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Trends in potentially preventable trauma deaths between 2005-2006 and 2012–2013

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ABSTRACT

Background: Most studies of trauma deaths include non-preventable deaths, potentially limiting successful intervention efforts. In this study we aimed to compare the potentially preventable trauma deaths between 2 time periods at our institution.
Methods: Trauma patients who died in our hospital in 2005–2006 or 2012–2013 were included, non-preventable deaths were excluded from analysis. The Mann-Whitney and chi square test were used to compare variables between both time periods.
Results: 80% of deaths were non-preventable. Between the study time periods there was a decrease in potentially preventable deaths, from 29% to 12%, $p < 0.001$. Head injury deaths significantly decreased (40.6%–24.6%, $p = 0.03$), while hemorrhage deaths were stable during both time periods (47.6%–43.1%, $p = 0.55$).
Conclusion: Potentially preventable trauma deaths decreased during the study period. Hemorrhage remains constant as the leading cause of potentially preventable deaths. Continued research to improve survival from hemorrhage is warranted.

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Introduction

Injury is currently the 3rd leading cause of death and is the leading cause of death for persons under 46 years of age.[1] Between the year 2000 and 2010, the number of trauma-related deaths has increased relative to overall population growth.[2] Additionally, the average age of patients has also increased during this time period.[3] Studies have shown that the main causes of death in this population are head injuries (42–52%), hemorrhage (30–39%) and multiple organ failure (7–11%).[4,5] Many efforts to improve trauma care have been directed at decreasing mortality from these specific causes.

The traditional trimodal distribution of death following trauma was first described by Trunkey in 1983 and consisted of an initial peak in mortality within 1 h of injury, followed by a second peak within hours of injury and a third peak several days to weeks after injury.[6] However, over time this model has changed and is no longer valid. Meislin and Demetriades both reported bimodal distributions of mortality in 1997 and 2005, respectively.[7,8] In both these studies the initial peak was within 1 h of injury whereas the second peak was within 48 h in Meislin's study and 6 h in Demetriades' study. Recently, we demonstrated that the bimodal distribution had changed again to a unimodal distribution with a single peak in mortality within 1 h of admission, and documented an 80% non-preventable death rate in our single center analysis of 1029 deaths.[9]

Concurrent with the modern epidemiologic descriptions of trauma deaths has been renewed emphasis on describing trauma deaths as non-preventable (NP), potentially preventable (PP) and preventable deaths.[10] Primary prevention efforts are clearly the optimal pathway to decrease injury deaths, however, current interventions have little to offer patients suffering catastrophic non-preventable deaths, which in some studies account for up to 97.5% of injured patients.[11] A recent study performed at our institution showed that in 2014 10.5% of prehospital deaths were PP whereas 44.4% of initial acute care setting deaths were PP.[12] Including these non-survivable deaths in studies designed to guide new intervention efforts can obscure data driven efforts to improve outcomes. It

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is therefore important to focus efforts on the group dying from potentially survivable injuries. This approach has served the military well in the current war and provided the basis for rapid improvements in effective interventions and improved survival.[10]

Our previous study described decreased adjusted overall trauma mortality (24%), with most of the effect in those suffering hemorrhagic shock (31%), largely resulting from utilizing a multidisciplinary bundle of care approach.[9] However, included in that single center review were many patients with devastating non-preventable deaths. In order to focus our efforts on those patients who have the potential to survive, in this study we aimed to determine the cause and timing of preventable and potentially preventable deaths after trauma.

Materials and methods

Patients

All in-hospital mortalities at Memorial Hermann Hospital in Houston, TX from 2 time periods were included (2005–2006 and 2012–2013, our center was a Level 1 trauma center during both periods). Patients with primary burn injuries and pediatric age (<16) patients were excluded.

Data collection

The trauma registry, weekly Morbidity & Mortality (M&M) reports, autopsy reports and electronic medical records were reviewed. For each patient, data was collected on baseline characteristics, which included age, sex, mechanism of injury, cause of death, time of hospital arrival and time of death (same as discharge time). The time to death was calculated from time of hospital arrival to physician pronouncement of death or discharge time. The primary cause of death was determined by the faculty trauma surgeons at our weekly M&M conference, by reviewing medical records and autopsy data. Patients were classified into one of several groups: (1) head injuries—fatal brain injury; (2) hemorrhage—uncontrolled bleeding; (3) multiple organ failure and/or systemic infection (MOF + Sepsis); (4) Respiratory Failure—inadequate exchange of gases by the lungs (Respiratory Fail); (5) Cardiac—sudden cardiac arrest; (6) Comorbid—presence of a significant secondary disease contributing to mortality; (7) Pulmonary Embolism—embolus lodging in pulmonary arteries (PE); (8) Other—primary cause of death not described by previous primary categories; (9) Unknown—missing sufficient data to determine cause of death (UNK). For patients with more than one factor contributing to death, each cause was counted separately to provide a more accurate representation. Non-preventable (NP) deaths were classified as mortality arising from injuries which could not have successfully been treated even with optimal medical or surgical interventions, whereas potentially preventable (PP) deaths (including both potentially preventable and preventable deaths) were classified as those arising from injuries which could potentially have been treated with optimal use of interventions. These definitions were the similar to those recently published by Drake et al. in a review of all trauma deaths in Harris county.[12]

Penetrating injuries were defined as traumatic wounds that were a primary result of an object puncturing the skin and entering the underlying tissue. Blunt injuries were defined as injuries primarily resulting from the application of a non-penetrating mechanical force. In-hospital mortalities excludes all patients that were dead on arrival and did not receive any resuscitative efforts. Mortality rates were directly adjusted for age, gender and mechanism of injury using direct standardization.

Statistical analysis

Results are expressed comparing 2005–2006 with 2012–2013 as well as preventable and non-preventable deaths. The Mann-Whitney rank sum and chi square tests were used to compare variables between periods, with significance set at 0.05. Data is presented as medians and intra-quartile ranges (IQR). Analysis was conducted using STATA 13.1.

Results

Patient demographics

After reviewing 15,874 patient admissions, a total of 1027 trauma deaths were identified of which 496 were from 2005 to 2006 and 531 were from 2012 to 2013. Patient demographics are displayed in Table 1. Of these deaths 143/496 (28.8%) were PP in 2005–2006 whereas 65/531 (12.2%) were PP in 2012–2013, a significant decrease between the two time periods ($p < 0.001$). Injury severity was similar between both periods (injury severity score; 29 vs. 26, $p = 0.12$). There were no differences in patient age, sex or ethnicity.

Mechanism of injury

With regard to mechanism of injury, in the PP population the proportion of blunt injuries decreased while penetrating injuries increased during both periods (90.9% vs. 80%, $p = 0.03$, and 9.09% vs. 20.0%, $p = 0.03$, respectively, see Fig. 1). There was a decrease of motor vehicle collision deaths (47.6%–26.2%, $p < 0.01$). Subsequently, the leading mechanism of injury leading to death changed from motor vehicle collisions (47.6%) in 2005–2006 to falls (27.7%) in 2012–2013. Motor vehicle injuries still accounted for a substantial percentage of deaths (26.2%) in 2012–2013.

Cause of death

There was decrease in deaths from head injuries (40.6%–24.6%, $p = 0.03$, see Fig. 2). Hemorrhage continues to be the leading cause of PP death and remained stable during both time periods (47.6% versus 43.1%, $p = 0.55$). Deaths from all other causes remained similar during the two time periods.

Time to death

The overall time to death decreased from a median of 85.3 h–67.3 h ($p = 0.05$, Table 2). There were significant changes in time to death for both head injuries (152 h–102 h; $p = 0.04$) and hemorrhage (11.9 h–3.08 h; $p = 0.03$). In total, 18.3% of PP deaths occurred in the first 4 h, 34.1% of deaths occurred in the first day and 47.6% occurred in the first 72 h, (Figs. 3 and 4).

Discussion

Most studies of trauma deaths include a large percentage (50–98%) of non-preventable deaths in their calculations, potentially biasing their intervention efforts. Previously, we had shown that implementing a bundle of care focused on resuscitation and hemorrhage control resulted in a substantial decrease in hemorrhagic death. In this study we aimed to compare the potentially preventable trauma deaths between 2 time periods at our institution, allowing us to focus intervention efforts on those with the highest likely hood for improvement. Overall potentially preventable deaths represented 20% of all 1027 deaths and decreased between the two time periods (29% vs 12%, $p < 0.05$).

Table 1
Patient demographics and characteristics of potentially preventable deaths.

	Total N = 208	2005–2006 N = 143	2012–2013 N = 65	p
PP Deaths	208/1027 (20.3)	143/496 (28.8)	65/531 (12.2)	< **0.001**
Age, median (IQR)	51 (32–72)	51 (34–71)	52 (30–79)	0.58
Male, n (%)	141/208 (67.8)	98/143 (68.5)	43/65 (66.2)	0.73
Ethnicity				
Black, n (%)	36/208 (17.3)	20/143 (14.0)	16/65 (24.6)	0.06
Hispanic/Latino, n (%)	39/208 (18.8)	25/143 (17.5)	14/65 (21.5)	0.49
Other, n (%)	9/208 (4.33)	7/143 (4.90)	2/65 (3.08)	0.43
White, n (%)	124/208 (59.6)	91/143 (63.6)	33/65 (50.8)	0.08
Type of Trauma				
Blunt (Total)	182/208 (87.5)	130/143 (90.9)	52/65 (80.0)	**0.03**
MCC, n(%)	25/208 (12.0)	20/143 (14.0)	5/65 (7.69)	0.20
MVC, n (%)	85/208 (40.9)	68/143 (47.6)	17/65 (26.2)	< **0.01**
Falls, n (%)	45/208 (21.6)	27/143 (18.9)	18/65 (27.7)	0.15
Pedestrian, n (%)	20/208 (9.62)	12/143 (8.39)	8/65 (12.3)	0.38
Other Blunt, n (%)	7/208 (3.37)	3/143 (2.10)	4/65 (6.15)	0.14
Penetrating (Total)	26/208 (12.5)	13/143 (9.09)	13/65 (20.0)	**0.03**
GSW, n (%)	20/208 (9.62)	10/143 (6.99)	10/65 (15.4)	0.06
SW, n (%)	5/208 (2.40)	2/143 (1.40)	3/65 (4.62)	0.18
Other Penetrating, n (%)	1/208 (0.48)	1/143 (0.70)	0/65 (0.00)	0.69
Cause of Death				
Head Injury, n (%)	74/208 (35.6)	58/143 (40.6)	16/65 (24.6)	**0.03**
Hemorrhage, n (%)	96/208 (46.2)	68/143 (47.6)	28/65 (43.1)	0.55
MOF + Sepsis, n (%)	47/208 (22.6)	34/143 (23.8)	13/65 (20.0)	0.55
Respiratory Failure, n (%)	18/208 (8.65)	14/143 (9.79)	4/65 (6.15)	0.28
Cardiac, n (%)	17/208 (8.17)	11/143 (7.69)	6/65 (9.23)	0.71
Comorbid, n (%)	8/208 (3.85)	7/143 (4.90)	1/65 (1.54)	0.23
Other, n (%)	5/208 (2.40)	3/143 (2.10)	2/65 (3.08)	0.50
UNK, n (%)	1/208 (0.48)	0/143 (0.00)	1/65 (1.54)	0.31
PE, n (%)	5/208 (2.40)	3/143 (2.10)	2/65 (3.08)	0.50
ISS, median (IQR)	27 (20–41)	29 (20–41)	26 (17–38)	0.12

Abbreviations: PP – potentially preventable; MCC- Motorcycle Collision; MVC- Motor Vehicle Collision; Pedestrian- Pedestrians struck by vehicles; GSW- Gun Shot Wound; SW- Stab Wound; MOF- Multiple Organ Failure; PE- Pulmonary Embolism; UNK- unknown.

Our results are significantly different from those in our previous study describing overall deaths (NP + PP). While overall mortality from head injuries remained constant between both time periods, our results showed a reduction in the percentage of PP deaths. In recent years there have been several developments that could have contributed to this decrease in head injury-related mortality. First of all, efforts to optimize intracranial pressure using of decompressive craniectomy may have contributed to this change.[13,14] In addition, new approaches to resuscitation may have improved outcomes by decreasing

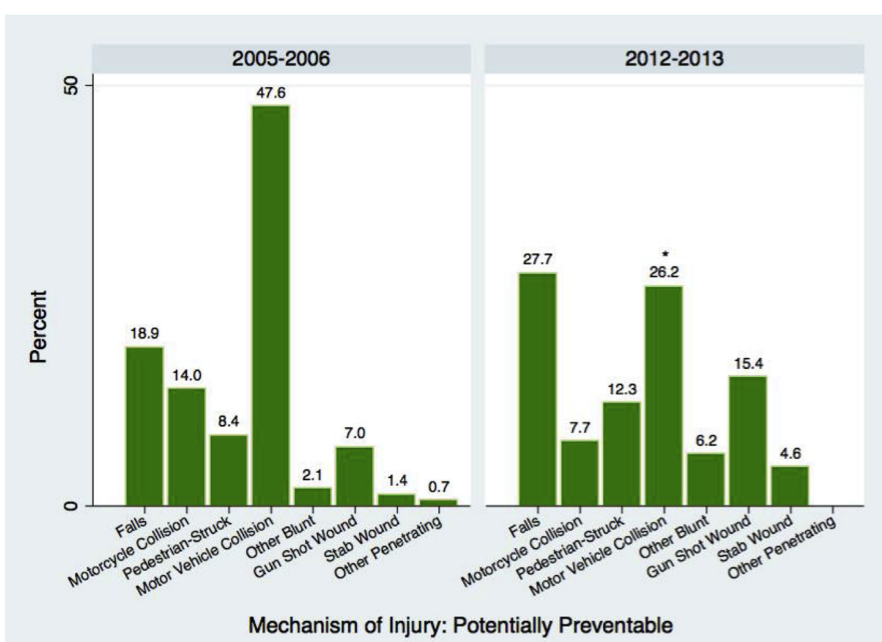

Fig. 1. Mechanisms of injury of trauma deaths in 2005–2006 and 2012–2013.

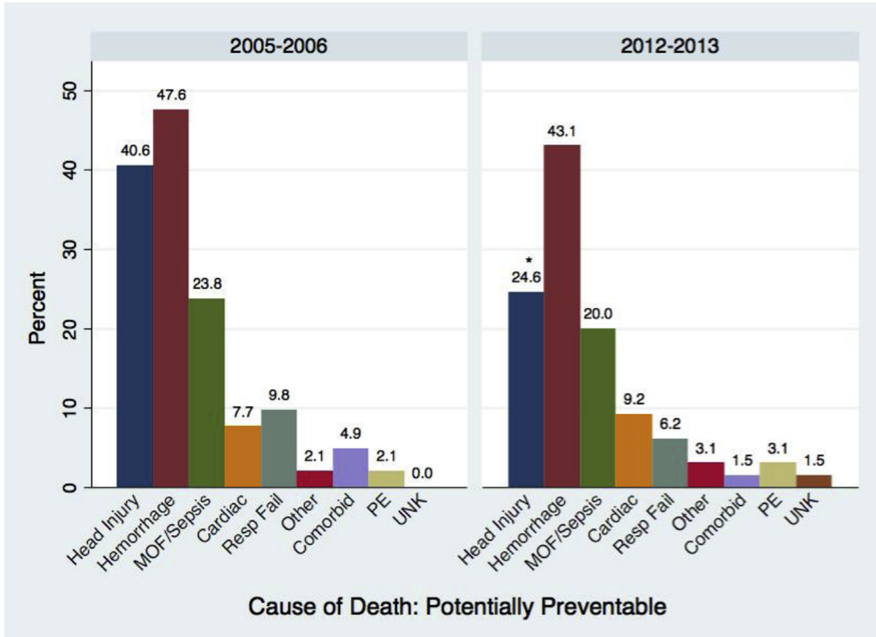

Fig. 2. Causes of death of 2005–2006 and 2012–2013.

secondary injury and edema. Within both periods, there was a trend towards a more balanced transfusion approach for these patients.[15] While recent data from the PROPPR trial did not show a decrease in deaths from head injuries using a 1:1:1 transfusion ratio, it is important to note that there were only small numbers of deaths in both groups and it therefore may have been underpowered to demonstrate any difference for head injuries.[16] Additionally, recent animal and clinical data suggest improved outcomes of traumatic intracranial hemorrhage with early plasma resuscitation.[17–19] The PAMPer trial also demonstrated improved 30-day survival in patients with head injuries who received prehospital plasma transfusion.[20]

The lack of improvement in head injury mortality in our previous study may be due to the fact that non-preventable devastating head injury deaths were included in the analysis. These injuries can only be prevented, and are not amenable to treatment. While the decrease in PP deaths from head injuries is likely due to the aforementioned improvements in resuscitation and clinical care, it is important to consider our results do not include functional status. Future research aimed at further mitigating the secondary effects of traumatic brain injury may help improve these outcomes.[19] Novel adjunctive treatments such as anti-epileptics and stem cell therapy appear promising but require additional research to determine their efficacy.[21,22]

Multiple authors have shown that hemorrhage remains a leading cause of PP death in trauma patients.[23–25] While our previous study showed a significant decrease in the proportion of overall deaths from hemorrhagic shock, the proportion of PP deaths from hemorrhage remained constant in this study.[9] A potential explanation for this difference may be that the proportion of PP deaths changed over time due to advances in therapy, and a larger number of deaths are considered PP due to the availability of new diagnostic modalities sand interventions. These results suggest that there is still substantial room for improvement, emphasizing the importance of continued research for earlier and more effective hemorrhage control interventions.[26] Prehospital transfusion, whole blood transfusions, and catheter base-hemorrhage control are examples of new strategies being implemented to improve survival from hemorrhagic shock.

When evaluating only PP deaths, the proportion of deaths from blunt injuries and motor vehicle accidents decreased significantly between both time periods. Between 2000 and 2013 overall traffic deaths decreased by 22% in the United States.[27] This change was also observed at our institution, and is likely attributable to several different factors. First of all, graduated driver licensing systems have shown reductions in teenage motor vehicle collisions in several states.[28,29] Additionally, preventative measures aimed at reducing drunk and distracted driving habits have also shown to be

Table 2
Time to death of potentially preventable deaths.

	Total (N = 208)	2005–2006 (N = 143)	2012–2013 (N = 65)	p
Overall (hours), med (IQR)	78.1 (10.4–266)	85.3 (.7–301)	67.3 (7.12–193)	**0.05**
Head Injury, med (IQR)	144 (49.5–301)	152 (62.5–359)	102 (30.4–214)	**0.04**
Hemorrhage, med (IQR)	8.34 (2.08–62.6)	11.9 (2.88–96.8)	3.08 (1.63–21.5)	**0.03**
MOF + Sepsis, med (IQR)	277 (124–454)	285 (124–477)	255 (140–406)	0.32
Respiratory Failure, med (IQR)	250 (147–493)	266 (198–748)	157 (72.5–334)	0.14
Cardiac, med (IQR)	128 (77.9–327)	85.3 (7.8–359)	131 (116–146)	0.62
Comorbid, med (IQR)	153 (97.1–370)	142 (73.7–485)	164 (164–164)	0.83
Other, med (IQR)	74.6 (19.3–219)	74.6 (19.3–999)	120 (2.3–238)	0.56
PE, med (IQR)	68.2 (13.0–313)	313 (13.0–412)	40.2 (12.2–68.2)	0.25

Abbreviations: Med-median; MOF- multiple organ failure; PE-pulmonary embolism.

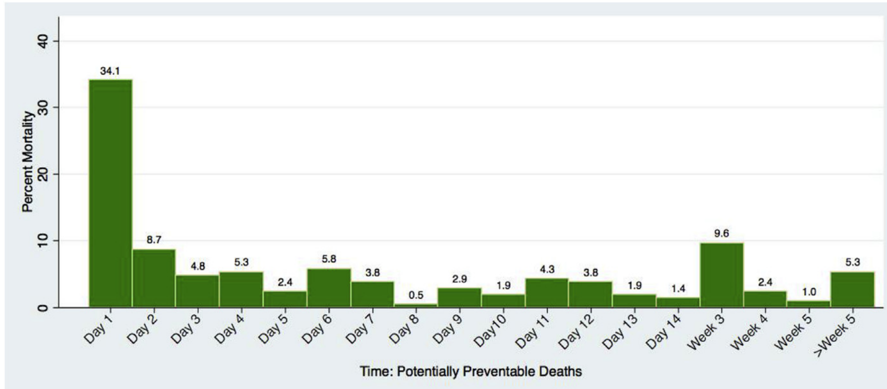

Fig. 3. Temporal distribution of trauma mortality in 2005–2006 and 2012–2013.

effective in reducing motor vehicle collision incidence.[29] Lastly, improved automobile safety features are likely to have contributed to these changes.

On the other hand, the proportion of PP deaths resulting from penetrating injuries increased during both time periods as a result of decreased PP deaths from blunt injuries. This trend suggests that there has been greater improvement in management of blunt injuries at our institution than penetrating injuries. A recent study from the National Trauma Data Bank showed a nationwide decrease in overall in-hospital mortality from penetrating injuries between 2007 and 2014.[30] However, it is unclear from the data whether these same changes were seen for PP deaths.

Overall, the proportion of NP deaths was substantial, consisting of 71% of deaths during the first time period compared to 88% during the second time period. In a study by Teixeira et al. 97.5% of deaths were considered non-preventable whereas Stewart et al. reported that 93% of trauma deaths were non-preventable.[11,31] Of the preventable deaths in the study by Teixeira et al., 39% died from hemorrhage which is comparable to the rates at our institution during both time periods, but deaths from head injuries were not reported in their study. Drake et al. described that 55.1% of PP prehospital deaths were due to hemorrhage, whereas 73.1% of initial acute care setting deaths were due to hemorrhage, sepsis, and traumatic brain injury.[12] In our study, the most likely explanation for the increase in these non-preventable deaths between time periods is the concomitant decreased mortality rates of PP deaths due to improved treatment methods during both time periods. However, the large number of remaining non-preventable deaths shows that these cases need to be addressed, and because these cases are currently considered untreatable with current technology there should be renewed focus on injury prevention. It is very clear that truly substantial reductions in trauma deaths rates are in the realm of prevention. Examples of such interventions to prevent head injuries include helmet legislation, which has resulted in reductions in head injuries in several states.[32] Additionally, interventions to improve bystander awareness such as the Stop the Bleed campaign may help improve hemorrhage outcomes by decreasing the time to intervention.[33]

This study has several limitations. Primarily, our data only included in-hospital mortality, with no prehospital information. Additionally, the retrospective nature of our data makes it susceptible to bias. Conversely, the determination of preventability occurred each week at our division M&M meetings, utilizing with a liberal definition of PP, similar to the approach of Eastridge et al..[10]

Conclusions

In conclusion, the rate of PP trauma deaths has decreased at our institution. While the proportion of deaths from head injuries has significantly decreased, death from hemorrhage remains constant and is still the leading cause of potentially preventable deaths. Given the large percentage (71–98%) of non-preventable deaths, it is important to understand the causes of deaths in the PP group to help focus research and intervention efforts.

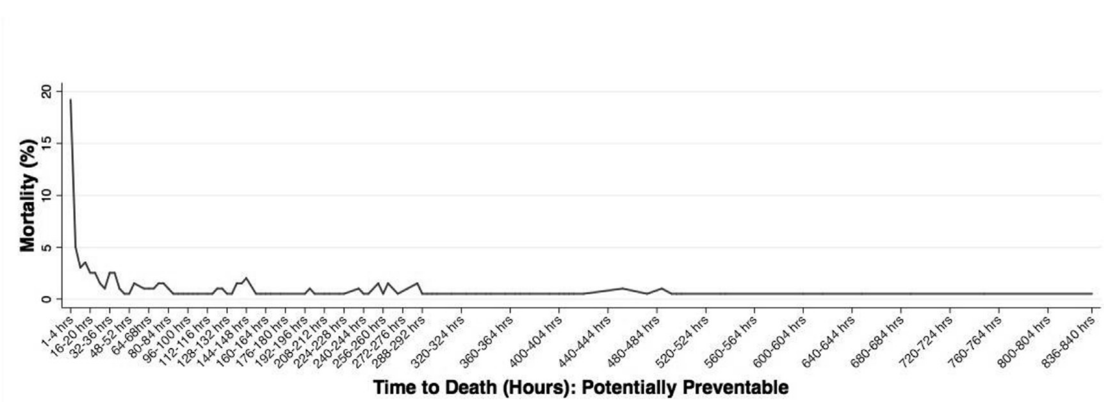

Fig. 4. Temporal distribution of trauma deaths showing a unimodal distribution in mortality.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2018.12.022.

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