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ORIGINAL ARTICLE

Delays in diagnosis in early trauma care: evaluation of diagnostic efficiency and circumstances of delay

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Abstract
Background Trauma centers, trauma management concepts, damage control surgery and the integration of whole-body CT scanning into early trauma care have reduced mortality in traumatized patients significantly. However, some injuries are still initially missed. In this study, the diagnostic efficiency of early trauma care and the circumstances of delays in diagnosis were evaluated.
Materials and methods Initially missed diagnoses in 111 traumatized patients were recorded retrospectively. "Primary diagnoses" after the emergency room (ER) phase including CT scanning with immediate data evaluation were compared to "secondary diagnoses" after a secondary survey of the CT data, as well as to discharge diagnoses. Circumstances of delay were assessed according to injury severity score (ISS), hospital admission, mechanism of injury, diagnostics, treatment, time in the intensive care unit, hospitalization and mortality.
Results 73% of the patients arrived at the ER during on-call hours. In 23% of all patients, diagnoses were missed after the ER phase, while in 12% of the patients diagnoses were missed after the secondary survey of the CT data. One half of the missed diagnoses were almost impossible to detect; the other half were judged to be acceptable. During on-call hours, 9% more patients with delays in diagnosis were observed. Injury severity in patients with delays in diagnosis was significantly higher than in patients without.
Conclusions Although diagnostic quality in early trauma care has improved, some diagnoses are initially missed. Severely injured patients with life-threatening or potentially life-threatening injuries arriving at the ER during on-call hours were at higher risk for delays in diagnosis. A secondary evaluation of acquired CT data and repetitive examinations are essential.

Keywords Emergency surgery · Polytrauma · Trauma systems · Quality assessment

Introduction

Centralized trauma care has reduced the incidence of preventable death after injury dramatically [1–8]. Improvement in computed tomography (CT) technology has led to the introduction of multislice CT in early trauma diagnostics [9–13]. Despite the implementation of trauma centers and trauma management concepts in the 1980s and 1990s, delays in diagnosis in early trauma care with underestimations of injury severity and consecutive delays in surgery still occur [14–22].

Provider-related delays in diagnosis are differentiated between justified and acceptable and unjustified and unacceptable, with no morbidity being encountered from justified and acceptable delays. Unjustified delays in diagnosis have led to delays in surgery and are caused by misinterpretations of initial radiographic or diagnostic procedures with significant morbidity [15, 16]. Most delays

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in diagnosis are justified and acceptable, with some being unjustified, unacceptable and potentially life-threatening [14–16, 23].

Although the integration of whole-body CT into early trauma care has significantly reduced mortality in patients with polytrauma, still some injuries were initially missed and detected during radiologic re-evaluation of acquired CT data or clinical follow-up [13, 24]. Routine CT scans were found to be of high diagnostic value for the body trunk in patients with blunt trauma [25–27].

The aim of this study was to evaluate the efficiency of early trauma diagnostics in an emergency department based on delays in diagnosis, and to describe the circumstances of delay.

Materials and methods

From June 2008 to May 2009, data on 112 multiply traumatized patients treated in the emergency room (ER) were evaluated retrospectively. All patients were treated in the ER of a level I trauma center according to the criteria established by the American College of Surgeons (ACS) with a 24 h computed tomography and operating facility. Trauma care was provided according to the principles of ATLS™ [28]. In 111 cases, the ER phase (including emergency diagnostics) was able to be completed. One patient died under resuscitation efforts in the ER. No other patient was in severe hypovolemic shock that required immediate damage control surgery. Demographic data were recorded as well as concomitant diseases.

Computed tomography

CT was performed according to a standardized protocol with criteria for a CT scan, such as that of Nast-Kolb et al. [29], published for ER admission. For trauma of the head, a cranial scan including the cervical spine was performed. For trauma of the body, a "whole-body" scan was performed, including a cranial scan and a scan of the torso ending at the lesser trochanter of the femur. The criteria for a whole-body scan and cranial scan are listed in Table 1. If the patient had suffered an isolated injury of the head, a cranial scan was performed. All other patients received a

Table 1 Criteria for a whole-body scan and cranial scan according to the criteria for emergency room admission of Nast-Kolb et al. [29]

Criteria for whole-body scan	Criteria for cranial scan
Mechanism of injury	GCS < 13
Collision with a pedestrian or cyclist (velocity > 30 km/h)	GCS < 15 persisting for 2 h after injury
High-speed accident	
Ejection out of a motor vehicle	Open skull fracture
Significant intrusion of a passenger cabin	Clinical signs of a subcranial or cranial fracture
Fall higher than 3 m	
Blast injury	Severe headache after trauma
Entrapment/burying	More than two episodes of vomiting
Collision with a railway vehicle	Retrograde amnesia >30 min
Death or severe injury of a fellow passenger	Patients with a head trauma and altered sensorium
Pattern of injuries	
Polytraumatized patient	Infants, toddlers, children
Suspicion of an injury of a visceral cavity (thorax, abdomen, pelvis)	Geriatric patients
Paralysis or suspicion of a severe spinal injury	Alcohol, drugs, medication
Unstable pelvis	Intubation
At least two fractures of long bones of the lower extremities	
Severe single injury (e.g., fracture with severe soft tissue injury, amputation)	
Altered vital signs due to an injury	
Initial loss of consciousness, unconscious patient, intubation	
GCS < 14	
Blood pressure <90 mmHg, signs of shock	
Respiratory rate <10 or >30	
Oxygen saturation <90%	

whole-body scan. If there was any hint or suspicion of any injury of the extremities clinically or in the CT scout an additional scan was performed, especially for the shoulder, elbow, wrist, carpus, knee, ankle joint, and foot. For long bones, a conventional X-ray was usually performed. This approach saves time if there is no hint of any injury, but provides flexibility for severe injures of the extremities. In patients who did not fit the criteria for a CT scan, a conventional X-ray is usually performed.

Diagnostic efficiency

The diagnostic efficiency of the emergency department was determined based on missed diagnoses in traumatized patients in different phases of trauma care. If diagnoses were not documented in the admission chart they were considered to have been "missed." Diagnoses of the admission chart, usually documented directly after the ER phase, were called "primary diagnoses." These diagnoses relied on clinical examination, Focused Assessment with Sonography for Trauma (FAST), laboratory parameters, X-rays, or radiologic evaluation of the CT scan immediately after data acquisition. To evaluate the diagnostic efficiency, primary diagnoses were compared to "secondary diagnoses," which were taken from the radiologist's CT report. These diagnoses were assessed after the ER phase and after a secondary survey and evaluation of the acquired CT data. Primary and secondary diagnoses were compared to the discharge diagnoses (Fig. 1). Each "missed" diagnosis was evaluated as being justified or acceptable according to Hoyt et al. [15, 16].

Injury severity

The Injury Severity Score (ISS) [30] was calculated for the primary, secondary and discharge diagnoses of each patient. The ISS is an anatomical score for patients with multiple injuries. Each injury was assigned to an Abbreviated Injury Scale (AIS) and allocated to one of six body regions (head, face, chest, abdomen, extremities and pelvis, external) [31]. The ISS correlates to mortality and morbidity.

Circumstances of delay

In order to evaluate reasons for delays in diagnosis, two groups were formed: group A consisted of patients without delays in diagnosis, and group B with delays in diagnosis. Different parameters were compared: mechanism of injury, need for prehospital technical rescue, NACA scale [32], time and day of admission to the ER, Glasgow Coma Scale (GCS) [33] after the injury and at the time of hospital admission, need for intubation and mechanical ventilation, need for CT scan, emergency surgery, number of operations, admission to and time spent in the intensive care unit (ICU), as well as the total duration of hospitalization and the ISS of primary, secondary and discharge diagnoses. Admission to the ER was stratified into four categories: during the working week or during the weekend from 08.01 to 16.00 h and from 16.01 to 08.00 h. The weekend and the time period from 16.01 to 08.00 h during the working week are considered to be on-call hours.

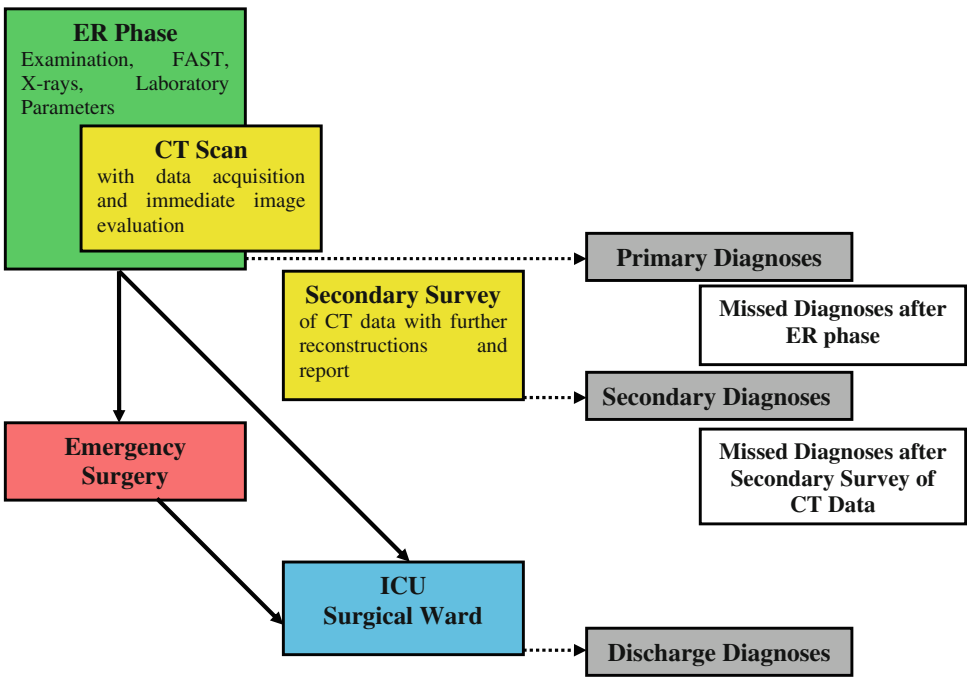


Fig. 1 Diagram of intervals for determining diagnoses and missed diagnoses (*ER* emergency room, *FAST* focused assessment with sonography for trauma, *ICU* intensive care unit, *CT* computed tomography)

Statistical methods

Microsoft Excel™, PowerPoint™ and SAS/STAT™ software were used for statistical evaluation and to draw histograms. The Shapiro–Wilk test was used to test for a normal distribution. A normal distribution was not present for any parameter. Therefore, the Wilcoxon rank-sum test was applied to test for a significant difference between the two groups, except for the GCS. This parameter was classified as severe (GCS 3–8), moderate (GCS 9–12) or minor (GCS 13–15) brain injury and the chi-square test was applied. The Department of Medical Statistics, Biomathematics and Information Processing, Faculty of Clinical Medicine Mannheim, University of Heidelberg, Germany performed the significance testing. Percentages were rounded to integers.

Results

Seventy-two percent ($n = 80$) of the evaluated ER patients were male. The average age was 43 years (range: 11–85 years). 32% ($n = 36$) had concomitant diseases before injury. Descriptive statistics for the two groups can be found in Table 4.

Delayed diagnoses

Five hundred eighteen diagnoses in a total of 111 patients were documented in the discharge letters (Table 2). Four hundred sixty-two of these were found initially. In a total of 25 patients (23%), 56 diagnoses (11%) were missed after the ER phase. After the radiologist's secondary survey of acquired CT data, 35 more diagnoses were identified, which decreased the number of patients with missed diagnoses to 12% ($n = 13$). Twenty-one diagnoses (4%) were missed after the secondary survey of the CT data (Table 3).

All diagnoses listed under the category "Abdomen" in Table 3 were considered to be justified, because in all cases an acute abdomen with free fluid and/or free air in the abdominal cavity was diagnosed and laparotomy was performed without delay. All diagnoses were identified either after a secondary survey and evaluation of the acquired CT data or, if detection was not possible from the CT scan, they were identified and communicated after laparotomy.

Most of the fractures were identified no later than the secondary survey of the CT data. None of the missed fractures were judged to be unacceptable misses in the ER phase. One case of serial rib fracture was missed after the secondary survey of the CT data. Fractures of the distal parts of the extremities were found during the follow-up examination.

Isolated ligamentous or tendinous injuries are difficult to detect in the ER phase by physical examination. Also, CT scan is not the most appropriate diagnostic tool for such injuries. Therefore, it was considered acceptable for these types of injuries to be missed in the ER phase. All of them were detected in the follow-up examination. Similar to ligamentous or tendinous injuries, it is nearly impossible to identify nerve injuries in a polytraumatizied patient because hardly any information is available from the CT data in this context. Both patients in our study with nerve injuries were intubated. These injuries were found in the

Table 2 Diagnoses at the time of discharge from hospital

Discharge diagnoses					
Category	Diagnosis	No.	Category	Diagnosis	No.
Cranium	Hemorrhage	18	Thorax	Pulmonary contusion	30
	Edema	21		Cardiac contusion	13
	Fracture	39		Fracture	57
	Concussion	28		Pneumothorax	11
Abdomen	Parenchyma	23	Spine	Cervical	14
	Mesenteric	15		Thoracal	13
	Gall bladder	1		Lumbar	16
	Bladder	1		Sacral	3
Arteries	Central	2	Nerve	Spinal cord	2
	Peripheral	1		Peripheral	6
Pelvis	Fracture	14	Ligaments/tendons		17
Extremities	Fracture	74	Distortions/luxations		17
Soft tissue	Wound	43	Myocardial infarction		1
	Contusion	30			
			Drug abuse		7
Total numbers of diagnoses					518

Table 3 List of missed diagnoses after the emergency room phase (left) and after a secondary survey of the CT data (right)

Category	Missed diagnoses after emergency room phase	No.	Missed diagnoses after secondary survey of CT data	No.
Fractures	*Serial rib fractures*	6	Serial rib fractures*	1
	Calcaneal fracture	2	Calcaneal fracture	1
	Patella fracture	2	Patella fracture	2
	Medial malleolar fracture	1	Medial malleolar fracture	1
	Metacarpal fracture	1	Metacarpal fracture	1
	Clavicle fracture	4		
	Orbital fracture (floor, roof)	2		
	Nasal bone fracture	1		
	Spinous process fractures	2		
	Scapular fracture	2		
	Vertebral fracture	1		
	Sternal fracture			
	Iliac wing fracture	1		
	Fibular fracture	1		
	Basal skull fracture	1		
	Sternoclav. joint dislocation	1		
Thorax	*Pneumothorax*	1		
	Aortic rupture	1		
Ligaments/ tendons	Cruciate ligament rupture	4	Cruciate ligament rupture	4
	Medial collateral lig. (knee)	1	Medial collateral lig. (knee)	1
	Lateral collateral lig. (knee)	2	Lateral collateral lig. (knee)	2
	Extensor tendon rupture distal phalanx hand	1	Extensor tendon rupture distal phalanx hand	1
Abdomen	Splenic rupture	1		
	Pancreatic contusion	1		
	Bowel perforation	4		
	Hepatic rupture	2		
	Bladder perforation	1		
	Renal contusion	1		
Heart	Cardiac contusion	3	Cardiac contusion	3
	Myocardial infarction	1	Myocardial infarction**	1
	Coronary artery dissection	1	Coronary artery dissection**	1
Nerves	Ulnar nerve contusion	1	Ulnar nerve contusion	1
	Radial nerve paresis	1	Radial nerve paresis	1
Total number of missed diagnoses		56		21

Diagnoses *in italics* were detected by the radiologist after a secondary survey of the CT data. All other diagnoses were identified on clinical follow-up

* Missed diagnosis that is assumed to have been detected in the secondary survey of the CT data

** Missed diagnoses (same patient) that could have had an impact on outcome

follow-up. Both lesions were subject to humeral bone fractures.

The initially missed pneumothorax was small, could not be seen on the X-ray, and had no therapeutic consequences. The aortic rupture was an aortic dissection without any obvious cardiocirculatory effect. This patient had multiple abdominal injuries such as hepatic rupture and bowel perforations. After multiple laparotomies, the patient died of multiple organ failure before any therapeutic procedures for the aortic rupture could be performed.

Ten of 13 cardiac contusions were detected in the ER phase. Three contusions and one myocardial infarction due to a coronary artery dissection were initially missed. In these cases, the ER phase was finished before the analysis of the laboratory parameters of cardiac contusion and myocardial infarction was completed. There was no indication of myocardial infarction in the ECG. Three hours after admission to the ICU, the myocardial infarction was detected due to additional laboratory parameters and transesophageal echocardiography.

Admission to the emergency room

Seventy-three percent of the patients arrived at the ER during on-call hours, and 27% during routine duty hours. In group B 80% and in group A 71% of the patients arrived at

the ER during on-call hours. Thus, during on-call hours, there was a 9% increase in patients with delays in diagnosis (Table 4).

Mechanism of injury

Sixty-one percent ($n = 68$) of the patients suffered a traffic accident (35% car, 21% motorcycle, 4% bicycle, 2% pedestrian), 25% ($n = 28$) suffered a fall of <3 m, and 8% ($n = 9$) suffered a fall of >3 m. Other mechanisms of injury were observed in 5% ($n = 6$). Technical rescue was necessary in 15% ($n = 17$) of the accidents. Proportionally more of the patients in group B suffered a motor vehicle accident than in group A. A fall of >3 m occurred more frequently in group B, whereas a fall of <3 m was observed more frequently in group A. The need for technical rescue was about the same in both groups. The NACA scale in group B was higher than in group A (Table 4).

In summary, in patients with delays in diagnosis, the mechanisms of injury were more severe than in patients without delays in diagnosis. Also, the NACA scale, as judged by the prehospital emergency physician, was higher in patients with delays in diagnosis.

Diagnostics and therapy

All patients received a FAST, while 84% ($n = 93$) underwent a CT scan. Seventy percent ($n = 78$) had a whole-body scan, 14% ($n = 15$) a cranial scan, while 16% ($n = 18$) did not receive a CT scan at all. All patients who did not receive a CT scan belonged to the group of patients without delays in diagnosis. Patients with delays in diagnosis underwent either a cranial or whole-body scan. In 2 of 15 patients who received a cranial scan, 2 diagnoses were initially missed. In one patient it was an orbital fracture; in the other patient it was a nasal bone fracture. All other initially missed diagnoses belonged to the group of patients with a whole-body scan. In 23 of 78 patients, 54 diagnoses were missed initially (Table 3). Patients with delays in diagnosis had 28% more whole-body scans but only half as many cranial CT scans than patients without delays in diagnosis (Table 4).

There was no difference in the GCS between the two groups after the injury and at the time of hospital admission. However, about twice as many patients in group B were intubated and mechanically ventilated at the time of hospital admission or after the ER phase than in group A (Table 4).

In 42% ($n = 47$) of the patients, emergency surgical procedures were performed according to damage control surgery concepts (Table 5). Nearly twice as many patients in group B underwent emergency operations as in group A (Table 4). Patients with delays in diagnosis had much more life-threatening or potentially life-threatening injuries than patients without delays in diagnosis.

Forty-five percent ($n = 50$) of the patients did not need any operation at all. In a total of 61 patients (55%), 161 operations were performed: an average of 2.6 operations per patient (range 1–17). Patients with delays in diagnosis underwent highly significantly more operations during hospitalization than patients without delays in diagnosis (Table 4).

Injury severity score

The mean ISS calculated from the primary diagnoses of all ER patients was 19.4 (range 1–50); the mean ISS from the secondary diagnoses was 21.1 (range 1–66). This value was similar to the mean ISS from the discharge diagnoses (21.2; range 1–66).

When evaluating patients with delays in diagnosis, the mean ISS increased from 25.7 (primary diagnoses) to 27.4 (secondary diagnoses) and to 28.1 (discharge diagnosis). In 6 patients the ISS increased from primary to secondary diagnoses. The ISS increased from secondary to discharge diagnoses in 3 cases. Patients without delays in diagnosis revealed a mean ISS of 17.0, which was highly significantly different to the ISS values of patients with delays in diagnosis (Table 4).

Time of hospitalization and discharge from hospital

After initial emergency care with or without surgery, 58% ($n = 64$) of the patients were admitted to the ICU with a mean intensive care period of 5.4 days (median 2 days). The mean stay in a surgical ward was 10 days (median 6.5 days), with an overall mean duration of hospitalization of 15.1 days (median 10.5 days). Almost all patients in group B, which was about twice the number of patients who were treated in the ICU in group A. The mean time spent in the ICU as well as the duration of hospitalization of patients with delays in diagnosis were highly significantly higher than in patients without delays in diagnosis. The need for intensive care was twice as high in patients with delays in diagnosis than in patients without delays in diagnosis. Patients with delays in diagnosis spent more than three times longer in the ICU and twice as long in the hospital as patients without delays in diagnosis (Table 4).

More patients in group A were discharged from the hospital to their own home; more patients were dismissed to a rehabilitation center in group B (Table 4).

Mortality

Ten (9%) of the ER patients died. Three patients died from multiple organ failure, 2 from intracranial hemorrhage, 2

Table 4 Comparision of patients with and without delays in diagnosis

Comparison of patients with and without delays in diagnosis				
		Group A (without delay in diagnosis)		Group B (with delay in diagnosis)
Descriptive data				
Number of patients (n)		86		25
Age (years) (mean ± SD; range)		44 ± 22 (11–86)		42 ± 16 (17–80)
Sex: male:female (*n*)		61:25 (71% male)		19:6 (76% male)
Admission to the emergency room				
	Time interval	All patients *n* (%)	Group A (without delay in diagnosis) *n* (%)	Group B (with delay in diagnosis) *n* (%)
Work week (h)	08.01–16.00	30 (27)	25 (29)	5 (20)
(Monday–Friday)	16.01–08.00	47 (42)	36 (42)	11 (44)
Weekend (h)	08.01–16.00	10 (9)	7 (8)	3 (12)
(Saturday, Sunday)	16.01–08.00	24 (22)	18 (21)	6 (24)
Circumstances of delay				
			n (%)	*n* (%)
Mechanism of injury				
Traffic accident				
Car			29 (34)	11 (44)
Motorcycle			15 (7)	7 (28)
Bicycle			4 (5)	1 (4)
Pedestrian			2 (2)	1 (4)
Fall				
>3 m			5 (6)	3 (12)
<3 m			26 (30)	3 (8)
Others			6	
NACA				
II			1 (1)	
III			18 (25)	3 (14)
IV			40 (55)	9 (41)
V			13 (18)	10 (46)
VI			1 (1)	
Diagnostics and therapy				
FAST			86 (100)	25 (100)
CT				
Cranial scan			13 (15)	2 (8)
Whole body scan			55 (64)	23 (92)
None			18 (16)	
Intubation and mechanical ventilation			13 (15)	8 (32)
Emergency surgical procedures			30 (35)	17 (68)
Laparotomy due to abdominal bleeding			12 (14)	7 (28)
Craniotomy due to intracerebral bleeding			2 (2)	3 (12)
External stabilization of the pelvis			2 (2)	2 (8)
Stabilization of long bones			3 (3)	7 (28)

Table 4 continued

Circumstances of delay							
				n (%)			*n* (%)
ICU				41 (47)			24 (96)
Discharge and mortality							
Discharge from hospital							
Own home				67 (79)			17 (68)
Rehabilitation center				5 (6)			4 (16)
Mortality (intra-hospital)				7 (8)			3 (12)
	Group A (without delay in diagnosis)			Group B (with delay in diagnosis)			*p* value
	Mean ± SD	Median	Range	Mean ± SD	Median	Range	
GCS							
Time of injury	13.6 ± 3.0	15	3–15	13.6 ± 2.2	15	5–15	0.535
Time of hospital admission	14.0 ± 3.0	15	3–15	13.9 ± 2.2	15	5–15	0.367
Operations during hospitalization	1.1 ± 1.7	0	0–9	14.0 ± 3.0	2	0–17	<0.0001
ISS							
Primary diagnosis	17.0 ± 10.8	16	1–48	26.9 ± 12.0	25	4–50	<0.0001
Secondary diagnosis	17.0 ± 10.8	16	1–48	29.2 ± 12.8	25	5–66	<0.0001
Discharge diagnosis	17.0 ± 10.8	16	1–48	29.9 ± 13.2	25	5–66	<0.0001
Mean time on ICU (d)	3.2 ± 6.4	0	0–35	11.3 ± 12.9	6	0–58	<0.0001
Hospitalization (d)	12.2 ± 12.4	7.5	0–55	24.9 ± 19.5	21	2–81	<0.001

Table 5 Emergency surgical procedures after the emergency room phase

Emergency surgical procedures	No. of emergency surgical procedures
External fixator (extremities, pelvis)	19
Laparotomy	14
Soft tissue procedures	8
Craniotomy	5
Open reduction internal fixation (ORIF)	5
Thoracotomy	3
Closed reduction internal fixation	2
Total number of emergency surgical procedures	56

from cerebral edema, and 2 from high cervical paraplegia due to vertebral dislocation and consecutive complications. The mean ISS by the time of death was 33.2 (range 16–66, median 28.5). Proportionally more patients in group B died in the hospital than in group A (Table 4).

Discussion

Malhorta et al. [17] evaluated missed diagnoses up to 13 months postdischarge and found missed injuries in 2.5% of the cases. Most of these did not require any specific therapy. Like many other authors, we concentrated on missed diagnoses in early trauma care ending with discharge from hospital [14–21, 23]. This is why missed injuries were called "delays in diagnosis:" they were detected during hospitalization. Missed diagnoses after hospital discharge were not observed. Therefore, in this study, not diagnostic quality but rather diagnostic efficiency in early trauma care was evaluated. Like most studies in the literature dealing with missed diagnoses in trauma care, the limitation of this study is its retrospective study design as well as the limited number of patients it includes. A prospective multicenter study should be performed.

Delays in diagnosis

After the ER phase with CT diagnostics and immediate data evaluation, 56 single diagnoses (11%) in a total of 25 patients (23%) were missed in our study. Enderson et al. [18] reported 41 missed injuries in 26 of 399 patients (9%). Zintl et al. [23] reported 44 missed diagnoses in 32% of the patients after the ER phase. They judged five missed diagnoses as unjustified and potentially life-threatening. In one of the latest studies, Emet et al. [19] found missed injuries in 89 of 670 patients (11%), with 1.64 missed injuries per patient on average.

Although Deunk et al. [25–27] reported that routine CT scans in patients with blunt trauma were of high diagnostic value, a CT scan was not performed routinely in all ER

patients in our study. A CT scan was performed selectively according to the previously mentioned criteria (Table 1).

In patients who did not initially receive a whole-body or cranial scan, no more diagnoses were detected in the follow-up examinations. Also, many more whole-body scans were performed in the group of patients with delays in diagnosis than in the group of patients without delays in diagnosis. In two patients who received only a cranial scan, one diagnosis was delayed in each patient. Both diagnoses were located in the anatomical region of the head. On the one hand, these results confirm that our criteria for a whole-body scan or a cranial scan are appropriate; on the other hand, they show that not performing a whole-body scan is not the reason for delays in diagnosis.

According to data from the trauma registry of the German Society of Trauma Surgery, the mean duration from admission to the ER until the beginning of the CT scan was 24 min in 2007 [34]. According to Rieger et al. [24], it takes 12 ± 4.9 min for the radiologist to perform the CT scan and immediately evaluate the image. Applying that data to this study, 89% of the diagnoses were detected after about 35–40 min. After the secondary survey of the acquired CT data with further reconstructions performed by the radiologist, 21 single diagnoses (4%) in a total of 13 patients (12%) were missed. These results correlate with the results of Hoyt et al. [15], who found 2.8% missed diagnoses and judged more than half of those to be justified or acceptable.

Usually diagnoses that were additionally found in the secondary survey of CT data were communicated as soon as detected by the radiologist, and no later than the next morning after the CT data had been re-evaluated by the senior radiologist. Therefore, no secondary diagnosis was discovered more than 24 h after the ER phase. According to Davis et al. [14], a delay in diagnosis is defined as when the diagnosis is made more than 24 h after admission. Thus, in this study, only 4% of the diagnoses were detected after 24 h and were therefore considered to be delayed.

As in the study of Hoyt et al. [15], in which more than half of the diagnoses were judged to be justified or acceptable, in this study it was nearly impossible to detect 10 (50%) of the missed diagnoses in the emergency department. Nerve injuries could not be detected in intubated patients. For the identification of ligamentous injuries of the knee or a tendon rupture of the finger, a cooperative patient or an MRI is needed. We do not perform MRI diagnostics in the emergency department.

Although a serial rib fracture was identified after the secondary survey of the CT data, none of the 6 missed fractures in this study had any adverse effect on patient survival or outcome, so they were all acceptable.

Cardiac contusion or myocardial infarction is difficult to detect in the ER phase. CT is the wrong diagnostic tool for identifying cardiac contusion or myocardial infarction. In conventional ECG, the detection of a myocardial infarction is unreliable; a 12-channel ECG is needed. We do not perform 12-channel ECG in the ER. The only indications for these diagnoses are the laboratory markers creatine kinase (CK) and creatine kinase MB (CKMB), which are determined in the ER phase but take some time to obtain. More specific laboratory markers for myocardial infarction, such as troponin I, are not determined in the ER phase. If the ER phase is finished before the analysis of laboratory parameters is completed, a cardiac contusion might be missed. The only potentially life-threatening diagnosis (0.2%) was a myocardial infarction due to a coronary artery dissection. The patient died from multiple organ failure in the ICU. These results correlate with the results of Davis et al., who detected 114 delays in diagnosis; 6 patients suffered preventable deaths out of the 22,577 patients in their study, which means that the rate of unjustified and unacceptable missed diagnoses was 0.5% [14].

We considered that all of the missed diagnoses after the ER phase were justified and acceptable in our study. However, diagnoses must be detected as soon as possible to prevent relevant morbidity and mortality.

The concept of a tertiary trauma survey, as introduced by Enderson et al. [18], is appropriate for detecting missed diagnoses quickly and reliably. This survey should be performed after the initial operative or nonoperative phase, within 24 h after admission, and after the patient has regained consciousness [20–22].

Circumstances of delay

In our study, 73% of the patients reached the emergency department during on-call hours. During on-call hours, a 9% increase in patients with delays in diagnosis was observed. Much effort must be directed into providing the same high level of quality of diagnostics and treatment during on-call hours as during the working week. Medical resources (personnel as well as CT and operating capacity) must be provided day and night [24, 29, 35].

Davis et al. and Hoyt et al. [14–16] analyzed the reasons for preventable death in trauma care. Davis et al. identified phases in the process of trauma care such as errors in the resuscitative, operative and critical care phases. Hoyt et al. [14, 15] reported on provider-related events such as delays in team activation, disposition, surgery, and diagnosis, as well as errors in diagnosis, technique and judgement. Janjua et al. as well as Emet et al. [19, 20] reported circumstances in which delays in diagnosis occurred.

In order to evaluate injury severity of ER patients, different factors were evaluated retrospectively from the time of the accident until the time of hospital discharge. In

comparison to patients without delays in diagnosis, patients with delays in diagnosis

- Suffered more severe injuries
- Had a higher ISS
- Had a higher NACA scale
- Were intubated and mechanically ventilated twice as often
- Received more whole-body scans
- Had to undergo twice as many emergency operations
- Had more life-threatening or potentially life-threatening injuries
- Spent a longer time in the ICU.

In patients with delays in diagnosis,

- The number of emergency laparotomies was twice as high
- The need for intensive care was twice as high
- The hospitalization was twice as long
- The hospital mortality was higher.

In addition to the ISS, all of this information implies that the injury severity in patients with delays in diagnosis was higher than in patients without delays in diagnosis. The difference in mortality was not due to delays in diagnosis, but rather to the more severe injuries suffered by the group of patients with delays in diagnosis. Janjua et al. and Emet et al. published similar results; they found that patients with missed injuries had more motor vehicle accidents, more injuries per patient, higher injury severities and ISS, and a higher mortality rate [19, 20].

Conclusion

Despite the establishment of trauma centers, trauma management concepts, and multislice CT technology in emergency departments, some diagnoses are still missed in early trauma care. In our study, we found that most diagnoses were detected after a secondary survey and evaluation of acquired CT data, or after the follow-up examination. In about half of the diagnoses, detection in the emergency department was not possible. The other half of the initially missed diagnoses had no adverse effects on patient survival or outcome, and were therefore acceptable.

Severely injured patients with life-threatening or potentially life-threatening injuries who arrived at the ER during on-call hours were at higher risk for delays in diagnosis. Not performing whole-body scans is not the reason for delays in diagnosis. Severely injured patients who arrive at the ER during on-call hours must be closely observed so that relevant injuries are not missed. A secondary evaluation of the acquired CT data and a tertiary trauma survey after the initial operative or nonoperative phase, within 24 h after admission and after the patient has regained consciousness, are essential.

Conflict of interest None.

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