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Prehospital Helicopter Transport and Survival of Patients With Traumatic Brain Injury

Kimon Bekelis, MD^{#*}, Symeon Missios, MD^{#†}, and Todd A. Mackenzie, PhD^{‡,§,||}

*Section of Neurosurgery, Dartmouth-Hitchcock Medical Center, Lebanon, NH

†Department of Neurosurgery, Cleveland Clinic, Cleveland, OH

‡Department of Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, NH

§Department of Community and Family Medicine, Dartmouth-Hitchcock Medical Center, Lebanon, NH

||The Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, NH.

These authors contributed equally to this work.

Abstract

Objective—To investigate the association of helicopter transport with survival of patients with traumatic brain injury (TBI), in comparison with ground emergency medical services (EMS).

Background—Helicopter utilization and its effect on the outcomes of TBI remain controversial.

Methods—We performed a retrospective cohort study involving patients with TBI who were registered in the National Trauma Data Bank between 2009 and 2011. Regression techniques with propensity score matching were used to investigate the association of helicopter transport with survival of patients with TBI, in comparison with ground EMS.

Results—During the study period, there were 209,529 patients with TBI who were registered in the National Trauma Data Bank and met the inclusion criteria. Of these patients, 35,334 were transported via helicopters and 174,195 via ground EMS. For patients transported to level I trauma centers, 2797 deaths (12%) were recorded after helicopter transport and 8161 (7.8%) after ground EMS. Multivariable logistic regression analysis demonstrated an association of helicopter transport with increased survival [OR (odds ratio), 1.95; 95% confidence interval (CI), 1.81–2.10; absolute risk reduction (ARR), 6.37%]. This persisted after propensity score matching (OR, 1.88; 95% CI, 1.74–2.03; ARR, 5.93%). For patients transported to level II trauma centers, 1282 deaths (10.6%) were recorded after helicopter transport and 5097 (7.3%) after ground EMS.

Multivariable logistic regression analysis demonstrated an association of helicopter transport with

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Reprints: Kimon Bekelis, MD, Section of Neurosurgery, Dartmouth-Hitchcock Medical Center, One Medical Center Dr, Lebanon, NH 03756. kbekelis@gmail.com..

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increased survival (OR, 1.81; 95% CI, 1.64–2.00; ARR 5.17%). This again persisted after propensity score matching (OR, 1.73; 95% CI, 1.55–1.94; ARR, 4.69).

Conclusions—Helicopter transport of patients with TBI to level I and II trauma centers was associated with improved survival, in comparison with ground EMS.

Keywords

ground emergency medical services; helicopter; traumatic brain injury; mortality; NTDB

Traumatic brain injury (TBI) contributes to a substantial number of deaths and cases of permanent disability in the United States.¹ Every year, at least 1.7 million TBIs occur either isolated or in the setting of multitraumas.¹ Significant improvements in survival for this patient population have been achieved through widespread use of evidence-based guidelines, centralization of care, and advances in neurocritical care.¹ Other important factors that allow patients to capitalize on the aforementioned developments are improvements in emergency medical services (EMS) and timely transport to specialized trauma centers, capable of providing life-saving interventions. In this setting, helicopter utilization and its effect on outcomes of TBI remain an issue of debate.^{2–7}

Several studies have attempted to answer this question. Most are retrospective analyses of single-institution experiences,^{8–10} demonstrating results with limited generalization, given their inherent selection bias. The interpretation of other multicenter studies^{11,12} is equally limited because of their methodological drawbacks. The National Trauma Data Bank (NTDB) has been used to demonstrate the superiority of air transport over ground EMS for general trauma patients.^{13–16} These analyses, however, have not focused on the subgroup of patients with TBI. The latter population needs to be examined separately, because these patients are particularly in need for expedited transport to trauma centers, where specialized neurosurgical and neurocritical care can be provided.

We hypothesized that helicopter transport is associated with improved survival in comparison with ground EMS for patients with TBI. We tested this hypothesis using a regression model incorporating the results of propensity score matching of all patients who required transport to level I and II trauma centers in the United States and whose data were recorded in the 2009–2011 NTDB.

METHODS

National Trauma Data Bank

All patients with TBI who were registered in NTDB (Committee on Trauma, American College of Surgeons) between 2009 and 2011 were included in the analysis. The NTDB is the largest collection of US trauma registry data ever assembled. It includes data collected from more than 900 institutions in the United States.¹⁷ We merged the available data sets for the variables of interest, using source codes provided by the NTDB.¹⁸ More information about the NTDB is available at <http://www.facs.org/trauma/ntdb>.

Cohort Definition

To establish the cohort of patients, we used International Classification of Diseases, Ninth Revision, Clinical Modification (*ICD-9-CM*), codes to identify patients in the registry who were hospitalized for TBI. Codes 800.0–801.99, 803.0–804.99, or 850.0–854.19 were eligible for inclusion. Patients older than 16 years transported to level I and II trauma centers by helicopter or ground EMS were included for analysis. Exclusion criteria consisted of other modes of transportation to the trauma centers, patients who were dead on arrival to the emergency department (ED), transfers to/from other hospitals, and incomplete record information on transport and disposition.

Primary Outcome and Exposure Variables

The primary outcome variable was in-hospital survival after TBI. The effect on the outcome of the pertinent exposure variables was examined. Age, systolic blood pressure (SBP), heart rate (HR) on arrival to the ED, average number of neurosurgeons, and average number of trauma surgeons per hospital were continuous variables. Transport mode (helicopter, ground EMS), sex, race (African American, Hispanic, Asian, white, American Indian, and other), insurance (private insurance, self-pay, Medicaid, and Medicare and other), injury type (blunt, penetrating, and other), and mechanism of injury (derived from *ICD-9-CM* e-codes for primary and secondary diagnoses) were categorical variables. Glasgow Coma Scale (GCS) score and the locally calculated Injury Severity Score (ISS) were ordinal variables. The hospital characteristics used in the analysis as categorical variables included hospital region (West, South, Midwest, and North), hospital status (community, nonteaching, and university), and hospital bed size (<200, 200–400, 400–600, and >600 beds).

Variables were included in the final models after ensuring that the proportion of missing data points was less than 20%. Illicit drug use, alcohol use, medical comorbidities, respiratory rate, O₂ saturation, temperature, total elapsed EMS time from dispatch to the ED, EMS time at the scene, and patient-days in the intensive care unit and/or on a ventilator were excluded because they were found to have a prevalence of missing data of more than 20%.

Statistical Analysis

The effect of the exposure variables on the primary outcome was examined using a multivariable logistic regression model and a logistic regression model incorporating the results of propensity score matching. Multiple imputation was performed for each variable associated with missing values, using the Amelia II package.¹⁹ Other methods of dealing with missing data, such as listwise deletion, mean substitution, or single imputation, are in common circumstances biased, inefficient, or both. Imputation was used for the following missing data: sex, payer source, race, injury type, ISS, SBP, HR, and GCS score. First, the proportion of missing data for variables of interest was calculated. The Amelia II program was used to impute missing data based on the other available variables. This process was repeated 5 times, creating 5 separate imputed data sets. These 5 data sets were combined to create a full-pooled data set with no missing values, which was used in a multivariable logistic regression (logit) model utilizing the Zeilg statistical package.^{20,21} The method of multivariable logistic regression was used to determine the association of helicopter transport with survival controlling for age, sex, race, payer, injury type, injury mechanism,

SBP, GCS score, HR, hospital status, hospital bed size, number of neurosurgeons, number of trauma surgeons, ISS, and mechanism of injury based on the *ICD-9* e-codes.

To address any potential confounding in differences between the 2 groups (transport by helicopter, or ground EMS), we used propensity score matching methods.^{22,23} Matched patient cohorts were created after balancing the covariates to reduce the risk of confounding by indication, using the *MatchIt* package.²⁴ The 5 imputed data sets were matched across the following variables: age, sex, race, payer, injury type, injury mechanism, SBP, GCS score, HR, hospital status, hospital bed size, number of neurosurgeons, number of trauma surgeons, ISS, hospital facility key, and mechanism of injury based on the *ICD-9* e-codes. Cohorts were matched using nearest neighbor propensity score matching with subclassification. Balance among the covariates after propensity score matching was assessed with numerical diagnostics, quantile-quantile plots, histograms, and jitter plots (see Figure Supplemental Digital Contents 1, 2, 3, and 4, available at <http://links.lww.com/SLA/A549>). The matching quality achieved was excellent for level I and II trauma center data sets (see Table Supplemental Digital Contents 1 and 2, available at <http://links.lww.com/SLA/A549>). After each imputed set underwent propensity score matching, the matched imputed cohorts were imported into the Zeilg statistical package using the multiple imputation (mi) commands and used in a logistic regression (logit) model with the same variables as our prior logistic regression. As part of sensitivity analysis, we repeated the calculations using inverse propensity weighting methods.²⁵ This yielded similar results, which are therefore not reported. In an additional sensitivity analysis, we included individual facility key in the regression models for level I and II trauma centers. Finally, we performed a separate logistic regression with list-wise deletion including total elapsed time from dispatch to the ED as a variable. These analyses did not alter the primary relationship between helicopter transport and survival and therefore the results are not further reported.

Regression diagnostics were performed for all logistic regression models. The Hosmer-Lemeshow and Pearson goodness-of-fit tests were used to confirm that the models adequately fit the data ($P > 0.10$). Absolute risk reduction (ARR) calculations were made after calculating the number needed to treat (NNT) based on the adjusted odds ratios (ORs),²⁶ using the formula:

$$NNT = \{1 - [PEER * (1 - OR)]\} / [(1 - PEER) * (PEER) * (1 - OR)]$$

where PEER is the patient expected event rate [the survival rate in the control (ground transport) group].

ARR confidence intervals were calculated as follows:

$$ARR \pm 1.96 \text{ } SQRT \left[\frac{PEER * (1 - PEER)}{\text{number of control patients}} + \frac{EER * (1 - EER)}{\text{number experimental pat}} \right]$$

where EER is the experimental event rate, in our case the survival rate in the treatment (helicopter transfer) group.

This study, based on more than 104,000 ground transport and more than 23,000 helicopter transport patients, has sufficient power (90%) at a 5% type I error rate to detect differences in mortality as small as 0.7% (corresponding to a number needed to treat as large as $1/0.007 = 142$). All statistical analyses were performed using the 64-bit version of R.2.12.2 (R Foundation for Statistical Computing). All probability values are the results of 2-sided tests, and the level of significance was set at $P < 0.05$.

RESULTS

Patients

From 2009 to 2011, there were 209,529 patients (Fig. 1) with TBI who were registered in the NTDB and met the inclusion criteria for the study. Of these patients, 127,831 (61%) were transported to level I and 81,698 (39%) were transported to level II trauma centers. A total of 35,334 (16.9%) were transported via helicopters, and 174,195 (83.1%) were transported via ground EMS. The respective distribution of exposure variables between the 2 modes of transportation can be found in Tables 1 to 4. Patients transported by helicopters were associated with significantly worse initial neurological status, higher ISS, higher HR, lower SBP, and, not unexpectedly, higher unadjusted in-hospital mortality.

Primary Outcome for Level I Trauma Centers

Of the 127,831 patients transported to level I trauma centers, 2797 (12%) deaths were recorded after helicopter transport and 8161 (7.8%) after ground EMS utilization. However, patients in the former group were more severely impaired neurologically with a mean GCS score of 10.5 (SD = 5.4) than that of 13.1 (SD = 3.7) for ground EMS. As demonstrated in Table 5, helicopter transport was associated with decreased unadjusted survival in comparison with ground EMS (OR, 0.62; 95% CI, 0.59–0.65; $P = 0.001$). This relationship was reversed after logistic regression application and propensity score matching (Table 5; see Table Supplemental Digital Content 1, available at <http://links.lww.com/SLA/A549>). Multivariable logistic regression analysis demonstrated an association of helicopter transport with increased survival (OR, 1.95; 95% CI, 1.81–2.10; ARR, 6.37%; $P = 0.001$). This persisted after propensity score matching (OR, 1.88; 95% CI, 1.74–2.03; ARR, 5.93%; $P = 0.001$). This ARR corresponded to 17 patients needed to be transported to save 1 life. The disposition of these patients is demonstrated in Table 6.

Primary Outcome for Level II Trauma Centers

Of the 81,698 patients transported to level II trauma centers, 1282 (10.6%) deaths were recorded after helicopter transport and 5097 (7.3%) after ground EMS utilization. However, the former group was more severely neurologically impaired with a mean GCS score of 11 (SD = 5.2) than that of 13.3 (SD = 3.5) for ground EMS. Helicopter transport was associated with decreased unadjusted survival in comparison with ground EMS (OR, 0.66; 95% CI, 0.62–0.71; $P = 0.001$). Multivariable logistic regression analysis (Table 5; see Table Supplemental Digital Content 2, available at <http://links.lww.com/SLA/A549>) demonstrated an association of helicopter transport with increased survival (OR, 1.81; 95% CI, 1.64–2.00; ARR, 5.17%; $P = 0.001$). This again persisted after propensity score matching (OR, 1.73;

95% CI, 1.55–1.94; ARR, 4.69%; $P = 0.001$). This ARR corresponded to 21 patients needed to be transported to save 1 life. The disposition of these patients is demonstrated in Table 6.

DISCUSSION

Helicopter transport is one of the most expensive interventions in modern emergency medicine. Annual cost ranging from \$114,777 to \$4.5 million per institution has been demonstrated.²⁷ In the context of Accountable Care, cost-effectiveness should be established for most interventions. In patients with TBI, we demonstrated that helicopter transport was associated with increased survival in comparison with ground EMS. Although the beneficial effect of helicopter transport has been described for patients with severe trauma,¹⁴ its significance in TBI is under debate.²⁸ Patients with TBI are some of the most severely injured patients, in need of timely, efficient, and specialized care.

In a carefully designed study, using the NTDB data from 2007 to 2009, Galvagno et al¹⁴ demonstrated an association of helicopter transport with improved survival in patients with severe trauma. We followed a similar methodology in the present analysis and demonstrated that the magnitude of the association is higher when only patients with head injury are considered. Galvagno et al¹⁴ have shown that to save 1 life you would need to transport 65 general trauma patients. This effect is more pronounced for patients with TBI in our study, with only 17 patients needed to be transported to save 1 life. In a recent analysis, Delgado et al²⁹ concluded that helicopter transport needs to provide a minimum of 17% relative reduction in mortality (1.6 lives saved every 100 patients) to be cost-effective. These data are compatible with the number of TBI patients needed to be transported to save 1 life reported in our study, supporting the cost-effectiveness of helicopter transport for this population.

Other studies on general trauma patients, with less robust methodologies have shown mixed results. Brown et al,¹³ using a regression model, demonstrated a positive association of helicopter transport with survival. Mitchel et al⁴ and Sullivent et al¹⁶ found a similar effect. Common biases in these studies have been the lack of adjustment for missing data and the lack of differentiation of transfers from scene calls. In a more geographically limited study, Thomas et al³⁰ demonstrated a benefit of helicopter transport in patients with blunt trauma, examining a registry of the state of Massachusetts over a 4-year period. In a similar analysis¹⁵ of trauma centers in Oklahoma, helicopter transport provided a survival benefit but not for all trauma severity categories. Finally, Frankema et al³¹ failed to identify a benefit of using a specialized helicopter crew for the general trauma population. The main limitation of these studies is the lack of appropriate matching between the examined groups to control for known confounders. Given that a randomized study would be impractical or potentially unethical, propensity score matching is an effective way to adjust for covariates and balance the comparison groups.

More controversial data exist on the association of transport mode and outcome in patients with TBI. In the largest study to date, Davis et al¹¹ examined 10,314 patients from the San Diego County Trauma Registry. The authors were able to demonstrate a survival benefit for patients transported with a helicopter. Although propensity scores were calculated, no

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diagnostics were performed to compare how balanced the groups were. Di Bartolomeo et al¹² used a population-based, prospective cohort study to investigate the effect of the 2 transport modes for patients with TBI in a region of Italy. There was no observed association in their analysis. Three much smaller single-center studies have demonstrated mixed results.^{8–10} In a pooled analysis of all these studies by a recent Cochrane review,²⁸ no benefit was found for helicopter transport in patients with TBI. These studies, however, have limited generalizability, given their focus on single-center or regional analyses.

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This study has several limitations common to administrative databases. First, indication bias and residual confounding could account for some of the observed associations. We used propensity score matching, achieving good balance among covariates as demonstrated by numerical and graphic diagnostics. Although this technique cannot control for unmeasured confounders, it adjusts for known covariates.^{22,23} Second, some coding inaccuracies will undoubtedly occur and can affect our estimates. This is no different from other studies involving the NTDB. Third, the NTDB during the years studied did not include all trauma centers from all states. It is expected to preferentially include larger hospitals and younger and more severely injured patients.¹⁷ Although this introduces a selection bias, the NTDB is the most extensive trauma registry available. Fourth, there is a large number of missing data for some variables in the database. The values missing are not expected to be random.³² We addressed this issue by excluding variables with more than 20% missing values, as previously established for the NTDB,¹⁴ and applying multiple imputation methods for the remaining missing data.³³ However, this is still inferior to using real data.

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Fifth, the observed differences can be the result of some combination of speed, crew expertise, and disposition to a designated trauma center.⁶ Physicians are part of helicopter crews in some areas. Although this information is not available through the NTDB, future studies should identify the particular components of this mode of transport that provide the survival benefit. In addition, the NTDB does not provide any direct information on prehospital treatment patterns, limiting our ability to control for these factors. Sixth, the NTDB does not provide any information on the post-acute course of the patients. Seventh, we used largely ecological data and therefore causality cannot be established on the basis of them.

CONCLUSIONS

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Helicopter utilization and its effect on outcomes of TBI remain an issue of debate. We investigated the association of helicopter transport with survival of patients with TBI, in comparison with ground EMS, using regression models incorporating the results of propensity score matching. Among patients with TBI transported to level I and level II trauma centers, helicopter transport compared with ground services was associated with improved survival after controlling for known confounders.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.
Cohort selection for the study.

TABLE 1

Socioeconomic and Hospital Characteristics for Patients Transported to Level I Trauma Centers

	All Patients	Helicopter	Ground	<i>P</i>
Sample size	127,831	23,283	104,548	
Age, mean (SD), yr	44.38 (20.72)	40.25 (18.28)	45.30 (21.11)	<0.0001
Sex				
F	39,809 (31.15)	6,868 (29.51)	32,941 (31.51)	<0.0001
M	87,993 (68.85)	16,408 (70.49)	71,585 (68.49)	<0.0001
Unreported data	29	7	22	
Region				
North	15,696 (12.28)	1,697 (7.29)	13,999 (13.39)	<0.0001
South	44,961 (35.17)	11,652 (50.05)	33,309 (31.86)	<0.0001
Midwest	32,860 (25.71)	5,567 (23.91)	27,293 (26.11)	<0.0001
West	34,314 (26.84)	4,367 (18.76)	29,947 (28.64)	<0.0001
Payer				
Medicare	18,208 (16.13)	2,087 (10.04)	16,121 (17.50)	<0.0001
Medicaid	13,089 (11.59)	2,476 (11.91)	10,613 (11.52)	0.028
Private payer	31,846 (28.21)	7,067 (33.98)	24,779 (26.90)	<0.0001
Self-payer	22,402 (19.84)	4,057 (19.51)	18,345 (19.92)	0.657
Other	27,354 (24.23)	5,109 (24.57)	22,245 (24.15)	0.025
Unreported data	14,932	2,487	12,445	
Race				
White	82,837 (66.39)	18,210 (87.56)	64,627 (63.43)	<0.0001
African American	16,900 (13.54)	1,365 (6.56)	15,535 (15.25)	<0.0001
Asian	1,042 (0.84)	336 (1.62)	706 (0.69)	<0.0001
American Indian	2,888 (2.31)	210 (1.01)	2,678 (2.63)	<0.0001
Hispanic	16,688 (13.37)	2,131 (10.25)	14,557 (14.29)	<0.0001
Other	4,422 (3.54)	639 (3.07)	3,783 (3.71)	<0.0001
Unreported data	3,054	392	2,662	
Hospital status				
Community	36,049 (28.20)	6,184 (26.56)	29,865 (28.57)	<0.0001
Nonteaching	1,636 (1.28)	72 (0.31)	1,564 (1.50)	<0.0001
University	90,146 (70.52)	17,027 (73.13)	73,119 (69.94)	<0.0001
Bed size				
<200	1,467 (1.15)	242 (1.04)	1,225 (1.17)	0.086
200–100	14,715 (11.51)	3,531 (15.17)	11,184 (10.70)	<0.0001
400–600	51,010 (39.90)	8,306 (35.67)	42,704 (40.85)	<0.0001
>600	60,639 (47.44)	11,204 (48.12)	49,435 (47.28)	0.021
No. neurosurgeons, mean (SD)	6.2 (2.9)	6.5 (3.0)	6.1 (2.9)	<0.0001
No. trauma surgeons, mean (SD)	6.3 (1.9)	6.5 (2.0)	6.2 (1.9)	<0.0001

The values are reported as number (%), unless otherwise specified.

TABLE 2**Injury and Patient Characteristics Transported to Level I Trauma Centers**

	All Patients	Helicopter	Ground	<i>P</i>
ISS				
1–24	99,796 (80.40)	15,331 (68.10)	84,465 (83.12)	<0.0001
24–49	22,313 (17.98)	6,489 (28.82)	15,824 (15.57)	<0.0001
50–75	2,021 (1.63)	694 (3.08)	1,327 (1.31)	<0.0001
Unreported data	3,701	769	2,932	
Injury type				
Blunt	119,188 (93.27)	22,068 (94.79)	97,120 (92.94)	<0.0001
Penetrating	4,292 (3.36)	763 (3.28)	3,529 (3.38)	0.451
Other	4,304 (3.37)	450 (1.93)	3,854 (3.69)	<0.0001
Unreported data	47	2	45	
Cause of injury				
Motor vehicle accidents	58,456 (45.74)	16,435 (70.59)	42,021 (40.21)	<0.0001
Falls	34,962 (27.36)	2,853 (12.25)	32,109 (30.72)	<0.0001
Pedestrians struck by motor vehicles	9,558 (7.48)	1,002 (4.30)	8,556 (8.19)	<0.0001
Unarmed assaults	5,402 (4.23)	168 (0.72)	5,234 (5.01)	<0.0001
Assaults with a weapon, other than stabbing or shooting	6,878 (5.38)	432 (1.86)	6,446 (6.17)	<0.0001
Stabbings/cutting accidents	714 (0.56)	80 (0.34)	634 (0.61)	<0.0001
Shootings	2,612 (2.04)	617 (2.65)	1,995 (1.91)	<0.0001
Adult abuse	171 (0.13)	16 (0.07)	155 (0.15)	0.003
Other	9,035 (7.07)	1,678 (7.21)	7,357 (7.04)	0.360
Unreported data	43	2	41	
Died on arrival	1,308 (1.02)	159 (0.68)	1,148 (1.10)	<0.0001
Died	10,958 (8.57)	2,797 (12.01)	8,161 (7.81)	<0.0001
SBP, mean (SD), mm Hg	138.1 (30.9)	133.4 (31.6)	139.1 (30.7)	<0.0001
GCS score, mean (SD)	12.6 (4.2)	10.5 (5.4)	13.1 (3.7)	<0.0001
HR, mean (SD), beats/min	91.5 (22.8)	93.9 (24.2)	90.9 (22.4)	<0.0001
Temperature, mean (SD), °C	36.1 (2.8)	35.7 (4.1)	36.2 (2.4)	<0.0001

The values are reported as number (%), unless otherwise specified. Comparisons between groups for each variable were performed using the χ^2 test, and the *t* test as appropriate.

F indicates female; M, male.

TABLE 3

Socioeconomic and Hospital Characteristics of Patients Transported to Level II Trauma Centers

	All Patients	Helicopter	Ground	<i>P</i>
Sample size	81,698	12,051	69,647	
Age, mean (SD), yr	47.21 (22.08)	41.28 (18.72)	48.23 (22.46)	<0.0001
Sex				
F	27,218 (33.32)	3,520 (29.33)	23,698 (34.03)	<0.0001
M	54,461 (66.68)	8,528 (70.77)	45,933 (65.96)	<0.0001
Unreported data		3	16	
Region				
North	10,416 (12.75)	705 (5.85)	9,711 (13.95)	<0.0001
South	13,579 (16.62)	3,347 (27.77)	10,232 (14.69)	<0.0001
Midwest	23,292 (28.51)	2,479 (20.57)	20,813 (29.88)	<0.0001
West	34,411 (42.12)	5,520 (45.81)	28,891 (41.48)	<0.0001
Payer				
Medicare	14,875 (19.94)	1,140 (10.26)	13,735 (21.64)	<0.0001
Medicaid	6,479 (8.68)	1,028 (9.26)	5,451 (8.58)	0.008
Private payer	23,340 (31.28)	3,871 (34.86)	19,469 (30.65)	<0.0001
Self-payer	13,441 (18.01)	2,040 (18.37)	11,401 (17.95)	0.127
Other	16,480 (22.09)	3,027 (27.25)	13,453 (21.18)	<0.0001
Unreported data	7,083	945	6,138	
Race				
White	54,365 (70.00)	8,567 (75.59)	45,798 (69.05)	<0.0001
African American	7,838 (10.09)	433 (3.82)	7,405 (11.16)	<0.0001
Asian	570 (0.73)	117 (1.03)	453 (0.68)	<0.0001
American Indian	2,762 (3.56)	252 (2.22)	2,510 (3.78)	<0.0001
Hispanic	8,997 (11.58)	1,655 (14.61)	7,342 (11.07)	<0.0001
Other	3,135 (4.04)	309 (2.73)	2,826 (4.26)	<0.0001
Unreported data	4,031	718	3,313	
Hospital status				
Community	47,941 (58.68)	6,597 (54.74)	41,344 (59.36)	<0.0001
Nonteaching	19,496 (23.86)	3,868 (32.10)	15,628 (22.44)	<0.0001
University	14,261 (17.46)	1,586 (13.16)	12,675 (18.20)	<0.0001
Bed size				
<200	4,493 (5.50)	250 (2.08)	4,243 (6.09)	<0.0001
200–400	43,399 (53.12)	7,395 (61.36)	36,004 (51.69)	<0.0001
400–600	22,785 (27.89)	3,081 (25.57)	19,704 (28.29)	<0.0001
>600	11,021 (13.49)	1,325 (10.99)	9,696 (13.93)	<0.0001
No. neurosurgeons, mean (SD)	4.8 (2.6)	4.6 (1.9)	4.8 (2.7)	<0.0001
No. trauma surgeons, mean (SD)	6.1 (2.2)	6.2 (2.3)	6.1 (2.2)	<0.0001

The values are reported as number (%), unless otherwise specified.

TABLE 4**Injury and Patient Characteristics Transported to Level II Trauma Centers**

	All Patients	Helicopter	Ground	P
ISS				
1–24	68,230 (83.76)	8,794 (73.14)	59,436 (85.60)	<0.0001
25–49	12,197 (14.97)	2,933 (24.39)	9,264 (13.34)	<0.0001
50–75	1,029 (1.26)	296 (2.46)	733 (1.06)	<0.0001
Unreported data	242	28	214	
Injury type				
Blunt	75,773 (92.75)	11,468 (95.30)	64,305 (94.26)	<0.0001
Penetrating	1,939 (2.37)	337 (2.81)	1,602 (2.35)	0.001
Other	2,543 (3.11)	228 (1.89)	2,315 (3.39)	<0.0001
Unreported data	1,443	18	1,425	
Cause of injury				
Motor vehicle accidents	34,214 (42.62)	8,015 (66.61)	26,199 (38.39)	<0.0001
Falls	26,586 (33.11)	1,690 (14.04)	24,896 (36.48)	<0.0001
Pedestrians struck by motor vehicles	5,219 (6.50)	584 (4.85)	4,635 (6.79)	<0.0001
Unarmed assaults	3,231 (4.02)	172 (1.43)	3,059 (4.48)	<0.0001
Assaults with a weapon, other than stabbing or shooting	3,491 (4.35)	226 (1.89)	3,265 (4.78)	<0.0001
Stabbings/cutting accidents	373 (0.46)	39 (0.32)	334 (0.49)	0.019
Shootings	1,196 (1.49)	251 (2.08)	945 (1.38)	<0.0001
Adult abuse	126 (0.16)	12 (0.10)	114 (0.17)	0.098
Other	5,848 (7.28)	1,044 (8.68)	4,804 (7.04)	<0.0001
Unreported data	1,414	18	1,396	
Died on arrival	491 (0.60)	49 (0.41)	442 (0.63)	0.003
Died	6,379 (7.81)	1,282 (10.64)	5,097 (7.32)	<0.0001
SBP, mean (SD), mm Hg	139.8 (30.7)	134.7 (30.8)	140.7 (30.6)	<0.0001
GCS score, mean (SD)	12.9 (3.8)	11.0 (5.2)	13.3 (3.5)	<0.0001
HR, mean (SD), beats/min	89.7 (22.2)	92.4 (23.9)	82.3 (21.9)	<0.0001
Temperature, mean (SD), °C	36.3 (1.8)	36.2 (1.9)	36.3 (1.7)	<0.0001

The values are reported as number (%), unless otherwise specified. Comparisons between groups for each variable were performed using the χ^2 test, and the *t* test as appropriate.

F indicates female; M, male.

TABLE 5

Models Demonstrating the Association of Helicopter Transport With Survival of Patients With TBI

	OR (95% CI)	P	ARR, % (95% CI)
Level I trauma centers			
Unadjusted survival	0.62 (0.59–0.65)	<0.001	2.82 (2.49–3.14) *
Logistic regression			
Standard	1.95 (1.81–2.10)	<0.001	6.37 (5.89–6.85)
Incorporating propensity score matching	1.88 (1.74–2.03)	<0.001	5.93 (5.46–6.40)
Level II trauma centers			
Unadjusted survival	0.66 (0.62–0.71)	<0.001	2.36 (1.93–2.79) *
Logistic regression			
Standard	1.81 (1.64–2.00)	<0.001	5.17 (4.55–5.79)
Incorporating propensity score matching	1.73 (1.55–1.94)	<0.001	4.69 (4.08–5.31)

Propensity score matching was performed across the following variables: mode of transfer (helicopter or ground), age, sex, race, payer, injury type, injury mechanism, SBP, GCS score, HR, hospital status, hospital bed size, number of neurosurgeons, number of trauma surgeons, ISS, hospital facility key, and mechanism of injury based on the *ICD-9* e-codes.

* Indicates greater mortality for transport with helicopter.

TABLE 6

Disposition of Patients Transported to Level I and Level II Trauma Centers

	Helicopter		Ground		
Disposition	23,283	%	104,548	%	P
Level I centers					
Home without services	11,990	55.19	62,324	66.25	<0.0001
Rehabilitation center	4,567	21.02	10,778	11.46	<0.0001
Intermediate facility	685	3.15	2,076	2.21	<0.0001
Home with services	679	3.13	3,021	3.21	0.826
Nursing home	1,260	5.80	7,396	7.86	<0.0001
Hospice	71	0.33	465	0.49	0.003
Left against medical advice	128	0.59	1,500	1.59	<0.0001
Other	2,343	10.79	6,509	6.92	<0.0001
Unreported data	1,560		10,479		
	12,051	%	69,647	%	
Level II centers					
Home without services	6,422	58.64	36,582	61.11	0.120
Rehabilitation center	2,110	19.27	8,179	13.66	<0.0001
Intermediate facility	392	3.58	1,328	2.22	<0.0001
Home with services	321	2.93	3,204	5.35	<0.0001
Nursing home	529	4.83	5,302	8.86	<0.0001
Hospice	36	0.33	379	0.63	<0.0001
Left against medical advice	104	0.95	968	1.62	<0.0001
Other	1,038	9.48	3,924	6.55	<0.0001
Unreported data	1,099		9,781		