Impact of US hospital center and interhospital transfer on spinal cord injury management: An analysis of the National Trauma Data Bank

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BACKGROUND: Traumatic spinal cord injury (SCI) is a serious public health problem. Outcomes are determined by severity of immediate injury, mitigation of secondary downstream effects, and rehabilitation. This study aimed to understand how the center type a patient presents to and whether they are transferred influence management and outcome.

METHODS: The National Trauma Data Bank was used to identify patients with SCI. The primary objective was to determine association between center type, transfer, and surgical intervention. A secondary objective was to determine association between center type, transfer, and surgical timing. Multivariable logistic regression models were fit on surgical intervention and timing of the surgery as binary variables, adjusting for relevant clinical and demographic variables.

RESULTS: There were 11,744 incidents of SCI identified. A total of 2,883 patients were transferred to a Level I center and 4,766 presented directly to a level I center. Level I center refers to level I trauma center. Those who were admitted directly to level I centers had a higher odd of receiving a surgery (odds ratio, 1.703; 95% confidence interval, 1.47–1.97; $p < 0.001$), but there was no significant difference in terms of timing of surgery. Patients transferred into a level I center were also more likely to undergo surgery than those at a level II/III/IV center, although this was not significant (odds ratio, 1.213; 95% confidence interval, 0.099–1.48; $p = 0.059$).

CONCLUSION: Patients with traumatic SCI admitted to level I trauma centers were more likely to have surgery, particularly if they were directly admitted to a level I center. This study provides insights into a large US sample and sheds light on opportunities for improving pre hospital care pathways for patients with traumatic SCI, to provide the timely and appropriate care and achieve the best possible outcomes. (*J Trauma Acute Care Surg.* 2021;90: 1067–1076. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Care management, Level IV.

KEY WORDS: Spinal cord injury; hospital arrival; surgical intervention.

Traumatic spinal cord injury (SCI) is a serious public health concern, warranting study of system-level challenges and solutions, in an effort to standardize care and provide the best outcomes.[1–5] Traumatic SCI encompasses immediate traumatic injury, such as fracture and/or spinal cord contusion, as well as the secondary downstream injury. Traumatic SCI is associated with severe physical, emotional, and economic burden to the patient, as well as their families, caregivers, and society at large.

Injuries often occur in males who are at a young age (30% in 15- to 24-year age group), although trends show an increase in the average age at time of injury.[6] Survival has considerably improved with modern advances in emergency medicine and intensive care, with life expectancy following traumatic SCI approaching that of the general population, for all but the most severely impaired individuals.[7] Life after SCI, however, may be accompanied with increased secondary health complications, activity limitations, and reduced community participation, which all impact overall quality of life. Despite a relatively low incidence, the human and societal impacts of SCI are extremely high, with the lifetime cost in the United States in the range of US $500,000 to US $2 million.[8]

The first 24 hours after any traumatic injury are the most critical, requiring prompt recognition, early evaluation, and appropriate management in a suitable setting to achieve medical and spinal stabilization and the best possible outcomes.[9] Expert consensus and guidelines recommend expedited transfer of any new SCI patient (within 24 hours of injury) to a center that is equipped to provide comprehensive state-of-the-art care by an expert multidisciplinary team. Expedited transfer enables more rapid diagnosis and intervention with critical spinal interventions and potential pharmacologic therapies that can enhance neuroprotection and possible recovery of neurological function

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and prevent secondary complications. Delays in reaching appropriate centers can increase the occurrence of complications such as avoidable pressure injuries, urinary tract infections, respiratory problems, and contractures, potentially increasing morbidity and length of stay (LOS), delaying or impeding rehabilitation, and adversely affecting long-term well-being, function, and independence-related outcomes.

The 2012 STASCIS (Surgical Timing in Acute Spinal Cord Injury Study) trial demonstrated a 2.8-fold higher odds of improved outcomes following early decompressive surgery (defined as surgery within 24 hours following injury) as compared with late surgery (more than 24 hours following injury).[10] The level of trauma center also plays a role in determining the timing and operative intervention offered to a traumatic SCI patient, as this has implications for the number of specialists/experts available, ongoing clinical trials, and time to arrival at center based on level and severity of injury.[3,11,12]

Because individual surgeon and center can heavily influence treatment decisions, an important consideration in traumatic SCI outcomes is interhospital transfer (IHT). While there are scarce data available regarding IHT for traumatic SCI, data on center level and transfers exist for other pathologies and trauma. For example, in general surgery, IHT patients had worse outcomes[13] and increased risk of mortality than patients who were not transferred-in from other centers.[14] In acute ischemic stroke patients, IHT was associated with a delay in endovascular therapy initiation and an increased risk for developing complications.[15] For aneurysmal subarachnoid hemorrhage, among patients who underwent IHT, there was a significant increase in mortality for those transported >20 miles compared with those transported <20 miles.[16] For patients with isolated severe head injury, better outcomes were achieved if the patient was initially treated at a designated trauma center.[11] A closely related study found that patients with isolated, severe head injury had improved outcomes when initially treated in designated trauma centers as compared with the considerable number of patients who were triaged to nontrauma centers.[17] In sum, these studies argue for admission of trauma patients directly to trauma centers to improve outcome.

Spinal cord injury is a large unmet clinical need and public health concern, with variation in practice patterns and expertise. We hypothesize that patients with traumatic SCI receive different levels of surgical intervention and care based on the type of center they are admitted or transferred to. Patients with SCI may benefit from standardization and direct admission to trauma centers versus IHT. The purpose of our study was to identify the role of center type (i.e., trauma center versus other) and IHT in the management and care of patients with traumatic SCI. We hypothesized that patient's at level 1 centers and those transferred to level 1 centers would be more likely to have surgery and early surgery.

PATIENTS AND METHODS

Population

We used the National Trauma Data Bank (NTDB) Research Data Set to identify incidents of traumatic SCI between January 1, 2011, and December 31, 2014. Since NTDB is an incident-based data bank and there is no patient linking between incidents, this study was conducted under the assumption that each incident represented a single patient. Patients were included if they were 18 years or older at the time of injury and had cervical spine fractures with SCI or thoracolumbar spine fractures with SCI. Cervical spine fractures with SCI were represented by codes 806.0 (0–9) and 806.1 (0–9), and thoracolumbar spine fractures with SCI were represented by codes 806.2 (0–9), 806.3 (0–9), 806.4, and 806.5. Patients were excluded if they had concurrent traumatic brain injury (*International Classification of Diseases, Ninth Revision, Clinical Modification* codes 800, 850, 854, and 959), had more than one self-reported race (because of lack in consistent recording in the database), or had missing surgery records, missing interhospital transfer status, or American College of Surgeons–verified trauma center level. Race and ethnicity were determined based on patient self-report as recorded in the database. Race and ethnicity are shown to be associated with outcomes in spine surgery and therefore were included as a key demographic variable (Shivanand P. Lad, 2013 #6).[18] Those with Injury Severity Score (ISS) of <2 (as they did not qualify as severe injury) or systolic blood pressure of <40 mm Hg in the emergency department or emergency medical services were also excluded. Patients in level I trauma centers with 0 neurosurgeons, 0 orthopedic surgeons, or 0 intensive care unit (ICU) beds were considered invalid records and thus were excluded as well. Patients with invalid prehospital arrival time (missing or >1,440 minutes) or patients transferred out of level 1 centers were excluded from the subgroup analysis consistent with prior work using the NTDB (Fig. 1).[19]

Study Design

The primary objective was to evaluate the effect of trauma center on surgical intervention of SCI. All SCI patients with fracture and SCI were included with the limitation that there is not a code to indicate surgical candidacy. Surgery *International Classification of Diseases, Ninth Revision*, codes included were as follows: 03.0 to 03.5, exploration and decompression of spinal canal structures and operations on spinal cord and spinal canal structures, and 78.59 to 84.8, internal fixation, closed reduction with internal fixation, open reduction without internal fixation, open reduction with internal fixation, debridement of open fracture, closed reduction with internal fixation, other operation, spinal fusion, refusion of spine, other procedures on spine, implantation of other musculoskeletal devices and substances (cages, bone morphogenetic protein, cement), replacement of spinal disc, insertion, replacement, and revision of posterior spinal motion preservation devices. For the post hoc analysis of complications by surgery type, these codes were grouped into decompression/debridement/cervical decompression alone, fusion, and other spinal procedures.

Since the NTDB collected relatively less information from level II and level IV centers, we combined level II, III, and IV centers into one category for comparison with level I centers. A secondary objective was to examine the effect of trauma center on timing of surgical intervention (early vs. late) among patients who underwent surgical intervention, with early surgical intervention being defined as surgery within 24 hours of hospital arrival. Other secondary outcomes included in-hospital complications and discharge outcomes of the SCI patients. Discharge outcomes include hospital LOS, ICU LOS, mechanical ventilation days, and type of discharge. Our study cohort was stratified

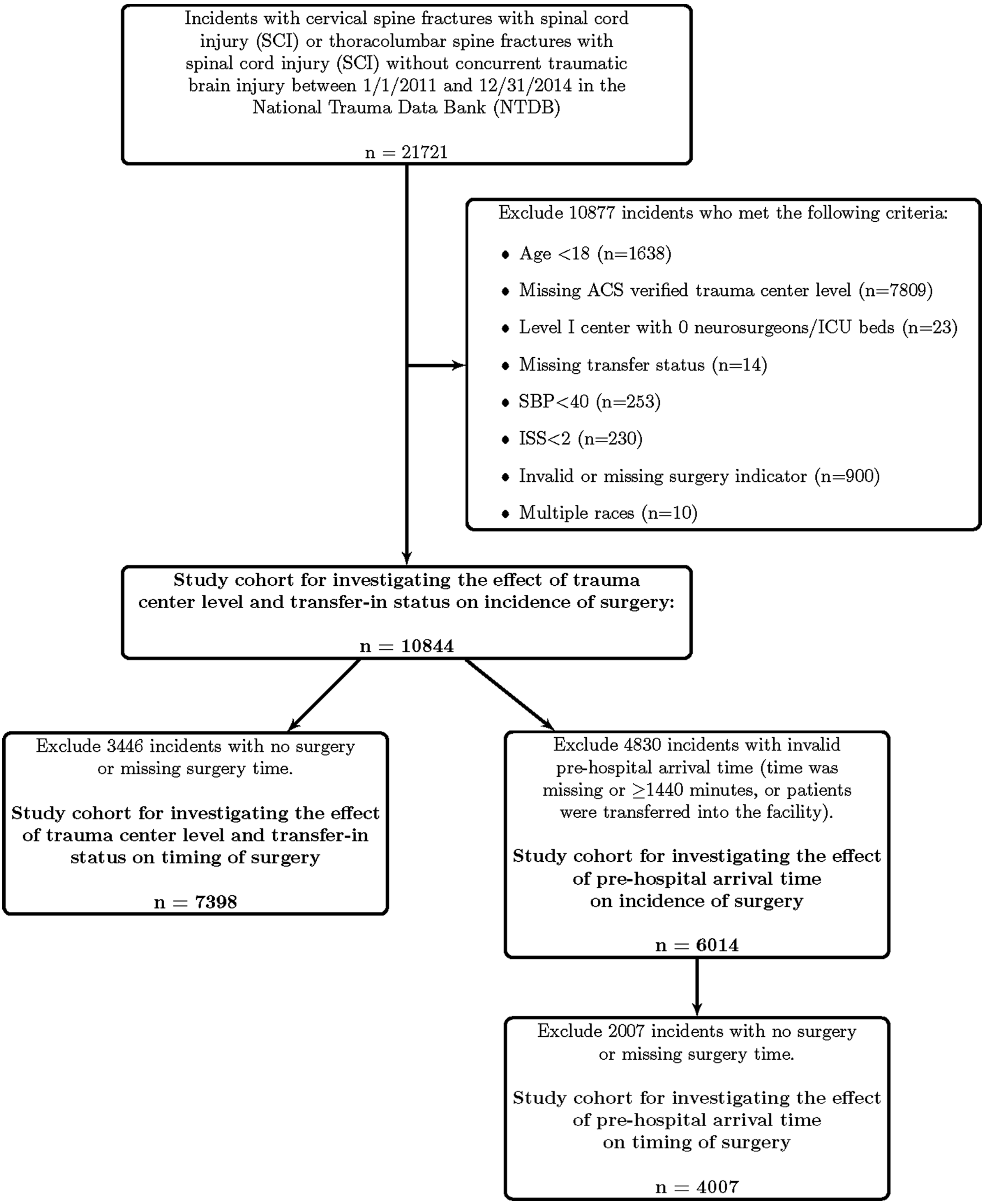

Figure 1. Consort diagram of study design.

by transfer-in status when summarizing baseline characteristics and conducting analyses, meaning that patients were counted as transferred if they transferred into a higher-level center of care from a lower-level center. Prehospital arrival time was not collected for patients transferred to another hospital; therefore, subgroup analyses were conducted in nontransferred patients to evaluate the effect of prehospital arrival time on the aforementioned outcomes.

Statistical Analysis

Continuous variables were summarized with means, SDs, median, and first and third quartiles (Q1, Q3), and categorical variables were summarized with frequency counts. The generalized estimating equations with a logic link function were used to fit multivariable models onsurgical intervention (surgery vs. no surgery) and timing of the surgery (early vs. late) as binary outcome variables, adjusting for trauma center level, hospital teaching status, interhospital transfer or prehospital arrival time, region of hospital, age, sex, race, ethnicity, payment method, ISS, the spine injury score of the Abbreviated Injury Scale (AIS), alcohol use drug use, systolic blood pressure, mechanism of injury, injury type, and multiple comorbid conditions. Interaction terms between trauma center level and transfer status were added into the models. The models were also controlled for the clustering effect of hospital centers using a repeated measurement approach in generalized estimating equations. Forest plots were created to illustrate the odds ratios (ORs) and 95% confidence intervals (CIs) of the regression analyses. Statistical significance was assessed at level $\alpha = 0.05$. All analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC).

Institutional Review Board

This study received approval from the Duke University Health System Institutional Review Board. Because this was a study of deidentified data, it was determined exempt from informed consent.

RESULTS

Summary of Baseline Characteristics

A total of 11,744 incidents of traumatic SCI were identified from January 1, 2011, to December 31, 2014, in the NTDB. Patient demographic information and facility-related information for hospitals where patients were admitted is summarized in Table 1. The median age of the cohort was 45 years (Q1–Q3, 28–62) with the majority being male (75.0%) and of White race (70.2%). Of 11,744 incidents, 7,649 (65.1%) were admitted to level I trauma centers and 4,095 (34.8%) were admitted to level II/III/IV trauma centers. An incident was considered to be managed at a level I center if the patient was either directly admitted to the facility, that is, not transferred (n = 4,766, 62.3%) or transferred into the facility from a lower level center (n = 2,883, 37.7%). For patients at level II/III/IV centers, 2,990 (73.0%) were not transferred, while 1,105 (27.0%) were transferred in from another facility. Among the 1,105 patients who were transferred into level II/III/IV centers, 97.6% (n = 1,078) were transferred to a level II center.

Compared with patients who were transferred into level I centers, patients who were directly admitted to level I centers without transfer were younger (median age, 41 vs. 51 years), had a higher percentage of male (77.9% vs. 70.7%), non-White (37.5% vs. 21.9%), and regionally west (24.5% vs. 18.6%) cases. Among cases directly admitted to level I centers, there was a lower percentage of diabetes (8.2% vs. 12.7%), a higher percentage of drug use disorder (6.7% vs. 4.6%), and a higher ISS (median 25 vs. 17). Among all incidents, cases that were directly admitted to level I centers had the highest ISS, highest percentage of penetrating injury, and highest percentage of injury due to firearms.

Surgical Intervention and Discharge Outcomes by Trauma Center Level

In general, patients at level I centers had a higher rate of receiving surgery relative to patients admitted to level II/III/IV centers, regardless of whether they were transferred in or directly admitted to the level I center (Table 2). Patients transferred into a level I center were just as likely to have surgery as those who directly admitted (67.9% vs. 64.3%).

Patients admitted directly to level I centers had a higher rate of early surgical intervention (defined as <24 hours after incident) than those admitted to lower level centers (35.4% vs. 28.6%).

Patients who were transferred were more likely to go home without services than those who started at a level I center shown by 19.1% of patients who started at a level I center going home without services compared with 24.2% of those who were transferred in going home without services. Level I direct admits were more likely to be discharged to rehabilitation centers compared with those at lower level centers and compared with patients who were transferred from a lower level center into a level I center (54.0% vs. 46.0%). There was a similar rate of patients being discharged to skilled nursing facilities across groups.

Patients at level I centers did have higher in-hospital complication rates for certain complications compared with patients at lower level centers (Table 2). This was particularly true in terms of cardiopulmonary complications. For example, patients who started at a level I center had a 4.1% incidence of cardiac arrest versus 2.5% at other level centers. Transferred patients followed a similar pattern. Deep vein thrombosis was present in 6.1% of patients who started at a level I center versus 4.6% among those transferred to a level I center and 3.4 to 4.4% of those at level II/III/IV centers. Pulmonary embolus rates followed a similar trend. Other complications were more evenly dispersed across groups. Deep surgical site infection was less than 1% in all groups. Of note, the rate of "other" for complications was higher at level II/III/IV centers than at level I centers.

To determine if rate of complication was related to type of surgery, we performed a post hoc analysis of complication by surgery type, center level, and transfer status but found a similar distribution of surgery types across groups (Supplementary Tables 1–4, http://links.lww.com/TA/B942).

Surgical Intervention and Discharge Outcomes by Timing of Surgical Intervention

Patients who received early surgery had a shorter median LOS compared with those with late surgery (10 vs. 13 days; Q1–Q3, 6–18 days) as well as shorter median ICU LOS (4 vs. 6 days; Q1–Q3, 2–10 days; Table 3). Of note, the median LOS for level I and II/III/IV centers was similar with average LOS for nontransferred level I patients being 11 days and transferred into a level I center being 9 days and level II/III/IV being 9 and 8 days, respectively. A greater percentage of early surgery patients were discharged to rehabilitation centers relative to late surgery patients (63.4% vs. 53.4%). Patients with late surgery

TABLE 1. Patient Baseline Characteristics

	Level I		Level II/III/IV		
	Not Transferred (n = 4,457)	Transferred in (n = 2,662)	Not Transferred (n = 2,727)	Transferred in (n = 998)	Total (N = 10,844)
Age at admission	40 (27–57)	51 (32–66)	44 (28–61)	48 (30–66)	45 (28–61)
Male	3,491 (78.3%)	1,886 (70.8%)	2,085 (76.5%)	726 (72.7%)	8,188 (75.5%)
Race					
White	2,790 (62.6%)	2,068 (77.7%)	1,918 (70.3%)	808 (81.0%)	7,584 (69.9%)
Black or African American	927 (20.8%)	267 (10.0%)	314 (11.5%)	43 (4.3%)	1,551 (14.3%)
Other/unknown	740 (16.6%)	327 (12.3%)	495 (18.2%)	147 (14.7%)	1,709 (15.8%)
Hispanic or Latino	595 (13.3%)	216 (8.1%)	296 (10.9%)	48 (4.8%)	1,155 (10.7%)
Region					
Northeast	583 (13.1%)	338 (12.7%)	249 (9.1%)	75 (7.5%)	1,245 (11.5%)
West	1,017 (22.8%)	489 (18.4%)	1,039 (38.1%)	320 (32.1%)	2,865 (26.4%)
Midwest	1,195 (26.8%)	943 (35.4%)	908 (33.3%)	462 (46.3%)	3,508 (32.3%)
South	1,662 (37.3%)	892 (33.5%)	531 (19.5%)	141 (14.1%)	3,226 (29.7%)
Hospital teaching status					
University	3,561 (79.9%)	2,182 (82.0%)	375 (13.8%)	147 (14.7%)	6,265 (57.8%)
Nonteaching	13 (0.3%)	0 (0.0%)	765 (28.1%)	286 (28.7%)	1,064 (9.8%)
Community	883 (19.8%)	480 (18.0%)	1,587 (58.2%)	565 (56.6%)	3,515 (32.4%)
Comorbidities					
Diabetes mellitus	371 (8.3%)	345 (13.0%)	260 (9.5%)	104 (10.4%)	1,080 (10.0%)
Current smoker	925 (20.8%)	542 (20.4%)	456 (16.7%)	216 (21.6%)	2,139 (19.7%)
Bleeding disorder	135 (3.0%)	127 (4.8%)	75 (2.8%)	45 (4.5%)	382 (3.5%)
ISS	25 (16–33)	18 (13–26)	21 (14–29)	17 (10–25)	21 (14–29)
AIS — spine	4 (3–5)	4 (3–4)	4 (3–4)	4 (3–4)	3 (3–5)
Injury type					
Blunt	3,608 (81.0%)	2,450 (92.0%)	2,345 (86.0%)	934 (93.6%)	9,337 (86.1%)
Penetrating	779 (17.5%)	141 (5.3%)	321 (11.8%)	27 (2.7%)	1,268 (11.7%)
Other/unspecified	70 (1.6%)	71 (2.7%)	61 (2.2%)	37 (3.7%)	239 (2.2%)
Mechanism of injury					
Transport	1,981 (44.4%)	1,111 (41.7%)	1,232 (45.2%)	462 (46.3%)	4,786 (44.1%)
Fall	1,476 (33.1%)	1,214 (45.6%)	994 (36.5%)	420 (42.1%)	4,104 (37.8%)
Firearm	745 (16.7%)	135 (5.1%)	311 (11.4%)	26 (2.6%)	1,217 (11.2%)
Other/unspecified or unknown	255 (5.7%)	202 (7.6%)	190 (7.0%)	90 (9.0%)	737 (6.8%)
Systolic blood pressure, mm Hg					
<90	481 (10.8%)	145 (5.4%)	258 (9.5%)	51 (5.1%)	935 (8.6%)
90–180	3,764 (84.5%)	2,342 (88.0%)	2,344 (86.0%)	888 (89.0%)	9,338 (86.1%)
>180	164 (3.7%)	96 (3.6%)	118 (4.3%)	41 (4.1%)	419 (3.9%)
Payment method					
Private/commercial insurance	1,749 (39.2%)	1,023 (38.4%)	1,300 (47.7%)	456 (45.7%)	4,528 (41.8%)
Medicare	572 (12.8%)	626 (23.5%)	459 (16.8%)	215 (21.5%)	1,872 (17.3%)
Medicaid	721 (16.2%)	303 (11.4%)	290 (10.6%)	93 (9.3%)	1,407 (13.0%)
Self-pay	669 (15.0%)	331 (12.4%)	358 (13.1%)	128 (12.8%)	1,486 (13.7%)
Other/unknown	746 (16.7%)	379 (14.2%)	320 (11.7%)	106 (10.6%)	1,551 (14.3%)

were more likely to be discharged to a skilled nursing facility or home without services than those who had early surgery.

Association Between Center Type, Transfer, and Surgical Intervention

A total of 7,251 patients (63.0%) received surgical intervention (Table 1). The multivariable regression model results on the association between surgical intervention and trauma center level, adjusting for potential confounders that included transfer-in status, ISS, AIS spine injury score, blood pressure, teaching status of the hospital, region of the hospital, age, sex, race, injury type, mechanism of injury, insurance type, bleeding disorder, smoking status, and interaction term between trauma center level and transfer-in status, are reported in the forest plot (Fig. 2).

Those who were admitted directly to level I centers had a higher odd of receiving a surgery (OR, 1.61; 95% CI, 1.25–2.09; $p < 0.001$). Patients transferred into a level I center were also more likely to undergo surgery than those at a level II/III/IV center, although this was not significant (OR, 1.20; 95% CI, 0.92–1.57; $p = 0.185$). Patients transferred into a level II/III/IV center, typically transferred to a level II, had higher odds of

TABLE 2. Patient Surgical Intervention and Discharge Outcomes by Trauma Center Level and Transfer Status

	Level I		Level II/III/IV		
	Not Transferred (n = 4,457)	**Transferred in (n = 2,662)**	**Not Transferred (n = 2,727)**	**Transferred in (n = 998)**	**Total (N = 10,844)**
Surgical intervention	3,066 (68.8%)	1,957 (73.5%)	1,663 (61.0%)	716 (71.7%)	7,402 (68.3%)
Time of surgical intervention					
Early surgical intervention	1,686 (37.8%)	1,020 (38.3%)	856 (31.4%)	396 (39.7%)	3,958 (36.5%)
Late surgical intervention	1,379 (30.9%)	935 (35.1%)	806 (29.6%)	320 (32.1%)	3,440 (31.7%)
No surgical intervention	1,391 (31.2%)	705 (26.5%)	1,064 (39.0%)	282 (28.3%)	3,442 (31.7%)
LOS, d	11 (7–21)	9 (6–17)	9 (5–17)	8 (5–14)	10 (6–18)
Length of ICU stay, d	5 (2–12)	3 (1–9)	4 (1–10)	4 (1–8)	4 (1–10)
Ventilator days	0 (0–6)	0 (0–4)	0 (0–3)	0 (0–3)	0 (0–4)
Discharge disposition					
Missing	69 (1.5%)	28 (1.1%)	209 (7.7%)	23 (2.3%)	329 (3.0%)
Home with no services	820 (18.4%)	633 (23.8%)	484 (17.7%)	252 (25.3%)	2,189 (20.2%)
Home with services	107 (2.4%)	99 (3.7%)	75 (2.8%)	22 (2.2%)	303 (2.8%)
Rehabilitation	2,488 (55.8%)	1,241 (46.6%)	1,328 (48.7%)	481 (48.2%)	5,538 (51.1%)
Skilled nursing facility	556 (12.5%)	364 (13.7%)	399 (14.6%)	141 (14.1%)	1,460 (13.5%)
Palliative care center	14 (0.3%)	12 (0.5%)	10 (0.4%)	8 (0.8%)	44 (0.4%)
Expired	316 (7.1%)	233 (8.8%)	190 (7.0%)	61 (6.1%)	800 (7.4%)
Other	87 (2.0%)	52 (2.0%)	32 (1.2%)	10 (1.0%)	181 (1.7%)
In-hospital complications					
Acute kidney injury	92 (2.1%)	44 (1.7%)	47 (1.8%)	12 (1.2%)	195 (1.9%)
ARDS	226 (5.2%)	129 (5.0%)	105 (4.1%)	42 (4.3%)	502 (4.8%)
Cardiac arrest with resuscitative efforts by healthcare providers	189 (4.4%)	107 (4.2%)	66 (2.6%)	20 (2.1%)	382 (3.7%)
Decubitus ulcer	257 (5.9%)	138 (5.4%)	127 (4.9%)	42 (4.3%)	564 (5.4%)
Deep surgical site infection	29 (0.7%)	10 (0.4%)	7 (0.3%)	3 (0.3%)	49 (0.5%)
Drug or alcohol withdrawal syndrome	61 (1.4%)	49 (1.9%)	34 (1.3%)	19 (2.0%)	163 (1.6%)
DVT/thrombophlebitis	274 (6.3%)	124 (4.8%)	122 (4.7%)	36 (3.7%)	556 (5.3%)
Extremity compartment syndrome	16 (0.4%)	7 (0.3%)	5 (0.2%)	0 (0.0%)	28 (0.3%)
Graft/prosthesis/flap failure	3 (0.1%)	2 (0.1%)	4 (0.2%)	1 (0.1%)	10 (0.1%)
Myocardial infarction	16 (0.4%)	18 (0.7%)	7 (0.3%)	6 (0.6%)	47 (0.4%)
Organ/space surgical site infection	40 (0.9%)	10 (0.4%)	26 (1.0%)	4 (0.4%)	80 (0.8%)
Pneumonia	686 (15.9%)	366 (14.2%)	330 (12.8%)	106 (10.9%)	1,488 (14.2%)
Pulmonary embolism	96 (2.2%)	51 (2.0%)	32 (1.2%)	5 (0.5%)	184 (1.8%)
Stroke/CVA	26 (0.6%)	16 (0.6%)	7 (0.3%)	4 (0.4%)	53 (0.5%)
Superficial surgical site infection	42 (1.0%)	15 (0.6%)	9 (0.3%)	7 (0.7%)	73 (0.7%)
Unplanned intubation	205 (4.7%)	103 (4.0%)	81 (3.1%)	35 (3.6%)	424 (4.1%)
Urinary tract infection	401 (9.3%)	202 (7.9%)	138 (5.3%)	46 (4.7%)	787 (7.5%)
Catheter-related blood stream infection	23 (0.5%)	9 (0.3%)	10 (0.4%)	1 (0.1%)	43 (0.4%)
Osteomyelitis	6 (0.1%)	3 (0.1%)	0 (0.0%)	2 (0.2%)	11 (0.1%)
Unplanned return to the OR	62 (1.4%)	20 (0.8%)	21 (0.8%)	12 (1.2%)	115 (1.1%)
Unplanned admission to the ICU	129 (3.0%)	64 (2.5%)	41 (1.6%)	15 (1.5%)	249 (2.4%)
Severe sepsis	73 (1.7%)	30 (1.2%)	35 (1.4%)	8 (0.8%)	146 (1.4%)
Other	1,211 (28.0%)	682 (26.5%)	933 (36.2%)	317 (32.7%)	3,143 (30.1%)

ARDS, adult respiratory distress syndrome; CVA, cerebrovascular accident; DVT, deep vein thrombosis; OR, operating room.

receiving a surgery compared with nontransferred level II/III/IV center patients (OR, 1.34; 95% CI, 1.15–1.57; $p < 0.001$). For nontransferred patients, prehospital arrival time was not significantly associated with likelihood of undergoing surgical intervention (OR, 1.00; $p = 0.577$; Supplementary Tables 5 and 6, http://links.lww.com/TA/B942). There was not a statistically significant difference in the odds of undergoing surgery based on whether the hospital was a nonteaching or university hospital (OR, 0.80; 95% CI, 0.56–1.15; $p = 0.231$; Fig. 2).

Clinical features such as spinal abbreviated injury score and injury severity were significantly associated with likelihood of undergoing surgery in that more severely injured patients on the spinal ISS were more likely to have surgery (1-U change; OR, 1.31; 95% CI, 1.22–1.41; $p < 0.001$) and patients with more severe total body injuries were less likely to undergo surgery (5-U change; OR, 0.97; 95% CI, 0.94–0.99; $p = 0.003$; Fig. 2).

There were also differences in terms of age, mechanism of injury, and insurance status in terms of rates of surgical

TABLE 3. Patient Surgical Intervention and Discharge Outcomes by Timing of Surgical Intervention

	Early Surgical Intervention (n = 3,958)	Late Surgical Intervention (n = 3,440)	No Surgical Intervention (n = 3,442)
LOS, d	10 (6–18)	13 (8–22)	7 (3–15)
Length of ICU stay, d	4 (2–10)	6 (2–14)	2 (0–6)
Ventilator days	0 (0–4)	0 (0–8)	0 (0–3)
Discharge disposition			
Missing	28 (0.7%)	30 (0.9%)	271 (7.9%)
Home with no services	657 (16.6%)	725 (21.1%)	806 (23.4%)
Home with services	79 (2.0%)	115 (3.3%)	109 (3.2%)
Rehabilitation	2,511 (63.4%)	1,838 (53.4%)	1,186 (34.5%)
Skilled nursing facility	439 (11.1%)	531 (15.4%)	490 (14.2%)
Palliative care center	7 (0.2%)	10 (0.3%)	27 (0.8%)
Expired	158 (4.0%)	126 (3.7%)	516 (15.0%)
Other	79 (2.0%)	65 (1.9%)	37 (1.1%)
In-hospital complications			
Acute kidney injury	53 (1.3%)	76 (2.2%)	66 (1.9%)
ARDS	184 (4.6%)	198 (5.8%)	120 (3.5%)
Cardiac arrest with resuscitative efforts by healthcare providers	108 (2.7%)	122 (3.5%)	152 (4.4%)
Decubitus ulcer	174 (4.4%)	247 (7.2%)	143 (4.2%)
Deep surgical site infection	14 (0.4%)	23 (0.7%)	12 (0.3%)
Drug or alcohol withdrawal syndrome	46 (1.2%)	76 (2.2%)	41 (1.2%)
DVT/thrombophlebitis	184 (4.6%)	245 (7.1%)	127 (3.7%)
Extremity compartment syndrome	10 (0.3%)	5 (0.1%)	13 (0.4%)
Graft/prosthesis/flap failure	5 (0.1%)	2 (0.1%)	3 (0.1%)
Myocardial infarction	16 (0.4%)	16 (0.5%)	15 (0.4%)
Organ/space surgical site infection	18 (0.5%)	24 (0.7%)	38 (1.1%)
Pneumonia	551 (13.9%)	598 (17.4%)	339 (9.8%)
Pulmonary embolism	56 (1.4%)	86 (2.5%)	42 (1.2%)
Stroke/CVA	11 (0.3%)	23 (0.7%)	19 (0.6%)
Superficial surgical site infection	31 (0.8%)	22 (0.6%)	20 (0.6%)
Unplanned intubation	171 (4.3%)	152 (4.4%)	101 (2.9%)
Urinary tract infection	283 (7.2%)	311 (9.0%)	193 (5.6%)
Catheter-related blood stream infection	10 (0.3%)	19 (0.6%)	14 (0.4%)
Osteomyelitis	5 (0.1%)	5 (0.1%)	1 (0.0%)
Unplanned return to the OR	40 (1.0%)	43 (1.3%)	32 (0.9%)
Unplanned admission to the ICU	89 (2.2%)	89 (2.6%)	71 (2.1%)
Severe sepsis	38 (1.0%)	53 (1.5%)	55 (1.6%)
Other	1,098 (27.7%)	1,008 (29.3%)	1,034 (30.0%)

ARDS, adult respiratory distress syndrome; CVA, cerebrovascular accident; DVT, deep vein thrombosis; OR, operating room.

intervention. Overall, older patients were less likely to have surgery (OR, 0.79; 95% CI, 0.76–0.82; $p < 0.001$). Patients with blunt injury were more likely to have surgery than those with penetrating injuries (OR, 11.77; 95% CI, 5.84–23.73; $p < 0.001$). Patients without private insurance were less likely to have surgery than those with private insurance including comparing those with Medicare and self-pay (Fig. 2).

Association Between Center Type, Transfer, and Timing of Surgical Intervention

Among the 7,398 patients who received surgical interventions, 3,958 (53.5%) received the surgery within 24 hours of hospital arrival (early surgical intervention, Table 3). For nontransferred patients, those who were in level I centers had higher odds of receiving an early surgery, although not statistically significant (OR, 1.24; 95% CI, 0.97–1.58; $p = 0.081$). Transfer status and level of center otherwise were not significantly associated with surgical timing as well (Fig. 3). Prehospital arrival time was not significantly associated with timing of surgical intervention (Supplementary Table 7, http://links.lww.com/TA/B942).

DISCUSSION

The goal of this study was to address national practice patterns in traumatic SCI, specifically how those patterns look different depending on where a patient with SCI arrives for their treatment. This is important because it will allow health systems and first responders to identify opportunities to streamline care and improve outcomes for patients with traumatic SCI. Our study had the following key findings: (1) patients who were directly admitted to level I trauma centers were more likely to have surgery than those directly admitted to level II/III/IV centers and

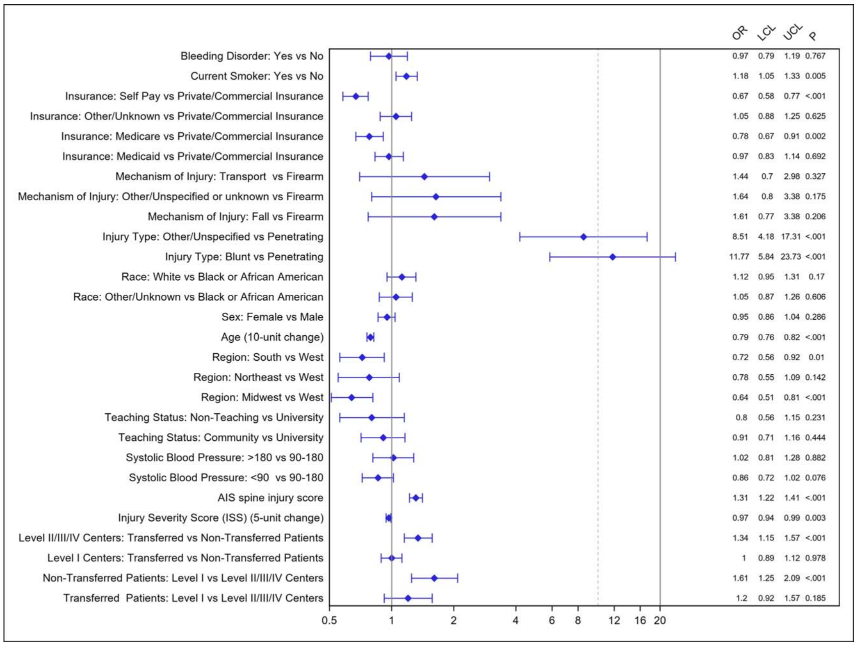

Figure 2. Forest plot of regression analysis demonstrating association between center type and transfer status and surgical intervention (yes/no).

(2) patients who were transferred into the level I center had slightly higher odds of receiving operative intervention than patients transferred to level II/III/IV centers, but this was not significant and there was no difference in timing of surgery between the two groups. These findings correlated with outcomes, as patients treated at level I centers were more likely to be discharged to rehabilitation centers, as opposed to patients who were taken care of at level II/III/IV centers who were more likely to be discharged home without services.

Based on prior studies, the field of SCI is moving in the direction of surgical decompression (early when possible) to improve patient outcomes.[10,20] While we try to improve access to level I center care in the United States directly, we also must understand the reality that not every patient can reach a level I center directly. Canada has worked on the geographic distribution of SCI patients and resources.[21] Our study shows that IHT may still be the best for patients to receive an intervention, as patients transferred to a level I center were slightly

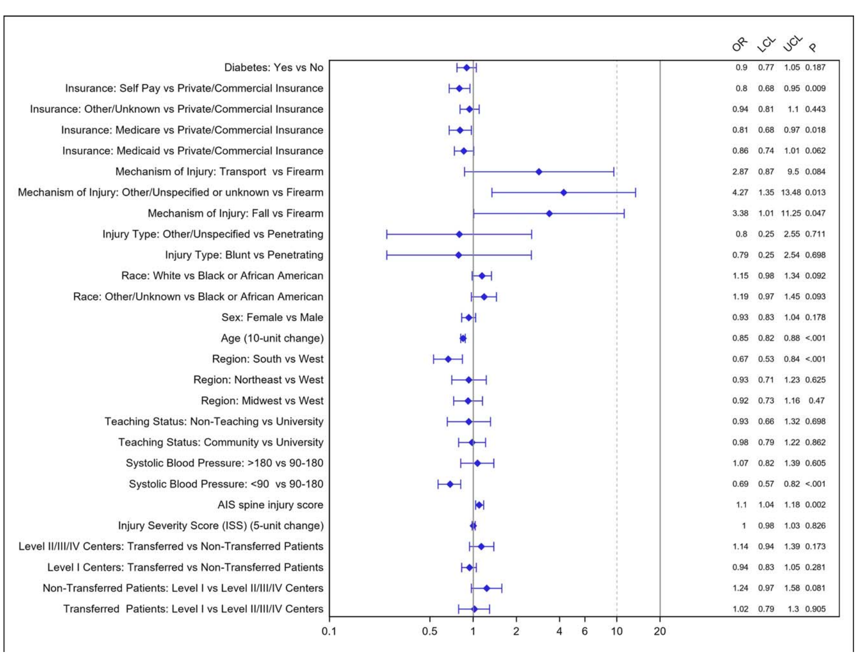

Figure 3. Forest plot of regression analysis demonstrating association between center type and transfer status and timing of surgical intervention (early/late).

more likely to have surgery than patients in level II/III/IV centers. This is important, because when thinking about the importance of surgical decompression, many might worry that a transfer would waste key time and make a patient less likely to have surgery. It is important to note however that timing of surgery was not significantly associated with level of center. Further research should look into the barriers transfer presents to surgical intervention for SCI patients and how to best ensure prompt access to care.

Patents directly admitted to level I trauma centers appear more likely to receive surgery, and this may be regardless of timing. About 30% of patients at these centers received early surgery. Prehospital arrival time was not significantly associated with surgical intervention. Further study is needed regarding timing of surgery and why only 30% of patients received early surgery, as there may represent disagreement about the utility of early surgery, variations in injury severity, and/or availability of appropriate care teams.

It is important to note that, although level I centers had increased rates of surgery and discharge to rehabilitation centers, there was also an increase in complication rates. Although our analysis of the distribution of surgery types across hospital centers showed a fairly even distribution, it is still worth studying the severity of injuries and specific details of injuries and surgery that may be different across groups. Other possible explanations for higher complications at level I centers include having patients of higher acuity and a higher intervention rate, leading to higher rates of complications that could not be controlled for due to the granularity of the data available. It must also be considered that taking more patients to surgery could mean poorer patient selection, leading to more complications. This is an area that requires further study.

Level of trauma center is far from the only factor associated with surgical intervention in SCI. There are several key clinical factors that have expected associations with surgical intervention. For example, those with more severe spinal injuries, measured by the AIS spine injury score, were more likely to have surgery. Demographic factors would not be expected to play as large of a role in decision making as clinical factors. Payment status and age were associated with likelihood of having surgery. Disparities in outcomes in traumatic SCI have been identified in the literature. Future study is required to better understand the mechanism of these associations and how they interplay with center type and IHT.

Ideal treatment of traumatic SCI depends on effective and coordinated health care infrastructure and personnel capable of recognizing and treating patients with a suspected traumatic SCI as medical emergencies, using proper spinal precautions and rapidly and directly transporting them to an appropriate center, without delaying potential treatments. Our study represents one of the first large-scale real-world examinations of population level data on the size and nature of the effect on outcomes of delayed transport to a level I center.

Overlaying population level patient flow data in the context of available health service infrastructure (e.g., designation of hospital trauma center level, ICU and ward availability, spine surgery and staffing profile, availability of magnetic resonance imaging scanner, operating room availability for trauma/spinal injury cases), policies, protocols, care processes, and resource utilization across counties and states will enable future improvements in quality and efficiency of health care delivery.

Limitations

There are several key limitations of our study. These are retrospective data and therefore not causative. Missing data had to be excluded. Data are also limited about the journey of a patient with suspected traumatic SCI from the time of injury to definitive care, the specific practices and processes that may cause delay, and their degree of impact on achieving optimal outcomes. Specific data about type of procedure and imaging localization of the level of injury were not available. In addition, the granularity of clinical data did not include features such as physical examination or American Spinal Cord Injury Association score, and therefore, we were unable to fully understand differences in surgical candidacy of individual patients across center types. Prehospital time was difficult to interpret because of variations in recording and the difference in time between transferred and nontransferred patients. Demographic data were also limited and did not include variables such as education status, zip code, or income.

CONCLUSION

Patients with traumatic SCI directly admitted to level I trauma centers were more likely to have surgery and early surgery than those directly admitted to level II/III/IV centers. Patients who were transferred into a level I center received operative intervention more frequently than patients treated at level II/III/IV centers or transferred into level II/III/IV centers, but the differences did not reach significance. These findings correlated with outcomes, as patients treated at level I centers were more likely to be discharged to rehabilitation centers but also more likely to have complications. The current study provides insights into a large US population-based real-world sample and sheds light on opportunities for improving prehospital care pathways for patients with traumatic SCI, to provide the timely and appropriate care and achieve the best possible outcomes.

AUTHORSHIP

T.W. contributed in the literature search, study design, data interpretation, writing, and critical revision. S.H. contributed in the literature search, study design, data interpretation, and writing. L.Z.Y. contributed in the study design, data collection, data analysis, data interpretation, writing, and critical revision. H.-J.L. contributed in the data collection, data analysis, data interpretation, and critical revision. M.G. contributed in the literature search and critical revision. B.U. contributed in the data interpretation, critical revision, and revised study design. M.B. contributed in the data interpretation, critical revision, and revised study design. C.I.S. contributed in the study of manuscript review, manuscript conceptualization. C.R.G. contributed in the study design, data interpretation, and critical revision. I.O.K. contributed in the study design, data interpretation, and critical revision. S.L. contributed in the study design, data interpretation, and critical revision. M.A.-E.-B. contributed in the study design, data interpretation, and critical revision.

DISCLOSURE

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