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Mortality after acute trauma: Progressive decreasing rather than a trimodal distribution

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ABSTRACT

Objective: To characterize the pattern of mortality for major trauma patients.

Methods: Retrospective study of major trauma patients admitted in a Level I trauma center, during the latest 5 years was conducted. Selection criteria included (1) injury severity score (ISS) > 16 and (2) in-hospital death.

Results: There were 47 patients, with a mean age of 37.2 ± 19.9 years. The mean ISS was 37.6 ± 12.7 and the mean revised trauma score was 4.5 ± 2.2 . Computed tomography scan on admission was done in 18 (38%) patients, 20% being hemodynamically unstable ($P = 0.001$). The diagnostic peritoneal lavage was performed in 10 (22%) cases, 23.3% being hemodynamically unstable ($P > 0.05$). The mean number of intraabdominal injuries was 3. The need for transfusion was 8.2 ± 6.7 units. The mean time to death was 4.9 days. Early death was secondary to hemorrhagic shock (HS) (ISS = 35.2 ± 15.9 , $P > 0.05$, revised trauma score = 3.74 ± 2.70 , $P = 0.008$) and multiple organ failure (ISS = 36.6 ± 14.1 , $P > 0.05$, revised trauma score = 5.94 ± 1.34 , $P = 0.008$) was the cause for later mortality. Combined liver and splenic injuries were found in 13 cases, with secondary death through HS in 5 and multiple system organ failure (MSOF) in 8 cases. Combined liver, splenic and kidney injuries were found in 5 cases (cause of death: HS 2 cases, MSOF 3 cases). A total of 14 patients had associated head, thorax, abdomen and extremity trauma (cause of death: cerebral trauma 6 cases, MSOF 5 cases, HS 2 cases); 5 patients had thorax and abdomen trauma (cause of death: HS 5 cases); 8 patients had thorax, abdomen and extremity trauma (cause of death: MSOF 5 cases, HS 3 cases); 3 patients had abdomen and extremity trauma (HS 2 cases). We did not find a trimodal time distribution for mortality.

Conclusions: The trimodal time distribution of mortality remains a milestone in trauma education and research. Nevertheless, it must be questioned in the modern and very efficient trauma systems, but still very actual for developing trauma care systems. In conclusion, the pattern of mortality due to major trauma seems decreasing continuously with time rather than presenting high peaks of frequency at some moments.

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1. Introduction

In 2020 it is expected as 8.4 million of deaths per year secondary to trauma^[1]. The organization of the modern trauma systems is based on the trimodal distribution of mortality, proposed by Donald Trunkey in 1983^[2]. This concept is very useful for educational purposes, but inconsistent with the more recent evidence^[3-5]. According to this trimodal pattern, there are three peaks of mortality secondary to trauma. The first peak is immediately after traumatic injury, the second one is during the first hour of the posttraumatic period. This generated the concept of “golden hour”. These deaths are caused by major cardiovascular injuries, severe abdominal lesions, or pelvic fractures with subsequent exsanguination or by major intracranial bleeding^[6]. Nowadays complex approach for the trauma patients, with highly organized prehospital and in-hospital care, may decrease the morbidity and mortality, in the very early period after trauma^[7]. The third peak of mortality occurs during the second week, with the development of sepsis and multiple organ failure^[6,8]. The main objective of this study is to correlate the timing and cause of mortality in major trauma patients. The secondary objective is to compare our pattern of mortality with the trimodal pattern.

2. Materials and methods

Retrospective study of major trauma patients admitted in a Level I trauma center, during the latest 5 years was conducted. Selection criteria included (1) injury severity score (ISS) > 16 and (2) in-hospital death^[9]. We collected the following data: demographics, physiological conditions, imagistic and intraoperative findings, Intensive Care Unit data, fluid and blood resuscitation, in-hospital course, time of death. Categorical variables were compared by the *Chi*-square test or Fisher exact test and continuous variables by the Mann–Whitney *U* test, independent samples *t* tests or One-way ANOVA. A level of *P* < 0.05 was used to declare statistical significance. For statistical analysis we used IBM SPSS Statistics 20 software.

3. Results

There were 47 patients included in this study, 17% were female and 83% male patients, with a mean age of 37.2 ± 19.9 years (Figure 1).

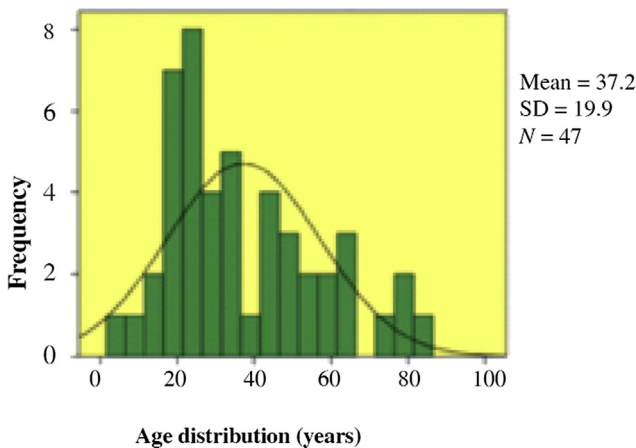


Figure 1. Age distribution of patients.

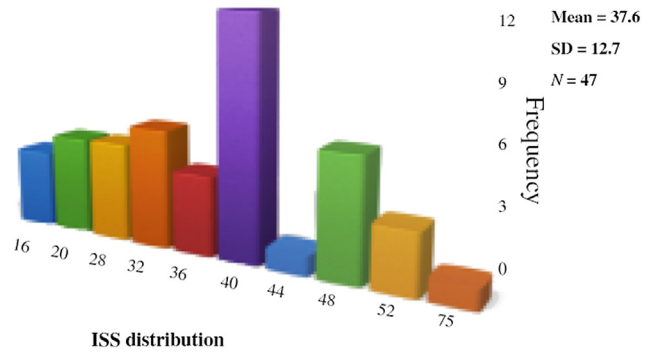


Figure 2. ISS distribution of the patients.

The trauma etiology was related to traffic (68.3%), falls (22%), human aggression (4.9%) and other causes (4.9%). The mean ISS was 37.6 ± 12.7 (Figure 2) and the mean revised trauma score (RTS) was 4.5 ± 2.2 (Figure 3).

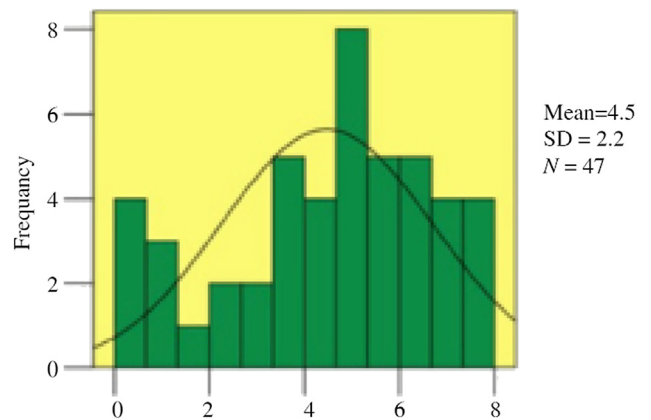


Figure 3. RTS distribution of the patients.

Computed tomography scan on admission was done in 18 (38%) patients, 20% being hemodynamically unstable (*P* = 0.001). The diagnostic peritoneal lavage was performed in 10 (22%) cases, 23.3% being hemodynamically unstable (*P* > 0.05). The mean number of intraabdominal injuries was 3 (Figure 4). The need for transfusion was 8.2 ± 6.7 units (Figure 5).

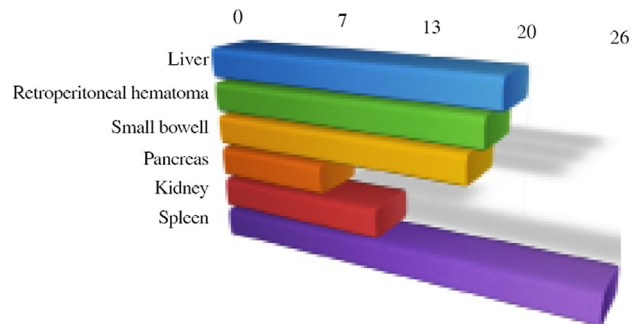


Figure 4. Intraabdominal injuries of the patients.

The mean time to death was 4.9 days. Early death was secondary to hemorrhagic shock (HS) (ISS = 35.2 ± 15.9, *P* > 0.05, RTS = 3.74 ± 2.70, *P* = 0.008) and multiple organ failure (ISS = 36.6 ± 14.1, *P* > 0.05, RTS = 5.94 ± 1.34, *P* = 0.008) was the cause for later mortality (Figure 6).

Combined liver and splenic injuries were found in 13 cases, with secondary death through HS in 5 and multiple system organ failure (MSOF) in 8 cases. Combined liver, splenic and kidney

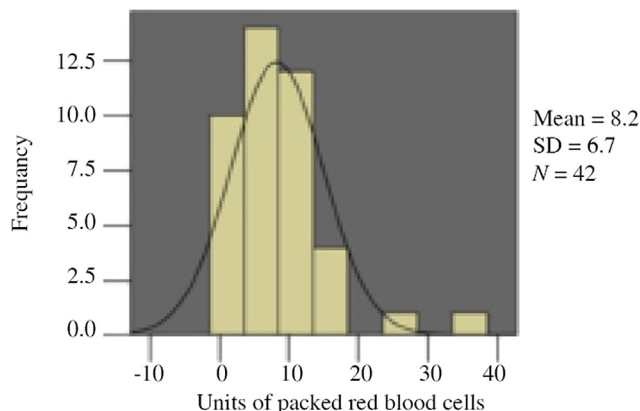


Figure 5. Number of units of packed red blood cells transfused to the patients.

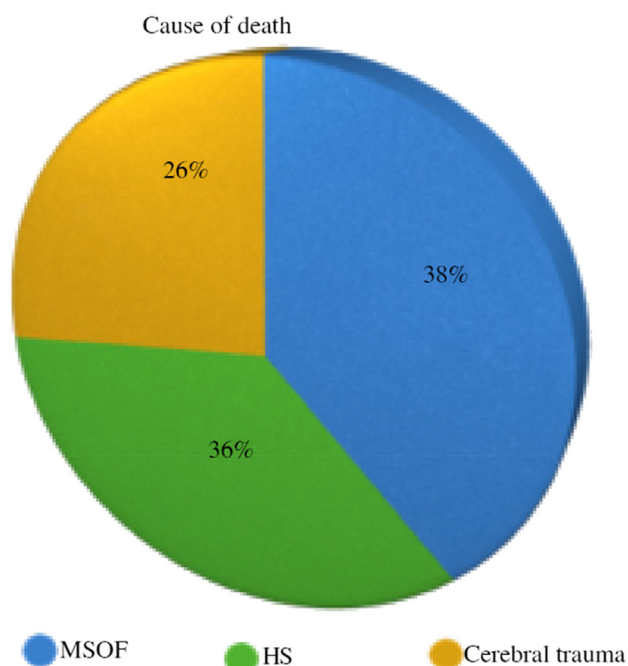


Figure 6. Cause of death for trauma patients.

injuries were seen in 5 cases (cause of death: HS 2 cases, MSOF 3 cases). A total of 14 patients had associated head, thorax, abdomen, extremity trauma (cause of death: cerebral trauma 6 cases, MSOF 5 cases, HS 2 cases); 5 patients with thorax and abdomen trauma (cause of death: HS 5 cases); 8 patients with thorax, abdomen and extremity trauma (cause of death: MSOF 5

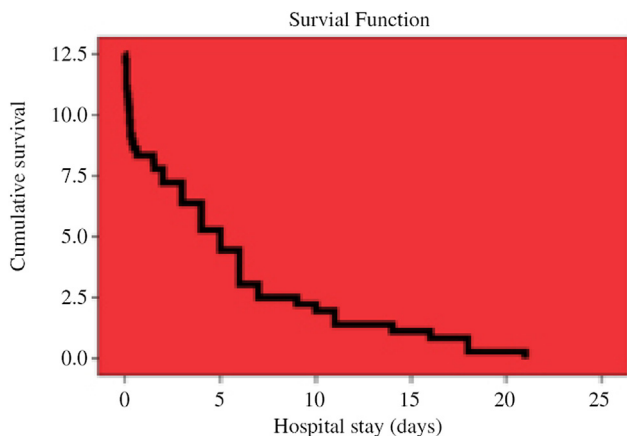


Figure 7. Time of death for trauma patients.

cases, HS 3 cases); 3 patients with abdomen and extremity trauma (HS 2 cases). We did not find a trimodal time distribution for mortality (Figures 7 and 8).

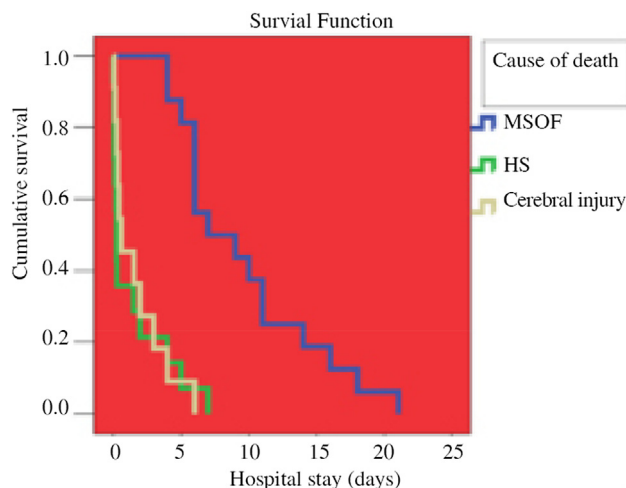


Figure 8. Time of death according to its determining cause.

4. Discussion

Gunst *et al.* showed that half of the trauma deaths occur within 30 days, while the remaining 50% occur over a period of 1 year^[10]; 61% are immediate (on scene), 29% early (in hospital, 4 h) and 10% late deaths (>4 h)^[10]. A systematic review analyzing the influence of prehospital time on patients outcome concluded that rapid transportation is beneficial for neurotrauma injuries and for hemodynamically unstable penetrating lesions^[11]. For the other undifferentiated trauma patients, hemodynamically stable, increased on-scene time and total prehospital time do not increase mortality^[11]. A study of the National Trauma Data Bank, investigated mortality in 15 109 patients with a laparotomy in the night time versus day time^[12]. The authors found no difference in the risk-adjusted mortality rate between the two groups^[12]. Strnad *et al.* compared 40 survivors with 30 non-survivors^[13]. ISS, glasgow coma scale (GCS) and age were found to be independent predictors of in-hospital mortality. A lactate level of 3.4 mmol/L or more was 82% sensitive and 75% specific for predicting death during hospitalization, indicating a more severe hypoperfusion^[13]. Dutton *et al.* analyzed the impact of lower limb fractures on mortality and concluded that these are not a determinant factor for sepsis and do not contribute to mortality^[14].

Dutton *et al.* analyzed the pattern of mortality over a 12 year interval, between 1997 and 2008^[15]. While overall mortality slightly worsened, ranging between 3% and 3.7% ($P = 0.04$), for patients with an ISS of 17–25, there was a significant improvement ($P = 0.0003$). Traumatic brain injury (TBI) accounted for 51.6% of deaths, acute hemorrhage for 30% and MSOF for 10.5%. Median time to death was 2 h for acute hemorrhage, 24 h for TBI and 15 days for MSOF, and this pattern did not change over time. The conclusion of the authors is that recent advances in trauma care have balanced the aging population and greater severity of injury, without overall improvement of survival^[15]. We had an overall mean time to death of 4.9 days.

An analysis of 753 deaths from a Level I trauma center concluded that a theoretical dramatic improvement of therapy (no errors, cure of the multiple organ failure, sepsis and pulmonary embolism) in a modern trauma system would decrease the mortality by 13%^[16]. In contrast more than half of all deaths are preventable by pre-injury behavioral changes. In this study, the mean GCS was 5, mean RTS was 4, mean ISS was 41, and mean probability of survival was 0.25. About 52% of patients died within 12 h, 75% died within 48 h, and 86% died within 7 days. The cause of death was TBI in 51%, irreversible shock in 21%, combined TBI and shock in 9%, and MSOF in 3% of cases^[16]. We had a mean ISS of 37.6 and a mean RTS of 4.5. We observed that the cause of death consisted of MSOF in 38% of cases, hemorrhagic shock in 36%, and TBI in 26% of cases. We may observe a very high rate for late mortality, suggesting that a more aggressive evaluation process and audit may decrease our mortality. The recent evidence showed that management of severely injured patients with an associated head injury in the absence of an organized trauma system increases the risk-adjusted mortality^[17]. Gabbe *et al.* compared 4 064 major trauma from Victoria State Trauma Registry (Australia) with 6 024 cases from Trauma Audit and Research Network (United Kingdom)^[17]. After adjusting for age, gender, cause of trauma, head injury severity, GCS, and ISS, Trauma Audit and Research Network cases had an odds of death of 3.22 compared to Victoria State Trauma Registry^[17]. Another analysis of the Victoria State Trauma Registry found quality indicators associated with mortality: abdominal surgery after 24 h from admission, blunt compound tibial fracture treatment after 8 h, and non-fixation of femoral diaphyseal fracture^[18,19].

An analysis of 30-day mortality of injured patients from Karolinska Institute, showed 10.5% of deaths not related to the trauma. The median age was 71 years, ISS was 29 and time to death was 24 h^[20]. TBI accounted for 58.6% of death, hemorrhage for 16.3%, organ dysfunction for 15% and other causes for 10.1%^[20]. A 15-year analysis of outcomes from a Level I trauma center from Italy revealed 17.2% overall mortality^[21]. TBI were the cause of death in 58.4%, hemorrhagic shock in 28.4% and multiple organ failure/sepsis in 13.2%. During the study period a reduction for TBI and an increase for multiple organ failure were observed^[21]. Trajano *et al.* evaluated the epidemiology of trauma deaths in a Brazilian university hospital^[22]. Out of 467 cases, 30.4% were classified as death on arrival. Mean age was 35.3 years, 73% being blunt trauma. About 60% of deaths occurred within less than 24 h. TBI was the cause of death in 56.3%, hemorrhage in 18.1% and multiple organ failure in 17.1% of cases. Mean ISS for patients with signs of life was 26.4 ± 9.0 ; mean RTS was 5.24 ± 2.05 , and only 25.8% had a probability of survival less than 0.5^[22]. Leow *et al.* analyzed the effect of race and ethnicity on trauma mortality in patients with an ISS of 9 in a study coming from a 1 300-bed trauma center, from Singapore^[23]. Out of 4 186 patients, there were 76.3% male with a mean age of 40 years. They found independent predictors of mortality as age (OR = 1.05), severe head injury (OR = 1.75), and increased ISS. The authors found no increased risk for mortality in Malay or Indian patients compared with Chinese people, in contrast to USA, where black and hispanic are at increased risk^[23]. An analysis of 268 deaths from Korea found a mean age of 35.2 years, 90.8% being blunt trauma^[24]. Independent predictors of mortality were age over 55 years,

ISS 16, major cerebral trauma, cardiopulmonary resuscitation on arrival and a probability of survival according to trauma and injury severity score less than 25%^[24]. An evaluation of the trauma mortality supports that traumatic brain injuries and hemorrhage, as causes of deaths, remain constant over time, while late mortality secondary to MSOF and sepsis significantly decreased^[25].

The trimodal time distribution of mortality remains a milestone in trauma education and research. Nevertheless, it must be questioned in the modern and very efficient trauma systems, but still very actual for developing trauma care systems. In conclusion, the pattern of mortality due to major trauma seems decreasing continuously with time rather than presenting high peaks of frequency at some moments.

Conflict of interest statement

The authors report no conflict of interest.

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