Incidence and etiology of mortality in polytrauma patients in a Dutch level I trauma center

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Background Earlier studies assessing mortality in polytrauma patients have focused on improving trauma care and reducing complications during hospital stay. The same studies have shown that the complication rate in these patients is high, often resulting in death. The aim of this study was to assess the incidence and causes of mortality in polytrauma patients in our institute. Secondarily, we assessed the donation and autopsy rates and outcome in these patients.

Patients and methods All polytrauma patients (injury severity score ≥ 16) transported to and treated in our institute during a period of 6 years were retrospectively analyzed. We included all patients who died during hospital stay. Prehospital and in-hospital data were collected on patients' condition, diagnostics, and treatment. The chance of survival was calculated according to the TRISS methodology. Patients were categorized according to the complications during treatment and causes of death. Logistic regression analysis was used to design a prediction model for mortality in major trauma. A statistical analysis was carried out.

Results Of the 1073 polytrauma patients who were treated in our institute during the study period, 205 (19.1%) died during hospital stay. The median age of the deceased patients was 58.8 years and 125 patients were men. Their mean injury severity score was 30.4. The most common mechanism of injury involved fall from height, followed by bicycle accidents. Almost 50% of the patients underwent an emergency intervention. Almost 92% of the total population died because of the effects of the accident (primary trauma). Of these, 24% died during primary assessment in the emergency department. Most patients died because of the effects of severe head injury (63.4%), followed by exsanguination (17.6%). The most common type of complications causing death during treatment was respiratory failure (6.3%), followed by multiple organ failure (1.5%). Autopsy was performed in 10.4%. Organ donation procedure was performed in 14.5%. Permission for donation was not provided in almost 20% of the population.

Conclusion The mortality rate in polytrauma patients in our institute is considerable and comparable with the international literature. Most patients die because of the effects of the accident (primary trauma). Autopsy and organ donation rates are low in our institution and leave room for substantial improvements in the future. *European Journal of Emergency Medicine* 00:000–000 Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

European Journal of Emergency Medicine 2015, **00**:000–000

Keywords: autopsy, donation, mortality, polytrauma, trauma, TRISS

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Received 4 September 2014 **Accepted** 24 June 2015

Introduction

The pattern of traumatic death is a subject of great interest in the worldwide literature. Most studies have aimed to improve trauma care and raise awareness of avoidable complications [1,2]. Articles addressing causes of death in polytrauma patients show that, in general, central nervous system (CNS) injury continues to be the predominant cause of death after trauma, followed by exsanguination, sepsis, and multiple organ failure (MOF) [1]. Furthermore, CNS injury is also known to be the leading cause of death in polytrauma patients admitted to the ICU [3].

Immediate and early traumatic deaths are predominantly determined by primary CNS injury or exsanguination, whereas late mortality is caused by secondary brain injuries and host defense failure [4].

Despite evidence of considerable public support for organ donation, many countries still report significant refusal rates, that is rates of 26 and 23.6%, in the UK and Spain, respectively [5–7].

Autopsy is a reliable means to detect missed injuries; for physicians, it is a form of feedback on their work. It is also a means to investigate preventable deaths. The outcome of autopsies could aid in setting up new (trauma) protocols and can be of added value in training and education.

Some studies have been published in other European countries [8,9], but little is known about mortality rates in the Dutch trauma system [10]. The aim of this study is to examine the rate and causes of mortality in polytrauma patients in a Dutch level I trauma center. Secondarily, we analyzed predictors of mortality in major trauma and assessed the donation and autopsy rates in these patients.

DOI: 10.1097/MEJ.0000000000000293

Patients and methods

We carried out a retrospective study, assessing all polytrauma patients [defined as: injury severity score (ISS) $\geq$ 16] who were transported directly after the accident by helicopter emergency medical services and road ambulances (emergency medical services) to the VU University medical center, a level I trauma center in Amsterdam, during a period of 6 years (1 July 2004–1 July 2010).

Selection criteria

We included all patients who died during hospitalization. All deaths occurring at the scene of the accident were excluded. The mechanism of injury was divided into two groups: blunt and penetrating trauma. Causes of death were divided into the following groups: CNS injury, exsanguination, respiratory failure, MOF, sepsis, and unknown. CNS injury was defined as injuries to the brain, brain stem, and high cervical spine. Exsanguination was defined as exsanguinating injuries in the chest, abdomen, and extremities. Respiratory insufficiency was defined as airway-breathing injury, airway obstruction, lung contusion, or aspiration pneumonia. MOF was defined as failure in multiple vital organs [11]; single-organ failure was excluded. Sepsis was based on the finding of a septic focus with the presence of at least four of the following five criteria: I, fever above 38.8°C or hypothermia below 35.5°C; II, tachypnea (>24/min) or hypocapnia ($PaCO_2$ < 32 mmHg); III, tachycardia (>100 bpm); IV, leukocytosis (≥15 000/mm^3) or leukopenia (>5000/mm^3); and V, the presence of at least one indicator for inadequate organ perfusion such as mental alterations, hypoxemia ($PaCO_2$ < 75 mmHg while breathing room air), hyperlactatemia (>1.6 mmol/l), diuresis below 30 ml/h, decrease in systolic blood pressure below 100 mmHg [12], or sepsis proven by bacteriologic analysis.

The database included prehospital and in-hospital information on the helicopter emergency medical services [(H)EMS] onscene time, length of hospital stay, mechanism of injury, ISS, Glasgow Coma Scale, Revised Trauma Score (RTS), cause of death, and whether death was caused by a complication or because of primary injury.

Using the Trauma–Injury Severity Score (TRISS) methodology, we predicted the survival rate [13]. Patients were classified on the basis of causes of death, such as CNS injury, and complications while in treatment such as respiratory failure. To identify predictors of mortality, we entered demographic (sex, age) and several prehospital (mechanism of injury, helicopter emergency medical services involvement, RTS, prehospital intubation) and in-hospital (RTS, pH, and base excess) values and intubation in the emergency department (ED), emergency intervention within 6 h, ICU admission, amount of packed cells used within 24 h, Abbreviated Injury Scale (AIS) cranial $\geq$ 4, AIS thoracic $\geq$ 3, AIS abdominal $\geq$ 3, and ISS parameters in stepwise backward logistic regression analyses using a cut-off value of *P* equal to 0.05. Statistical analyses were carried out using SPSS (SPSS 20.0 for windows; SPSS, Chicago, Illinois, USA). Time of death was calculated from the time of the accident until death occurred. The donation procedures were analyzed and documented by tracing back in the medical file as to whether donation was performed. Eligibility for organ donation was determined using the Dutch national criteria for heart beating and non-heart beating donations of the Dutch transplant foundation [14].

For the autopsy analysis, we assessed the autopsy rates, the results, and if permission for autopsy was given by patient's relatives, by researching the medical files of the research population. Autopsies were performed according to the Dutch law on autopsies (*Wet op de lijkbezorging*) and no additional criteria were used in our institution.

According to the Dutch Medical Research Involving Human Subjects Act (WMO), this study was exempted from review by the Medical Research Ethics Committee because of the retrospective and anonymized nature of the study.

Results

Patient and injury characteristics

In total, 1073 polytrauma patients were transported to our center during the study period, of whom 205 (19.1%) died during hospitalization and were further analyzed (Tables 1 and 2). The distribution of major parameters between surviving and deceased patients is shown in Table 3. The median age of the patients who died was 58.8 years and 125 (61%) patients were men. There were 20 pediatric patients in the study (< 18 years) (9.8%). The mean ISS was 30.4. The median length of hospital stay was 2 days (range P25–P75 is 1–6).

The majority of the population sustained blunt injuries (*n* = 192, 93.7%). The predominant mechanisms of injury were falls from height (*n* = 55, 26.8%), followed by bicycle accidents (*n* = 33, 16.1%) (Table 1). The median RTS at arrival in the hospital was 8 (range 0–9.5). Almost half of the population had an indication for an emergency

Table 1 Mechanism of injury

Mechanism of injury	*N* (%)
Fall from height	55 (26.8)
Fall from standing height	25 (12.2)
Pedestrian	24 (11.7)
Bicycle	33 (16.1)
Scooter/motor	22 (10.7)
Car	24 (11.7)
Truck/metro/bus	1 (0.5)
Assault	4 (2.0)
Crushed	3 (1.5)
Gunshot	8 (3.9)
Stab	5 (2.4)
Other	1 (0.5)

Table 2 Characteristics of trauma death ($n=205$)

	N (%)
Cause of death	
Primary cause of death	188 (91.7)
Cause of death because of complication	17 (8.3)
Unknown	2 (1)
CNS	1 (0.5)
Exsanguination	1 (0.5)
Respiratory insufficiency	10 (4.9)
Multiple organ failure	2 (1)
Sepsis	1 (0.5)
Median length of stay in days	2
P25–P75	1–6
Ps (TRISS) (mean)	0.417
Patients with TRISS > 0.5	86

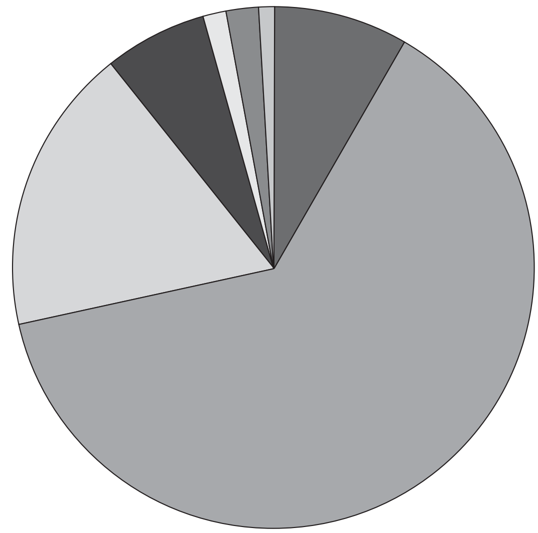
CNS, central nervous system; TRISS, Trauma–Injury Severity Score.

Table 3 Distribution of major parameters between deceased patients and patients who survived

	Deceased ($n=205$)	Survived ($n=868$)	P-value
Male [n (%)]	125 (60.9)	602 (69.3)	0.025
Age (mean)	54	43.6	< 0.001
Length of hospital stay (mean days)	7.49	20.1	< 0.001
Blunt trauma [n (%)]	192 (93.6)	836 (96.3)	0.1
Prehospital intubation [n (z)]	133 (64.9)	153 (17.6)	< 0.001
Emergency intervention [n (%)]	97 (47.3)	309 (35.6)	0.001
ISS (mean)	30.4	23.4	< 0.001
Cranial AIS ≥ 4 [n (%)]	154 (75.1)	549 (63.2)	0.001

AIS, abbreviated injury scale; ISS, injury severity score.

Fig. 1



Causes of death
Unknown
CNS
Exsanguination
Respiratory insufficiency
MOF
Medical file not available
Sepsis

Causes of death, without difference in primary injury or complications. CNS, central nervous system; MOF, multiple organ failure.

intervention ($n=97$, 47.3%) after assessment in the ED (neurological indications in 32.7% of the cases).

Cause of death

More than 91% of the total population died because of the consequences of the primary injury, with CNS injury as a predominant cause of death (63.4%), followed by exsanguination (17.6%). Of these patients, 24% died in the ED. The predominant cause of death because of complications during hospitalization was respiratory failure (4.9%), followed by MOF (1%) (Table 1 and Fig. 1).

Predictors of mortality

Backward stepwise logistic regression analyses of the total population ($n=1073$ survivors and nonsurvivors) (Table 4) yielded 10 independent predictors of mortality after major trauma, specifically female sex, age older than 59 years, a prehospital RTS below 6, prehospital intubation, in-hospital RTS below 6, pH below 7.35, intubation in the ED, amount of packed cells within 24 h above 4, AIS cranial at least 4, and AIS abdominal at least 3.

Time of death

Of the 205 patients, 45.4% ($n=93$) died within 24 h after the accident. The mortality rate after 24 h and before 7 days was 32.6% ($n=67$). Death after 7 days occurred in 45 patients (22.0%) (Fig. 2).

Autopsy

In 21 cases (10.4%), permission for autopsy was provided by the patient's relatives. In 55 cases (27.4%), no permission was provided. In 121 cases (60.5%), it was unclear whether permission was asked. Four autopsy reports were missing. In four cases (2.0%), there was no clinical finding for the cause of death. Nevertheless, autopsy showed myocardial infarction in two patients, aortic rupture in one, and brain hypoxia in another. The clinical cause of death matched the autopsy findings in 12 cases (57.2%). One autopsy report conflicted with the clinical cause of death. Autopsy reported liver failure as a cause of death, whereas the clinical cause of death was CNS injury.

Organ donation

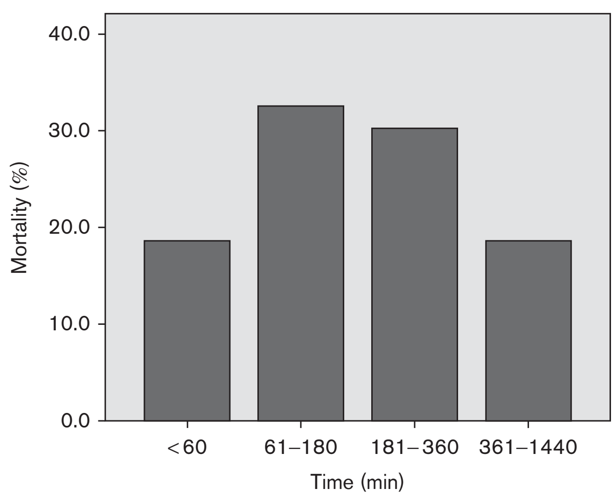
Organ donation was performed in 29 patients (14.5%). In 40 cases, permission for donation was not provided. In 5%, consent for donation was obtained, but the patient was not suitable because of malignancy. In all other cases, it was not clear whether donation was taken into consideration.

Table 4 Predictors of mortality in major trauma

	ß	SE	Wald	OR	Lower	Upper	*P*-value
Demographic parameters							
Female	0.7	0.26	7.5	0.5	0.3	0.8	0.006
Age ≥ 60 years	1.8	0.29	39.5	6.2	3.5	10.9	< 0.001
Prehospital parameters							
Revised Trauma Score < 6	2.6	0.6	18	12.9	3.9	42.1	< 0.001
Prehospital intubation	1.9	0.3	30.1	6.4	3.3	12.6	< 0.001
In-hospital parameters							
Revised Trauma Score < 6	1.3	0.7	3.3	3.5	0.9	14	0.007
pH < 7.35	0.57	0.3	4.6	1.8	1	2.9	0.03
Intubation in the ED	1.3	0.4	11.6	3.6	1.7	7.6	0.001
Amount of packed cells used within 24 h ≥ 5	1.3	0.4	10.3	3.6	1.6	7.8	0.001
AIS cranial ≥ 4	1.4	0.3	19.1	4	2.2	7.6	< 0.001
AIS Abdominal ≥ 3	0.9	0.5	4.6	2.7	1.1	6.7	0.03
Constant	−3.941	0.427	–	–	–	–	< 0.001

AIS, abbreviated injury scale; ED, emergency department; OR, odds ratio.

Fig. 2



Mortality rate in percentages of the first day.

Discussion

Trauma death studies are very important as these serve as a medical audit and a measure for quality of care provided to trauma patients in the prehospital and in-hospital setting [8]. These studies are also a useful tool to revise, renew, and improve assessment and therapeutic methods in early trauma care. For example, it has been shown during the last decade that overall mortality because of exsanguination has decreased as trauma death studies are performed. These improvements are because of improvements in hemorrhage management, developments in the availability of multislice computed tomography, widespread implementation of advanced trauma life support (ATLS) concepts, and improved logistics of emergency rescue [1].

The mortality rate after polytrauma in our institute is relatively low and comparable with the European literature [8,9,15,16]. An explanation for this could be that the quality of early trauma care in the Netherlands is high. This is because of the designation of trauma centers, short prehospital times, and the advanced medical care at the scene of the accident [i.e. (H)EMS, highly trained paramedic staff].

After revision of the literature, we conclude that the mortality rate is similar to that in other European countries. This can be explained by the comparable patient and injury characteristics, such as ISS (mean ISS in this study 30.4; literature range: 25–38) [8,9,15,16].

A major finding in this study was that the majority of the patients (91.7%) died because of the consequences of primary trauma and not because of complications during hospitalization. The mortality rate because of complications is very low (8.3%). This can be a result of many improvements in trauma and intensive care during the past decades. Furthermore, considerable attention has been paid to prehospital triage in the Netherlands. Within minutes, advanced medical care arrives at the scene of the accident and the patient is directly transported to the nearest trauma center for appropriate care. Interhospital transfers occur occasionally. Therefore, no valuable time is wasted and the patient arrives most times within the 'Golden Hour' in the hospital [17]. In the hospital, all trauma patients are assessed according to the ATLS guidelines [18]. A recent study in our center showed that the missed injury rate in trauma patients is low: 8.2% of all patients [19]. This is crucial as missed injuries can cause complications, longer hospital stay, and even mortality. Improvements in diagnostics for trauma patients, such as early computed tomography scanning, play a key role in the correct detection of traumatic injuries [20].

The predominant cause of death in our study was CNS injury (63.4%), followed by exsanguination (17.6%). The predominant cause of death because of complications was respiratory failure (6.3%), followed by MOF (1.5%). When comparing this with the European literature, a similar pattern can be observed, with CNS injury ranging from 21.6 to 71.5%, exsanguination ranging from 10.0 to

26.6%, and MOF ranging from 1.6 to 9%, respectively [8,15,16].

The TRISS methodology offers a standard approach for evaluation of the outcome of trauma care. Anatomic, physiologic, and age characteristics are used to quantify the probability of survival as related to severity of injury [13]. In our study, the expected survival rate of all trauma patients was 78.8%. However, within the study population, there was an observed survival of 80.9%, showing that the actual survival was higher than expected. Thus, 42% of the patients who eventually died had a predicted survival rate of higher than 50%. We believe that the differences between predicted and observed survival rates are the effect of differences in the timing that the TRISS is being measured. In this study, we used the first measured on-scene parameters. In the Netherlands, and especially in the region of Amsterdam, the (H)EMS arrival times are relatively short. Because of this, patients who were initially stable showed a high probability of survival.

A common mechanism of injury was bicycle accidents (16.1%). This may be because bicycles are a very common mode of transportation in Amsterdam. Remarkably, most of these patients sustained CNS injury (87.9%).

Distribution of time to death

The classical trimodal distribution of trauma deaths was described by Trunkey in 1983. This distribution was based on the time interval from injury to death. It shows three peaks of 'immediate deaths', 'early deaths', and 'late deaths' [2].

Comparing this with the percentages in our study, we note that this model fits our results, but with a shift in timeline. For instance, in our study, we observed a first peak with 45.4% of the patients dying the first day. Almost 33% die during the time interval of 2–7 days and the final group consists of 22% of the patients who died more than 1 week after trauma. In our study, we do not observe a peak in the first hour (18.6%), but in the time interval of 1–3 h after trauma (32.6%). This can be explained by the short (H)EMS arrival times (within 15 min after the call on-scene). Therefore, the patients who used to be in the group of 'immediate death' have a delay because of the hospital care and they eventually die in our 'new peak' of 1–3 h.

Our study population predominantly had blunt injuries (93.7%). If our case-mix consisted more of (penetrating) injuries, mortality rates could have been higher.

Autopsy

Autopsy is a sensitive issue. Families often do not provide permission. In our study, we observed an explicit refusal of autopsy in 27.4% of the cases. Only in 10.4% of cases did relatives provide permission for autopsy. In 62.2% of the cases, we could not trace back in the medical files whether the physician had asked the relatives' permission for autopsy.

Organ donation

Despite attempts to increase awareness of the importance of organ donation [21], donation rates remain low. Our study shows that in only 14.5% of the cases the relatives provided permission or the deceased individual was a registered organ donor. In 20% of the cases, organ donation was refused and 5% did not fulfill the donation criteria. In 60.5% of the cases, it was unclear whether the physician had asked for permission and organ donation was not performed.

Several studies have examined the reasons why relatives of potential donors refuse consent for organ donation, showing different factors relating to the relative's approach [5–7]. These include ensuring the right timing to approach relatives, an appropriate setting, and providing specific information, particularly on the definition of brain death [22,23].

This study has several limitations. Mainly, this was a retrospective study. Consequently, the data are subject to the limitations of a retrospective review, including missing data and possible data entry errors. Furthermore, some data points may be subject to recall bias, such as the time of injury and the categorization of causes of mortality. There is also a selection bias of unknown deaths at the scene of the accident, which could yield a different mortality rate. Even though some data were missing, the data presented are credible and were obtained either from reports of the prehospital or in-hospital providers. Also, every mortality cause was categorized clearly.

Future recommendations

For future studies investigating trauma deaths, we suggest continued attention for autopsy and organ donations as important performance indicators for trauma care.

Conclusion

After evaluation of the European literature, we conclude that the mortality rate in our institute is comparable with that in other countries. CNS injury is the leading cause of death, followed by exsanguination. The predominant cause of death because of complications is respiratory failure, followed by MOF. A similar pattern is observed in other studies. The temporal analysis of traumatic death indicates a time shift from the classic trimodal distribution to a new bimodal one, with the peak not in the first hour, but at a time interval of 1–3 h. This study found several parameters that can predict early mortality after major trauma.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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