Identifying patients with time-sensitive injuries: Association of mortality with increasing prehospital time

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These data were presented as a poster presentation at the 77th Annual Meeting of the American Association for the Surgery of Trauma, September 26-29th, 2018 in San Diego, CA.
**Background:** Trauma is a time-sensitive disease. However, recognizing which patients have time-critical injuries in the field is challenging. Many studies failed to identify an association between increasing prehospital time (PHT) and mortality due to evaluation of heterogenous trauma patients, as well as inherent survival bias from missed deaths in patients with long PHT. Our objective was to determine if a subset of existing trauma triage criteria can identify patients in whom mortality is associated with PHT.

**Methods:** Trauma patients age ≥16 years transported from the scene in the NTDB 2007-2015 were included. Cubic spline analysis used to identify an inflection where mortality increases to identify a marginal population in which PHT is more likely associated with mortality and exclude biased patients with long PHT. Logistic regression determined the association between mortality and PHT, adjusting for demographics, transport mode, vital signs, operative interventions, and complications. Interaction terms between existing trauma triage criteria and PHT were tested, with model stratification across triage criteria with a significant interaction to determine which criteria identify patients that have increased risk of mortality associated with increasing PHT.

**Results:** Mortality risk increased in patients with total PHT≤30min, comprising a study population of 517,863 patients. Median total PHT was 26 min (IQR 22-28) with median ISS of 9 (IQR 4-14) and 7.4% mortality. Overall, PHT was not associated with mortality (AOR 0.984 per 5-min increase; 95% CI 0.960—1.009, p=0.20). Interaction analysis demonstrated increased mortality associated with increasing PHT for patients with SBP<90mmHg (AOR 1.039; 95% CI
1.003—1.078, p=0.04), GCS ≤ 8 (AOR 1.047; 95%CI 1.018—1.076, p<0.01), or non-extremity firearm injury (AOR 1.049; 95%CI 1.010—1.089, p<0.01).

**Conclusions:** Patients with prehospital hypotension, GCS ≤ 8, and non-extremity firearm injury have higher mortality with increasing PHT. These patients may have time-sensitive injuries and benefit from rapid transport to definitive care.

**Level of Evidence:** III, Prognostic

**Key Words:** Emergency medical services; Prehospital; Transport; Time; Triage
BACKGROUND

Trauma is a time-sensitive disease. This has been embodied by the "golden hour" concept. The underlying theory is that minimizing the time from injury to definitive care at a trauma center improves outcomes. This has led to the "scoop and run" approach to emergency medical services (EMS) in which rapid transport is favored with few or no prehospital interventions. However, many studies have not identified an association between increasing prehospital time and mortality, calling into question this tenet of trauma care.

This lack of relationship between prehospital time and outcome may have been seen in prior studies for two reasons. First is the inherent survival bias in trauma registry data used in prior studies. Registry data are collected from only patients brought to a participating trauma center. Thus, patients farther from the trauma center with long prehospital times that survive long enough to get to the trauma center are likely to survive their injuries. Patients far from the trauma center who die in the field or at a closer non-trauma center are not captured. Only patients that survive to arrive at the trauma center are included in registry data and bias the true relationship between prehospital time and mortality for patients with longer prehospital times. This may result in paradoxical findings in which longer prehospital time appears to be associated with lower mortality.

Second, prior studies evaluate a heterogeneous population of all trauma patients. Ultimately, many patients do not have time-sensitive injuries. Absence of any selection criteria produces a heterogeneous population in which prehospital time is unlikely to be associated with mortality. The key issue becomes recognizing which patients have time critical injuries in the field. However, this remains challenging, as EMS providers have few resources to identify these patients and act accordingly. To our knowledge, no prior studies have evaluated whether injured
patients with time-sensitive injuries could be identified in the field. Triage criteria that identify
time-sensitive trauma patients represent actionable information for EMS providers, allowing
them to prioritize rapid transport with scoop and run or activating helicopter emergency medical
services (HEMS) to minimize prehospital time.

Thus, it was our objective was to determine if a subset of existing field trauma triage
criteria can identify patients in whom mortality is associated with increasing prehospital time
after accounting for potential survival bias.

METHODS

Study Population

All patients ≥16 years transported by EMS from the scene in the National Trauma
Databank (NTDB) 2007-2015 were included. Patients with burn injury, missing total prehospital
time, or total prehospital time greater than 3 hours were excluded. Prehospital times longer than
3 hours were excluded as this is >90th percentile of total prehospital time in the dataset and are
not representative of typical EMS transports across the United States. A subset of these patients
was studied in further detail using the Pennsylvania Trauma Outcomes Study (PTOS) 2007-
2015. The PTOS includes more detailed prehospital data to allow further exploratory analysis of
factors affecting prehospital time. The same inclusion/exclusion criteria and definitions were
applied to the PTOS subset.

Total prehospital time was defined as the time elapsed from dispatch of EMS by the 911-
system to arrival of EMS with the patient at the hospital. This incorporates three intervals of
prehospital time, including response (time from dispatch to arrival at the scene), scene (time
from arrival at the scene to leaving the scene), and transport time (time from leaving the scene to
hospital arrival). Total prehospital time was chosen as it accounts for the entire prehospital care period and each time interval component may be modifiable through different strategies.

**Missing Data**

Multiple imputation was performed to account for the missing values. Imputed variables included sex, race, insurance status, injury severity score (ISS), admission SBP, and mechanism of injury. Multiple imputation using chained equations developed five imputed datasets. Outcome models combined coefficients and standard errors from each imputed dataset while adjusting for the variability between imputed datasets. Missing data for imputed variables ranged from 0.1% (mechanism, PTOS) to 12.9% (insurance status, NTDB). Sensitivity analysis with complete cases was performed and similar results were seen, thus results from imputed data are presented below. Imputation was not used for variables affecting triage criteria (prehospital Glasgow Coma Scale [GCS], systolic blood pressure [SBP], respiratory rate [RR]). These variables were not imputed as different values could be imputed for the missing observations in each of the five imputed datasets. Thus, a patient might have a positive triage criterion in some but not all imputed datasets for criteria using these variables. This would make it impossible to analyze a stratified sample based on interaction testing if the criterion was different within the same patient across imputed datasets. Prehospital GCS, SBP, RR were missing in 5.1%, 7.0%, and 5.2% of patients respectively.

**Survival Bias**

Since the databases utilized suffer from the survival bias noted above, we addressed this by excluding patients with long prehospital times which represent a biased group where only
patients surviving long enough to reach a trauma center were captured in the dataset. We sought the prehospital timeframe where mortality drops off and remains relatively constant to identify this biased group. To determine the prehospital time threshold to exclude this biased group, we used restricted cubic spline analysis which evaluates the non-linear relationship between mortality and prehospital time. This allowed us to empirically select the prehospital time threshold to exclude patients with longer times based on data rather than using an arbitrary threshold.

Restricted cubic splines were created for total prehospital time with 3 knots. Logistic regression was then performed with mortality as the dependent variable and cubic splines as the independent variables. The adjusted odds ratio (AOR) and 95% confidence interval (95%CI) were estimated for each minute of total prehospital time relative to 180minutes. The AOR and 95%CI were plotted across prehospital time. This identified a marginal population with a shorter prehospital timeframe that allowed patients to reach a trauma center regardless of injury severity and would be less likely to suffer from survival bias. All further analyses were performed only on patients within this prehospital timeframe.

**Statistical Analysis**

The primary outcome was in-hospital mortality. Logistic regression was used to determine the association between in-hospital mortality and total prehospital time. Total prehospital time was evaluated as a continuous variable. The model was adjusted for age, gender, race, insurance status, transport mode, mechanism of injury, ISS, prehospital SBP, admission SBP, need for urgent operation (emergency department disposition of operating room), need for mechanical ventilation, in-hospital complications, and trauma center level. Models were also
adjusted for isolated severe (abbreviated injury scale [AIS]≥3) head, chest, or abdominal injury, as well as combinations of severe head, chest, or abdominal injury to account for differing anatomic patterns of injury. Interactions between prehospital time and anatomic injury pattern were tested to determine if prehospital time had a different effect on mortality based on the anatomic injury pattern. Robust variance estimators were used to account for clustering at the center level.

Existing triage criteria were evaluated to identify patients with time-sensitive injuries, including SBP<90mmHg, GCS≤13, GCS≤8, RR<10 or >29bpm, penetrating injury, unstable chest wall, open skull fracture, ≥2 proximal long bone fractures, pelvic fracture, crush injury, amputation, paralysis, hemothorax or pneumothorax, multisystem trauma (≥3 body regions injured), and combination of physiologic plus anatomic triage criteria from the national field triage guidelines. Penetrating injury was further classified as firearm versus non-firearm injury based on external injury codes (e-codes), and non-extremity (head, face, neck, chest, abdomen, or spine) versus extremity location of penetrating injury based on AIS body regions. Interaction terms between these triage criteria and total prehospital time were tested.

A significant interaction indicates prehospital time has a different effect on mortality based on the presence or absence of the criterion. Models were stratified across triage criteria with significant interactions. This allowed determination of which criteria, when present, identify patients with increased risk of mortality associated with increasing prehospital time. Combinations of positive criteria were also tested. To account for multiple comparisons, false discovery rate correction was used.

Continuous data are presented as median (IQR) and compared using Mann-Whitney tests. Proportions were compared using $\chi^2$ tests. A two-tailed p value of $\leq 0.05$ was considered
significant. Adjusted odds ratios (AOR) with 95%CI were obtained from regression models. Regression coefficients were transformed to obtain the adjusted odds of mortality per 5-minute increase in prehospital time. Model performance was assessed using the c-statistic and graphic calibration. Data were analyzed using Stata v15MP (College Station, TX).

Subgroup Analysis

An exploratory subgroup analysis was conducted based on transport mode. Criteria identified in the main analysis were evaluated separately in patients transported by ground EMS (GEMS) and patients transported by HEMS, based on evidence that prehospital time may not be the only important factor across transport modes.\textsuperscript{12}

Subset Analysis

Analysis of the PTOS subset was aimed at evaluating the effect of transport distance, time of day, and prehospital interventions on prehospital time. After excluding biased patients with long prehospital times as above, similar models used in the NTDB were constructed. Given the lower power of the subset analysis, all patients with criteria identified through the NTDB analysis were included in each subset model.

To evaluate the effect of distance on prehospital time, transport distance was calculated between patients’ zip code centroid and the receiving trauma center address. Distance for patients transported by HEMS was calculated using straight-line Euclidean distance. Distance for patients transported by GEMS was calculated as the driving distance using geographic information systems network analysis. (ArcGIS v10.5, ESRI, Redlands, CA). Transport distance and its interaction with prehospital time were included in the model.
To evaluate the effect of time of day on prehospital time, patient transports were classified as peak or off-peak travel times based on recorded time of injury. Peak travel times were defined as weekdays between 6:00am to 10:00am, and 3:00pm to 7:00pm to identify periods of high traffic volume. Models were run separately on patients transported under peak and off-peak traffic conditions.

To evaluate the effect of prehospital interventions on prehospital time, three prehospital interventions available in PTOS were considered including intubation, crystalloid administration, and blood transfusion. Models were run separately on patients receiving none of these prehospital interventions and those receiving one or more of these interventions.

RESULTS

There were 2,508,215 patients eligible for inclusion (Fig. 1). Visual inspection of mortality plotted against prehospital time demonstrated a higher mortality for prehospital times ≤30 minutes (Fig. 2). Cubic spline analysis also demonstrated an inflection in the odds of mortality over a similar prehospital time frame (AOR 1.17; 95%CI 1.26—1.36, Fig. 2). Thus, prehospital time ≤30 minutes is the empiric threshold at which longer prehospital times represent a biased group based on the current data.

Further analysis was performed only on patients with total prehospital time ≤30 minutes, leaving 517,863 patients for analysis. The median prehospital time was 26 minutes (IQR 22, 28), with nearly a quarter of these patients sustaining penetrating injury, moderate injury by ISS (median 9; IQR 4, 14), but significant mortality rate at 7.4% (Table 1).

In the overall study population, mortality was not associated with total prehospital time (AOR 0.984; 95%CI 0.960—1.009, p=0.20). The model had excellent discrimination with a c-
statistic of 0.937. The model was also well calibrated when plotting predicted versus observed mortality (Supplemental Digital Content 1, Figure 1, http://links.lww.com/TA/B313).

Interaction testing demonstrated significant interactions between prehospital time and SBP (p=0.04), GCS (p=0.04), and mechanism of injury (p<0.001). Patients with SBP<90mmHg, GCS≤8, or non-extremity firearm injury had increased odds of mortality associated with increasing total prehospital time (Table 2), while patients without these criteria, including those with extremity firearm injuries and non-firearm penetrating injuries, had no association between mortality and prehospital time (p>0.05). Combinations of these criteria demonstrated higher odds of mortality per 5-minute increase in prehospital time, with the exception of patients presenting with all three criteria (Table 2). Patients presenting with all three criteria had 76.8% mortality and this may mitigate the effect of increasing prehospital time in this moribund group. Among these criteria, 24.7% of patients with SBP<90mmHg, 15.7% of patients with GCS≤8, and 42.7% of patients with non-extremity firearm injury required urgent operation. Patients with one or more of these criteria represented 21.1% of the study population and 81.6% of patients that died. Interactions between prehospital time and anatomic injury pattern were non-significant (p>0.05).

Among the transport mode subgroups, there were too few HEMS transports with total prehospital time ≤30minutes to allow meaningful analysis. Thus, to expand the number of patients available in the HEMS subgroup, restricted cubic spline analysis was performed on HEMS patients only, and an inflection with a decline in the odds of mortality was identified at 70minutes (Supplemental Digital Content 2, Figure 2, http://links.lww.com/TA/B314). Thus, we included patients with prehospital time ≤70minutes for the HEMS subgroup analysis.

The same three criteria again identified patients with increased odds of mortality associated with increasing prehospital time among those transported by GEMS (Table 3).
Among HEMS transports, SBP<90mmHg and non-extremity firearm injury identified patients with increased odds of mortality associated with increasing prehospital time, while patients with GCS≤8 had lower odds of mortality associated with increasing time (Table 3).

Of patients with GCS≤8, 16.3% of GEMS patients were intubated, while 49.4% of HEMS patients were intubated upon arrival to the emergency department. When further exploring patients with GCS≤8 by intubation status, those transported with GEMS had increased odds of mortality associated with increasing prehospital time whether intubated (AOR 1.087; 95%CI 1.025—1.153, p=0.01) or not intubated (AOR 1.035; 95%CI 1.010—1.065, p=0.02). Patients with GCS≤8 transported by HEMS had no association between mortality and prehospital time if not intubated (AOR 0.980; 95%CI 0.0942—1.011, p=0.17), but had lower odds of mortality associated with increased prehospital time if intubated (AOR 0.95; 95%CI 0.917—0.986, p=0.01).

In PTOS, mortality also increased at a prehospital time ≤30 minutes (Fig. 3), leaving 26,488 patients for subset analysis. This included 5,356 (20.2%) patients with SBP<90mmHg, GCS≤ 8, or non-extremity firearm injury. Patients with at least one of these criteria had 17% increase in odds of mortality per 5-minute increase in prehospital time (AOR 1.170; 95%CI 1.048—1.306, p<0.01).

When evaluating patients with at least one of these criteria, the interaction between transport distance and prehospital time was not significant (p=0.59), nor was distance itself (p=0.36) while prehospital time remained associated with mortality (p=0.01). An increase in mortality for longer prehospital time was seen during off-peak traffic (AOR 1.142; 95%CI 1.023—1.274, p=0.02); however, this effect was magnified during peak traffic (AOR 1.419; 95%CI 1.026—1.963, p=0.03). Finally, longer prehospital time was associated with higher
mortality odds among patients receiving any prehospital intervention (AOR 1.260; 95% CI 1.120—1.417, p<0.01), while there was no association between prehospital time and mortality among patients receiving no prehospital interventions (p=0.64). Patients with no prehospital interventions had shorter prehospital time (22 [IQR 18, 26] versus 24 [IQR 20, 27], p<0.01).

DISCUSSION

The current study demonstrated a subset of existing trauma triage criteria can identify patients in the field who have increased risk of mortality associated with increasing prehospital time, including SBP<90mmHg, GCS≤8, and non-extremity firearm injury in a cohort with prehospital time of ≤30minutes. These criteria may not be surprising, as they represent patients in shock, with severe traumatic brain injury, and need for operative control of hemorrhage. However, no study exists that has evaluated field criteria that can identify patients with time-sensitive injuries and may benefit from minimizing prehospital time. These criteria also represent current trauma triage criteria familiar to EMS providers, similar to the approach Champion and colleagues used in developing the triage version of the Revised Trauma Score based on categorized physiologic variables. Further, this data suggests these criteria represent 1 in 5 trauma patients with over 80% of deaths that may benefit from rapid transport to minimize prehospital time. This may be particularly salient as Drake et al demonstrated a preventable/potentially preventable death rate of 36% with hemorrhage the leading cause in prehospital deaths.

Results from prior work have been mixed regarding the relationship between mortality and prehospital time, and it unclear that reducing prehospital time translates to better outcomes after injury. Many recent studies in the US have not shown shorter prehospital times reduce
mortality. Newgard et al in a prospective cohort found no association between mortality and any prehospital time interval in patients meeting physiologic field criteria. Several others also found no association between outcome and prehospital time among undifferentiated trauma patients. Pepe found no association in hypotensive penetrating patients based on trauma score stratification. Some groups have reported lower mortality in patients with longer prehospital time, suggesting as noted above a survival bias.

Early data demonstrated mortality was associated with prehospital time, with up to a 5% increase in mortality odds per 1-minute increase in prehospital time. More recent data has suggested an association limited to specific subgroups of patients. Swaroop and colleagues demonstrated a stepwise increase in mortality as prehospital time increased for hypotensive patients with penetrating thoracic injury. Tien et al demonstrated a 3% increase in mortality odds for each 1-minute increase in patients with subdural hematomas. Alarhayem and colleagues also evaluated the NTDB and demonstrated increasing mortality with increasing prehospital time among patients with torso injuries, particularly in the first 30 minutes. Our group previously reported prolonged scene time relative to other prehospital time intervals was associated with increased mortality in patients with SBP<90mmHg, penetrating injury, and flail chest even when accounting for prehospital interventions. Holcomb clearly demonstrated death from severe truncal hemorrhage occurs before operative control is possible, highlighting the importance of minimizing prehospital time as well as pushing critical interventions to mitigate hemorrhage into the field for these patients. The military has shown over the recent conflicts that prehospital time is a significant factor driving mortality in battlefield injuries. Policy change that resulted in significant reductions in prehospital time was consistently associated with improved mortality.
Interestingly, in subset analysis distance was not associated with mortality, but prehospital time remained important. This suggests that strategies to limit prehospital time even at long distances such as HEMS transport may be a successful strategy to reduce mortality in these patients. Additionally, peak traffic time magnified the effect of prehospital time on mortality likely due to delays in response and transport. Thus, again use of HEMS at shorter distances during peak traffic may reduce prehospital time.\textsuperscript{30}

When evaluating the effect of prehospital interventions on prehospital time and mortality in subset analysis, patients that underwent any prehospital intervention had higher odds of mortality associated with longer prehospital time, while those that underwent no prehospital intervention had lower prehospital times which were no longer significantly associated with mortality. This suggests for patients meeting one of the time-sensitive criteria, a scoop and run approach may be favored as the time to perform field interventions results in an increase in mortality as prehospital time increases.

These findings have several potential implications. At the individual patient level, these criteria may help EMS providers make decisions about if and when to provide prehospital interventions based on the presence or absence of the criteria demonstrated here. These criteria allow EMS providers to take a more tailored approach to their patients, applying a scoop and run approach in patients who may truly benefit from it. This also may allow mitigation of risk to EMS providers and the public by informing appropriate utilization strategies for HEMS or use of lights and sirens transport.\textsuperscript{31, 32} At the system level, these criteria may be considered in triage protocols to encourage minimization of scene time. They may facilitate performance improvement review to identify opportunities to reduce delays in patients meeting these criteria.
These potential clinical and policy implications require further targeted study prior to consideration of wide-spread application.

In our transport mode subgroup analysis, patients transported by GEMS had increasing mortality associated with increasing prehospital time across all three criteria, while HEMS patients only had this relationship if they had SBP<90mmHg or non-extremity firearm injury. However, HEMS patients had lower mortality associated with increasing prehospital time if they had GCS≤8. When investigating the potential role of prehospital intubation in patients with GCS≤8, lower mortality was associated with longer prehospital time in patients intubated by HEMS crews, while increased mortality was associated with increasing prehospital time in GEMS patients regardless of intubation status. The point estimate for mortality odds was more than double for patients who were intubated compared with those not intubated by GEMS crews.

These finding suggest prehospital intubation significantly affects outcomes for injured patients with GCS≤8. Further, that effect is different across transport modes, and the additional time to perform intubation in the field may improve outcome in the hands of HEMS but not GEMS providers, which has been supported by prior reports as well.\textsuperscript{12, 33-35} GEMS and HEMS differ with respect to training, experience, and regulatory requirements. Additionally, there may be some selection bias as GEMS in some locations cannot perform medication assisted intubation. Mounting evidence suggests the speed of HEMS transport is not the only important factor, and the care received by HEMS crews influences outcome.\textsuperscript{12, 36, 37} These findings may also have implications for air medical triage policies in which HEMS may be considered if it would ultimately reduce prehospital time for patients with these criteria, or prehospital intubation is indicated for GCS≤8.
Taking the subset and transport subgroup data together, our results suggest patients with SBP<90mmHg and non-extremity firearm injury should undergo few if any prehospital interventions with priority placed on rapid transport to minimize prehospital time, while patients with GCS≤8 benefit from undergoing prehospital intubation by HEMS providers when available even if this may not result in the shortest prehospital time possible.

There are several limitations for consideration. First are those inherent to a retrospective observational design. Second are those documented for the NTDB. The advantage of the NTDB is a large national sample of patients; however, there are limited outcomes and variables for analysis. We supplemented this limitation by performing a subset analysis using the PTOS dataset which included more granular prehospital data. Missing data is always a limitation of registry studies; however, we used multiple imputation to mitigate this. Despite our large sample in the NTDB, cohorting based on triage criteria resulted in some small groups that limited our power to evaluate the relationship of mortality and prehospital time. This is a particular limitation in the PTOS subset analysis, requiring evaluation of patients with any one of the three criteria identified in NTDB to maintain adequate power for regression modeling.

As noted above, we restricted analysis to prehospital times ≤30 minutes to address the survival bias inherent to long prehospital times in registry data based on empirical analysis of the datasets utilized. This represents a trade-off in which we did not evaluate longer prehospital times where there may be even more opportunity to minimize prehospital time, and limits our generalizability. Our data likely are more representative of urban/suburban environments relatively close to trauma centers. This is particularly important in potential urban-rural differences of the prehospital time and outcome relationship, where different criteria may be useful across different geographies. We also do not have the time from injury to 911-system
notification which may be significant in some patients. A number of patients were missing prehospital time and excluded; however, this represented only 9% of eligible patients.

Our primary outcome was in-hospital mortality; however, longer-term outcomes and morbidity not available in the NTDB or PTOS are important outcomes for injured patients. Our subgroup and subset analyses are exploratory and should be viewed to motivate future research. We included HEMS patients with prehospital time ≥70 minutes in subgroup analysis for power reasons; however, this cutoff was based on data from similar cubic spline analysis used for the main analysis. We investigated prehospital intubation as a potential mechanism of the differences seen between HEMS and GEMS among patients with GCS≤8; however, there was limited data available regarding timing or other prehospital interventions and again is exploratory.

CONCLUSION

In patients with short total prehospital time, prehospital hypotension, GCS≤ 8, and non-extremity firearm injury identify patients with increased risk of mortality associated with increasing prehospital time. These patients may have truly time-sensitive injuries and benefit from rapid transport to definitive care with few or no prehospital interventions. An exception is patients with GCS≤ 8 that may benefit from intubation by HEMS providers. Further prospective research is necessary to refine the identification of patients with time-sensitive injuries in the field and overcome the survival bias for patients with longer prehospital times.
ACKNOWLEDGEMENTS

Committee on Trauma, American College of Surgeons. NTDB 2007-2015, Chicago, IL. The content reproduced from the NTDB remains the full and exclusive copyrighted property of the American College of Surgeons. The American College of Surgeons is not responsible for any claims arising from works based on the original data, text, tables, or figures.

AUTHOR CONTRIBUTIONS: X.C., F.X.G., and J.B.B. designed the study and performed the literature search. X.C and J.B.B. performed the data collection. X.C. and J.B.B performed the data analysis. X.C., F.X.G, and J.B.B. participated in initial manuscript preparation. All authors contributed to data interpretation and critical revision of the manuscript.
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FIGURE LEGEND

**Figure 1.** Patient selection from the National Trauma Databank (NTDB) from 2007 to 2015.

**Figure 2.** Mortality rate (left axis) and odds of mortality (right axis) from cubic spline regression plotted against total prehospital time in the NTDB. Top horizontal dashed line represents 5% mortality rate. Bottom horizontal dashed line represents odds of mortality of 1.0. The odds of mortality increase above 1.0 at prehospital times of ≤30 minutes (vertical gray line).

**Figure 3.** Mortality rate (left axis) and odds of mortality (right axis) from cubic spline regression plotted against total prehospital time in PTOS. Top horizontal dashed line represents 5% mortality rate. Bottom horizontal dashed line represents odds of mortality of 1.0. The odds of mortality increase above 1.0 at prehospital times of ≤30 minutes (vertical gray line).
Figure 1
Figure 3
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<td>N</td>
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<td>Urgent operation, n (%)</td>
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<td>Any complication, n (%)</td>
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<td>In-hospital mortality, n (%)</td>
<td>38,167 (7.4%)</td>
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**Triage Criteria**

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<tr>
<td>Prehospital SBP&lt;90mmHg, n (%)</td>
<td>37,642 (7.8%)</td>
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<tr>
<td>Prehospital RR&lt;10 or &gt;29, n (%)</td>
<td>39,642 (8.1%)</td>
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<td>Prehospital GCS≤13, n (%)</td>
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<td>Penetrating injury mechanism, n (%)</td>
<td>121,335 (23.4%)</td>
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<td>Non-extremity firearm injury, n (%)</td>
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<td>Unstable chest wall fractures, n (%)</td>
<td>20,688 (4.0%)</td>
</tr>
<tr>
<td>Open skull fracture, n (%)</td>
<td>10,431 (2.0%)</td>
</tr>
<tr>
<td>≥2 proximal long bone fractures, n (%)</td>
<td>6,905 (1.3%)</td>
</tr>
<tr>
<td>Pelvic fracture, n (%)</td>
<td>36,676 (7.1%)</td>
</tr>
<tr>
<td>Amputation, n (%)</td>
<td>1,335 (0.3%)</td>
</tr>
<tr>
<td>Crush injury, n (%)</td>
<td>1,640 (0.3%)</td>
</tr>
<tr>
<td>Paralysis, n (%)</td>
<td>2,280 (0.4%)</td>
</tr>
<tr>
<td>Hemothorax/Pneumothorax, n (%)</td>
<td>59,186 (11.4%)</td>
</tr>
<tr>
<td>Multisystem injury, n (%)</td>
<td>5,763 (1.1%)</td>
</tr>
<tr>
<td>Physiologic and anatomic criterion, n (%)</td>
<td>53,428 (10.3%)</td>
</tr>
</tbody>
</table>

IQR, interquartile range; ISS, injury severity score; ICU, intensive care unit; SBP, systolic blood pressure; RR, respiratory rate; GCS, Glasgow Coma Scale
Table 2. Adjusted odds ratio of in-hospital mortality per 5-minute increase in total prehospital time.

<table>
<thead>
<tr>
<th>Triage Criterion</th>
<th>AOR</th>
<th>95%CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP&lt;90mmHg</td>
<td>1.039</td>
<td>1.003—1.078</td>
<td>0.045</td>
</tr>
<tr>
<td>GCS≤8</td>
<td>1.047</td>
<td>1.018—1.076</td>
<td>0.001</td>
</tr>
<tr>
<td>Non-extremity firearm injury</td>
<td>1.049</td>
<td>1.010—1.089</td>
<td>0.011</td>
</tr>
<tr>
<td><strong>Combination of criteria</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP&lt;90mmHg + non-extremity firearm injury</td>
<td>1.079</td>
<td>1.015—1.147</td>
<td>0.015</td>
</tr>
<tr>
<td>SBP&lt;90mmHg + GCS≤8</td>
<td>1.069</td>
<td>1.027—1.112</td>
<td>0.001</td>
</tr>
<tr>
<td>GCS≤8 + non-extremity firearm injury</td>
<td>1.061</td>
<td>1.001—1.126</td>
<td>0.048</td>
</tr>
<tr>
<td>SBP&lt;90mmHg + GCS≤8 + non-extremity firearm injury</td>
<td>1.047</td>
<td>0.967—1.132</td>
<td>0.259</td>
</tr>
</tbody>
</table>

AOR, adjusted odds ratio; 95%CI, 95% confidence interval; SBP, systolic blood pressure; GCS, Glasgow Coma Scale
Table 3. Adjusted odds ratio of in-hospital mortality per 5-minute increase in total prehospital time by transport mode subgroup

<table>
<thead>
<tr>
<th>Triage Criterion</th>
<th>AOR</th>
<th>95%CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP&lt;90mmHg</td>
<td>1.042</td>
<td>1.004—1.082</td>
<td>0.030</td>
</tr>
<tr>
<td>GCS≤8</td>
<td>1.050</td>
<td>1.022—1.079</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Non-extremity firearm injury</td>
<td>1.090</td>
<td>1.040—1.142</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>HEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP&lt;90mmHg</td>
<td>1.042</td>
<td>1.005—1.081</td>
<td>0.020</td>
</tr>
<tr>
<td>GCS≤8</td>
<td>0.967</td>
<td>0.942—0.992</td>
<td>0.010</td>
</tr>
<tr>
<td>Non-extremity firearm injury</td>
<td>1.065</td>
<td>1.009—1.125</td>
<td>0.022</td>
</tr>
</tbody>
</table>

* Includes patients with total prehospital time ≤70 minutes

AOR, adjusted odds ratio; 95%CI, 95% confidence interval; GEMS, ground emergency medical services; HEMS, helicopter emergency medical services; SBP, systolic blood pressure; GCS, Glasgow Coma Scale
eFigure 1. Calibration curve of predicted versus observed mortality across predicted mortality risk deciles from the multivariable risk-adjustment logistic regression model.
eFigure 2. Mortality rate (left axis) and odds of mortality (right axis) from cubic spline regression plotted against total prehospital time in PTOS. Top horizontal dashed line represents 5% mortality rate. Prehospital times ≤30 minutes have a mortality rate of 5% or greater, whereas prehospital times >30 minutes have a mortality rate less than 5%. Bottom horizontal dashed line represents odds of mortality of 1.0. The odds of mortality increase above 1.0 at prehospital times of ≤30 minutes (vertical gray line).