2 %	66/97.1 %	54/69.2 %	
No	26/17.8 %	2/2.9 %	24/30.8 %	
Missing data	*5*	*2*	*3*	
Interventional angiography – 24/7				< 0.001
Yes	103/71.0 %	60/89.6 %	43/55.1 %	
No	29/20.0 %	2/3.0 %	27/34.6 %	
In most cases	13/9.0 %	5/7.5 %	8/10.3 %	
Missing data	*6*	*3*	*3*	

ÜTZ: Level-I-Trauma-Center; RTZ: Level-II-Trauma-Center; Missing data: Number of unanswered items of the questionnaire.

Structural characteristics of radiological care of severely injured patients

Temporal and spatial organizational structure of whole-body CT

With respect to whole-body CT examinations of severely injured patients in Germany, almost constant availability at level I and level II trauma centers can be assumed.

The CT scanner was installed either door-to-door or directly in the trauma room at half of the hospitals included in the study.

A study published in 1998 showed that installation of the CT scanner outside the trauma room causes a delay in repositioning and transport processes thereby resulting in an average time loss in diagnostics and treatment processes of 14.5 minutes [14].

In a study by Hilbert et al., the time requirements after installation of a CT scanner in the trauma room were compared to retrospective data from the same hospital. It was able to be shown that the installation of the CT scanner in the trauma room significantly reduced the time patients spent in the trauma room [15]. A study by Lee et al. was also able to show that installing the CT scanner in the trauma room significantly shortens the time between imaging and surgery. An influence on the average length of hospital stay or mortality rate could not be shown [16]. The studies by Gross and Saltzherr had similar results [17, 18].

However, a publication by Huber-Wagner from 2014 showed that a CT scanner located within 50 m of the trauma room significantly improves the probability of survival of severely injured patients. According to the publication, transport distances greater than 50 m significantly decreased the probability of survival [19].

In our opinion, a CT scanner located in the trauma room or in an adjacent room is advantageous particularly in unstable patients. A significantly greater distance to the scanner can potentially result in problems during transport and particularly with respect to provision of materials for anesthesiology.

Therefore, on the whole, the integration of a CT scanner in the trauma room reduces the time a patient spends in the trauma room, but based on currently available studies, there is no significant effect on the patient mortality rate. For economic reasons, it is often problematic for radiology departments to install CT scanners outside their own departments in emergency rooms where the scanners often cannot be optimally used by radiology personnel for routine examinations. It should be taken into consideration in hospital planning that a CT scanner should be located within 50 m of the trauma room.

Number of detector rows and backup concepts

The evaluated hospitals used CT scanners with at least 16 detector rows, with most hospitals using scanners with 64 detector rows. In principle, all CT scanners with at least 16 detector rows should be considered diagnostically sufficient. To our knowledge, there are no comprehensive studies comparing the diagnostic accuracy of scanners with different numbers of detector rows in the case of whole-body CT in polytrauma patients. However, a monocentric study was able to show that the sensitivity of multidetector CT increased from 51 % for 32-slice CT scanners to 68 % for 64-slice scanners in the case of blunt cerebrovascular injuries like dissection of the carotid artery or vertebral artery [20].

Process characteristics of radiological care of polytrauma patients

Presence of a radiologist in the trauma room

With respect to the composition of the trauma room team, a radiologist was present in the trauma room in the majority of the evaluated hospitals. This was more common at level I trauma centers than level II trauma centers, probably due to the 24-hour availability of a radiologist, who also performs sonographic evaluation with eFAST when necessary. In our opinion, radiology as a contact for surgical disciplines and as a direct clinical partner in the trauma room has significant advantages by minimizing possible information and communication errors and allowing dedicated direct inquiries in both directions. The use of teleradiology in level II trauma centers makes economic sense in the case of often insufficient staffing ratios but has risks in individual cases due to a lack of personal integration of radiology in the trauma room team. To our knowledge, a scientific evaluation of examinations personally performed by the radiology department on-site with respect to the effect on process and result quality has not yet been performed.

Ultrasound

According to the S3 guideline, eFAST ultrasound should be performed in the case of blunt or penetrating injuries. The guideline does not provide any specifications regarding the qualifications or certification of physicians performing ultrasound examinations. Primary eFAST is controversial in hospitals with a CT-first protocol.

The value of eFAST in severely injured patients must be viewed on a differentiated basis depending on the degree of severity of the injury. In a study by Becker et. al, the value of eFAST compared to computed tomography was evaluated in 3181 patients [21]. The patients were divided into 3 groups based on the injury severity score (ISS), with group 1 containing minor injuries with ISS values between 1 and 14, group 2 between 16 and 24, and group 3 ≥ 25. eFAST had the best sensitivity of 86 % in the group with minor injuries, a slightly lower sensitivity of 80 % in group 2, and a sensitivity of only 65.1 % in group 3 with the highest ISS values. In further comparative studies, sensitivities between 75 % and 87 % with high specificity could be achieved [22, 23]. Based on all publications, intraabdominal injuries cannot be ruled out by a negative eFAST or FAST ultrasound result.

In contrast, the mentioned studies show a specificity of at least 97 %. In the case of unstable trauma, ultrasound can provide important information and help to determine treatment when making time-critical decisions. Therefore, in our opinion, eFAST should continue to be used to ensure routine application in severely injured patients in the future. As in most sonographic examinations, the limitations regarding results depend on the qualifications and level of training of the examiner and the examination conditions in the trauma room. In addition, the examination quality is determined by the physiological conditions of the patient like overlying intestinal gas or obesity [24]. To our knowledge, there are no studies comparing the quality of eFAST ultrasound results between examiners in radiology and trauma surgery.

Whole-body CT reporting

All final findings were validated by a board-certified radiologist, with primary reporting often being performed by residents.

Teleradiology was used for whole-body CT reporting at night in 11.9 % of level II trauma centers which is probably due to fact that radiologists are often not available 24 hours a day at level II trauma centers. Teleradiology reporting was not used during the day and at level I trauma centers. Outside regular hours, primary reporting was performed by a resident in 53.0 % of cases at level I trauma centers and only in 32.5 % of cases at level II trauma centers. The greater amount of primary reporting performed by residents at level I trauma centers is probably due to the fact that these centers tend to serve as teaching centers at larger hospitals so that primary reporting tends to be performed by residents when on call. However, the final report must be reviewed by a board-certified radiologist or consultant at all hospitals. The literature shows that it is useful for a board-certified radiologist to reevaluate the findings. In a study by Hillier et al. in 2004, the CT findings for 331 polytrauma patients determined by residents were compared with the findings of board-certified radiologists. In total, the residents had an error rate of 21.5 % and 7 % of the incorrect findings would have resulted in a significant medical error [25]. In a study by Briggs et al., minor differences were seen between residents and board-certified radiologists with respect to 137 evaluated polytrauma CT scans [26]. In this study, there were discrepancies in 25 % of patients with 18 % of diagnoses being overlooked. However, these missed findings were highly clinically significant in only 6 of 130 cases. A study by Terreblanche investigated the evaluation of 1477 CT examinations at a level I trauma center in Johannesburg, South Africa resulting in a total error rate of 17.1 % with an error rate for severe discrepancies of 7.7 % [27]. A significant improvement in report quality was seen particularly in second- and third-year residents.

Availability of additional radiological diagnostic and therapeutic methods

The differences between level I and level II trauma centers regarding the ability to perform an MRI examination of polytrauma patients at any time of day were statistically highly significant (92.8 % and 44.9 %, respectively). Acute/subacute availability of MRI equipment for treating polytrauma patients is clinically necessary in special cases. In principle, an MRI examination is needed in the case of unclear CT findings, e. g., traumatic dissection of vertebral arteries or spinal pathologies, e. g., spinal cord damage,. Comparative multicenter prospective studies were able to show in a selected patient population that MRI examination identified additional pathological findings in 23.6 % of cases with inconspicuous CT examination of the cervical spine. However, they did not evaluate the clinical significance of the injuries [28]. However, at present, continuous availability of MRI examination is not specified as a requirement for trauma centers in the current White Book on Medical Care of the Severely Injured [9].

Angiographic diagnostics and especially angiographic interventions were available at any time of day in approximately 1/3 of the surveyed hospitals. The difference between level I (97.1 %) and level II (69.2 %) trauma centers was statistically significant.

The S3 guideline discusses various interventional radiology treatment methods for polytrauma patients, particularly in the case of injury to the parenchymatous organs of the upper abdomen and in pelvic fractures, as the primary or supplementary treatment approach, which can only be used with corresponding expertise. To our knowledge, systematic studies on the clinical relevance of angiography availability in the acute situation have not been performed. Only one retrospective analysis of two trauma centers in the USA shows a lower sensitivity of CT in comparison to angiography in penetrating cerebrovascular injuries [29]. However, for economic reasons, it is often not possible for highly specialized interventional radiologists to be continuously available, particularly at less specialized centers like level II trauma centers. To our knowledge, no systematic outcome analysis regarding the continuous availability of angiography in polytrauma patients has been performed.

Limitations

It was not possible to include all level I and level II trauma centers due to the voluntary nature of participation in the study and the time needed to complete the comprehensive questionnaire. Nonetheless, a participation rate of almost 50 % provided us with a solid basis for our evaluation. Although the number of misunderstandings regarding individual items was able to be limited by the personal support provided by the principal investigator, it was not possible to achieve absolute completion of all questions for all participants. In addition, we had to depend on the diligence and correct understanding of the participating hospitals with respect to the correctness of the content they provided.

Further detailed analysis of the CT protocols will be published separately by the working group since it exceeds the scope of the present study.

Conclusion

Significant heterogeneity between level I and level II trauma centers particularly regarding the distance of the CT scanner from the trauma room, the main participants in care in the case of ultrasound, and the composition of the trauma room team was seen in both the structural and the process characteristics in individual areas. However, on the whole, a high level of performance of radiology in German trauma centers can be assumed.

CLINICAL RELEVANCE OF THE STUDY

- This is the first study on the diagnostic reality of radiology in severely injured patients in Germany.
- There was heterogeneity regarding structures and processes with some significant differences between level I and level II trauma centers.
- Further studies based on these results will clarify whether this results in a diagnostic difference and a difference in result quality.

Conflict of Interest

The authors declare that they have no conflict of interest.

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