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It's All About Location, Location, Location:

A New Perspective on Trauma Transport

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Abstract

Objective: To determine the effect of aeromedical transport on trauma mortality when accounting for geographic factors.

Background: The existing literature on the mortality benefit of aeromedical transport on trauma mortality is controversial. Studies examining patient and injury characteristics find higher mortality, whereas studies measuring injury severity find a protective effect. Previous studies have not adjusted for the time and distance that would have been traveled had a helicopter not been used.

Methods: Retrospective analysis of an institutional trauma registry. We compared mortality among adult patients (≥ 15 years) transported from the scene of injury to our level I trauma center by air or ground (January 1, 2000–December 31, 2010) using univariate comparisons and multivariable logistic regression. Regression models were constructed to incrementally account for patient demographics and injury mechanism, followed by injury severity, and, finally, by network bands for drive time and roadway distance as predicted by geographic information systems.

Results: Of 4522 eligible patients, 1583 (35%) were transported by air. Patients transported by air had higher unadjusted mortality (4.1% vs 1.9%, $P < 0.05$). In multivariable modeling, including patient demographics and type of injury, helicopter transport predicted higher mortality than ground transport (odds ratio [OR] 2.4, 95% confidence interval [CI] 1.2–4.0). After adding validated injury severity measures to the model, helicopter transport predicted lower mortality (OR 0.7, 95% CI 0.3–0.9). Finally, including geographic covariates found that helicopter transport was not associated with mortality (OR 1.1, 95% CI 0.6–2.3).

Conclusions: Helicopter transport does not impart a survival benefit for trauma patients when geographic considerations are taken into account.

Keywords

aeromedical transport; helicopter transport; injury; prehospital care; trauma mortality

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Trauma is one of the fastest growing and most costly epidemics in the United States, affecting more than 42 million people, resulting in more than 170,000 deaths, and costing over \$406 billion annually.^{1,2} The majority of injured patients require professional medical transportation to the emergency department, activated by the emergency medical response system (EMS). The 2 predominant modes of transport are ground (via ambulance) and air (via helicopter), both of which have inherent strengths and weaknesses. In most areas, an ambulance is typically available readily, in close proximity to the scene of a trauma, and can travel in almost all weather conditions. A helicopter, on the other hand, is not immediately available in most locations and is sometimes hampered by weather conditions, but it can travel at great speeds, covering a much larger area in a shorter time. However, a helicopter's speed comes at approximately 10 times the cost of conventional ground transport.³⁻⁵ Furthermore, although the times from EMS activation to hospital arrival are similar when ambulances and helicopters are dispatched simultaneously, possibly resulting in a significant portion of non-critically injured patients being transported by helicopter, this time is longer for helicopter transport when initial responders are required to gauge injury severity prior to helicopter dispatch.⁶

In an era of clinical cost-effectiveness, expensive treatments such as helicopter transport need to be proven efficacious. The current literature exploring the clinical efficacy of helicopter transport for injured patients is controversial; some studies have shown that helicopters impart a survival benefit⁷⁻¹² whereas others have shown no such benefit.¹³⁻¹⁵ Table 1 shows the methods and findings of reports published over the past 15 years on the mortality benefit of aeromedical transport for trauma patients. Given the divergent conclusions indicated, it remains unclear whether the cost of helicopter transport, for which the airfare alone ranges from \$12,000 to \$25,000 per patient, is justifiable.³⁻⁵

Unlike many other interventions for injured patients, the use of transport services is directly affected by environmental factors such as available roadways and weather conditions. However, previous studies comparing ground with air transport modalities failed to adequately address these environmental variables (Table 1).⁷⁻¹⁵ Although they compared patients according to their demographic and injury-severity variables, they did not account for variability based on meteorological and/or geographic variables. Therefore, the present study was undertaken to determine whether helicopter transport imparted a survival benefit for injured patients when compared to ground transport after accounting for environmental factors. Specifically, in addition to clinical and demographic factors considered for risk adjustment in the existing literature, we sought to account for the time that ground transport would have taken should transport by air not have been possible.

METHODS

The University of Massachusetts Trauma Registry was queried from January 1, 2000, to December 31, 2010, for adult patients (ages ≥ 15 years) transported directly from the scene of injury to the University's level I trauma center located in central New England. A review of the institution's LifeFlight records and trauma registry data was conducted. Each day during the study period where at least 1 trauma patient was transported by helicopter was

considered a “fly-day” and patients transported by ground or by air on those dates were included in the study. All patients who were transported by ground on “no-fly days” were excluded to standardize the availability of helicopter transport across the patient population. To limit confounding by treatments rendered at intermediate hospitals or, conversely, absence of professional prehospital care, we also excluded all patients who were transferred from another hospital prior to being treated at our trauma center, as well as those transported without EMS activation (eg, by personal vehicles). Lastly, we excluded patients with missing geospecific trauma-scene data (eg, address where injury took place).

Cohorts were designated “air” if transported by helicopter and “ground” if transported by ground EMS vehicles. For univariate analyses, we compared patient characteristics, injury severity (by both injury severity score [ISS] and revised trauma score [RTS]), resource utilization, and outcomes between the air and ground cohorts using Pearson χ^2 test for categorical variables and the Kruskal–Wallis nonparametric test for continuous variables. A multivariable logistic regression model for mortality was constructed using a stepwise approach. Covariates were considered for this model if on univariate analysis their *P* was 0.10 and they were retained in our model at adjusted *P* 0.05. Covariates included the following: mode of transportation (ground and air), sex (male and female), age, race (white, black, Hispanic, Asian, and other), field intubation status (intubated and “own” airway), type of trauma (blunt or penetrating), grouped ISS (15, 16–25, 26–74, or 75), highest grouped abbreviated injury score (3 or >3), grouped RTS (12, 11, 10–3, or <3), presence of tachycardia (>90 beats per minute), presence of abnormal systolic blood pressure (<90 mm Hg), distance to trauma center from site of injury (by 5-mile driving distance increments) and ground travel time in 10-minute increments (actual for patients transported by ground and predicted for patients transported by air).

To account for the travel time a patient would have been subject to if transported by ground, as well as the distance from trauma center by roadways (as opposed to “crow-fly” radial distances), we used a geographic information system (GIS) software to generate network banding data. GIS has been used to address a number of questions related to injury prevention, health outcomes, and health systems development.^{16–20} Network bands were generated in 5-minute increments, using Maptitude GIS software (Caliper Corporation, Newton, MA). This software computed a predicted travel time from the scene of the trauma to our level I trauma center for every patient given the geographic location of their trauma, time of their trauma, and date of their trauma, using established roadways and known traffic patterns for dates and times of day. This specialized mapping software was also used to create driving proximity bands to the trauma center. These trauma center proximity distance bands were created in 5-driving-mile increments, where each band represented an additional 5 miles of driving by ground transport. Figure 1 shows an example of a GIS network banded map for driving-mile increments. Generalized estimating equations and robust variance calculations were used to account for clustering by injury mechanism (fall from height, fall from standing, motor vehicle collision, and other) and trauma center proximity (bands 1–20).

This study was approved by our Institutional Review Board.

RESULTS

Of 4015 possible fly-days in our study period, a helicopter was deployed at least once on 2179 days (54% of fly-days). A total of 4522 patients met the study inclusion criteria on these days; 1583 (35%) were transported by air and 2939 (65%) by ground (Fig. 2).

Univariate results (Table 2) showed that patients transported by air were more likely than those transported by ground to be male, of white race, and injured due to motor vehicle collision. There was no difference in the mean age (~39 years) between the air and ground cohorts. Patients transported by air had higher injury severity, a lower mean blood pressure, higher RTS, and were more likely to require field intubation.

A higher proportion of patients in the air cohort were admitted to the hospital after initial treatment compared with those in the ground cohort. The air cohort was also associated with a longer overall hospital length of stay and ICU LOS when compared with the ground cohort. Patients transported by air were more likely to die during index hospitalization (4.1% vs 1.9%, $P < 0.05$) in univariate comparisons.

Figure 3 shows the results of our multivariable models for mortality by covariates included in the model. In the first iteration of the multivariable mortality model, including only patient demographics and type of injury, helicopter transport predicted higher mortality compared with ground transport (odds ratio [OR] 2.4, 95% confidence interval [CI] 1.2–4.0). In the next iteration, including validated trauma risk and severity metrics (ISS, RTS, and any AIS >3), helicopter transport predicted decreased mortality compared with ground transport (OR 0.7, 95% CI 0.3–0.9). In the final iteration, including geographic covariates (network-banded distance from point of injury and estimated time of ground transport), helicopter transport was not an independent predictor of mortality compared with ground transport (OR 1.1, 95% CI 0.6–2.3). In the final model, only need for field intubation, hypotension, age, ISS, AIS, and RTS were independent predictors of mortality (Table 3). All other variables including, sex, race, mode of transport, mechanism of injury, and heart rate were not significant (data not shown).

DISCUSSION

The utility of helicopter transport for trauma patients has been debated widely in the literature, with varying conclusions.^{7,11,12,14,15,21–24} Unlike these previous studies, we eliminated no-fly days and accounted for geographic variables in our analyses, and we found that helicopter transport was not associated with mortality during index hospitalization. We did find that 12% of our patients who were transported by air did not meet criteria for hospital admission of greater than 24 hours. This is significantly less than the 26% that has been reported in a meta-analysis of aeromedical transport for trauma patients,²⁵ suggesting that triggers for initiating aeromedical transport in our cohort are as good, if not better, than other aeromedical transport systems.

Within our system, we found that airway compromise, hemodynamic instability, and advanced age did increase the risk of mortality as did higher calculated markers of risk of trauma mortality. Not surprisingly, others have shown that patients of advanced age and

more comorbidities suffer poorer outcomes after trauma compared to younger, healthier patients.²⁶ Along with age, however, severity of injury (as measured by ISS and AIS) and associated physiologic compromise (as measured by need for intubation, hypotension, and RTS) seem to be the greatest predictors of mortality. Need for intubation or hypotension in the field have previously been shown to indicate severity of the injury.²⁷ Furthermore, our findings are also in agreement with the current literature establishing ISS, AIS, and RTS as benchmarks for trauma risk adjustment.^{28–31} Importantly, when adjusting for these possible confounders for trauma mortality, we found that air transport conferred neither a protective nor a detrimental effect.

In the first iteration of our multivariable model, including only patient demographics and injury type, helicopter transport was associated with increased mortality. Previous studies by Wills et al and later by de Jongh et al reported similar conclusions.^{13,15} This is likely due to the fact that the air and ground cohorts in these studies, as well as our first iteration of the multivariable model, were viewing all injured patients as if they were equally ill. In reality, each injured patient has an associated severity based on injury burden and physiologic compromise; and, although all types of trauma patients are transported by ground, presumably only the most severely ill patients would be transported by helicopter. Therefore, we would expect those who were transported by helicopter to have a higher mortality rate because, in aggregate, they are more severely ill than those transported by ground. Not adjusting for injury severity over-estimates the difference between the 2 modes of transport and explains why analyses adjusting only for demographics and injury covariates show that helicopter transport is an independent predictor of mortality.

Owing to the lack of severity adjustment in the early literature on helicopter transport, more recent studies have included validated severity scores to account for the acuity differences between populations transported by air and ground.^{7,11,12,23,24} These studies, largely relying on multi-institution databases, have demonstrated that helicopter transport when compared with ground transport is protective against mortality.^{7,8,11,12,32} In the second iteration of our multivariable model, where we included ISS, RTS, and highest AIS, we found the same results. Risk adjustment is necessary to reduce the confounding caused by patients with minor injuries who are likely to be transported only by ground and, thus, would otherwise make it appear that ground transport protects against mortality. Given that patients with higher acuity illness are more likely to die if all other factors are equal, risk adjustment thus allows for a more appropriate comparison of the mode of transport.³³ Not surprisingly, therefore, our second iteration of a multivariable model for mortality including patient and injury characteristics as well as validated measures of injury severity found that helicopter transport reduced mortality. However, irrespective of acuity, air transport is not always available.

Thus, in our final multivariable mortality model, we also accounted for geographic variables, such as predicted or actual travel time by ground and proximity to the trauma center by ground, to measure the effect of being in the helicopter versus an ambulance for prehospital transport rather than the effect of travel-time differences between the 2 modes of transportation. When these distance and time confounders were controlled for, helicopter transport was not shown to be associated with mortality. A possible explanation for this

observation is that the presumed benefits of a helicopter may be mitigated by its long dispatch to arrival time, given its proximity to the patients. For example, the helicopters that service our University's level I center launch from a helipad adjacent to the center. Every time a helicopter is called into action, it must travel a great distance to the patient and then return, unlike ground transport, which launches from the nearest possible location. For example, the helicopter's mean (SD) dispatch-to-scene arrival time was 22 ± 3 minutes. Ground ambulances were usually much closer to the scene of the trauma as was evident by their mean dispatch to arrival time of 5 ± 1 minutes, which is comparable to what has been reported in the literature.^{6,34} Thus, after accounting for the distance by roadways between site of each injury and our trauma center as well as how long it would have taken for all patients to travel by ground based on location and time of day should the helicopter not have been available at the time of injury, we found that helicopter transport imparted no mortality benefit even when accounting for clinical acuity. It is possible that relocating helicopter dispatch from hospital locations (as in our center) to more remote locations more central to injury locations would eliminate delays in dispatch and, thus, possibly improve mortality. Moreover, as handheld GIS technology improves, it is possible that first responders may be able to use such technology to quickly assess the travel time benefit, if any, of helicopter transport based on location and time of day while also assessing trauma triage criteria prior to requesting helicopter transport for an injured patient.

Despite our unique incorporation of environmental adjustment in studying the utility of air transport for trauma patients, there are some limitations to the present study. First, this was a single-center retrospective study where patients were not randomly assigned to treatment groups. This selection bias was mitigated, although not eliminated, by the large size and 10-year period in which this study took place. Second, Massachusetts is a relatively small state with a high density of level I trauma centers; therefore, our results may not be generalizable to larger states or areas with different densities of trauma centers. For example, helicopter transport is still likely to be beneficial in cases of extreme transport, owing to either distance greater than 100 miles or scenes of geographic isolation, such as an island or mountain which is not part of our state's unique geography. Further, we cannot speak to the costs that might be incurred were larger fleets of ground transport needed to decrease use of aeromedical transport, in particular in rural areas with constrained basic or advance life support resources. Third, it is possible that we excluded some of the most severely ill patients by excluding inter-hospital transfer patients in our initial cohort selection. Often, the most severely ill are not initially taken directly to a level I center but to the hospital closest to the scene of a trauma for initial stabilization. As the records from these other hospitals were not available for analysis, we felt that including them was a greater confounder than excluding them, but this may have biased our results toward the null. Fourth, to avoid confounding due to lack of helicopter availability, we made an a priori decision to designate fly days and no-fly days based on a 24-hour period during which at least 1 trauma patient was transported by helicopter. This was the most parsimonious way to avoid a misclassification bias wherein patients who would have benefited from the intervention of interest did not receive it due to nonmedical concerns. Lastly, this study did not take into account the providers in the mode of transport or at the scene call (ie, basic life support vs paramedics). Sometimes, attending and resident-level physicians may be present in either

mode of transport, more often by air than by ground, which could potentially alter the availability of in-transit treatments for patients. However, helicopters staffed with experienced flight nurses and paramedics can produce equivalent outcomes compared to those staffed with physicians.³⁵

Despite these limitations, to our knowledge, our study is the first to use modern GIS to examine the true benefit of aeromedical transport on trauma mortality. Our findings represent a unique contribution toward our understanding of the utility of aeromedical transport for trauma care due to our incorporation of environmental variables in addition to those patient and injury factors studied in prior reports with conflicting conclusions. Although previous studies have attempted to determine travel time/distance equivalents between ground and air transport,^{36,37} no previous study comparing helicopter to ground transport for trauma mortality has considered anything other than crow-fly distances—which ground vehicles cannot take advantage of—when attempting to adjust for the confounding inherent in 2 different modes of transport. However, we took previously unused geospatial data and converted them into a quantifiable entity using modern GIS so that these variables could be controlled for, making this study unique.

CONCLUSIONS

When accounting for variability in availability of helicopters, travel times, patient characteristics, and mechanism and severity of injury, and excluding patients who had some need based on anatomy, physiology, or local EMS restraints to be transiently stabilized at an outlying facility before transport to the level I trauma center, there was no survival benefit for patients transported by helicopter in our study. Although the typical scene responder's reaction to a critically injured patient might be to call for aeromedical transport, our results suggest that ground transport is equally efficacious even with the most severely injured patients. Further research is needed into the complex area of EMS and critical care transport; however, given the added costs of aeromedical transport, policymakers should consider establishing criteria that would limit the use of a helicopter for the transport of traumatically injured patients who are geographically inaccessible by ground.

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FIGURE 1.

Network bands in 5-mile driving increments based on existing roadways from our level I trauma center.

FIGURE 2.
Cohort selection.

FIGURE 3.
Odds of mortality for air transport versus ground transport by adjustment covariates.

TABLE 1.
Previous Studies Measuring Mortality Benefit of Aeromedical Transport for Trauma Patients

Author (yr)	Data Source	Air Cohort	Ground Cohort	Patient Demographics	Adjusts for:			Identifies Mortality Benefit of Air
					Injury Severity	Environmental Factors		
Hannay (2014) ¹⁷	Regional Trauma Registry	2394	11,408	No	No	No		Yes
Galvagno (2012) ⁷	NTDB	62 k	162 k	Yes	Yes	No		Yes
de Jongh (2012) ¹⁸	Regional Trauma Registry	186	186	No	No	No		No
Brown (2010) ¹¹	NTDB	41 k	217 k	Yes	Yes	No		Yes
Mitchell (2007) ¹³	Provincial Trauma Registry	237	554	No	Yes	No		Yes
Frankema (2004) ¹⁹	Dutch Trauma System	107	239	Yes	Yes	No		Yes
Iirola (2006) ²⁰	Finnish Trauma System	88	77	No	Yes	No		No
Shatney (2002) ¹⁵	Trauma Registry	329	647	No	No	No		No
Wills (2000) ¹⁶	Australian Trauma Database	247	3,087	No	No	No		No

NTDB indicates National Trauma Data Bank.

Demographic and Clinical Characteristics and Outcome of Patients Transported From the Scene of Injury to a Level I Trauma Center by Ground* Versus Air

TABLE 2.

	Ground (n = 2939)	Air (n = 1583)	P†
Age, yr	38 (19)	40 (16)	NS
Male sex	64%	75%	<0.05
Race/ethnicity			
White	83%	87%	<0.05
Black	5%	2%	NS
Hispanic	8%	7%	NS
Asian	2%	1%	NS
Other	2%	1%	NS
Mechanism of injury			
Fall from height	14%	14%	NS
Fall from standing	8%	2%	NS
Motor vehicle collision	59%	71%	<0.05
Other	18%	12%	NS
Scene vitals/airway			
Heart rate (beats per minute)	90 (18)	92 (22)	NS
Systolic blood pressure (mm Hg)	132 (12)	118 (8)	<0.05
Required intubation	13%	24%	<0.05
Injury severity score			
15	74%	54%	<0.05
16–25	15%	21%	<0.05
26–74	10%	25%	<0.01
75	<1%	<1%	NS
Any abbreviated injury scale region >3	85%	88%	NS
Revised trauma score			
<3, N (%)	0.3	0.2	NS
3–10, N (%)	11	22	<0.05
11, N (%)	6	7	NS

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	Ground (n = 2939)	Air (n = 1583)	<i>P</i> [‡]
12, N (%)	82	72	NS
Hospital stay			
Not admitted after initial treatment	18%	12%	0.0001
Length of stay (days)	2(1)	4 (3)	0.0001
ICU length of stay (days)	2(1)	4 (2)	0.0001
Death (%)	1.9%	4.1%	<0.05

Data given as mean (SD) or %.

* Professional EMS-based ground transport only.

[‡] Pearson's χ^2 test of association for categorical variables and Kruskal–Wallis tests for continuous variables.
AIS indicates abbreviated injury scale; EMS, emergency medical response system; ICU, intensive care unit.

TABLE 3.

Multivariable Logistic Regression Model of Mortality During Index Hospitalization

Covariate (Referent)	Odds Ratio (95% CI)
Age (15–55 yr)	
>55–65	4.33 (1.89–9.59)
>65	16.43 (8.39–33.38)
Black, Hispanic, Asian, other (White)	1.44 (0.59–3.21)
Airway intubation (not intubated)	5.9 (3.14–11.34)
Injury severity score (15)	
16–25	4.05 (2.53–5.01)
26–74	9.90 (6.32–19.37)
>75	31.12 (15.67–56.54)
Any abbreviated injury scale region >3 (3)	7.10 (2.79–21.81)
Revised trauma score (12)	
11	1.73 (1.21–2.0)
3–10	2.91 (1.46–5.91)
<3	128.33 (14.36–1706.23)
Abnormal systolic blood pressure (normal blood pressure)	1.87 (1.13–3.04)