Association of Prehospital Mode of Transport With Mortality in Penetrating Trauma
A Trauma System–Level Assessment of Private Vehicle Transportation vs Ground Emergency Medical Services

Michael W. Wandling, MD, MS; Avery B. Nathens, MD, PhD; Michael B. Shapiro, MD; Elliott R. Haut, MD, PhD

IMPORTANCE  Time to definitive care following injury is important to the outcomes of trauma patients. Prehospital trauma care is provided based on policies developed by individual trauma systems and is an important component of the care of injured patients. Given a paucity of systems-level trauma research, considerable variability exists in prehospital care policies across trauma systems, potentially affecting patient outcomes.

OBJECTIVE  To evaluate whether private vehicle prehospital transport confers a survival advantage vs ground emergency medical services (EMS) transport following penetrating injuries in urban trauma systems.

DESIGN, SETTING, AND PARTICIPANTS  Retrospective cohort study of data included in the National Trauma Data Bank from January 1, 2010, through December 31, 2012, comprising 298 level 1 and level 2 trauma centers that contribute data to the National Trauma Data Bank that are located within the 100 most populous metropolitan areas in the United States. Of 2,329,446 patients assessed for eligibility, 103,029 were included in this study. All patients were 16 years or older, had a gunshot wound or stab wound, and were transported by ground EMS or private vehicle.

MAIN OUTCOME AND MEASURE  In-hospital mortality.

RESULTS  Of the 2,329,446 records assessed for eligibility, 103,029 individuals at 298 urban level 1 and level 2 trauma centers were included in the analysis. The study population was predominantly male (87.6%), with a mean age of 32.3 years. Among those included, 47.9% were black, 26.3% were white, and 18.4% were Hispanic. Following risk adjustment, individuals with penetrating injuries transported by private vehicle were less likely to die than patients transported by ground EMS (odds ratio [OR], 0.38; 95% CI, 0.31-0.47). This association remained statistically significant on stratified analysis of the gunshot wound (OR, 0.45; 95% CI, 0.36-0.56) and stab wound (OR, 0.32; 95% CI, 0.20-0.52) subgroups.

CONCLUSIONS AND RELEVANCE  Private vehicle transport is associated with a significantly lower likelihood of death when compared with ground EMS transport for individuals with gunshot wounds and stab wounds in urban US trauma systems. System-level evidence such as this can be a valuable tool for those responsible for developing and implementing policies at the trauma system level.
he time immediately following injury can be vitally important to the clinical outcomes of severely injured trauma patients. The term the golden hour is commonly used to emphasize the importance of time in trauma care. Trauma systems are developed at the local, state, or regional level to optimize the delivery of care to seriously injured patients and are associated with increased survival after injury. Although the focal points of trauma systems are specialized trauma centers, the prehospital care provided to injured patients prior to arriving at trauma centers is important because this care has implications on clinical outcomes. Prehospital care policies are typically established at the trauma system level. In accordance with these policies, first responders must determine what, if any, interventions should be performed prior to and during transport to the hospital. To our knowledge, most of the previous research into optimal prehospital trauma care policies has not evaluated their effects at a system level, limiting the generalizability of their findings and resulting in persistent variability in prehospital protocols and procedures across trauma systems.

The spectrum of prehospital care provided to injured patients ranges from no intervention to advanced life support, fluid resuscitation, and endotracheal intubation with mechanical ventilation. Although optimal prehospital care strategies following injury remain undefined, within the last 2 years, several major national initiatives have aimed to improve early bystander and first responder response to injury, including the Stop the Bleed campaign based primarily on the Hartford Consensus. Training of the lay public in hemorrhage control has also become increasingly common in urban areas with high levels of violence.

Private vehicle transportation to a trauma center represents perhaps the most basic form of prehospital care, where no intervention is performed and only transportation is provided. In essence, private vehicle transport is a pure example of the “scoop and run” approach to prehospital trauma care. In patients with penetrating injuries where time to definitive treatment is paramount, private vehicle transportation has been shown to be associated with improved survival when compared with transportation via ground emergency medical services (EMS). Although compelling, the results of this study are at the patient level and thus have been difficult to translate into trauma system-level policy. The objective of our study was to evaluate the association between the mode of transportation and mortality among individuals with penetrating injuries within urban trauma systems. We hypothesized that private vehicle transport is associated with a decreased mortality for penetrating injuries when compared with ground EMS transport.

Methods

The data source for this study was the American College of Surgeons National Trauma Databank (NTDB); the largest aggregation of US trauma registry data assembled. Data are entered into the NTDB by trained data abstractors, and the quality of the data is maintained through extensive statistical analyses and hospital audits performed by the American College of Surgeons Committee on Trauma. For this study, data from January 1, 2010, through December 31, 2012, were analyzed. Patients were included if they were aged 16 years or older, had a gunshot wound (GSW) or stab wound, were transported to the hospital by ground EMS or private vehicle, and were treated at a level 1 or level 2 trauma center. The design of this study is similar to previously published work comparing ground EMS and police department prehospital transport. Analyses were restricted to patients treated at trauma centers located within the 100 most populous US trauma systems to generate results capable of driving prehospital policy changes within large urban trauma systems. Cities were not used to define trauma systems because doing so would exclude trauma centers located outside a city’s limits that still provide trauma care to the city’s population. Patients were excluded if they had incomplete records for the primary outcome of in-hospital mortality or were transferred to or from another hospital.

Study participants were limited to individuals with GSWs or stab wounds because they represent a unique subpopulation of trauma patients most likely to benefit from timely surgical intervention and least likely to derive significant benefit from prehospital interventions. These mechanisms of injury were identified by International Classification of Diseases, Ninth Revision external causes of injury codes that are provided for each record in the NTDB. The 100 most populous US trauma systems were defined using 2010 US census information that ranks metropolitan areas based on Metropolitan Statistical Areas, an approach previously used in aggregating trauma centers into defined trauma systems. Metropolitan Statistical Areas are geographic areas containing a large population nucleus and adjacent communities with a high degree of integration with the population nucleus. Adult level 1 and level 2 trauma centers located within the most populous metropolitan areas were assigned to their respective trauma system. Institutional review board exemption was obtained from the Northwestern University Feinberg School of Medicine institutional review board. Individual patient consent was waived because all data used in this study were deidentified in the NTDB dataset prior to this study being conducted.

Key Points

Question: Does ground emergency medical services transport confer a survival advantage vs private vehicle transport for patients with penetrating injuries?

Findings: In this cohort study of 103,029 patients included in the National Trauma Data Bank, individuals transported by private vehicle were significantly less likely to die than similarly injured patients transported by ground emergency medical services, even when controlling for injury severity.

Meaning: Ground emergency medical services transport is not associated with improved survival compared with private vehicle transport among patients with penetrating injuries in urban trauma systems, suggesting prehospital trauma care may have a limited role in this subset of patients.
Baseline characteristics and unadjusted mortality rates between patients transported by ground EMS and those transported by private vehicle were compared using χ² and t tests. Unadjusted mortality rates by mode of transport were compared between GSW and stab wound subgroups of the patient sample. The primary outcome of in-hospital mortality included deaths in the emergency department (ED) and all deaths occurring prior to hospital discharge. We considered excluding ED deaths from our analysis to determine the correlation of transport mode with survival of only salvageable patients. However, this approach could introduce selection bias. For example, it cannot be determined whether ED deaths within the private vehicle cohort were owing to lack of prehospital intervention or rapid transport of patients with nonsurvivable injuries who EMS may have pronounced dead at the scene. Excluding these patients could bias important mortality data among these patients to favor a lower mortality rate, when prehospital cardiac arrest may in fact occur at higher rates and result in more deaths among these patients. Similarly, ED deaths could potentially have occurred in EMS-transported patients who might have survived if they had been transported by private vehicle with a shorter delay to definitive care. Patients with a documented discharge disposition of hospice were also defined as in-hospital deaths, as has been previously described for risk-adjusted mortality calculations in trauma.23

To evaluate the independent association between mode of prehospital transport and mortality, a general linear mixed-effects model accounting for hospital-level clustering was created. Consideration was given to using propensity score-matched cohorts, but this did not confer an advantage over multivariable modeling.24,25 Variables included in the risk adjustment for mortality were presenting heart rate, presenting systolic blood pressure, presenting Glasgow Coma Scale Motor Score, Injury Severity Score (ISS), age, sex, race/ethnicity, insurance status, and year of admission.26 Heart rate, systolic blood pressure, ISS, and age were treated as continuous variables, while sex, race/ethnicity, insurance status, and year of admission were categorical. Insurance status was categorized as private, governmental, self-pay, or other.26,27 Missing data for heart rate (n = 1624; 1.6%), systolic blood pressure (n = 2065; 2.0%), Glasgow Coma Scale Motor Score (n = 2119; 2.1%), ISS (n = 411; 0.4%), and sex (n = 18; 0.02%) were addressed using multiple imputation.28 Risk-adjusted mortality was assessed for all penetrating injuries as well as for the GSW and stab wound subgroups. Risk-adjusted mortality was also evaluated after stratifying by injury severity. Two stratified analyses were performed, 1 stratifying patients into ISS 15 or less and ISS greater than 15 categories and the other stratifying into mild (ISS ≤9), moderate (ISS, 9-15), severe (ISS, 16-24), and very severe (ISS ≥25) injury severity categories. To confirm the applicability of results to the top 100 most populous US trauma systems, sensitivity analyses were performed to evaluate risk-adjusted mortality across population strata. These strata included the most populous 10, 25, 50, and 75 systems, as well as the least populous 10, 25, 50, and 75 trauma systems within the 100 most populous US trauma systems (eTable in the Supplement). The results of this study were 2-sided and considered to be statistically significant at an α level of P < .05.

Results

Of the 2329446 patients at 869 hospitals included in the NTDB from January 1, 2010, to December 31, 2012, a total of 103029 patients at 298 hospitals were included in the study sample after applying the inclusion and exclusion criteria (Figure 1). Of the included patients, black and Hispanic patients were more frequently transported by private vehicle than by ground EMS (8545 [50.5%] vs 40775 [47.4%] and 3472 [20.5%] vs 15430 [17.9%], respectively), while white patients were more frequently transported by ground EMS than by private vehicle (23420 [27.2%] vs 3663 [21.6%]). Patients with stab wounds were more likely to be transported by private vehicle than those with GSWs (9462 [55.9%] vs 7470 [44.1%], P < .001). The mean ISS was significantly lower for patients transported by private vehicle than those transported by ground EMS (5.5 vs 10.1, P < .001). Full demographic and injury information is provided in Table 1.

Overall, unadjusted mortality was lower for private vehicle transport than for ground EMS (378 [2.2%] vs 9986 [11.6%], P < .001). Among patients with GSWs, unadjusted mortality was significantly lower for those transported by private vehicle when compared with ground EMS (339 [4.5%] vs 18807 [9.3%], P < .001). This difference was also found for the stab wound subgroup (39 [0.2%] vs 1179 [2.9%], P < .001). Private vehicle transport was associated with a lower unadjusted rate of death in the ED compared with ground EMS transport (1.2% vs 6.8%, P < .001). Unadjusted mortality rates are provided in Table 2.

Figure 1. Consort Diagram Illustrating the Selection of Patients From the National Trauma Data Bank Between January 1, 2010, and December 31, 2012

Table 1. Baseline Characteristics and Unadjusted Mortality Rates of Patients Transported by Private Vehicle or by Ground Emergency Medical Service

Table 2. Patients Stratified by Injury Severity and Transport Mode

Table 3. Patients Stratified by Injury Severity, Transport Mode, and Age

Table 4. Patients Stratified by Injury Severity, Transport Mode, and Race/ethnicity

Table 5. Patients Stratified by Injury Severity, Transport Mode, and Year of Admission

Table 6. Patients Stratified by Injury Severity, Transport Mode, and Insurance Status

Table 7. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode

Table 8. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Age

Table 9. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Race/ethnicity

Table 10. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Year of Admission

Table 11. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Insurance Status

Table 12. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Transport Mode

Table 13. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Age and Race/ethnicity

Table 14. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Age and Year of Admission

Table 15. Patients Stratified by Injury Severity, Transport Mode, and Transport Mode and Race/ethnicity and Year of Admission
After risk adjustment, patients with penetrating injuries transported by private vehicle were significantly less likely to die than patients transported by ground EMS (OR, 0.38; 95% CI, 0.31-0.47) (Figure 2). This association remained statistically significant on stratified analysis of the GSW (OR, 0.45; 95% CI, 0.36-0.56) and stab wound (OR, 0.32; 95% CI, 0.20-0.52) subgroups (Figure 2). Stratified injury severity analyses demonstrated a qualitatively similar survival benefit associ-
ated with private vehicle transport when compared with ground EMS transport for all but the lowest injury severity strata. Sensitivity analyses revealed statistically significant mortality benefits for patients with penetrating injuries transported by private vehicle when compared with ground EMS in 8 of 9 trauma system cohorts. Sensitivity analyses revealed the only group of trauma systems failing to demonstrate statistically significant risk-adjusted mortality differences was the 91 to 100 most populous trauma systems, where the sample size was too small to detect a significant difference (OR, 0.26; 95% CI, 0.06-1.15) (Figure 3).

Discussion

This study demonstrates that for individuals with penetrating injuries in urban trauma systems, private vehicle transport to a level 1 or level 2 trauma center is associated with significantly lower mortality when compared with similarly injured individuals who are transported by ground EMS. This mortality benefit holds true on subgroup analyses of the 100 most populous US trauma systems, making these findings generalizable at the trauma system level for the large urban trauma systems included in this study. These results are important because they identify a component of prehospital trauma care that is associated with significant differences in mortality and may present an opportunity to improve trauma care at the system level.

Previous research has demonstrated that variations in prehospital care can affect mortality among seriously injured pa-

Figure 2. Risk-Adjusted Odds Ratios for Mortality for Private Vehicle Transport Compared With Ground Emergency Medical Services Transport

<table>
<thead>
<tr>
<th>GSWs and stab wounds</th>
<th>GSW</th>
<th>Stab wounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted Odds Ratio for Mortality (95% CI)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GSW indicates gunshot wound.

Figure 3. Trauma System Subgroup Analyses of Risk-Adjusted Odds Ratios (ORs) for Mortality for Private Vehicle Transport Compared With Ground Emergency Medical Services Transport

<table>
<thead>
<tr>
<th>No. of Events</th>
<th>No. of Participants</th>
<th>OR (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>All penetrating</td>
<td>GSWs</td>
<td>Stab wounds</td>
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<tr>
<td>Most populous 10</td>
<td>3324</td>
<td>32584</td>
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<td>GSWs</td>
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<td>Stab wounds</td>
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<td>Most populous 25</td>
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<tr>
<td>Stab wounds</td>
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<tr>
<td>Least populous 10</td>
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<td>GSWs</td>
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<td>Stab wounds</td>
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<td>Overall</td>
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<tr>
<td>Stab wounds</td>
<td>1058</td>
<td>45278</td>
</tr>
</tbody>
</table>

GSW indicates gunshot wound; NA, not applicable.

Odds ratios cannot be derived due to small sample size.
patients, often in ways that may not be expected. For example, prehospital advanced life support care has been shown in multiple studies to be associated with higher mortality rates than basic life support when similarly injured patients are compared.\(^7,8\) Additionally, prehospital interventions, including endotracheal intubation, intravenous fluid administration, and spine immobilization, have been found to be associated with higher rates of mortality in certain groups of trauma patients.\(^9-11\) Previous work has also demonstrated outcome differences, or an absence of differences, based on mode of prehospital transportation including helicopter,\(^12\) ground EMS, police department transport,\(^29,30\) and private vehicle.\(^12,31\) These studies highlight the significance of prehospital trauma care and the effect that trauma system-level first responder policies can have on patient outcomes. However, these studies examine outcomes within single centers or aggregated at a national level, rather than the trauma system level, which has limited the ability to use the results to drive system-level policy change.

The results of this study confirm those that have been previously reported on mortality differences between ground EMS and private vehicle transport, but represent, to our knowledge, the first time the results have been analyzed on a trauma system level. Additionally, the results of this study were obtained through a larger patient sample that contained data through 2012, which is more recent than previous studies. The ability to use unblinded NTDB hospital identifiers to conduct system-level analyses that can inform trauma system policy is a major strength of this study and, to our knowledge, has never been published. Because trauma system policies are developed and implemented at the system level, it is important to provide system-level evidence to support the implementation of policies and protocols within each system. For example, consideration could be given to educating those at high risk for penetrating injury that individuals with these injuries may benefit from rapid private vehicle transport to the nearest level 1 trauma center instead of waiting for first responders to arrive. Furthermore, although EMS “scoop and run” policy was unable to be compared with EMS “stay and stabilize” policy in this analysis, these results suggest that a “scoop and run” policy for EMS may be beneficial given the similarities between private vehicle transport and “scoop and run” by EMS. Other strengths of this study include the large sample size and the consistently statistically significant results in nearly all strata, subgroups, and sensitivity analyses.

**Limitations**

This study is not without limitations. As with all large, multicenter database analyses, data quality is dependent on the accuracy of the data abstraction process and the amount of missing data. Although there are auditing mechanisms in place to identify errors in abstraction, errors cannot be entirely eliminated. Missing data were not a major factor in this analysis, but where they were present, the missing data were imputed. Another limitation of this study was the risk adjustment for mortality calculations, which was limited to the data available in the NTDB. As a result, it is likely that potential confounding risk factors for mortality were unable to be included in the risk-adjustment process. Specifically, prehospital transport time is one of the major confounders we were unable to include owing to the large amount of missing data. However, because patients transported by private vehicle do not wait for EMS to arrive and do not undergo any prehospital interventions, their prehospital times are unlikely to be longer than those transported by ground EMS. Differences in baseline characteristics between modes of transport, most notably mechanism of injury and injury severity, are also a limitation. Although patient randomization would optimally eliminate these differences, this was not (and realistically, will never be) feasible, and we accounted for these differences by adjusting for them in our mortality models. Furthermore, the results of this study only reflect the data from trauma centers that contribute to the NTDB. Although more than 800 centers contribute data to the NTDB each year, it is not a requirement for all US trauma centers, and thus, not all centers participate. Lastly, although the results of this study demonstrate a mortality benefit associated with private vehicle transport, such approaches may be associated with unintended consequences unable to be assessed by this study. Consequently, further study is necessary before private vehicle transport initiatives or “scoop and run” EMS transport policies can be definitively recommended for all urban gunshot and stab wound patients.

**Conclusions**

Private vehicle transport is associated with a significantly lower likelihood of death when compared with ground EMS transport for individuals with GSWs and stab wounds in urban US trauma systems. System-level data such as these can be a valuable tool for use in the development and implementation of policies at the trauma system level. The goal of trauma systems is to deliver optimal care to injured patients. An important part of accomplishing this is determining what constitutes optimal care in each trauma system because it may be different. The results of this study highlight the importance of system-level research and the need for additional such work to be conducted in the future.
Author Contributions: Dr. Wandling had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Wandling, Nathens, Haut.

Acquisition, analysis, or interpretation of data: Wandling, Shapiro, Haut.

Drafting of the manuscript: Wandling.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Wandling.

Obtained funding: Wandling.

Administrative, technical, or material support: Wandling.

Supervision: Nathens, Shapiro, Haut.

Conflict of Interest Disclosures: Dr. Wandling is the primary investigator for training grant F32GM113513 from the National Institute of General Medical Sciences of the National Institutes of Health. Dr. Nathens is a paid consultant for the American College of Surgeons Trauma Quality Improvement Program. Dr. Haut is primary investigator for research grant R01HS024547 from the Agency for Healthcare Research and Quality titled Individualized Performance Feedback on Venous Thromboembolism Prevention Practice. Dr. Haut is the primary investigator for 2 contracts from the Patient-Centered Outcomes Research Institute titled Preventing Venous Thromboembolism: Empowering Patients and Enabling Patient-Centered Care via Health Information Technology (CE-12-11-4489) and Preventing Venous Thromboembolism: Engaging Patients to Reduce Preventable Harm from Missed/Refused Doses of VTE Prophylaxis (DI-1603-34596). Dr. Haut receives royalties from Lippincott, Williams, and Wilkins for Avoiding Common ICU Errors. Dr. Haut was the paid author of an article commissioned by the National Academies of Medicine titled “Military Trauma Care’s Learning Health System: The Importance of Data Driven Decision Making,” which was used to support the report titled “A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury.”

REFERENCES:


