Interfacility Ambulance Versus Helicopter Transport of Traumatic Spinal Cord Injury Patients: Outcomes, Observations, and Utilization

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ABSTRACT

Introduction: Traumatic spinal cord injury (tSCI) is a devastating event that can cause permanent loss of function or disability. Time to surgical decompression of the spinal cord affects outcomes and is a critical principle in management of tSCI. One of the major determinants of time to decompression is transport time. To date, no study has compared the neurological outcomes of tSCI patients transported via ground/ambulance versus air/helicopter.

Objective: This retrospective cohort study sought to assess the association of the mode of transport on the neurological outcomes of tSCI patients.

Methods: Data from 46 ground transport and 29 air transport patients with tSCI requiring surgical decompression were collected. Outcomes were assessed by the change in American Spinal Injury Association Impairment Scale (AIS) grade from admission to discharge. Additionally, the utilization of air versus ground transport was assessed based on the distance from the admitting institution.

Results: Among the transport groups, there were no significant differences ($P > 0.05$) in patient demographics. Helicopter transport patients demonstrated higher rates of AIS grade improvement ($P = 0.004$), especially among AIS grade A/grade B patients ($P = 0.02$; $P = 0.02$, respectively), compared to the ambulance transport group. Additionally, within the cohort of patients undergoing decompression within 0 to 12 hours, helicopter transport was associated with higher AIS grade improvement ($P = 0.04$) versus the ambulance transport group. Helicopter transport was used more frequently at distances greater than 80 miles from the admitting institution ($P = 0.01$).

Conclusions: This study suggests that helicopter transport of tSCI patients requiring surgical decompression was associated with improved neurological outcomes compared to patients transported via ambulance.

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INTRODUCTION

Every year, over 12 000 patients in the United States sustain traumatic spinal cord injury (tSCI) resulting in significant loss of neurological function and permanent disability.[1–5] One critical factor in the surgical management of tSCI is the timing of surgical decompression.[6-9] Over the past 2 decades, several studies have suggested improvement of neurological outcomes measured by conversion of American Spinal Injury Association Impairment Scale (AIS) grades to less severe states in patients undergoing surgical decompression in less than 12 hours or from 12 to 24 hours after tSCI.[6,10-13] The most likely explanation of improved neurological outcomes in patients undergoing rapid surgical decompression is likely due to reversal of secondary injury mechanisms, such as ischemia, edema, and lipid peroxidation that are triggered by the initial cord lesion or primary mechanism of injury.[9-11,14-26]

One of the most critical determinants of time to decompression and, thus, potentially neurological outcomes is the time a patient spends in transport with emergency medical service (EMS) personnel.[27] Transport time is affected by the mode of transport, and, ultimately, the decision to transport trauma patients via ambulance/ground versus helicopter/air is at the discretion of the clinician.[28-30] This decision not only has the potential to affect clinical outcomes but also has significant financial implications. Among medical personnel, it is widely believed that

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interfacility helicopter transport results in decreased transfer time compared to ground transport, allowing for the potential of expedited intervention at the admitting institution.[31,32] Although the benefits of helicopter transport are widely held, currently there is no randomized, controlled trial to address whether ambulance or helicopter transport is faster or whether there is a meaningful difference in clinical outcomes among these modes of transport.[31,32] However, retrospective studies examining the outcomes of patients with other types of traumatic injuries, including traumatic brain injury, have suggested that helicopter transport decreases mortality and enhances outcomes compared to ground transport.[33-36]

To date, no study has examined the association of mode of transport with the neurological outcomes of tSCI patients requiring surgical decompression. Thus, this study aimed to (1) determine the association of mode of transport (ambulance vs helicopter) on neurological outcomes, (2) assess the association of mode of transport (ambulance vs helicopter) and time to surgical decompression on neurological outcomes, and (3) determine the utilization patterns of air versus ground transport for tSCI patients requiring surgical decompression.

METHODS

This retrospective cohort study was performed in accordance with the following guidelines: Strengthening the Reporting of Observational studies in Epidemiology (STROBE) and Enhancing the Quality and Transparency of Health Research (EQUATOR).[37,38]

Patient Population

This study was reviewed and approved at the academic university hospital and level I trauma center of the corresponding author. It underwent minimal risk institutional review board review at the University of Wisconsin-Madison (2020-0175) and was determined to meet criteria for exempt human subjects' research. We collected data from all interfacility acute tSCI trauma patients with imaging-confirmed spinal cord compression requiring surgical decompression from January 2013 through March 2020. Consent from patients was deemed unnecessary for this study as all data was extracted and stored in a deidentified database. Prior to study enrollment, strict inclusion and exclusion criteria were defined as previously described.[12] Briefly, inclusion criteria included adult patients age 18 or older, trauma patients requiring interfacility transport, patients with tSCI with spinal cord compression requiring surgical decompression, and imaging-confirmed spinal cord compression. Exclusion criteria included the following: patients who did not undergo interfacility transport, incomplete or neurological examinations that were not performed according to the standards established by the American Spinal Injury Association, patients with lumbar injuries below L2, no recorded EMS transport times or mode of transport, and patients who did not have tSCI.

Interfacility trauma patients requiring transport to a single level I trauma center were screened prior to enrollment through examination of the Trauma Base database. Trained trauma registrars enrolled patients into this registry at the time of their initial encounter in accordance with the National Trauma Data Bank guidelines and Trauma Quality Improvement National Standard supported by the American College of Surgeons. From January 2013 to March 2020 "spinal cord compression" and "tSCI" records were queried. Of the 203 patients screened from the Trauma Base database, 75 met inclusion criteria, 97 patients were excluded due to not having tSCI, 18 patients were excluded due to incomplete transport time/time to decompression records, 9 patients were excluded due to lumbar injuries below L2, and 4 patients were excluded due to incomplete neurological examinations/spinal cord decompression without imaging confirmation.

Statistical Analysis

All statistical analysis was performed as previously described.[12] Briefly, deidentified patient data were extracted from the medical record, including gender, age, injury severity score (ISS), admission/discharge AIS grades, length of stay (LOS), intensive care unit (ICU) length of stay, and discharge disposition. The Mann-Whitney U test for numerical variables and the Fischer exact test for categorical variables were utilized to analyze the differences in patient demographics, such as age, gender, ICU length of stay, and LOS, among cohorts.

Patients were divided into either the ambulance/ground transport group or the helicopter/air transport group. Changes in neurological outcomes were assessed based on the change in AIS score from admission to discharge following surgical decompression as previously described.[7,12] In order to examine the association of mode of transport on the neurological outcomes of tSCI patients, change in AIS score as a function of mode of transport groups was assessed via analysis of variance (ANOVA) with correction for multiple comparisons and subsequent posthoc analysis. From a clinical perspective, conversion of AIS grade A patients to higher AIS scores represents a major clinical change. Thus, in order to assess the association of transport modality on neurological outcomes, transport mode groups were further divided into subgroups based on their AIS grade on admission (grade A, B, C, or D), and the change in AIS grade following decompression as a function of transport modality was compared utilizing ANOVA.

Previous studies have suggested that time to surgical decompression following tSCI is associated with improved neurological outcomes.[6,10-12] Next, we assessed the association of time to surgical decompression and mode of transport on neurological outcomes. Time to decompression was extracted from the medical record and throughout this study was defined as the time from EMS dispatch to the time of surgical decompression, including time associated with intubation, exposure, case set-up, and

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Table 1. Patient Demographics of Association of Mode of Transport on Neurological Outcomes

	Ambulance N = 46	Helicopter N = 29	*P* value
No. of cervical/thoracic/lumbar SCI	42/4/0	24/4/1	
No. of male/female patients	33/13	22/7	
Average age (SEM)	51.6 (3.21)	52.4 (3.58)	0.84
Average Injury Severity Score (SEM)	22.4 (1.45)	22.8 (2.05)	0.76
Average ICU LOS (SEM)	4.02 (0.74)	6.21 (1.61)	0.15
LOS (SEM)	9.96 (1.40)	12.1 (2.32)	0.74
No. of AIS A[a] patients on admission	11	9	
No. of AIS B[a] patients on admission	4	4	
No. of AIS C[a] patients on admission	12	7	
No. of AIS D[a] patients on admission	19	9	
Average AIS on admission (SEM)	2.85 (0.18)	2.55 (0.23)	0.31

Abbreviations: AIS, American Spinal Injury Association Impairment Scale; ICU, intensive care unit; LOS, length of stay; SCI, spinal cord injury; SEM, standard error of the mean.

[a]Indicates AIS impairment grade.

Table 2. Patient Demographics and Injury Characteristics of Ambulance and Helicopter Transport Groups Subdivided into Time to Surgical Decompression Subgroups

Ambulance Transport Group	0–12 Hours	>12 Hours	*P* value 0–12 vs >12 Hours
No. of patients	18	28	
No. of cervical/thoracic/lumbar SCI	17/1/0	25/3/0	
No. of male/female patients	12/6	21/7	
Average age (SEM)	47.0 (4.63)	54.6 (7.06)	0.29
Average Injury Severity Score (SEM)	20.4 (1.52)	23.7 (2.17)	0.43
Average ICU LOS (SEM)	3.33 (1.13)	4.46 (0.98)	0.45
Average LOS (SEM)	8.39 (1.06)	11.0 (2.19)	0.99
No. of AISA A[a] patients on admission	2	9	
No. of AISA B[a] patients on admission	3	1	
No. of AISA C[a] patients on admission	5	4	
No. of AISA D[a] patients on admission	8	11	
Average AISA[a] patients on admission	2.71	3.06	0.36
Helicopter Transport Group			
No. of patients	19	10	
No. of cervical/thoracic/lumbar SCI	16/2/1	8/2/0	
No. of male/female patients	14/5	8/2	
Age (SEM)	52.3 (4.95)	52.7 (4.70)	0.84
Average Injury Severity Score (SEM)	21.32 (2.38)	25.7 (3.88)	0.34
Average ICU LOS (SEM)	7.47 (2.38)	3.50 (0.95)	0.33
Average LOS (SEM)	12.0 (2.51)	12.3 (4.94)	0.76
No. of AISA A[a] patients on admission	4	5	
No. of AISA B[a] patients on admission	4	0	
No. of AISA C[a] patients on admission	6	1	
No. of AISA D[a] patients on admission	5	4	
Average AISA patients on admission	2.63 (0.27)	2.40 (0.48)	0.64

Abbreviations: AISA, American Spinal Injury Association; ICU, intensive care unit stay; LOS, length of stay; SCI, spinal cord injury; SEM, standard error of the mean.

[a]Indicates ASIA impairment grade.

instrumentation. The ambulance transport group and helicopter transport group were subdivided into one of two time to decompression subgroups: 0 to 12 hours or >12 hours. These subgroups were constructed based on logistic regression analysis of AIS score as a function of time to decompression as described previously.[12] For each mode of transport group, change in AIS score as a function of time to decompression subgroup was assessed via ANOVA with correction for multiple comparisons and subsequent posthoc analysis to assess the association of time to surgical decompression and transport modality on neurological outcomes.

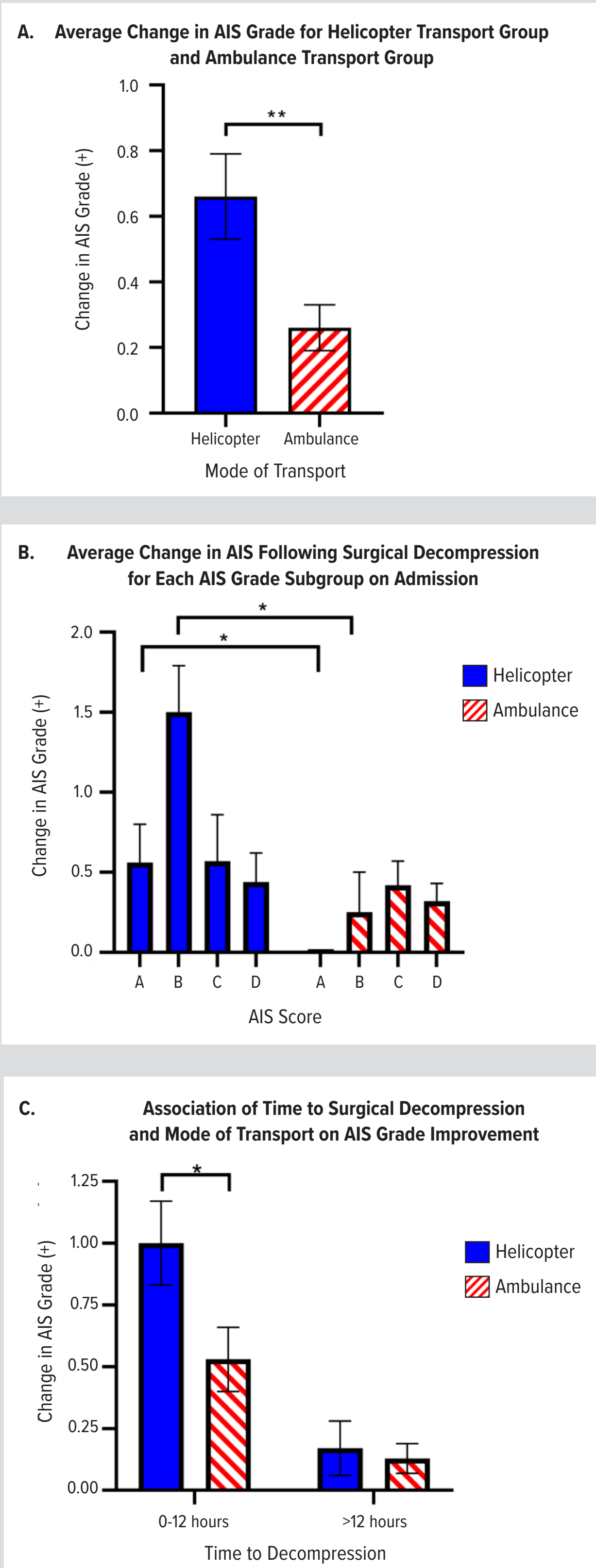
The outcomes of patients transported via ambulance versus helicopter also were assessed based on discharge disposition. Discharge dispositions were assigned the following numeric values: (1) expired, (2) long-term care, (3) skilled nursing facility, (4) rehabilitation unit, or (5) home. In order to assess transport resource utilization and practice patterns, the distance between the referring medical institution and the academic university hospital and level I trauma center of the corresponding author was determined. Longitudes, latitudes, distance, and nautical miles were determined using Great Circle Mapper and Google Maps software (Google Inc, Mountain View, California). Differences in discharge disposition and resource utilization among modes of transport were compared with ANOVA with subsequent posthoc analysis. All analyses in this study were performed using Graphpad Prism 8 and Microsoft Excel software.

RESULTS

Association of Mode of Transport with Neurological Outcomes

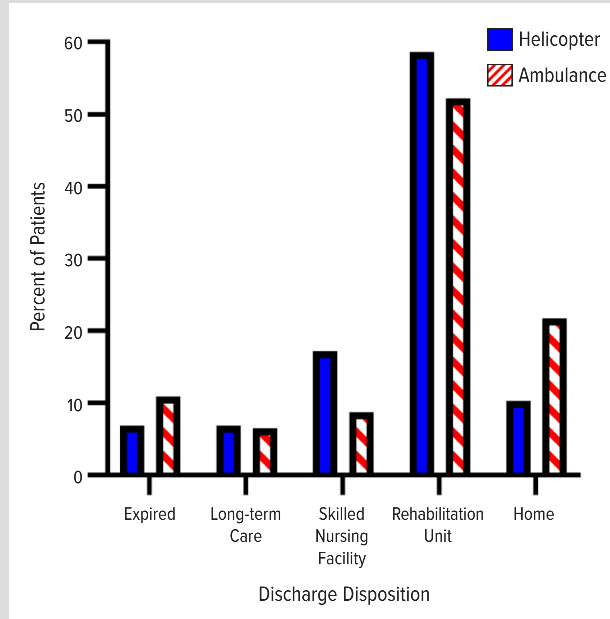
Over the course of the 7-year study period, 75 tSCI patients met inclusion criteria and required interfacility transport via ambulance or helicopter for surgical decompression. In total, 46 patients were transported via ambulance while 29 patients were transported via helicopter. Table 1 shows patient demographic data and injury characteristics of both transport groups. Among the ambulance and helicopter transport groups, there was no statistically significant difference ($P > 0.05$) in age, gender, ISS, LOS, and ICU length of stay. Additionally, there was no statistically significant preoperative difference in AIS grade ($P = 0.31$) among the transport groups. The association of mode of transport with neurological outcomes was assessed. First, the change in AIS grade from admission to discharge as a function of the mode of transport was compared using ANOVA with subsequent posthoc analysis. From this analysis, patients who were transported via helicopter had higher rates of average AIS grade improvement (0.66 ± 0.13, 0.26 ± 0.065; $P = 0.004$) compared to patients transported via ambulance (Figure 1A). Next, transport mode groups were stratified into subgroups based on their AIS grade on admission (ASIA A, B, C, or D), and the change in AIS grade following decompression as a function of transport modality was compared utilizing ANOVA. We were especially interested in the outcomes of AIS grade A patients on admission as conversion of AIS grade

Figure 1. Neurological Outcomes of Traumatic Spinal Cord Injury Patients Transported via Ambulance vs Helicopter



Abbreviation: AIS, American Spinal Injury Association Impairment Scale. Error bars are the standard error of the mean. Lines with a single asterisk above mark a statistically significant ($P < 0.05$) comparison via *t* test.

Figure 2. Discharge Dispositions of Traumatic Spinal Cord Injury Patients Transported via Ambulance vs Helicopter



A patients to higher AIS grades represents a significant clinical change. AIS grade A patients transported via helicopter had higher rates of AIS grade conversion compared to AIS grade A patients transported via ambulance ($P = 0.02$, Figure 1B). AIS grade B patients transported via helicopter also were found to have higher rates of AIS score improvement compared to AIS B patients transported via ambulance ($P = 0.02$). Among AIS grade C and AIS grade D patients, there was no statistically significant difference in patients transported via helicopter versus ambulance ($P = 0.5$, $P = 0.6$, respectively; Figure 1B).

Recently, studies have suggested that early surgical decompression of tSCI is associated with improved neurological outcomes. Thus, we sought to assess whether the association of helicopter versus ambulance transport on neurological outcomes persisted in patients who were decompressed within 0 to 12 hours versus >12 hours. Time to surgical decompression subgroup cutoffs were defined as described above and in prior publication.[12] Ambulance and helicopter transport groups were subdivided into 2 surgical decompression subgroups: 0 to 12 hours and >12 hours. Table 2 shows the patient demographic and injury characteristics of the ambulance and helicopter transport groups, which have been subdivided into time to surgical decompression subgroups. Among the time to decompression and mode of transport subgroup, there was no statistically significant difference ($P > 0.05$) in patient demographics, such as age, gender, ISS, LOS, or ICU stay. In the case of both patients transported via helicopter and ambulance (Figure 1C), patients who underwent surgical decompression within 0 to 12 hours had higher rates of AIS score improvement ($P < 0.05$) via ANOVA and subsequent posthoc analysis compared

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to patients who were transported via helicopter or ambulance and were decompressed at >12 hours. Importantly, patients decompressed within 0 to 12 hours and transported via helicopter had significantly higher rates of AIS grade improvement compared to patients decompressed within 0 to 12 hours and transported via ambulance (1.00 ± 0.17; 0.53 ± 0.13; $P = 0.04$). There was no statistical difference in change in AIS grade among patients transported via helicopter versus ambulance who underwent decompression at >12 hours ($P > 0.05$). The discharge disposition of tSCI patients undergoing surgical decompression transported via ambulance compared to those transported via helicopter is shown in Figure 2.

Utilization of Ambulance Versus Helicopter Transport

Next, the utilization of transport resources was assessed by subdividing the ambulance/helicopter transport groups based on the estimated transport distance into the following categories: (1) <45 miles, (2) 45-59 miles, (3) 60-80 miles, and (4) >80 miles. Helicopter transport was used more frequently ($P < 0.05$) than ambulance transport (Figure 3) in situations where the transport distance was relatively long (>80 miles). On the other hand, ambulance transport was utilized more frequently ($P < 0.05$) than helicopter transport in cases where transport distance was relatively short (<45 miles).

DISCUSSION

Key Results

This retrospective cohort study investigates (1) the association of mode of transport on neurological outcomes, (2) the association of mode of transport and time to surgical decompression on neurological outcomes, and (3) patterns of utilization of air versus ground transport for tSCI patients requiring surgical decompression. This study suggests that tSCI patients transported via helicopter have improved outcomes relative to patients transported via ambulance as overall patients transported via helicopter had higher rates of AIS grade improvement compared to patients transported via helicopter. Furthermore, patients with more severe spinal cord injuries (AIS A and B patients) had higher rates of AIS conversion when transported via helicopter compared to ambulance. In both the helicopter and ambulance transport groups, tSCI patients who underwent surgical decompression within 0 to 12 hours had higher rates of AIS score conversion compared to patients undergoing decompression >12 hours. Importantly, however, patients who underwent decompression within 0 to 12 hours and were transported via helicopter had statistically significantly higher rates of AIS grade improvement compared to patients undergoing decompression within 0 to 12 hours who were transported via ambulance. Therefore, this study suggests an association of helicopter transport with improved neurological outcomes in tSCI patients undergoing decompression within 12 hours, especially in the case of AIS grade A and B patients. This study also showed that a significantly higher number of patients were transported via helicopter from distances greater than 80 miles, while an ambulance was used more frequently for relatively short distances of less than 45 miles. These patterns of utilization are in line with previous helicopter utilization studies and practice patterns.[39]

Interpretation and Generalizability

Transport time is a critical determinant of time to surgical decompression and, thus, is a major barrier to potential improvements in neurological outcomes. To our knowledge, this is the first study that examines the association of mode of transport on neurological outcomes of tSCI patients requiring surgical decompression. Although no studies examine tSCI specifically, several studies – including a retrospective cohort study of nearly 75 000 patients comparing the outcomes of helicopter transport versus ground transport – suggested that helicopter transport significantly improved outcomes in patients with more severe injures as defined by an Injury Survival Score.[31-34,36] In studies of traumatic brain injury patients, helicopter transport compared to ambulance transport significantly decreased mortality and enhanced neurological outcomes.[35,36] Thus, the present study is in agreement with previous work as helicopter transport was associated with higher rates of AIS score conversion and improved outcomes among AIS grade A and B patients compared to patients transported via ambulance.

Recent studies also have suggested the importance of time to decompression on the neurological outcomes of tSCI patients. The present study supports this idea as patients undergoing surgical decompression within 0 to 12 hours who were transported via ambulance or helicopter had improved outcomes relative to patients undergoing decompression at >12 hours. However, this study suggests that helicopter transport has higher rates of improvement in patients undergoing decompression within 0 to 12 hours than patients transported via ambulance undergoing decompression within 0 to 12 hours. Therefore, although helicopter transport theoretically has the potential to be more rapid than ambulance transport, it is unlikely that improvement in the outcomes of patients transported via helicopter in the present study are due helicopter transport being faster than ambulance transport, as there was no significant difference in transport time among patients transported via ambulance versus helicopter (3.94 ± 0.49 hours, 8.48 ± 2.5 hours; $P = 0.17$). Previous studies have suggested that a possible explanation requiring further study is that air EMS personnel may have an enhanced skill level and more experience or training than ground EMS personnel. Other possible explanations for the improved outcomes of patients transported via helicopter could be an enhanced sense of urgency or differences in stabilization prior to air transport. Regardless, the present study suggests that the improvement in outcomes in

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patients transported via helicopter versus ambulance transport is not due primarily to the differences in the speed of transport modality but instead is likely due to other factors that require further study.

The question of when utilization of helicopter transport results in clinically meaningful improvements in outcomes remains unknown. To date, there is no randomized controlled trial comparing air versus ground patient transport. The present study suggests that helicopter transport is beneficial for transport of tSCI patients requiring surgical decompression, especially for AIS grade A and B patients who could undergo surgical decompression within 12 hours. A previous study suggested that ambulance transport is more rapid for distances less than 10 miles, while helicopter transport is faster at distances greater than 10 miles when simultaneously dispatched or greater than 45 miles in cases of non-simultaneous dispatch.[39] Although evidence-based guidelines for triage of air transport patients were generated recently, the decision of whether to transport a trauma patient via helicopter or ambulance is ultimately at the discretion of the clinician.[28] Selection of a mode of transport not only has a significant association with clinical outcomes but also has important financial consequences for the patient and institution. Cost analysis has demonstrated that the median cost of a helicopter is approximately $36 000, while the cost of ambulance transport is between $800 and $2000.[28,29,40] Although the utilization patterns described in this study are in line with previous helicopter utilization studies, further studies examining cost effectiveness are necessary in order to determine what constitutes "appropriate" use. Further expansion of telemedicine and dissemination of guidelines to rural hospitals are both factors that could be important in the future to continue to streamline transport and potentially improve neurological outcomes.

Limitations

The fact that this study is retrospective is limiting as retrospective studies can be subject to bias and have the potential to be limited by the exclusion of patients due to missing values or incomplete datasets. In the future, a randomized clinical trial would be optimal in order to more directly explore the associations of mode of transport on the neurological outcomes of tSCI patients. However, a randomized trial would be ethically challenging and, thus, an intermediary option would be a multicenter prospective cohort study using the thresholds and outcome measures described in this manuscript. Additionally, AIS grade is less precise than the International Standards for Neurological Classification of Spinal Cord Injury motor and sensory scores, which are now being utilized at our institution. Although this study was adequately powered to detect a statistical difference in the neurological outcomes among transport groups, the sample size of this study is a relative limitation.

CONCLUSIONS

This retrospective cohort study suggests that helicopter transport of tSCI patients requiring surgical decompression was associated with improved neurological outcomes compared to patients transported via ambulance.

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