Should they stay or should they go? Who benefits from interfacility transfer to a higher-level trauma center following initial presentation at a lower-level trauma center

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BACKGROUND: Interfacility transfer of patients from Level III/IV to Level I/II (tertiary) trauma centers has been associated with improved outcomes. However, little data are available classifying the specific subsets of patients that derive maximal benefit from transfer to a tertiary trauma center. Drawbacks to transfer include increased secondary overtriage. Here, we ask which injury patterns are associated with improved survival following interfacility transfer.

METHODS: Data from the National Trauma Data Bank was utilized. Inclusion criteria were adults (≥16 years). Patients with Injury Severity Score of 10 or less or those who arrived with no signs of life were excluded. Patients were divided into two cohorts: those admitted to a Level III/IV trauma center versus those transferred into a tertiary trauma center. Multiple imputation was performed for missing values, and propensity scores were generated based on demographics, injury patterns, and disease severity. Using propensity score–stratified Cox proportional hazards regression, the hazard ratio for time to death was estimated.

RESULTS: Twelve thousand five hundred thirty-four (5.2%) were admitted to Level III/IV trauma centers, and 227,315 (94.8%) were transferred to a tertiary trauma center. Patients transferred to a tertiary trauma center had reduced mortality (hazard ratio, 0.69; $p < 0.001$). We identified that patients with traumatic brain injury with Glasgow Coma Scale score less than 13, pelvic fracture, penetrating mechanism, solid organ injury, great vessel injury, respiratory distress, and tachycardia benefited from interfacility transfer to a tertiary trauma center. In this sample, 56.8% of the patients benefitted from transfer. Among those not transferred, 49.5% would have benefited from being transferred.

CONCLUSION: Interfacility transfer is associated with a survival benefit for specific patients. These data support implementation of minimum evidence-based criteria for interfacility transfer. (*J Trauma Acute Care Surg.* 2019;86: 952–960. Copyright © 2019 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Therapeutic/Care Management, Level IV.

KEY WORDS: Interfacility transfer; triage; secondary overtriage; undertriage; trauma systems.

The goal of interfacility transfer of severely injured trauma patients is to ensure that patients are at the right place at the right time to receive safe, reliable, high-quality care. American College of Surgeons (ACS)-verified trauma centers voluntarily maintain four categories (I–IV) of readiness based on the quantity of human and material resources at the respective centers.[1] Level I and II centers are considered tertiary trauma centers and are expected to have similar clinical outcomes.[2] Current evidence suggests that interfacility transfer of some injured patients from Level III/IV trauma centers to Level I/II centers is associated with improved outcomes, including reduction in mortality.[3,4]

Currently, it is agreed that the decision to transfer should be made based on the patient's clinical status and the facility's available resources.[1] The advantages are presumed to vary depending with the mechanism and severity of injury sustained by the patient; however, there are limited data regarding which specific patients actually derive a mortality benefit from interfacility transfer.[5]

In addition, secondary overtriage—patient transfers from a nontertiary trauma center to a tertiary trauma center with a length of stay shorter than 48 hours and not requiring operative intervention—poses a burden to already saturated tertiary trauma centers and can potentially jeopardize the care of severely injured patients at these centers. Studies suggest secondary overtriage occurs in approximately 7% to 38% of tertiary trauma transfers, with the majority being patients with head and neck injuries.[6–8] The overall lack of benefit data renders clinical practice ambiguous, and it continues to vary from center to center.

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Reliable transfer criteria are essential. Ideal criteria would be sensitive enough to identify all patients who could benefit from transfer while simultaneously limiting secondary overtriage. The objective of this study was to identify patient-level characteristics associated with mortality benefit from transfer from a Level III or IV trauma center to a Level I or II trauma center and to estimate mortality benefit of transfer in a national trauma cohort.

METHODS

Data Collection

The data source for this study was the ACS National Trauma Data Bank (NTDB), which is the largest trauma registry in the United States. It includes patient and hospital data on traumatic injuries and clinical outcomes for more than 700 trauma centers.

This study was approved by the University of Minnesota institutional review board (STUDY00001489). The need for individual patient consent was waived, because all data used in this study were already deidentified in the NTDB.

Participants

Patient-level data were obtained from the NTDB from January 1, 2007, through December 31, 2014. The *inclusion criteria* were as follows:

– Patients who were initially evaluated at a Level III or IV trauma center and subsequently admitted to a Level III or IV trauma center or those who were transferred from a prior hospital's emergency department (ED) to the ED of a Level I or II trauma center for evaluation and treatment.
– Age ≥ 16
– At least 1 valid *International Classification of Diseases, Ninth Revision*, Clinical Modification (ICD-9-CM) trauma code (range, 800–959.9)
– Admission to a US trauma center for definitive care
– Injury Severity Score (ISS) greater than 10 or missing

Exclusion criteria included patients with no signs of life at initial evaluation ED systolic blood pressure (SBP) = 0, pulse = 0, Glasgow Coma Scale (GCS) score = 3).

Analysis

Patients were divided into two cohorts for subsequent analysis: those who were initially evaluated at and subsequently admitted to a Level III/IV trauma center versus those who were transferred from a prior hospital's ED to a Level I/II trauma center for evaluation and treatment. The amount of missing data for clinically relevant variables was relatively low (mean, 4.1%; range, 0%–28.1%). Multiple Imputation by Chained Equations was used to impute missing variables.[9] Each missing variable was imputed once following five iterations using predictive mean matching based on full conditional regression modeling. Imputation included patients who were missing ISS (19,466 patients). After imputation, we analyzed the subset with an ISS greater than 10. There were 6,288 observations with missing ISS that received an imputed ISS greater than 10 and were included in the final analysis.

Injury types of interest included: any traumatic brain injury (TBI, ICD-9: 800.0–804.9, 850.0–854.1, 959.01), severe TBI (TBI with GCS score < 9), TBI with intracranial bleed (ICD-9: 852.0–853.9), TBI with no bleed and GCS score greater than 13, any cervical spine (C-spine) injury (ICD-9: 805.0–805.19, 806.0–806.19, 839, 952), C-spine injury with spinal cord injury (ICD-9: 806.0–806.19, 839, 952), all solid organ injuries (ICD-9: 864.0–866.9), grade 3 or higher solid organ injury (ICD-9: 864.03, 864.13, 864.04, 864.14, 865.03, 865.13, 865.04, 864.14, 866.03, 866.13, 866.04, 866.14), bowel or pancreas injury (ICD-9: 863.0–863.9), femur fracture (ICD-9: 820.0–821.9), all pelvis fractures (ICD-9: 808.0–808.9), complex pelvic fracture (ICD-9: 808.43, 808.53), rib fractures (ICD-9: 807.0–807.4), hemothorax or pneumothorax (ICD-9: 860.0–806.9), penetrating thoracic (ICD-9: 861.0–862.9 with penetrating mechanism), sternum fracture (ICD-9: 807.2–807.39), thoracic aorta injury (ICD-9: 901.0), subclavian artery injury (ICD-9: 901.1), carotid artery injury (ICD-9: 900–900.03), and major venous injury (ICD-9: 900.1–900.3, 900.81, 902.1). Additional physiologic and demographic parameters were also evaluated. Physiologic criteria were evaluated as physiologic thresholds have already been identified for a minimum full trauma activation (e.g., GCS score < 9 and SBP < 90) and are highly associated with poor clinical outcomes.[10] We specifically evaluated: age, ED respiratory rate, ED pulse, ED SBP, total GCS score, and ISS. The physiologic criteria analyzed were based on the most aberrant recorded value during ED resuscitation.

Our primary outcome was time from admission to death with censoring at hospital discharge.

Statistical Methods

A causal analysis for the survival benefit of interfacility transfer was performed using the imputed data set.[11] This analysis consisted of three aspects: (i) fitting a propensity score model, (ii) constructing propensity score strata, and (iii) fitting outcome models using propensity score–stratified Cox proportional hazards regression wherein each stratum is allowed its own nonparametric baseline hazard function.

A logistic additive model was used to estimate the propensity score (i.e., the probability of being transferred given patient characteristics). This model included the following variables: demographic (age, race, and sex), injury severity, ED SBP, ED pulse, ED respiratory rate, ED oxygen saturation, ED temperature, ISS, predicted mortality (using the Trauma Mortality Prediction Model ICD-9[12]), ED-assisted respirations, ED supplemental oxygen requirements, preinjury drug or alcohol use, mechanism of injury, GCS score, injury type, and work-related injury. The effect of each continuous variable on the propensity was modeled with a penalized spline term, which facilitates capturing a nonlinear association between the continuous covariate and the propensity score while guarding against overfitting by penalizing nonlinear curvature in the resulting estimate, whereas the effect of binary and categorical variables were modeled with standard linear terms.[13] Although the propensity score model included a large number of covariates, overfitting was not a concern because the number of nontransferred and transferred observations both are far more than 20 times larger than the number of covariates.[14]

The propensity score model provided 72% concordance and 0.048 Brier score.[15] Based on the estimated propensity scores, 78 strata were constructed by iteratively grouping observations by their propensity score until each stratum either had a t-statistic less than 1, comparing the mean propensity score across the two cohorts or a further split would have led to a stratum with fewer than 10 patients in either cohort.[11] Following this procedure, covariate balance across the resulting 78 strata was assessed based on within-stratum t-statistics for continuous covariates and χ^2 statistics for binary and categorical covariates. Comparing the empirical distribution of the resulting 3354 (78 strata × 43 covariates), p values with a uniform distribution indicated the absence of any severe covariate imbalance in the two cohorts within each stratum.

Using propensity score–stratified Cox proportional hazards regression, the hazard ratio (HR) of in-hospital death was estimated for transferred versus not transferred patients overall, as well as in subgroups defined by injury type, physiologic, and demographic variables that are measurable upon admission to the trauma center. In particular, patient characteristics were identified for which, on average, patient's experienced significant survival benefit or harm by interfacility transfer. Finally, the predicted mortality benefit of transfer was estimated at the individual patient level, with an HR less than 1, defining a patient who would benefit from transfer, and greater than 1, defining a patient who would not benefit from transfer.

Statistical significance was determined using the standard alpha value of 0.05. All data analyses were performed using R Version 3.5.1.[16]

RESULTS

In this study, there were 239,849 patients included (Fig. 1). Table 1 shows patient characteristics, and Table 2 shows injury types of patients admitted to a Level III/IV trauma center as compared with those transferred to a Level I/II trauma center. For Level III/IV trauma centers, 12,534 (5.2%), were admitted, whereas 227,315 (94.8%) were transferred into to a Level I/II trauma center. The median ISS was 16 (interquartile range [IQR], 13, 20) for patients admitted to a Level III/IV trauma center as compared with 17 (IQR: 14, 25) for patients transferred into a Level I/II trauma center. As compared with 9.1% for patients transferred into a Level I/II trauma center, 6.6% of patients admitted to a Level III/IV died.

Injury Types

Compared with the patients who were admitted to a Level III/IV trauma center, patients who were transferred to Level I/II trauma centers had reduced adjusted in-hospital mortality (HR, 0.69; 95% confidence interval [CI], 0.64–0.74; $p < 0.001$) (Fig. 2). Patients with the following injuries, on average, were shown to have a mortality benefit from transfer: any TBI, any pelvic fracture, penetrating thoracic trauma, solid organ injury, complex (Abbreviated Injury Scale grade 3+) solid organ injury, and great vessel (thoracic aorta, carotid, or subclavian artery) injury (Figs. 2 and 3).

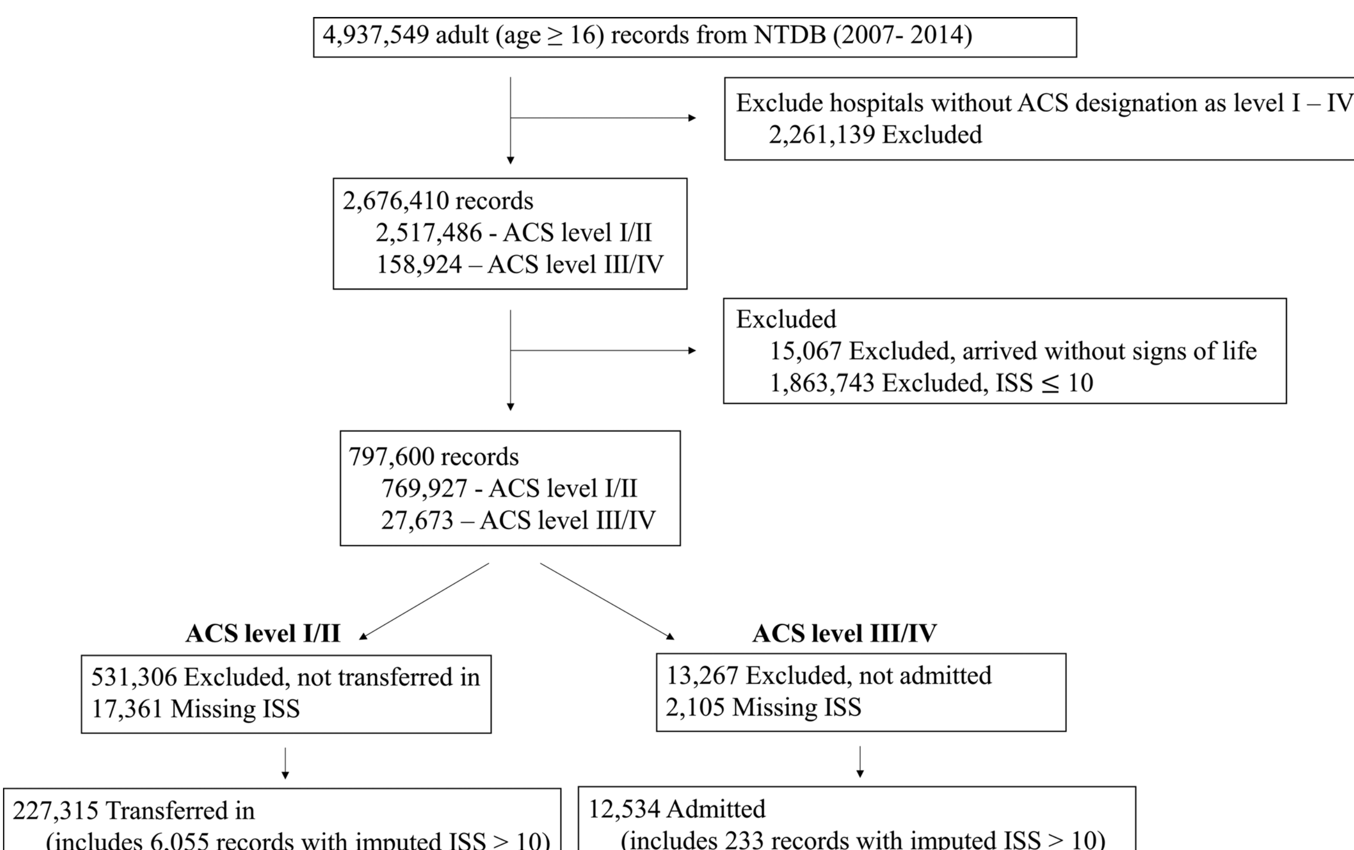

Figure 1. Study diagram detailing selection of patients in 2007–2014 NTDB.

TABLE 1. Patient Characteristics (p Values Are Based on the Wilcoxon Rank-Sum Test for Continuous Variables and the χ^2 Test for Dichotomous and Categorical Variables)

Variables	Not Transferred	Transferred	p
Overall	12,534	227,315	
Continuous variables, median (IQR)			
Age, y	55 [36, 74]	52 [32, 70]	<0.001
ED SBP, mm Hg	138 [122, 155]	135 [119, 152]	<0.001
ED pulse, bpm	85 [73, 98]	88 [75, 102]	<0.001
ED respiratory rate	18 [16, 20]	18 [16, 20]	<0.001
ED oxygen saturation	97 [95, 99]	98 [96, 100]	<0.001
ED temperature, °C	36.6 [36.0, 36.8]	36.6 [36.0, 37.0]	<0.001
ED GCS score	15 [15, 15]	15 [14, 15]	<0.001
ISS	16 [13, 20]	17 [14, 25]	<0.001
Dichotomous and categorical variables, n (%)			
Died in hospital	828 (6.6)	20,639 (9.1)	<0.001
Male	8,136 (64.9)	154,396 (67.9)	<0.001
Race			<0.001
White	10,854 (86.6)	180,224 (79.3)	
Black	622 (5)	15,630 (6.9)	
Hispanic or Latino	773 (6.2)	19,007 (8.4)	
Asian	98 (0.8)	2,882 (1.3)	
Other	187 (1.5)	9,572 (4.2)	
ED-assisted respirations	760 (6.1)	38,148 (16.8)	<0.001
ED supplemental oxygen	4,372 (34.9)	110,647 (48.7)	<0.001
EToH			<0.001
Not tested	5,856 (46.7)	102,361 (45)	
No (confirmed)	4,197 (33.5)	83,909 (36.9)	
Yes (<0.08 BAC)	676 (5.4)	13,501 (5.9)	
Yes (≥0.08 BAC)	1,805 (14.4)	27,544 (12.1)	
Positive for controlled substances	562 (4.5)	15,490 (6.8)	<0.001
Positive for illegal drugs	1,525 (12.2)	27,613 (12.1)	0.959
Work-related	498 (4)	10,044 (4.4)	0.019
RR	955 (7.6)	31,343 (13.8)	<0.001
Penetrating mechanism	447 (3.6)	9,991 (4.4)	<0.001

Physiologic and Demographic Patterns

We then evaluated physiologic (presence of ED respiratory distress [ED RR], < 10 or >29), penetrating mechanism (ED pulse, ED SBP, ED GCS score), demographic (sex, age, race/ethnicity), and other (illicit drug use or alcohol level >0.08) criteria for mortality benefit. Patients with RR and penetrating injuries, on average, benefited from transfer (Fig. 3). There was no statistically significant difference with regard to racial/ethnic status, sex, illicit drug use, or alcohol level greater than 0.08%. All age groups had a mortality benefit with transfer, with patients between 20 and 40 years of age benefitting the most (Fig. 4A). Patients with a pulse greater than 100 benefited the most from transfer (Fig. 4B). Patients with a GCS score less than 13 benefited from transfer (Fig. 4C). Patients with an elevated respiratory rate (respiratory rate, >20) benefited most from transfer (Fig. 4D). No significant blood pressure cutoffs were identified for transfer as nearly all patients benefitted from transfer (Fig. 4E). In general, patients with an ISS over 10 were more likely to have a mortality benefit with transfer. As the ISS increased, the likelihood of having a mortality benefit with transfer further increased. Maximum mortality benefit was observed for patients with an ISS between 45 and 60 (Fig. 4F).

Survival Benefit

Using multivariate Cox proportional hazards regression with propensity score stratification, we estimate that overall, 56.7% of patients in this sample either did have survival benefit from transfer or potentially would have had benefit from transfer (estimated HR, <1). Among those who were transferred, we estimate that 57.1% actually benefited. Among those who were not transferred, we estimate that 49.6% potentially could have benefited from being transferred.

DISCUSSION

This is one of the first studies to identify specific injury types and patient characteristics associated with survival benefit in interfacility transfer. In this national cohort of trauma patients presenting initially to a Level III/IV trauma setting, subsequent

TABLE 2. Injury Characteristics (p values Are Based on the χ^2 Test)

Injury Type, no (%)	Not Transferred	Transferred	p value
Any TBI	6,086 (48.6)	138,742 (61)	<0.001
TBI with intracranial bleed	3,154 (25.2)	87,609 (38.5)	<0.001
Severe TBI	575 (4.6)	31,228 (13.7)	<0.001
Mild TBI	5,033 (40.2)	99,082 (43.6)	<0.001
C-spine fracture	1,112 (8.9)	31,535 (13.9)	<0.001
C-spine fracture with cord injury	283 (2.3)	8,708 (3.8)	<0.001
Any pelvic fracture	959 (7.7)	25,767 (11.3)	<0.001
Complex pelvic fracture	57 (0.5)	4,166 (1.8)	<0.001
Femur fracture	1,034 (8.2)	14,829 (6.5)	<0.001
Pneumothorax or hemothorax	2,796 (22.3)	43,317 (19.1)	<0.001
Penetrating thoracic	148 (1.2)	2,875 (1.3)	0.436
Bowel or pancreas injury	337 (2.7)	6,833 (3)	0.045
Solid organ injury	1,684 (13.4)	29,897 (13.2)	0.368
Grade 3+ solid organ injury	665 (5.3)	13,036 (5.7)	0.046
Sternum fracture	396 (3.2)	8,032 (3.5)	0.029
Rib fractures			<0.001
NOS	515 (4.1)	8,537 (3.8)	
1 Rib fracture	235 (1.9)	2,805 (1.2)	
2 Rib fracture	821 (6.6)	12,102 (5.3)	
3 Rib fracture	592 (4.7)	9,592 (4.2)	
4 Rib fracture	750 (6)	8,457 (3.7)	
5 Rib fracture	892 (7.1)	10,461 (4.6)	
6 Rib fracture	499 (4)	5,871 (2.6)	
7 Rib fracture	359 (2.9)	4,504 (2)	
8+ Rib fracture	244 (1.9)	3,455 (1.5)	
Flail chest	384 (3.1)	7,835 (3.4)	
Thoracic aorta injury	24 (0.2)	1,308 (0.6)	<0.001
Any great vessel injury	44 (0.4)	3,022 (1.3)	<0.001
Major venous injury	16 (0.1)	350 (0.2)	0.537

NOS, not otherwise specified.

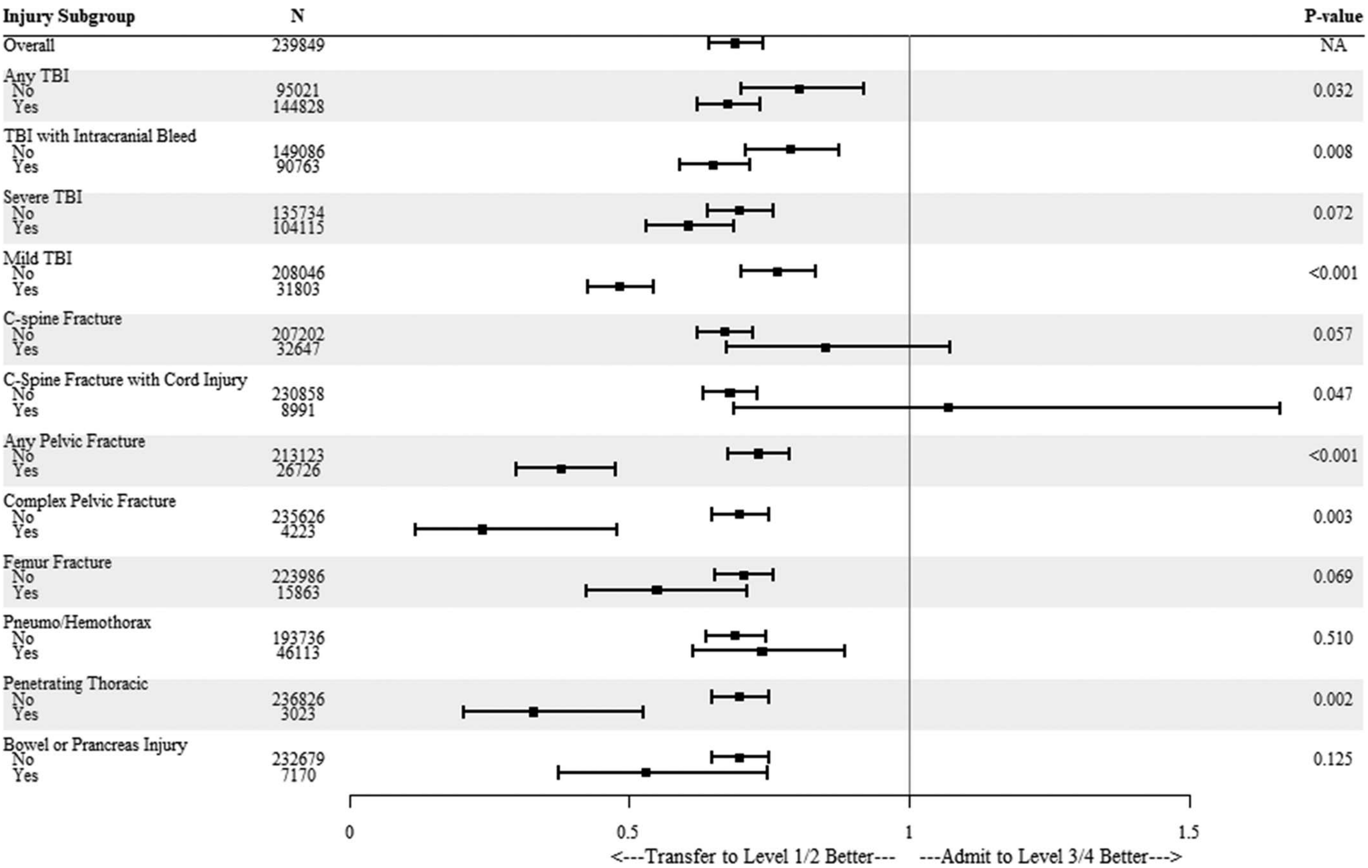

Figure 2. HR estimate and 95% CI by injury subgroups.

interfacility transfer to a Level I/II trauma center was associated with survival benefit for patients with moderate and severe TBI, particularly with CT finding of hemorrhage, pelvic fracture, penetrating thoracic mechanism, complex solid organ injury, great vessel injury, RR, and tachycardia at presentation. Almost 60% of patients derived survival benefit from transfer to a Level I/II trauma center. Approximately half of patients admitted to a Level III/IV trauma center potentially would have benefited from transfer.

While studies have compared outcomes at tertiary trauma centers following direct admission from the field and transfer from nontertiary facilities,[17,18] relatively few studies have examined the outcomes of injured patients who remained at nontertiary facilities in comparison with those patients who transferred to a tertiary trauma center. Still fewer studies have focused on classifying the specific subsets of patients that derive maximal survival benefit from transfer to a tertiary trauma center. An earlier study of approximately 10,000 patients in Oregon found that injured patients transferred from nontertiary hospitals to tertiary hospitals had improved survival.[4] They identified that mortality was 33% lower in transferred versus not transferred patients. Their study called for more standardized and objective transfer guidelines across nontertiary care hospitals. In another study, patients who met a state definition of major trauma had significantly improved survival if transferred to a Level I/II trauma center versus admitted to a Level III/IV trauma center. Unfortunately, only 43% of patients who met their definition of major trauma were transferred to a Level I/II trauma center.[3] The authors suggested that higher ISS, presence of severe TBI, and advanced age would be indications to transfer patients from a Level III/IV trauma center to a Level I/II trauma center. These studies highlight the variability surrounding patient transfers from nontertiary to tertiary trauma centers and the potential impact of implementing standardized interfacility transfer guidelines.

In the NTDB, the majority of patients with full outcome data reported were transferred, and among those who were transferred, 57.1% had an injury profile or physiologic derangement associated with mortality benefit to transfer. This implies that these transfers are indeed being performed strategically and that the majority of patients transferred likely had mortality benefit. The counterfactuals highlight that there is potential room for action examining the 43% of transferred patients without identified benefits to transfer or the 50% of nontransferred patients who potentially could have benefitted from transfer. Identification of injury types, demographic, or physiologic criteria associated with mortality benefit from transfer is an important first step to optimal care.

Results from our study suggest that TBI patients with CT findings of intracranial hemorrhage or GCS score less than 13 would derive the most mortality benefit from tertiary transfer. Additionally, patients with pelvic fracture, penetrating mechanism, solid organ injury, great vessel injury, RR, and tachycardia likely benefited. Surprisingly, in our analysis, C-spine fractures were not associated with mortality benefit from tertiary transfer;

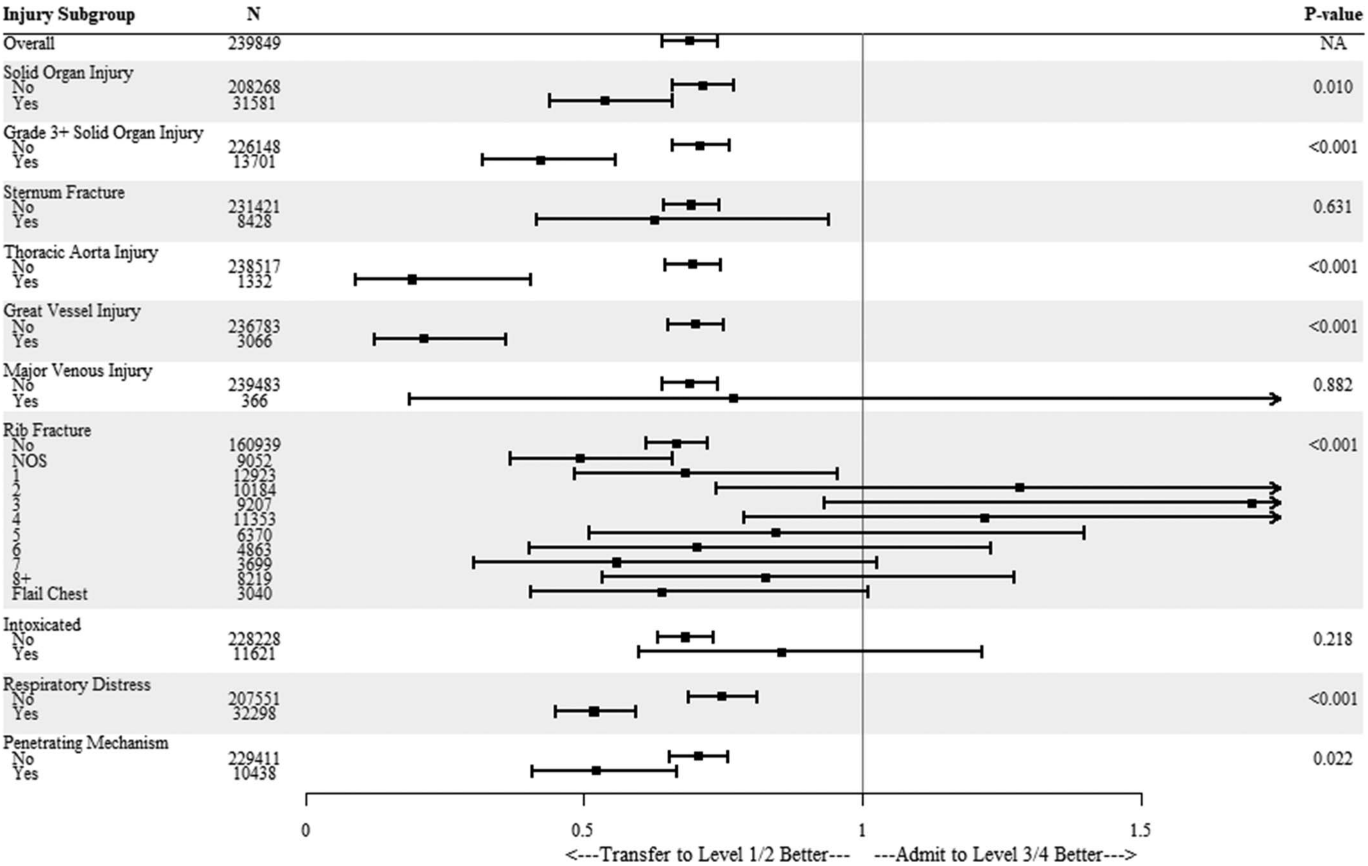

Figure 3. HR estimate and 95% CI by injury subgroups. NOS, not otherwise specified.

however, this may be due to the variable injuries that make up the ICD codes for C-spine fractures. For example, in severe cases where there is a fracture with spinal cord injury, mortality is extremely high regardless of transfer. On the other extreme, mortality in a patient with a C-spine transverse process fracture is not likely to be affected by transfer. The 2014 Resources for the Optimal Care of Injured Patients recommend that patients with a field GCS score of 13 or less, flail chest, pelvic fractures, or with penetrating injuries to the head, neck, or torso be directly transported from scene to the highest level trauma center.[1] Our findings bolster these recommendations and can be used as evidence that immediate transfer of such patients—even when they present initially to a Level III/IV trauma center—is important, indicated, and will save lives. ATLS guidelines for interfacility transfer are broadly defined and thus may contribute to unnecessary secondary overtriage. For example, Table 13.1 of the 9th edition of ATLS course manual recommends interfacility transfer for all patients with a GCS score less than 15 and all patients older than 55 years.[19,20] Our data do not support these broad recommendations. A GCS score of 14, for example, could occur secondary to a patient being intoxicated or perhaps due to dementia. The unnecessary transfer of these patients and other mildly injured patients can contribute in overburdening regional EMS and tertiary trauma facilities. Additionally, despite the broad criteria put forward in the ATLS guidelines, adherence is variable at Level III/IV trauma facilities and future national trauma QI efforts should improve monitoring of practice and transfer patterns within these facilities. Finally, ATLS guidelines reinforce the importance of clear communication between transferring and tertiary facilities. Modern capabilities, such as real-time ED telemedicine, can facilitate regional transferring and tertiary facility discussions regarding interfacility transfer and the use of diagnostic imaging prior to transfer. The findings of this study can serve to help guide regional trauma systems in evaluating the capabilities of referring and tertiary institutions.

Nevertheless, the economic impact of secondary overtriage cannot be ignored. It can overwhelm system resources and delay care. Often, secondary overtriage occurs from institutions that have limited resources, such as surgical specialists, blood products, and coverage.[21] One case of secondary overtriage has been estimated to cost US $5,917.[8] To put this in perspective, the average health care–related expenditure per person per year in the United States is US $8,047.[8] Patients most likely to undergo secondary overtriage include patients with ISS greater than 15, head or spine injuries, or pediatric patients.[7,22] In a study looking at secondary overtriage of neurologically intact, isolated spine injury patients in Rhode Island, transportation and ED costs were on average US $1,863 and US $12,895, respectively, for those meeting criteria for overtriage.[23] Forty-two percent of patients with isolated spinal injuries were considered to be inappropriately transferred. Eighty-seven percent of these patients were discharged directly from the receiving institution's ED. In today's rapidly changing health

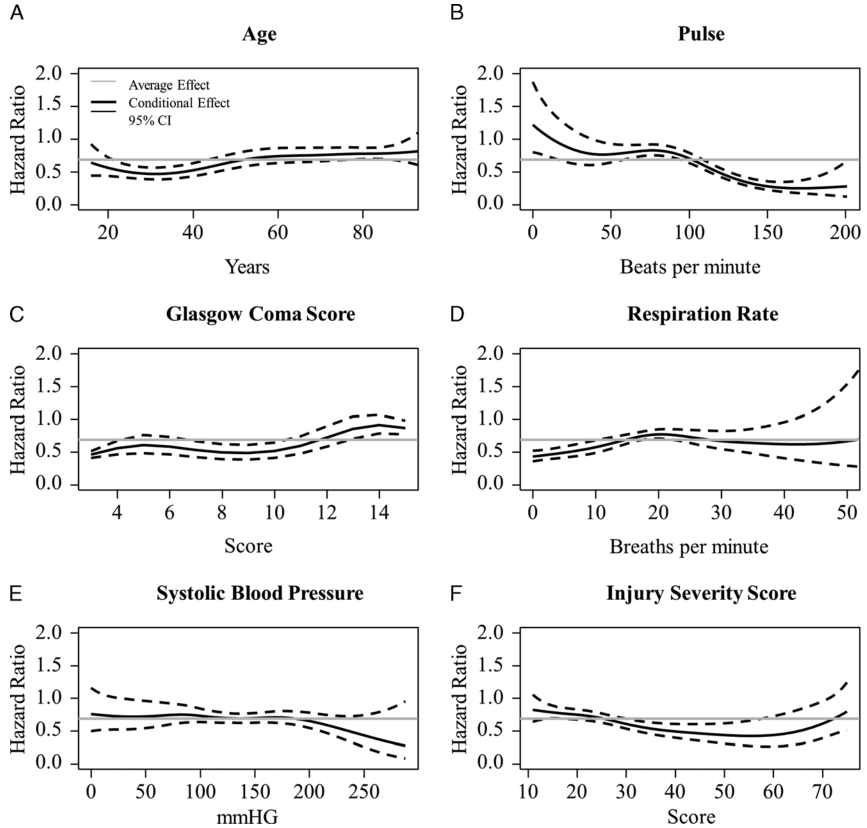

Figure 4. HR plots for continuous variables.

care economy, it is important to think about the implications of these costs to both private and public payers.

This study has several limitations. First, it is a retrospective analysis using data which was not specifically recorded to answer the question asked in our study. As with all trauma registry-based studies, there is the possibility of reporting bias, missing, or inaccurate data and absence of data pertaining to long-term outcomes. Hypotension, tachycardia, or tachypnea can be transient or sustained, and only the single most aberrant value is included in the NTDB. Additionally, the inclusion criteria were limited to patients with an ISS greater than 10. This potentially introduces bias, as patients included had more severe injuries, biasing toward beneficial transfer of patients. We also looked specifically at mortality benefits and did not evaluate complications and other morbidity. While most would agree patients with an ISS > 15 should be transferred to a tertiary trauma center, information to guide real-time calculation of ISS is not always available to calculate this metric a priori and Level III and IV centers rely on incomplete data available to them at the time prior to transfer. Reasons for initiating or declining transfer were not recorded. Future studies are needed to validate these findings to define evidence-based minimum criteria for interfacility trauma transfer, and additional approaches defining which populations clearly benefit, may benefit, and clearly do not benefit from transfer can be useful in further developing regional criteria to guide interfacility transfer in an evidence-based manner.

As it stands, considerable variability in interfacility transfer guidelines persists,[6] making the findings of this study directly relevant to future trauma care. These data can help to standardize interfacility transfer and to develop minimum transfer criteria to facilitate appropriate triage and reduce ineffective resource utilization.

CONCLUSION

Interfacility transfer of patients presenting to lower-level trauma centers was associated with a survival benefit for specific cohorts of patients. Patients with TBI, particularly those with CT findings of hemorrhage and GCS score less than 13, pelvic fracture, penetrating trauma, solid organ injury, great vessel injury, RR, and tachycardia benefited from transfer. These data suggest that implementation of minimum evidence-based criteria for interfacility transfer of trauma patients to higher level care would promote appropriate triage, reduce overall resource utilization, and save lives.

AUTHORSHIP

T.A. participated in the study design, data interpretation, writing, and critical revision. T.M. participated in the study design, data analysis, data interpretation, writing, and critical revision. P.J. participated in the data interpretation, writing, and critical revision. J.O. participated in the study design, data interpretation, writing, and critical revision. P.I. participated in the study design, data interpretation, writing, and critical revision. K.R. participated in the study design, data interpretation, writing, and critical revision. L.M.N. participated in the study design, data collection, data interpretation, writing, and critical revision. M.R.H. participated in the study design, data collection, data analysis, data interpretation, writing, and critical revision. J.G. participated in the study design, data interpretation, writing, and critical revision. P.K. P. participated in the study design, data interpretation, writing, and critical revision. C.J.T. participated in the study design, data collection, data analysis, data interpretation, writing, and critical revision.

DISCLOSURE

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DISCUSSION

JASON SPERRY, M.D., M.P.H. (Pittsburgh, Pennsylvania): I'd like to thank the AAST and the Program Committee for the privilege to discuss this manuscript, and to the authors for getting the manuscript to the Program Committee and myself on time, and for a very nice presentation.

So, the authors have presented a nicely written manuscript robustly characterizing the NTDB, which has its own limitations, regarding the transfer of patients from Level 3 and 4 centers to Level 1 and 2 centers.

They use high-level statistical propensity score modeling, and the results suggest a large proportion of moderately injured patients would benefit from transport. I agree with their results.

Their methods and results could be used to improve the appropriate transfer of patients and demonstrate those injuries where transfer may not be beneficial. I do have some questions for the authors.

First, as stated in the manuscript and the discussion, the authors utilized Injury Severity Score (ISS) in their model, and this variable is not typically available in the pre-hospital or in the Emergency Department setting at the time of transfer.

They also include specific injury types, which I agree with, in their methods. Are the authors able to do the same modeling with and without Injury Severity Score being included, and if so, do those results change?

Number two, does the NTDB database allow the authors to characterize those patients who underwent imaging and then transfer, and if imaging itself, such as head CT results, affects the results, and whether the authors recommend radiographic workup prior to transfer, which can sometimes delay definitive management.

Finally, the authors used a study cohort with an Injury Severity Score of greater than 10 as their inclusion criteria. If they were to look at lower ISS scores, or injury characteristics, there would likely be at an even higher rate of over-triage transfers.

The method is, thus, bias towards beneficial transfers of these patients. Do the authors have any recommendations for patients with an estimated ISS less than 10?

Thank you for the privilege of the podium to discuss this manuscript.

CHRISTOPHER J. TIGNANELLI, M.D. (Minneapolis, Minnesota): Thank you, Dr. Sperry. The first question was, can we do modeling with and without the Injury Severity Score. Yes, we can. We only used the Injury Severity Score in the generation of the propensity score.

My thoughts would be if we did pull it out, I don't think there would be a huge change, because in addition to the Injury

Severity Score, we also adjusted patients based on ED vitals, demographics, and their injury characteristics; but we could definitely take out Injury Severity Score and see how much that changes.

The next question is if the NTDB allows us to characterize patients that underwent imaging. That's a really good thought; we can definitely do that. We can use the ICD-9 procedure codes and use that to look at imaging the patients got before and after transfer.

And then, do we recommend imaging prior to transfer? That really depends on the comfort of the Level 3 and 4 centers, that they can do an accurate imaging study.

It needs to be decided on a region-to-region basis, and includes the development of regional protocols for transfer.

One potential way that I see applying these findings to Level 3 and 4 trauma centers would be, in the first phase, if a patient comes in, they have a GCS less than 13 or a penetrating mechanism of injury or sustained tachycardia, then, stabilize that patient, get your chest x-ray, FAST, pelvis x-ray, and then transfer them to a Level 1 or 2 center.

Alternatively, it gets a little more tricky if the patient is stable. If they can get an appropriate imaging study, and you have a regional protocol in place with tertiary trauma centers, then it would be ideal to image them at the Level 3 or 4 centers. If you identify a solid organ injury or a traumatic brain injury with a bleed, then transfer those patients to a Level 1 or 2 center.

Potentially a more sophisticated way to do it would actually be to leverage tele-medicine and actually call in to the Level 1 or 2 centers and, review the patient, discuss imaging decisions, and make sure that imaging actually gets to the tertiary trauma center.

And then the last question was thoughts on patients with an Injury Severity Score of less than 10. One of our figures, did look at the Injury Severity Score as a continuous variable, we saw that once we got below an Injury Severity Score of about 11 or 12, there was not a benefit for survival for transfer to a 1 or 2 center.

I think that it would be similar to, if you remember when we looked at the Grade 3 or above solid organ injuries, there's a pretty wide gap for benefit, with the patients with higher grade injuries having more benefit, and then we just looked at the patients who had just solid organ injuries, including the 1 and 2s, that benefit decreased some.

There would be a decreased benefit if we included all the patients with Injury Severity Score less than 10, but for the ones that were strongly statistically significant, that would hold, but we'd have to look at it.

Thank you very much.