Observational Study

Time distribution of injury-related in-hospital mortality in a trauma referral center in South of Iran (2010–2015)

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Abstract
In Iran, there are no studies addressing trauma death timing and factors affecting time of death after injuries. This study aimed to examine time distribution of trauma deaths in an urban major trauma referral center with respect to victims’ injury characteristics during 2010 to 2015. This was a cross-sectional study of adult trauma-related in-hospital deaths resulting from traffic-related accidents, falls, and violence-related injuries. Information on injury characteristics and time interval between admission and death was extracted from 3 hospital databases. Mortality time distribution was analyzed separately in the context of each baseline variable.

A total of 1117 in-hospital deaths (mean age 47.6±22.2 years, 80% male) were studied. Deaths timing followed an extremely positive skewed bimodal distribution with 1 peak during the first 24 hours of admission (41.6% of deaths) and another peak starting from the 7th day of hospitalization to the end of first month (27.7% of total). Subjects older than 65 years were more likely to die after 24 hours compared to younger deceased (P=.031). More than 70% of firearm-related deaths and 48% of assault-related mortalities occurred early, whereas 67% and 66% of deaths from falls and motorcycle accidents occurred late (P<.001). Over 57% of deaths from severe thoracic injuries occurred early, whereas this value was only 37% for central nervous system injuries (P<.001). From 2010 to 2015, percentage of late deaths decreased significantly from 68% to 54% (P<.001).

Considering 1 prehospital peak of mortality and 2 in-hospital peaks, mortality time distribution follows the old trimodal pattern in Shiraz. This distribution is affected by victims’ age, injury mechanism, and injured body area. Although such distribution reflects a relatively lower quality of care comparing to mature trauma systems, a change toward expected bimodal pattern has started.

Abbreviations: AIS-2005 = abbreviated injury score, CNS = central nervous system, ICD = international classification disease, ISS = injury severity score, IQR = interquartile range, SPSS = statistical package for social science, SUMS = Shiraz university of medical sciences, TRISS = trauma and injury severity score.

Keywords: injury severity score, mortality, statistical distribution, trauma, wounds and injuries

1. Introduction

Approximately 90% of global injury-related deaths occur in low- and middle-income countries, which places a large burden on developing countries, which lack trauma care resources.[1] Among the middle-income developing countries, Iran has experienced the transition from the dominance of communicable diseases to that of noncommunicable diseases and specifically injuries.[2] More than 15% of the mortalities occurring in Iran were because of injuries in 2001.[3] Data on overall injury-related mortality in Iran are limited, although a mortality rate of 31 per 100,000 for road traffic injuries alone is indicative of the extent this public health issue.[4]

Among important factors affecting trauma mortality, the time interval from injury to death has attracted much attention in the modern world of trauma epidemiology. The idea was introduced to nonmilitary trauma literature in 1980s by Trunkey et al.[5] who proposed a trimodal distribution of trauma deaths including immediate (within 1–2 hours of injury), early (up to 4 hours after injury), and late deaths (days to weeks after injury). Of these 3 groups, early and late deaths could potentially be prevented by optimizing postinjury management, whereas immediate deaths may be reduced by improving preventive strategies. During the recent 3 decades, an increasing number of studies have focused on trauma death timing and many have reported a changing pattern over time resulting from improvements in posttrauma care.[6-7]

Considering a relatively high burden of injuries in Iran, knowledge of mortality time distribution is important in
allocation of trauma care resources. This necessitates an ongoing research focus on injuries in Iran with persistent need for injury prevention and control. In Fars, there are a limited number of studies addressing the time distribution of mortality resulting from trauma. These studies have mainly focused on road traffic accidents and the main source of information was the Iranian forensic medicine organization.8–10 The proportion of victims dying in the first day of injury varied from 60% to 75% in Fars studies based on the injury mechanism. Nonetheless, timing of fatalities resulting from all-cause injuries has never been studied in Fars.

As a considerable proportion of trauma deaths occur after hospital admission, a hospital-based view of these deaths would provide invaluable information in devising preventive strategies. To address the limitations of previous research in Fars, this study aims to examine the time distribution of trauma deaths in an urban major trauma referral center with respect to victims’ age, sex, injury mechanism, injury severity, and injured body region among victims of injury who deceased after hospital admission during the years 2010 to 2015.

2. Methods

This cross-sectional study of mortality time distribution was carried out at trauma research center affiliated to Shiraz University of Medical Sciences (SUMS). We aimed to assess the timing of death among patients who referred to Shahid Rajaei (Emtiaz) hospital during the years 2010 to 2015 with respect to age, sex, injury mechanism, injury severity, injured body regions, and development of a nosocomial infection. Data from 3 hospital administrative databases were used: the admission unit database, the medical records unit database, and the nosocomial infection surveillance database.

2.1. Study population and sample size

Shahid Rajaei trauma hospital is the largest referral center for adult trauma patients in Shiraz. As individuals who are deceased at the scene are transferred directly to a mortuary in Shiraz, the hospital administrative databases only included those deaths occurring after hospital admission. The study population was constructed based on enumeration of all in-hospital fatalities occurring from January 1st, 2010 to December 30th, 2015 at emergency departments or other hospital wards. Inclusion criteria were: all adult (age ≥ 15 years) injury-related deaths resulting from traffic-related incidents (car, motorcycle, and pedestrian accidents), falls, violence-related incidents, firearm-related injuries, and those who were struck by/against objects. Fatalities occurring following burns, corrosion injuries, poisonings and environmental exposures were excluded. Finally, a total number of 1117 deceased individuals were studied.

2.2. Measurements and data collection

After a patient was screened and admitted, a unique 8-digit code entitled “serial number” is generated and then all baseline information and demographics including age, sex, admission date and time, and cause of injury was electronically recorded by the admission staff 24/7 (24 hours a day/7 days a week). After a patient was discharged, hard copy records were transferred to the medical archive record unit where trained file-keeping staff extracted information on the cause of injuries, diagnosis, and final result. Next, all the information was coded using International Classification of Disease (ICD)-10 coding system and entered to an electronic database. Information on nosocomial infectious complications is recorded separately in a data bank during the hospitalization. Using the above-mentioned Serial Code, all records of these 3 databases were merged resulting in a total of 75,950 records during 2010 to 2015 (Georgian calendar) of whom 1117 deceased individuals were eligible for analysis.

Injury severity score (ISS) was calculated by means of a newly developed algorithm based on converting each ICD-10 rubric to its relevant Abbreviated Injury Scale-2005 (AIS-2005) score where possible. To calculate an ISS, highest AIS severity code in each of the 3 most severely injured ISS body regions recognized, each AIS code was squared and the 3 squared numbers were added to produce the ISS (ISS = A2+B2 + C2, where A, B, C are the AIS scores of the 3 most sever injured ISS body regions).[11,12]

The algorithm was developed using the Microsoft Excel program text functions, which entailed transforming text strings into numbers. In the ICD-10 lexicon, each injury is described by a code ranging from S.00 to T77.90 and relative description. We excluded the ICD-10 diagnostic codes related to foreign bodies (T15-T19), burns and corrosion injuries (T20-T32), poisonings (T36-T65), and environmental exposures (T33-T35, T66–T78). Patients were considered to have hospital-acquired infections, if ≥ 1 positive cultures were obtained from blood, respiratory secretions, urinary system, surgical incision site, or cerebrospinal fluid and nosocomial infection team of the hospital labeled them as hospital-acquired infections. Individuals who deceased within 48 hours with a positive culture were not assessed to have a hospital-acquired infection.

2.3. Statistical analysis

The time interval between hospital admission and death was considered as the outcome variable measured on a 1-day scale unit calculated by subtracting death date from the admission date for each individual. Time interval was then divided into 2 categories (deaths within 24 hours [early] and deaths beyond this period [late]). The baseline variables of interest were patients’ demographics, injury characteristic, and infectious complications of medical care. Mortality time distribution was analyzed separately in the context of each baseline variable. To examine possible effect of hospital-acquired infections on mortality timing, individuals who died within 48 hours of admission were excluded as nosocomial infections were not assumed to have affected these deaths (n = 527). Thereafter, interval between admission and death was stratified into 2 categories (3–7 days, beyond 7 days). According to previous studies,[13,11] the cutoff point of 25 was mentioned as critical point of injuries and ISS was classified into 2 categories (ISS ≥ 25, ISS < 25). A null hypothesis of similar mortality timing for patients with and without infections was tested using a χ² test. All inferential statistical tests were conducted using the SPSS software (Statistical Package for Social Sciences, Version 18, SPSS Inc, Chicago, IL). Normality was checked using the 1-sample Kolmogorov-Smirnov test for continuous variables. Summary statistics were median and interquartile in case of non-normally distributed continuous variables. Categorical data were summarized using frequencies and proportions. As mortality timing is a continuous variable with extremely positive skewed distribution, nonparametric tests including χ² were used. A 2-sided P value of .05 was considered statistically significant.
### Table 1
Demographics and injury characteristics of the deceased patients.

| Variable                        | n (%)          |
|---------------------------------|----------------|
| Age, y                          |                |
| 15–44                           | 539 (48.3)     |
| 45–64                           | 256 (22.9)     |
| ≥65                             | 322 (28.8)     |
| Sex                             |                |
| Female                          | 226 (20.2)     |
| Male                            | 891 (79.8)     |
| Injury mechanism                 |                |
| Car accident                     | 497 (44.5)     |
| Motorcycle accident              | 222 (19.3)     |
| Pedestrian accident              | 167 (15.0)     |
| Fall                            | 165 (14.8)     |
| Assault                         | 25 (2.2)       |
| Stabbing by objects              | 23 (2.1)       |
| Firearm injury                   | 14 (1.3)       |
| Others                          | 4 (0.4)        |
| Injured body region              |                |
| Head and neck                   | 716 (64.1)     |
| Spinal cord and vertebral column| 63 (5.6)       |
| Thorax                          | 68 (6.1)       |
| Abdomen, lower back and pelvis  | 81 (7.3)       |
| Extremities                     | 126 (11.5)     |
| Multiple body regions            | 61 (5.5)       |
| Injury Severity Score (n=803)    |                |
| ISS < 24                        | 705 (87.8)     |
| ISS ≥ 25                        | 98 (12.2)      |
| Hospital-acquired infection      |                |
| No                              | 1021 (91.4%)   |
| Yes                             | 96 (8.6%)      |

### 3. Results

A total number of 1117 deceased cases were studied of whom 891 (79.8%) were male and the remaining 226 (20.2%) were female. There were 96 deaths (8.8%) complicated by hospital-acquired infections. Table 1 summarizes demographics and injury characteristics of the studied population. There were 465 cases of early death (41.6%, within 24 hours) and 652 cases of late death (58.4%, beyond 24 hours). In this population, the interval between admission and death followed an extremely positive skewed distribution (median 3 days, IQR [1–12 days]) (Figs. 1 and 2). Two peaks were observed, one of which occurred during the first 24 hours of admission (41.6%) and another rise was evident starting from the 7th day of hospitalization to the end of first month (27.7% of total).

From the year 2010 to 2015, percentage of late deaths decreased significantly from 68.3% to 53.8% (Fig. 3). Mortality time distribution was independent of sex. Individuals who were older than 65 years at the time of death were more likely to die after 24 hours comparing to younger deceased. Temporal mortality distribution was significantly related to injury mechanism. More than 71% of firearm-related deaths and 48% of assault related mortalities occurred early, whereas 67% and 66% of deaths from falls and motorcycle accidents occurred late. On a general perspective, violence-related deaths were early, whereas unintentional and traffic-related deaths were late. Death timing was also related to injured body region as 87% of mortalities resulting from multiple trauma and 37.5% of deaths from severe thoracic injuries occurred early. However, deaths from central nervous system (CNS) and extremity injuries were more likely to occur late. Regarding injury severity, death timing was similar for...
the critically injured (ISS ≥ 25) comparing to those without critical trauma (ISS < 25) (Table 2).

There were 590 deaths occurring after 48 hours of admission of which 96 (16.3%) were complicated by nosocomial infections (Table 3). In this subset of patients, death following a nosocomial infection was 15 times more likely to happen after 1 week of hospitalization (odds ratio = 15.0, 95% confidence interval [4.6–48.0], \( P < .001 \)).

### 4. Discussion

To the best of our knowledge, this study is the first of its kind addressing the mortality time distribution for various injury mechanisms in the largest trauma center in Fars. As this hospital is a major referral center for adult trauma in Shiraz, we estimate that mortalities recorded in our databases would satisfactorily represent traumatic deaths from road traffic accidents, unintentional injuries, falls, and violence in Shiraz. Our findings are in favor of a bimodal mortality timing based on hospital administrative data. From previous reports, we know that >50% of deaths occur at the scene (immediate) in Fars\(^{48–10}\) and such mortalities are never recorded in hospital databases. Therefore, the true mortality time distribution in our region logically follows the classic trimodal pattern, 1 peak before reaching hospital, another peak in early hours of admission and the third, beyond 24 hours of admission (mostly after the first week). Herein, we emphasized the third peak explained by a considerable proportion of traumatic deaths occurring beyond the first 24 hours (38.4%).

Although a higher percentage of female mortalities were early comparing to male fatalities, this difference did not reach statistical significance. Therefore, mortality timing is not assumed to be affected by victim’s sex. Almost half of deaths were in the 15- to 44-year age group, representing a significant amount of active work force lost because of injuries. In accordance with other studies\(^{14,15}\), victims’ age significantly affected the timing of trauma death, that is, mortalities of the elderly were more likely to occur late in hospital. One solution to successfully reduce the proportion of late deaths as an important representative of trauma care would be to implement principals of geriatric trauma care more actively in trauma centers of the region.

### Table 2

**Mortality time distribution by injury characteristics and severity.**

| Variable                        | Death timing | \( P^* \) |
|---------------------------------|--------------|-----------|
|                                | Within 24 h, n (%) | Beyond 24 h, n (%) | Total |
| **Age, y**                      |              |           |       |
| 15–44                           | 219 (40.6)   | 320 (59.4) | 539 (100.0) |
| 45–64                           | 124 (48.4)   | 132 (51.6) | 256 (100.0) |
| ≥65                             | 122 (37.9)   | 200 (62.1) | 322 (100.0) |
| **Sex**                         |              |           |       |
| Female                          | 98 (43.4)    | 128 (66.6) | 226 (100.0) |
| Male                            | 367 (41.2)   | 524 (58.8) | 891 (100.0) |
| **Injury mechanism**            |              |           |       |
| Car accident                    | 233 (46.9)   | 264 (53.1) | 497 (100.0) |
| Motorcycle accident             | 76 (34.2)    | 146 (65.8) | 222 (100.0) |
| Fall                            | 54 (32.7)    | 111 (67.3) | 165 (100.0) |
| Assault                         | 12 (48.0)    | 13 (52.0)  | 25 (100.0)  |
| Pedestrian accident             | 67 (40.1)    | 100 (59.9) | 167 (100.0) |
| Struck by/against objects       | 10 (43.5)    | 13 (56.5)  | 23 (100.0)  |
| Firearm injury                  | 10 (71.4)    | 4 (28.6)   | 14 (100.0)  |
| **Injured body region**         |              |           |       |
| Head and neck                   | 268 (37.4)   | 448 (62.6) | 716 (100.0) |
| Spinal cord and vertebral column| 21 (33.3)    | 42 (66.7)  | 63 (100.0)  |
| Thorax                          | 39 (57.4)    | 29 (42.6)  | 68 (100.0)  |
| Abdomen, lower back, and pelvis | 41 (50.6)    | 40 (49.4)  | 81 (100.0)  |
| Extremities                     | 43 (33.6)    | 85 (66.4)  | 128 (100.0) |
| Multiple Body region            | 53 (86.9)    | 8 (13.1)   | 61 (100.0)  |
| **ISS**                         |              |           |       |
| ISS < 25                        | 227 (32.2)   | 478 (67.8) | 705 (100.0) |
| ISS ≥ 25                        | 25 (25.5)    | 73 (74.5)  | 98 (100.0)  |

\* All \( P \) values are 2-tailed asymptotic significance levels of \( \chi^2 \) test.
The nature of mortality time distribution may be regarded as an index of quality of care following trauma. The acceptability of classic trimodal distribution has been questioned in developed nations along with high-income neighboring countries. [15, 16] This has been achieved through successfully reducing late trauma deaths to <9% in the light of advanced trauma care. [17, 18] Although this value was up to 58.4% in our study. Multiple studies have outlined the potential causes of late trauma death, which are namely septic complications and multiple organ failure. [19] We could not exactly investigate the cause of death by autopsy reports in our center, although we observed that 96.9% of deaths complicated by hospital-acquired infections occurred after 1 week of hospitalization. This finding signifies the importance of in-hospital infectious incidents as determinants of late trauma death in Shiraz. In this regards, proper preventive/therapeutic actions should be undertaken to reduce the incidence of late deaths.

Apart from the nature of temporal mortality distribution, trauma centers in Shiraz should increase their efforts to minimize late deaths. In our center specifically, considerable improvements have occurred since we experienced a 14.5% decrease in the proportion of late deaths during the recent 6 years. This may be regarded as an increase in the overall quality of care. However, such changes may be interpreted with caution considering the decreasing pattern of severe injured cases being treated in Shadid Rajaee hospital. To overcome this challenge in future studies, TRISS methodology may be used as an index of trauma quality of care. [18] Although assessing trauma quality of care must be an integral part of each system, there are limited number of studies in Iran evaluating trauma care through TRISS method. [19–22]

The majority of deaths were caused by traffic-related accidents. This is in accordance with results of previous studies in our region. [23, 24] In addition, our findings both confirm and extend the relationship between temporal mortality distribution and injury mechanism. Deaths resulting from traffic accidents were mostly late mainly because traffic accidents frequently result in blunt trauma and such injury pattern is shown to cause late death. [18] However, violence-related deaths (assault and firearm mortalities) were mostly early as a result of penetrating nature of such injuries, which are shown to cause early death. [17] The most important injury mechanisms causing late death were falls, motorcycle and pedestrian accidents. These findings mainly imply a potential area for research toward identifying key components of reducing late deaths from traffic events. This may be achieved by improving in-hospital care, whereas violence-related deaths may be salvaged through improvements of prehospital care, reducing interval from injury to admission and implementing violence preventive strategies.

In this series of patients, the most common cause of death following trauma was CNS injury, a less surprising finding since multiple authors have previously concluded that CNS trauma is the leading cause of death for those who survive long enough to reach hospital. [6, 8, 20] However, mortality timing varied considerably according to anatomic site of injury causing death. Our results are in agreement with western literature, [17, 20] in that the majority of deaths from thoracic injuries occurred early, whereas mortalities from head trauma were mostly late. Therefore, improving the surgical outcome and intensive care of patients sustaining traumatic brain injuries could be a promising step toward reduction of late traumatic death.

Unlike other studies in which ISS has been shown to affect mortality timing, [14, 27] our findings failed to document such relationship, that is, deceased individuals with critical trauma (ISS ≥ 25) had similar death timing compared to dead patients without critical injury (ISS < 25). This finding may be explained by the fact that data were not available to calculate ISS for 314 cases (approximately 28% of total). As ISS calculation was attempted by cross-walking from ICD-10 injury diagnosis codes to AIS-2005, a considerable number of patients were missed because ICD-10 codes were not convertible to relevant AIS-2005 and this concept remains to be studied in future works. We propose that quality of injury diagnosis coding should be improved in hospital administrative databases to be properly used in various aspects of trauma research.

4.1. Limitations, strengths and future directions

The most important limiting factor was that our study did not cover immediate deaths since they are not referred to hospitals in Shiraz. The exact cause of death was not investigated for each patient by autopsies and quality of injury severity coding was subjected to question. However, this study was the first in Fars to provide a hospital-based view of trauma mortality timing. These results may serve as a point of reference while examining changes of temporal mortality distribution as trauma care evolve through time. Furthermore, we documented the role of hospital-acquired infections affecting late deaths and such complications may be prevented. To capture a comprehensive picture of regional mortality time distribution in future, data should be retrieved from all trauma centers and forensic medicine organizations. In addition, risk factors for immediate, early, and late deaths should be studied in depth.

5. Conclusion

Mortality time distribution follows the old trimodal pattern in Shiraz and this distribution is affected by victims’ age, injury mechanism, and injured body area. Comparing to mature trauma systems, this reflects a relatively lower quality of care, although the distribution has started a change toward expected bimodal pattern. Improving care of the elderly patients who are injured through falls/pedestrian accidents along with those sustaining head injuries may steepen the slope of changes in the desired direction.

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