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Timing of Surgical Intervention for Traumatic Spinal Injury and Its Association With 30-Day Functional Outcomes: A Single-Center Retrospective Study

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Abstract

The optimal timing of surgical intervention after traumatic spinal injury (TSI) remains uncertain, particularly with respect to patients with less severe injuries. We conducted a retrospective observational cohort study of patients who underwent surgical fixation for traumatic spinal injury at a single medical center to evaluate the association between timing of surgery and short-term functional outcomes. Patients were categorized based on whether surgery occurred within 24 hours of hospital presentation. Functional outcomes were assessed using the Modified Rankin Scale (mRS) 30 days after surgical fixation, with an mRS score of ⩽2 defined as a favorable functional outcome and an mRS score of ⩾3 defined as an unfavorable functional outcome. In our cohort, predominantly composed of patients with American Spinal Injury Association (ASIA) D or E injuries, surgical intervention within 24 hours was not significantly associated with improved functional outcomes. Younger age and less severe ASIA scores were significantly associated with better recovery.

Categories: Orthopedics, Neurosurgery
Keywords: retrospective studies, spinal cord injuries, spinal injury, time-to-treatment, treatment outcome

Introduction

The optimal timing of surgical intervention for traumatic spinal injury (TSI) remains uncertain [1]. Surgeons have largely favored early decompression and stabilization of the spine, and recent meta-analyses have shown that surgical treatment within 24 hours is associated with improved neurological recovery and better outcomes [1-6]. Clinical guidelines developed by AO Spine and the Cervical Spine Research Society strongly recommend early surgical intervention for TSI and acknowledge that this recommendation is supported by moderate-grade evidence [2]. The Modified Rankin Scale (mRS) has been used to quantify neurological function following spinal trauma [7,8]. Given the predominance of patients with relatively mild neurological impairment in our cohort, we selected the mRS to assess overall functional status following surgical intervention. We hypothesized that patients who underwent surgical intervention for TSI at our hospital within 24 hours of hospital presentation would be more likely to have mRS scores of ⩽2 at 30 days after surgical fixation compared to patients who had operative intervention more than 24 hours after presentation.

Materials And Methods

The Institutional Review Board of Baylor Scott & White Research Institute reviewed this study and waived the requirement for informed consent. We used a retrospective observational study design. Patients who sustained a TSI and underwent surgical fixation at Baylor Scott & White Medical Center (Temple, TX, USA) from January 1, 2019, through December 31, 2023 were included in the final analysis. Exclusion criteria included all patients without a 30-day follow-up appointment, patients who had significant concurrent injuries that affected their mRS (e.g., a fractured lower extremity), and patients who underwent nonsurgical or surgical management without stabilization. A study investigator retrieved demographic, physical, and clinical data from our electronic medical record (Epic Systems, Verona, WI, USA) and entered it into Research Electronic Data Capture hosted at the Baylor Scott & White Research Institute. This study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Patients who had surgical intervention within 24 hours of hospital presentation were considered to have early decompression. The time of hospital presentation and the time of surgery were determined from the electronic medical record. Because the exact time of injury was not consistently available or reliably documented, the timing of surgery was defined relative to hospital presentation rather than time of injury. Our primary outcome was the mRS score at 30 days after surgery. We considered an mRS score of ⩽2 to be a 'good' outcome and an mRS of ⩾3 to be a 'poor' outcome. Investigators received Strategies to Innovate Emergency Care Clinical Trials Network (SIREN)-Neurological Emergencies Treatment Trials (NETT) mRS

certification before determining the appropriate mRS score from chart review.

We performed a bivariate analysis between patients with a 30-day mRS score of ⩽2 and ⩾3 who underwent surgical treatment for spinal trauma. We used the chi-square test for categorical variables that had cell counts of five or greater and Fisher's exact test for categorical variables that had cell counts of four or less. We assessed the normality of continuous variables with the Kolmogorov-Smirnov test. We used the Wilcoxon rank-sum test for continuous variables that did not fit a normal distribution. Variables with significant or near-significant associations in the bivariate analysis were included in a multivariate logistic regression model to identify independent predictors of mRS 30 days after surgery. Model discrimination was assessed with the c-statistic. All analyses were performed with SAS version 9.4 (SAS Institute, Cary, NC, USA). Statistical significance was set at $\alpha = 0.05$, with a two-sided alpha level specified a priori.

Results

There were 147 patients who had TSI and met the inclusion criteria. Of these, 69 and 78 patients had mRS scores of ⩽2 and ⩾3, respectively, 30 days following surgery. The ASIA impairment scale has been used to quantify neurological impairment following spinal trauma [9]. In our bivariate analysis, patients who had a greater functional impairment 30 days after surgery had more severe ASIA impairment upon presentation, a longer length of stay, and were older. Complete data for our bivariate analysis are presented in Table *1*.

Variable		30-day mRS score ≤2 (n=69)	30-day mRS score ≥ 3 (n=78)	p-value
Age, years (median and IQR)		46 (29-59)	56 (31-71)	0.06
Current smoking history, n (%)		26 (38%)	37 (47%)	0.29
History of coronary artery disease, n (%)		3 (4%)	8 (10%)	0.22
History of chronic obstructive pulmonary disease, n (%)		2 (3%)	3 (4%)	1.00
History of congestive heart failure, n (%)		1 (1%)	3 (4%)	0.62
History of diabetes mellitus type 2, n (%)		6 (9%)	10 (13%)	0.45
History of hyperlipidemia, n (%)		11 (16%)	20 (26%)	0.17
History of hypertension, n (%)		19 (28%)	29 (37%)	0.26
Mechanism of injury, n (%)	Motor vehicle collision	28 (41%)	39 (50%)	0.23
	Motorcycle collision	4 (6%)	3 (4%)	
	All-terrain vehicle	2 (3%)	2 (3%)	
	Pedestrian	2 (3%)	4 (5%)	
	Fall	26 (38%)	29 (37%)	
	Other	7 (10%)[a]	1 (1%)[b]	
ASIA score, n (%)	A	0	18 (23%)	<0.001
	B	0	4 (5%)	
	C	0	6 (8%)	
	D	13 (19%)	13 (17%)	
	E	56 (81%)	37 (47%)	
Procedure performed, n (%)	Anterior cervical fixation	18 (26%)	12 (15%)	0.25
	Posterior cervical fixation	8 (12%)	11 (14%)	
	Percutaneous thoracic or lumbar fixation	10 (14%)	7 (9%)	
	Open thoracic or lumbar fixation	33 (48%)	48 (62%)	
Procedure performed within 24 hours of admission, n (%)		16 (23%)	25 (32%)	0.23
Length of stay, days (median and IQR)		5 (4-9)	12 (8-23)	<0.001

TABLE 1: Bivariate analysis examining factors associated with better functional outcomes

[a] Fell from a horse (n = 2), diving injury (n = 1), fell from a bicycle (n = 1), fell from a tractor (n = 1), parachuting injury (n = 1), and struck by a tree branch (n = 1); [b] Struck in the head by a skid loader (n = 1)

mRS: Modified Rankin Scale, ASIA: American Spinal Injury Association

The multivariate logistic regression found that a five-year increase in age (aOR 0.87; 95% CI 0.78-0.97; p=0.01) and a one-point increase in ASIA score upon presentation (aOR 3.45; 95% CI 1.96-6.06; p<0.001) were independently associated with an mRS score of ⩽2, 30 days after surgery. Surgical intervention within 24 hours was not associated with better functional outcomes in either the bivariate or multivariate analysis. The c-statistic of the multivariate logistic regression was 0.79. Complete data for the multivariate logistic regression are presented in Table *2*.

Variable	Units	Odds ratio	95% Confidence intervals		p-value
Age	5 years	0.87	0.78	0.97	0.01
Hyperlipidemia	Yes	0.54	0.21	1.37	0.19
ASIA score	One point	3.45	1.96	6.06	<0.001
Procedure performed less than 24 hours after presentation	Yes	0.82	0.33	2.05	0.68

TABLE 2: Multivariate logistic regression to predict mRS of 2 or less at 30 days

mRS: Modified Rankin Scale, ASIA: American Spinal Injury Association

Discussion

We found that surgical intervention for TSI within 24 hours of hospital presentation was not independently associated with improved short-term functional outcomes in our cohort, based on the mRS at 30 days after surgery. The ASIA score and age were independently associated with functional disability. Our findings contrast with several meta-analyses and multicenter studies showing improved neurologic outcomes associated with early surgical management [4-6].

However, they also align with the findings of several retrospective and randomized controlled trials showing no difference in neurologic outcomes in relation to surgical timing [10-12]. The differing results from these studies could be due to differences in patient populations, mechanisms of injury, surgical technique, definitions of early versus late surgical timing, and measures used to assess disability, though our study showed no significant association between mechanism of injury or surgical technique and outcomes.

There is limited consensus on what constitutes early surgical intervention, with timeframes ranging between eight to 72 hours after injury [13]. Studies have reported improved neurologic recovery within 72 hours, 36 hours, 24 hours, 12 hours, and eight hours for surgical intervention [4,14,15]. However, a meta-analysis reported that significant data are lacking to determine the effectiveness of ultra-early (e.g., <8 hours) surgical timeframes [5].

Furthermore, there is conflicting evidence in the medical literature regarding how the optimal surgical timeline varies with the severity of spinal cord injury (SCI). Many studies have not formally evaluated the differential effectiveness or safety of surgical timing in patients with ASIA A (complete SCI) versus ASIA B, C, or D (incomplete SCI) [5]. Surgeons tend to favor early surgery for incomplete SCI over complete SCI, and many studies have not found sufficient evidence to support increased effectiveness of early surgical intervention specifically for ASIA A injuries [16-19]. Conversely, a meta-regression across studies that separately reported data for complete and incomplete SCI suggests that completeness of injury does not modify the effect of early versus late surgery [5].

Although AO Spine stated in its new guidelines that early surgical intervention is recommended for SCI regardless of severity, they also noted that future research is needed to determine the impact of surgical timing on milder forms (ASIA D) of central cord injury [20]. Of note, 119 (81%) of our patients had ASIA D or ASIA E injuries, and therefore our results suggest that surgical timing is not associated with improved short-term outcomes in milder forms of TSI.

Our use of the mRS may capture different dimensions of recovery than the ASIA scale or other methods of measuring disability. Since most of our patients had ASIA D or E injuries (and therefore had little to no motor or sensory deficits), the mRS was chosen due to its ability to measure functional status in these cases. Our finding that increased age predicts greater functional impairment may reflect increased rates of pre-existing functional limitations and/or complications in older patients after SCI [21].

The lack of a significant association between surgical timing and improved mRS outcomes in our study does not negate the potential benefits of early surgical intervention. Rather, it highlights the importance of determining which subsets of patients would benefit most from early intervention, as well as which surgical timeline is associated with improved outcomes. Our results indicate that in populations consisting predominantly of patients with milder spinal injuries, surgical timing may not be associated with short-term functional improvement.

One limitation of this study is its single-center, retrospective nature, which relies on the accuracy of data entered by providers and limits the diversity of our population. Our sample size of 147 patients, 41 of whom received surgery within 24 hours of presentation to the hospital, limits our ability to detect smaller effects on functional outcomes. We focused on short-term outcomes, which limits our ability to detect potential

long-term improvements associated with early surgical intervention. Moreover, long-term outcomes are influenced by variables that are difficult to capture retrospectively. We were also limited by the lack of data on patients with severe spinal injuries, with only 28 (19%) of our patients having ASIA A-C injuries upon presentation. Every patient with an ASIA A-C injury had an mRS score of ⩾3 at 30 days after their surgery. We defined early surgical intervention as within 24 hours, which we chose because it is frequently cited in the literature, but this limits our ability to detect significant differences associated with 72-hour, 48-hour, or other commonly used definitions of early surgery. One limitation was that we were unable to quantify the impact of associated injuries because of our retrospective study design. Additional limitations include potential retrospective selection bias and confounding by indication, as our dataset may not have fully captured the clinical factors influencing the decision to perform surgery within 24 hours. Lastly, although our c-statistic showed good predictive ability, unmeasured confounders may have influenced our results.

Conclusions

Our study found that surgical fixation within 24 hours of presentation for spinal trauma was not independently associated with significantly improved short-term functional outcomes in a population consisting predominantly of patients with relatively mild spinal injuries (ASIA D or E). Larger, multicenter prospective studies are needed to further determine the optimal surgical timeline across different severities of spinal injury. These studies should also evaluate the potential long-term benefits of early surgical intervention.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: James Garda, Awais Z. Vance, Michael Hofkamp, Manu Nair

Acquisition, analysis, or interpretation of data: James Garda, Awais Z. Vance, Michael Hofkamp, Manu Nair

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Review Board, Baylor Scott & White Research Institute issued approval 024-325. The Institutional Review Board of Baylor Scott & White Research Institute reviewed this study (024-325) and waived the requirement for informed consent. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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