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Every minute counts: The impact of pre-hospital response time and scene time on mortality of penetrating trauma patients

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ABSTRACT

Background: Prompt surgical control of hemorrhage is crucial in penetrating trauma patients. We aimed to study the impact of prehospital response time (PreRespT) and scene time (SceneT) on hospital mortality.

Methods: Using the Trauma Quality Improvement Program (TQIP) 2010–2016 database, we identified all adults with penetrating injury. We defined PreRespT as time from EMS dispatch to scene arrival, and SceneT as time spent on scene. Univariate then multivariable logistic regression analyses were performed to study the independent correlation between PreRespT and SceneT on hospital mortality, adjusting for several covariates.

Results: Out of a total of 1,403,470 patients, 43,467 patients were included. Multivariable analyses suggested that: 1) every minute increase in PreRespT independently correlates with a 2% increase in mortality (OR 1.02, $p < 0.0001$), and 2) every minute increase in SceneT independently correlates with a 1% increase in mortality (OR 1.01, $p = 0.001$).

Conclusion: In the penetrating injury trauma patient, PreRespT and SceneT independently correlate with hospital mortality. This data suggests that a faster PreRespT and a "scoop and run" strategy may be more beneficial in this population.

Background

According to the Centers for Disease Control and Prevention, injury is the leading cause of death in people 44 years and younger in the United States.[1] Violence with penetrating injury is the 3rd leading cause of injury after falls and motor vehicle crashes, and prompt surgical intervention continues to play a crucial role in rescuing these patients.[2,3] To achieve prompt surgical intervention for hemorrhage or sepsis control, rapid response to the scene by pre-hospital services is essential.[4,5] However, the decision-making challenges faced by prehospital personnel responding to the scene cannot be overstated, because of the need to balance the importance of transiently stabilizing the patient versus the necessity to quickly transport them to the trauma center. In addition, there are multiple non-modifiable factors that affect pre hospital transport times such as distance from a trauma center and specific patient factors.

Several studies have attempted to analyze the correlation between prehospital transport times and patient outcomes. In a systematic review, Harmsen et al. concluded that swift transport is beneficial in the hemodynamically unstable penetrating injury patient, while longer on scene and pre-hospital transport time in the hemodynamically stable undifferentiated trauma patient is not associated with higher mortality.[6] In this study, we aimed to evaluate the association between prehospital transport times and mortality of penetrating trauma patients across North America with specific emphasis on the separate impact of prehospital response time (PreRespT) and time spent on scene (SceneT) on outcomes of penetrating injury patients, while accounting for various covariates and other pre-hospital time intervals. We hypothesized that longer PreRespT and SceneT in the penetrating trauma population are each independently associated with worse outcomes.

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Methods

Using the Trauma Quality Improvement Program (TQIP) database from 2010 to 2016, we included all patients 16 years or older that sustained a penetrating traumatic injury. Patients that were transferred to another institution were excluded because of the effect of transfer time on outcome. Patients with missing or incomplete prehospital time data were excluded. A total of 22,486 patients had missing pre-hospital transport time data. Mortality, the main outcome in the study, was defined as in-hospital death during the index admission.

The mechanism of injury was identified using the International Classification of Diseases, Ninth and Tenth Revision external causes of injury codes, provided in the TQIP database, based on the year of patient admission.

Pre-hospital response time (PreRespT) was defined as the time (in minutes) from the dispatch of the Emergency Medical Services (EMS) transporting unit to scene arrival. Scene time (SceneT) was defined as the time (in minutes) from EMS scene arrival to departure from the scene. Transport time (TranspT) was defined as the time (in minutes) from leaving the scene to hospital arrival. The overall prehospital time (OverallT) was defined as the sum of PreRespT + SceneT + TranspT.

The additional variables used from the TQIP database included: age, gender, race/ethnicity, injury severity score (ISS), comorbidities, first recorded systolic blood pressure on scene, Glasgow Coma Scale (GCS) on scene, pulse on scene, primary transport mode (Ground ambulance vs. Helicopter ambulance vs. fixed wing ambulance vs. police transport vs. other transport mode) and the region in the USA where the trauma facility is located (Northeast vs. Midwest vs. West vs. South). Age, ISS, prehospital times, systolic blood pressure and pulse on scene were treated as continuous variables. Gender, race/ethnicity, comorbidities, GCS score, transport mode and region were treated as discrete or categorical variables.

Univariate analyses were initially performed to compare variables in survivors and non-survivors. A logistic regression model was then developed to identify the independent correlation between prehospital time intervals and mortality.

Categorical variables were presented as totals and percentages. Continuous variables were presented as means and medians. A chi-square test was used for discrete variables, and the Student's t-test or Wilcoxon rank sum test (Mann-Whitney) was used for continuous variables depending on the distribution of the variable. Missing data was coded as suc. Variables that were potentially associated ($p < 0.20$) with mortality in the univariate analyses were included in the multivariable logistic regression model. A stepwise logistic regression model was used. Statistical significance was defined as $p < 0.05$. STATA, version 15, was used to perform the statistical analyses for this study. Institutional Review Board (IRB) approval was obtained.

Results

A total of 43,467 patients met the inclusion criteria, out of an initial 1,403,470 patients in the TQIP database. Table 1 describes in detail the characteristics of this population. In summary, the majority of patients were male (88.04%), the median age was 30 years (IQ range 23–41) and the median ISS was 13 (IQ range 9–21). The median systolic blood pressure, pulse and GCS on scene were 122 mmHg (IQ range 100–140), 97 beats per minute (IQ range 80–112), and 15 (IQ range 14–15), respectively. The median PreRespT, SceneT, TranspT, and OverallT were 5 min (IQ range 4–8), 6 min (IQ range 3–10 min), 18 min (IQ range 13–25), and 29 min (IQ range 24–40), respectively. A total of 6729 patients died during the initial hospitalization (15.48%), 5583 (83%) of which died within the first 48 h.

In univariate analyses, the non-survivors were older (mean 36.3 years vs. 32.9 years; $p < 0.0001$), had a higher ISS (mean 28.7 vs. 14.1; $p < 0.0001$), a lower systolic blood pressure on scene (mean 92.1 vs 122.3 mmHg; $p < 0.0001$), a longer preRespT (mean 6.55 min vs. 6.16 min; $p < 0.0001$) and a longer SceneT (mean 7.47 min vs. 6.99 min; $p < 0.0001$).

A detailed description of the multivariable logistic regression analyses can be seen in Table 2. After accounting for potential covariates in the TQIP database, including all other prehospital time intervals, every minute increase in PreRespT independently correlated with a 2% relative increase in odds of mortality [OR 1.02 (95% CI 1.01–1.03) $p < 0.0001$]. In addition, every minute increase in SceneT independently correlated with a 1% relative increase in the odds of mortality [OR 1.01 (95% CI 1.003–1.01) $p = 0.001$]. (see Fig. 1) The adjusted odds ratio for TranspT was 0.991 [(95% CI 0.99–0.995) $p < 0.0001$]. The Area Under the Curve of the model was 0.90, and the pseudo R2 was 0.35.

Other significant predictors of mortality in our penetrating trauma population included age, race/ethnicity, various comorbidities, vitals on scene, ISS score, transport mode and region where the injury occurred. The adjusted odds ratio for ISS score was 1.12 ($p < 0.0001$). When ISS increased by 1, the odds of mortality increased by 12%. The Southern region in the United States was associated with 49% higher odds in mortality when compared to the Northeast (OR 1.49, p=<0.0001), while the Midwest was associated with a 33% increase in odds of mortality when compared to the Northeast (OR 1.33, $p < 0.0001$). Compared to ground transport, police transport had the lowest odds of mortality (OR 0.21; 95% CI 0.08–0.55).

Discussion

To the best of our knowledge, this is the first nationwide study of penetrating injury to quantify that each additional minute of EMS response time independently correlates with a 2% relative increase in odds of mortality, and that each additional minute of EMS time on scene independently correlates with a 1% relative increase in odds of mortality. We acknowledge that these findings represent a correlation and not necessarily causation, and that this is a relative risk increase. However, such findings suggest that policy changes that improve EMS reach to injured patients, as well as a "scoop and run" strategy could significantly impact the ability to rescue penetrating injury trauma patients. Multiple previous studies showed results from a single institution, included undifferentiated trauma patients, were limited due to residual confounding or low number of patients, did not find a significant correlation between prehospital time and mortality after accounting for the severity of injuries, or were from a single geographical region.[7–23] In a study of one regional trauma center, Lerner et al. found no significant correlation between total prehospital transport time and mortality.[24] Similarly, Newgard et al. found no association between different prehospital time intervals and mortality in a North American cohort of patients.[25] On the other hand, Pham et al. states that shorter on scene times are associated with better survival,[26] while Rhinehart et al. states that longer dispatch times and travel distance are associated with higher mortality in patients transported by helicopter.[27]

Prehospital transport times in rural areas differ from urban regions due to longer driving distance to reach patients. In addition, fewer trauma level centers exist in certain regions in the USA, which may require EMS to travel further when transporting a patient. Although the specific zip codes, counties or states in the US where the injury occurred are not included in the TQIP database to

Table 1
Sample population characteristics of trauma patients (univariate analysis).

	n (%) All Patients	Survived (%) (n = 36,738)	Died (%) (n = 6729)	P Value
Population Size	43,467			
Overall mortality	6729 (15.5)			
48 h mortality	5583 (13.0)			
LOS, days				
Mean (SD)	8.0 (11.8)			
Median (IQR)	4.6 (1.9–9.2)			
Age, years				
Mean (SD)	33.5 (13.8)	32.9 (13.1)	36.3 (16.4)	
Median (IQR)	30 (23–41)	29 (23–41)	31 (23–47)	<0.0001
Female sex	5196 (12.0)	4326 (11.8)	870 (12.9)	0.007
Race/Ethnicity				<0.0001
White	15,303 (36.4)	12,341 (33.6)	2962 (44.0)	
Asian	527 (1.3)	435 (1.2)	92 (1.4)	
Black/African American	21,063 (50.0)	18,310 (49.8)	2753 (7.5)	
Other	5206 (12.4)	4553 (12.4)	653 (9.7)	
Unknown	1368 (3.2)	1099 (3.0)	269 (4.0)	
ISS score				
Mean (SD)	16.4 (11.1)	14.1 (8.2)	28.7 (15.8)	
Median (IQR)	13 (9–21)	10 (9–17)	25 (20–30)	<0.0001
SBP on scene				<0.0001
Mean (SD)	118.2 (37.1)	122.3 (30.2)	92.1 (59.3)	
Median (IQR)	122 (100–140)	124 (102–140)	100 (60–134)	
Pulse on scene				<0.0001
Mean (SD)	96.1 (28.2)	98.2 (22.9)	83.7 (46.2)	
Median (IQR)	97 (80–112)	98 (82–112)	88 (57–120)	
GCS on scene				<0.0001
Mean (SD)	13.0 (4.1)	14.3 (2.3)	6.0 (4.6)	
Median (IQR)	15 (14–15)	15 (15–15)	3 (3–9)	
PreRespT, mins				
Mean (SD)	6.2 (3.9)	6.2 (3.8)	6.6 (4.4)	<0.0001
Median (IQR)	5 (4–8)	5 (4–8)	5 (4–8)	0.004
SceneT, mins				
Mean (SD)	7.1 (7.2)	7.0 (6.9)	7.5 (8.7)	<0.001
Median (IQR)	6 (3–10)	6 (3–9)	6 (3–10)	0.0682
TranspT, mins				
Mean (SD)	20.8 (12.3)	20.9 (12.3)	20.4 (12.1)	0.0008
Median (IQR)	18 (13–25)	18 (13–25)	18 (13–24)	<0.001
OverallT, mins				
Mean (SD)	34.1 (16.7)	34.1 (16.6)	34.4 (17.8)	<0.0001
Median (IQR)	30 (24–40)	30 (24–40)	30 (23–40)	0.2702
Transport mode				<0.001
Ground Ambulance	39,799 (91.6)	33,847 (92.1)	5952 (88.5)	
Helicopter Ambulance	2505 (5.8)	1857 (5.1)	648 (9.6)	
Fixed Wing Ambulance	6 (<0.1)	4 (<0.1)	2 (<0.1)	
Police	175 (0.4)	167 (0.5)	8 (0.1)	
Other	548 (1.3)	492 (1.3)	56 (0.8)	
Unknown	434 (1.0)	371 (1.0)	63 (0.9)	
Region of Facility				<0.0001
Northeast	5051 (11.6)	4341 (11.8)	710 (10.6)	
Midwest	9109 (21.0)	7709 (21.0)	1400 (20.8)	
West	7256 (16.7)	6242 (17.0)	1014 (15.1)	
South	19,538 (45.0)	16,439 (44.8)	3099 (46.1)	
Unknown	2513 (5.8)	2007 (5.5)	506 (7.5)	
Comorbidities				
Alcoholism	3600 (8.3)	3367 (9.2)	233 (3.5)	<0.0001
Bleeding Disorder	378 (0.9)	301 (0.8)	77 (1.1)	0.008
Chemotherapy	23 (0.1)	17 (0.1)	6 (0.1)	0.16
Current Smoker	11,468 (26.4)	11,097 (30.2)	371 (5.5)	<0.0001
Chronic Renal Failure	65 (0.2)	50 (0.1)	15 (0.2)	0.09
Diabetes	1418 (3.3)	1260 (3.4)	158 (2.3)	<0.0001
Disseminated Cancer	58 (0.1)	27 (0.1)	31 (0.5)	<0.0001
History of MI	86 (0.2)	67 (0.2)	19 (0.3)	0.09
Hypertension	3681 (8.5)	3342 (9.1)	339 (5.0)	<0.0001
Respiratory Disease	1564 (3.6)	1445 (3.9)	119 (1.8)	<0.0001
Cirrhosis	100 (0.2)	68 (0.2)	32 (0.5)	<0.0001
Psychiatric Illness	3672 (8.5)	3253 (8.9)	419 (6.2)	<0.0001
Drug Abuse	5988 (13.8)	5695 (15.5)	293 (4.4)	<0.0001
ADHD	174 (0.4)	161 (0.4)	13 (0.2)	0.003
Congenital Anomalies	70 (0.2)	61 (0.2)	9 (0.1)	0.544
Congestive Heart Failure	160 (0.4)	131 (0.4)	29 (0.4)	0.354
History of CVA	134 (0.3)	109 (0.3)	25 (0.4)	0.31
Functionally Dependent	106 (0.2)	93 (0.3)	13 (0.2)	0.359

Table 1 (*continued*)

	n (%) All Patients	Survived (%) (n = 36,738)	Died (%) (n = 6729)	P Value
History of Angina	11 (<0.1)	10 (<0.1)	1 (<0.1)	0.558
History of PVD	28 (0.1)	25 (0.1)	3 (<0.1)	0.485
Steroid Use	62 (0.1)	54 (0.2)	8 (0.1)	0.574
Dementia	56 (0.1)	44 (0.1)	12 (0.2)	0.218

Abbreviations: SD, standard deviation; IQR, interquartile range; ISS, Injury Severity Score; SBP, systolic blood pressure; GCS, Glasgow Coma Scale; LOS, length of stay; PreRespT, time from EMS dispatch to scene arrival; SceneT, time from EMS scene arrival to departure; TranspT, time from scene departure to hospital arrival; OverallT, total transport time (PreRespT + SceneT + TranspT); MI, Myocardial Infarction; ADHD, Attention Deficit Hyperactivity Disorder; CVA, Cerebrovascular Accident; PVD, Peripheral Vascular Disease.

decipher urban from rural areas in a definitive way, higher odds of mortality in the South and Midwest were found and may be, at least partly, related to longer transport times because of both fewer existing trauma centers and a more rural setting in general.

Moreover, our study accounts for the primary mode of transport that brought the patient to the trauma center. Ground ambulance differs with regards to the level of care that it can deliver when compared to a helicopter ambulance because of the level of care that helicopter staff can provide. Previous studies stated that police and private vehicle transport of trauma patients was associated with same or lower odds of mortality when compared to ground EMS.[28–33] Our data also suggests that police transport had the lowest odds of mortality when compared to ground ambulance, possibly due to a "scoop and run" strategy and minimal interventions that police officers use when dealing with penetrating injury patients.

Table 2
Predictors of mortality in penetrating trauma patients (multivariable logistic regression analyses).

	Adjusted Odds Ratio (95% CI)	P value
PreRespT, mins	1.02 (1.01–1.03)	0.001
SceneT, mins	1.01 (1.003–1.013)	<0.0001
TranspT, mins	0.991 (0.99–0.995)	<0.0001
Age, years	1.02 (1.015–1.021)	<0.0001
ISS Score	1.12 (1.12–1.13)	<0.0001
SBP on scene	0.99 (0.988–0.99)	<0.0001
Pulse on scene	0.99 (0.989–0.991)	<0.0001
Transport mode		
Ground Ambulance (reference)	1	
Helicopter Ambulance	1.60 (1.36–1.89)	<0.0001
Fixed Wing Ambulance	6.99 (0.57–85.14)	0.128
Police Transport	0.21 (0.08–0.55)	0.001
Other Transport	0.30 (0.21–0.44)	<0.0001
Region		
Northeast (Reference)	1	
Midwest	1.33 (1.15–1.54)	<0.0001
West	0.97 (0.83–1.14)	0.737
South	1.49 (1.31–1.71)	<0.0001
Race/Ethnicity		
White (Reference)	1	
Asian	0.88 (0.64–1.21)	0.416
Black/African American	0.50 (0.45–0.54)	<0.0001
Other	0.52 (0.45–0.59)	<0.0001
Comorbidities		
Bleeding Disorder	1.46 (1.03–2.06)	0.032
Chronic Renal Failure	2.47 (1.14–5.35)	0.022
Disseminated Cancer	4.19 (2.08–8.45)	<0.0001
Hypertension	0.46 (0.39–0.55)	<0.0001
Respiratory Disease	0.61 (0.47–0.79)	<0.0001
Cirrhosis	4.24 (2.39–7.54)	<0.0001
Psychiatric illness	0.79 (0.69–0.92)	0.002
Alcoholism	0.51 (0.42–0.62)	<0.0001
Drug abuse	0.41 (0.35–0.48)	<0.0001
Current smoker	0.19 (0.16–0.22)	<0.0001

Abbreviations: PreRespT, time from EMS dispatch to scene arrival; SceneT, time from EMS scene arrival to departure; TranspT, time from scene departure to hospital arrival; ISS, Injury Severity Score; SBP, systolic blood pressure.

While our study supports that the faster we respond to a penetrating injury on scene and the least amount of time we spend on the scene can improve mortality and rescue, we also acknowledge that EMS personnel judgment on scene plays an important role. For example, if the trauma scene is hours away from the nearest hospital, and the patient is not protecting his/her airway, then perhaps spending the extra few minutes to secure the airway before a long transport is justified. Meizoso et al. concludes that pre-hospital interventions in severely injured trauma patients are associated with a lower odd of mortality and do not delay transport of patients,[34] while Smith et al.[5] and Haut et al.[35] believe that some field maneuvers have little positive influence on patient outcomes, may delay transport times and consequently result in negative outcomes. In addition, some EMS systems in the nation include physicians, such as helicopter ambulances, which may affect patient outcomes. We acknowledge that the decision to stabilize the patient versus quick transport is sometimes injury and system dependent.

Our study has a few limitations. First, this is a retrospective analysis from an existing database, and residual confounding might still be present despite our rigorous attempts in the multivariable analyses. Second, prehospital interventions by EMS staff, extrication times and amount of time to secure the scene were factors that were not available from the database. Third, we did not have the specific zip codes of the injuries, which would have allowed us to perform more geospatial analyses of the response and scene times to account for proximity to trauma centers.

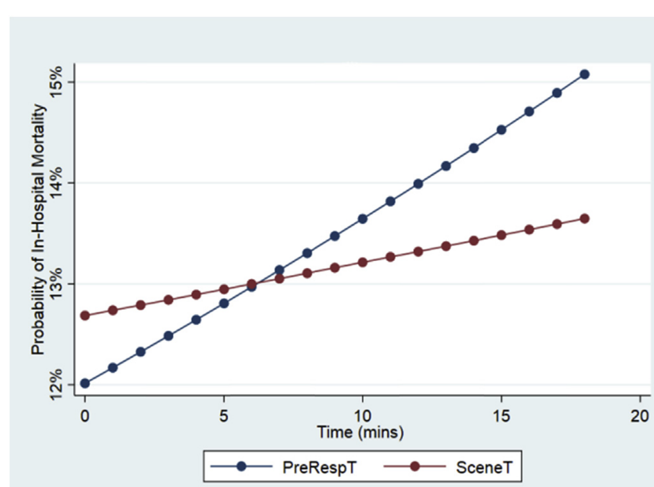

Fig. 1. The Absolute Mortality Risk versus. the 95th percentile of PreRespT and SceneT.

Conclusion

In the penetrating injury trauma patient, every additional minute spent in prehospital response and on scene may count and independently correlates with hospital mortality. This data suggests that a faster response time and a “scoop and run” strategy may be more appropriate in this specific patient population. Further research should examine potentially existing variations in any EMS dispatch time across regions and providers, and advocacy efforts with EMS should establish injury scene protocols focused on “scoop and run” strategies for the penetrating trauma patients.

Declaration of competing interest

The authors declare no financial support or conflict of interest during this research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.11.018.

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