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Early Surgery for Traumatic Spinal Cord Injury: Where Are We Now?

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Abstract

Study Design: Narrative review.

Objective: There is a strong biological rationale to perform early decompression after traumatic spinal cord injury (SCI). With an enlarging clinical evidence base, most spine surgeons internationally now favor early decompression for the majority of SCI patients; however, a number of pertinent questions remain surrounding this therapy.

Methods: A narrative review evaluating the status of early surgery for SCI. In particular, we addressed the following questions: (1) Which patients stand to benefit most from early surgery? 2) What is the most appropriate time threshold defining early surgery?

Results: Although heterogeneity exists, the evidence generally seems to support early surgery. While the best evidence exists for cervical SCI, there is insufficient data to support a differential effect for early surgery depending on neurological level or injury severity. When comparing thresholds to define early versus late surgery—including a later threshold (48-72 hours), an earlier threshold (24 hours), and an ultra-early threshold (8-12 hours)—the 2 earlier time points seem to be associated with the greatest potential for improved outcomes. However, existing prehospital and hospital logistics pose barriers to early surgery in a significant proportion of patients. An overview of recommendations from the recent AOSpine guidelines is provided.

Conclusion: In spite of increasing acceptance of early surgery post SCI, further research is needed to (1) identify subgroups of patients who stand to derive particular benefit—in particular to develop more evidence-based approaches for central cord syndrome and (2) investigate the efficacy and feasibility of ultra-early surgery targeting more aggressive timelines.

Keywords

spinal cord injury, early surgery, surgical timing, review article

Introduction

With principles surrounding the vascular mechanisms of secondary injury after traumatic spinal cord injury (SCI) well established for decades, the practice of early surgical decompression postinjury has long made strong biological sense.[1,2] Specifically, removing compression and restoring perfusion to the injured cord should serve to attenuate the cascade of harmful biochemical processes initiated and potentiated by local compression-induced ischemia.[3-5] Across a number of animal models, early spinal cord decompression post SCI has been associated with improved neurobehavioral, electrophysiological, and pathological outcomes.[6]

In the clinical realm, there has historically existed substantial concern amongst clinicians surrounding the safety of early surgical decompression after SCI.[7,8] However, over the past 1 to 2 decades, there has been a general reversal in perception and

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practice among spinal surgeons on this topic, to the point where the majority of spinal surgeons now favor early surgery for the majority of SCI patients.[9] While there are a number of reasons for this changing sentiment, the most obvious explanation is the growing body of evidence that demonstrates not only the safety but also the potential to improve neurologic outcomes, reduced adverse events, and lower costs of early care.[10-12]

In spite of increased acceptance globally, there remain a number of unanswered questions regarding the optimal method for instituting early surgical decompression. Such questions include: (1) Are all patients likely to benefit from early surgery, or are there subgroups with certain levels (cervical vs thoracolumbar SCI) or severity (complete vs incomplete) that stand to derive particular benefit? (2) What is the most appropriate time threshold defining early surgery post SCI which balances the key priorities of efficacy and feasibility?

Here we perform a narrative review of the status of early surgical therapy for patients with acute SCI shedding particular light on the 2 questions posed above. Throughout the article we attempt to focus discussions on more recent (published in the past 5-10 years) and higher quality (prospective studies with larges sample sizes) studies wherever possible.

Do Certain SCI Patients Stand to Derive Particular Benefit from Early Surgery?

SCI patients occupy a clinical spectrum ranging from minimally impaired to significantly disabled, with much of the variability between patients explained by injury severity and neurological level. Below we evaluate the existing evidence to explore the possibility that the effects of early surgery after SCI may vary depending on the level and severity of injury at the time of patient presentation.

Effect of Early Surgery in Complete Versus Incomplete SCI Patients

To date, few studies have examined the differential impact of early surgery in complete versus incomplete SCI. In an analysis of the Rick Hansen Spinal Cord Injury Registry involving 888 patients, Dvorak et al[13] analyzed the impact of early surgery (<24 hours post SCI) on motor recovery. When considering all patients together, early surgery was not associated with significant improvements in motor function. However, when considering only motor incomplete patients (AIS [American Spinal Injury Association Impairment Scale] grade B-D), early decompression was associated with an additional 6.3 points in ASIA motor score recovery at 6 months follow-up. No significant effect for early surgery was observed in the motor complete (AIS grade A) patient cohort. In another Canadian prospective cohort study, investigators examining a cohort of 55 cervical AIS grade A SCI patients, found no significant difference in rates of AIS grade conversion with early as compared with late surgery defined by a 24-hour threshold.[14] Unfortunately, since incomplete patients were not enrolled in this study, the relative effects of this treatment on complete versus incomplete patients were not truly assessed.

With regard to nonneurological outcomes, the study by Dvorak et al[13] discussed above found that while early surgery (<24 hours postinjury) resulted in significantly reduced length of stay for individuals with motor complete SCI (7.5 fewer days for AIS A and 12.8 days fewer for AIS B), early surgery did not affect length of stay for motor incomplete patients.[13] While additional analyses have confirmed early surgery to reduce length of stay in patients with complete SCI, no other recent study has shown early surgery to affect this metric differentially for incomplete versus complete patients.[11,12]

Although no large prospective study has confirmed the superior effects of early surgery on neurological outcome for incomplete versus complete patients described by Dvorak et al[13] above, these findings are supported by biological rationale. For incomplete SCI patients in whom the primary mechanical injury is less severe, there may be greater therapeutic potential for neuroprotective interventions such as surgical decompression that aim to limit secondary injury mechanisms. The converse, however, is likely true: that for many patients with "complete" AIS A injuries, the primary mechanical injury is so severe that no neuroprotective treatment (including surgical decompression) will result in improvements detectable on the standard neurologic assessments. This may explain why many patients with AIS A injuries do not "convert" or improve their AIS grade, regardless of the timing of surgery. That said, all of these arguments are somewhat theoretical and further study exploring the differential impact of timing to surgery on outcome depending injury severity is warranted.

Effect of Early Surgery by Neurological Level of Injury

Neurological level is known to have significant impact on patients' potential for recovery.[15] However, there is a paucity of modern studies considering specifically how the effects of treatments, including early surgery, differ depending on neurological level. That said, there are a number of separate studies that look at this treatment in cervical or thoracolumbar cohorts independently, and in combined cohorts involving cervical and thoracolumbar patients. Table 1 provides an overview of results from key studies according to the neurological level of injury considered.

Studies Examining Differential Effects of Early Surgery in Cervical and Thoracolumbar Patients. Bourassa-Moreau et al[14] found early surgical decompression (<24 hours) to result in improved rates of AIS conversion among 20 cervical AIS grade A patients but no such effect for early surgery was observed among 33 patients with AIS A thoracolumbar SCI. Unfortunately, however, this study did not include incomplete SCI patients and other outcomes such as changes in motor score were not considered.

Table 1. Summary Table of Neurological Outcomes Between Early (≤24 Hours) and late (>24 Hours) Decompression by Neurological Level of Injury (Modified From Wilson JR, Tetreault LA, Kwon BK, et al. *Global Spine J*. 2017;7(3 suppl):95S-115S).

First Author, Year Study Design	Measure	Early (≤24 Hours)	Late (>24 Hours)	Effect Size
Cervical SCI				
Fehlings, 2012	AIS Improvement at 6	n = 131	n = 91	OR_{adj}[a]:
Prospective cohort	≥1 grade improvement	74 (56.5)	45 (49.5)	1.37 (95% CI 0.80 to 2.57), *P* = .31
study months	≥2 grade improvement	26 (19.8)	8 (8.8)	2.83 (95% CI 1.10 to 7.28), *P* = .03
Cervical and thoracic and lumbosacral SCI				
Dvorak, 2015	AIS Improvement			Adjusted estimates[b]
Prospective cohort study	"Improved score" in AIS A patients	n = NR	n = NR	Beta: 0.068 (95% CI −0.625 to 0.76); *P* = .848 IRR: 1.07 (95% CI 0.54 to 2.14)
	"Improved score" in AIS B, C, and D patients	n = NR	n = NR	Beta: 6.258 (95% CI 0.618 to 11.897); *P* = .03 IRR: 522.17 (95% CI 1.855 to 146825.5)
Wilson, 2012	AIS improvement (preoperative to acute care discharge [mean 24.8 ± 29.2 days])	n = 33	n = 49	Unadjusted RR
Prospective cohort study	≥1 grade improvement, n (%)	7 (21.2)	9 (18.4)	1.15 (95% CI 0.48 to 2.79), *P* = .7499
	≥ 2 grade improvement, n (%)	3 (9.1)	1 (2.0)	4.45 (95% CI 0.48 to 41.0), *P* = .2974
	AIS improvement (preoperative to inpatient rehabilitation discharge [mean 89.6 ± 47.4 days])	n = 22	n = 33	Unadjusted RR:
	≥1 grade AIS improvement, n (%)	9 (40.9)	10 (30.3)	1.33 (95% CI 0.61 to 2.93), *P* = .4700
	≥2 grade AIS improvement, n (%)	6 (27.2)	1 (3.0)	8.9 (95% CI 1.12 to 70.64), *P*= .0154
	AIS Motor Score improvement (mean)	6.2	9.7	*P* = .18
	Multivariate analysis predicting change in AIS Motor Score at rehabilitation discharge	NR	NR	Adjusted effect estimate[c] = 13.0, *P* = .01
Thoracolumbar SCI				
Rahimi-Movghar, 2014	ASIA Impairment Grade at 12 months	n = 16	n = 19	RR:
RCT	≥1 grade improvement, n (%)	5 (31.2)	7 (44)	0.85 (95% CI 0.33 to 2.16)
	≥2 grade improvement, n (%)	3 (18.1)	1 (5.2)	3.56 (95% CI 0.41 to 30.99) Difference in means
	Mean change (±SD) from baseline in motor score improvement[d]	15 (±14.34)	14 (±13.3)	1 (95% CI −8.5 to 10.5, *P* = .8320)
Wilson, 2018 Retrospective cohort study involving prospective data	Total Motor Score improvement at mean of 8 months	n = 25	N = 43	Unadjusted Beta: 7.74 (95% CI: 0.58 to 14.88), *P* = .03 [e]Adjusted Beta: 7.01 (95% CI: 1.14-13.03), *P* = .02
Acute central cord injury without instability				
Lenehan, 2010		n = 17	n = 56	OR_{adj}[f]
Prospective observational study	AIS improvement at 6 months[c]	NR	NR	3.39 (95% CI 0.75 to 15.34), *P* = .1131
	AIS improvement at 12 months[c]	NR	NR	2.81 (95% CI 0.48 to 16.60), *P*= .2548
	Total Motor Score improvement at 6 months	NR	NR	Group difference[f]: 7.47 (95% CI −0.04 to 14.91), *P* = .0511
	Total Motor Score improvement at 12 months	NR	NR	6.31 (95% CI 0.44 to 12.18), *P* = .0359

Abbreviations: ASIA, American Spinal Injury Association; AIS, ASIA Impairment Score; CI, confidence interval; NR, not reported; OR, odds ratio; IRR, incidence rate ratio; RR, risk ratio; SCI, spinal cord injury.
[a]Odds ratio adjusted for preoperative neurological status and steroid administration.
[b]Authors reported estimates adjusted for age, injury severity score, and injury type.
[c]Controlling for neurological level of injury and baseline neurological status, an additional 13 points in motor recovery was seen in patients treated within 24 hours of injury compared with those who underwent late decompression.
[d]Authors report no improvement in mean AIS motor score for either early or late decompression in patient with complete SCI. In contrast, improvement was observed in both groups in patients with incomplete SCI; data are not provided for comparison between early and late.
[e]Adjusted for baseline AIS grade and MPSS (methylprednisolone sodium succinate) administration.
[f]Authors report that regression with propensity scoring was done to adjust for potential selection bias; however, details were not provided.

Studies Examining Cervical SCI Patients Only. The largest study involving a cervical-only SCI cohort was the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS).[16] Published in 2012, this prospective cohort study compared neurological outcome, as defined by ordinal change in AIS grade at 6 months postinjury in 313 cervical SCI patients receiving either early (<24 hours post SCI) or late surgical decompression (≥24 hours post SCI). In the adjusted analysis, while there was no significant difference between the groups in the odds of experiencing a 1 AIS grade improvement, the odds of at least a 2 AIS grade improvement were significantly higher (odds ratio 2.57, 95% CI 1.11-5.97) among those undergoing early surgery. There was a nonsignificant trend toward a reduced rate of acute in-patient complications among early patients (24% vs 30% complication rate, respectively). Strengths of this study include the multicenter prospective nature of data collection, large sample size and relatively high rates of long-term follow-up (70%). The main weakness is the possibility of selection bias due to nonrandomized nature. In addition, there was an imbalance of severity between treatment groups with less severe injuries over represented in the late decompression group; due to ceiling effects of the primary outcome, this may have diminished the likelihood of patients in the late group experiencing the outcome of a 2 grade AIS improvement.[17]

Studies Examining Thoracolumbar SCI Patients Only. In a small randomized controlled trial (RCT involving) 35 patients, Rahimi-Movaghar et al,[18] randomized patients with SCI and a neurological level between T1 and L1 to early versus late surgical decompression and fusion as defined by a 24-hour threshold. In considering both complete and incomplete patients, there was no difference between ASIA motor score recovery at 12 months post SCI. With respect to AIS grade conversion, there was a weak trend toward a higher rate of a 2-grade conversion among early surgery patients (risk ratio [RR] = 3.56, 95%CI 0.41-30.99) which did not reach statistical significance. Although less subject to the effects of selection bias because of its randomized nature, this study was underpowered to detect a treatment effect and therefore the results are challenging to interpret.

A recent retrospective analysis of prospectively collected data within the North American Clinical Trials Network for SCI (NACTN) data registry evaluated recovery, predictors of outcome and response to treatment in 86 SCI patients with a neurological level of injury between T1 and L1.[19] With respect to treatments effects, early surgery (<24 hours post SCI) was found to be associated with an additional 7 points of ASIA motor score recovery and approximately 60% reduction in the incidence of acute respiratory complications after adjusting for possible confounders. While these findings are interesting, the effects of possible selection bias, leading to early surgery being performed in patients with a perceived better opportunity for recovery cannot be ignored. Furthermore, the sample size was somewhat limited, preventing more extensive regression analyses adjusting for additional possible confounders.

Studies Involving Both Cervical and Thoracolumbar SCI Patients. In an Ontario-based prospective cohort study involving all 84 patients with all levels of SCI, surgery prior to 24 hours was associated with a nonsignificant trend toward increased motor recovery (5 additional ASIA Motor Score [AMS] points) at rehabilitation discharge (89 days postinjury).[20] In adjusted analyses, although injury level was found to be a significant covariate in predicting motor recovery post SCI, the authors did not specifically investigate whether the effects of early surgery differed depending on level of injury. Finally, in the analysis described above from Dvorak et al[13] involving all level neurological levels, while incomplete patients in particular were found to benefit from early surgery, the differential impact of surgery depending on neurological level was not examined.

In summary, based on the works of Bourassa-Moreau et al[14] and Fehlings et al[16] (STASCIS) discussed above, it would seem that the strongest evidence supporting early surgical decompression exists for those with cervical-level SCI, although support for a differential effect depending on the neurological level is not overwhelming. A well-powered analysis of a large dataset examining neurological level as an effect modifier governing the relationship between timing of surgery and clinical outcomes is needed to more definitively address this question. Until such time that better evidence is available, based on the suggestions found within the recent AOSpine evidence-based guidelines for SCI (discussed below), the authors prioritize early decompressive surgery whenever feasible regardless of the level.

The Special Case of Central Cord Syndrome

Although the practice of early surgery continues to gain popularity as the preferred approach for the treatment of SCI among spine surgeons globally, practices surrounding the timing of surgery for central cord syndrome (CCS), the most common incomplete SCI syndrome, remain varied.[9] As originally described by Schneider in 1954, CCS is characterized by significantly greater motor and sensory deficits in the upper as compared with the lower extremities, often secondary to low-velocity trauma in elderly patients with preexisting spinal stenosis, without significant spinal instability.[7,8,21] Reports surrounding the natural history of neurological recovery for CCS patients have been generally favorable with most patients shown to be independent ambulators with normal sphincter function at long-term follow-up with nonoperative treatment.[22,23] As a result, historically speaking, nonoperative management has been the mainstay for CCS patients, out of concern that early operative intervention might derail this otherwise favorable natural history. Such concerns were founded in part on Schneider's original description of CSS in which 1 patient incurred a significant neurologic injury after acute surgical treatment.[8]

When considering modern survey studies, it appears that many surgeons internationally continue to adhere to the historical practices surrounding CCS treatment. A 2010 survey of almost 1000 spine surgeons globally found that while >80% of respondents preferred to decompress the spinal cord within 24 hours in most clinical cases, only 50% of respondents preferred to perform decompression within 24 hours for cases of CCS.[9] A similar trend was observed in a more recent European survey of 88 spine surgeons in which only 44% of respondents preferred to operate within the first 24 hours for CCS.[24]

For several reasons, however, it is likely that traditional practices surrounding the surgical treatment of CCS should be reconsidered. First, although there are few high-quality studies on this topic, the best evidence does support the practice of early surgery in CCS. In the largest modern study, Lenehan et al[25] performed a retrospective analysis of surgical timing in 73 CCS patients within the Spine Trauma Study Group prospective dataset. In summary, patients treated with early surgery (<24 hours post SCI) experienced an additional 6.3 points of motor recovery and had 2.8 times greater odds of AIS grade conversion at 12 months as compared with late surgery patients. Also, those treated with early surgery demonstrated an additional 7 points of Functional Independence Measure score recovery at 6 months postinjury. Importantly, no significant perioperative morbidity was noted among patients treated with early surgery. Second, while Schneider's reports are of immense historical significance, the surgical approach involved in the case in which perioperative morbidity was encountered—a posterior directed, intradural approach to a cervical disc with spinal cord retraction—would not be in the realm of acceptable practice today. With the incorporation of improved surgical techniques and technologies, coupled with advancements in anesthetic and perioperative management, surgery can be performed effectively and safely for this pathology. As a result, surgical outcomes encountered in such historical studies are no longer relevant in the modern day. Third, although the favorable natural history often ascribed to CCS patients holds true for outcomes such as ambulation, motor recovery, and sphincter control, many patients may experience reduced quality of life secondary to ongoing spasticity, neuropathic pain and impairments in hand dexterity[26]. As a result, it is erroneous to conclude that all patients with CCS and ongoing cord compression treated with late or no surgery do "well" long term, without including assessments of spasticity, pain, and hand dexterity. To date, no study, to the authors' knowledge, evaluating the timing of surgery in CCS has included assessments of these metrics.

In summary, in spite of historical teaching advocating for nonoperative or a less aggressive surgical approach in the context of CCS, examination of current evidence suggests that perhaps these principles may be antiquated and in need of revision. That said, better more definitive evidence is required before a dramatic change in practice is likely to occur globally.

What Is the Most Appropriate Threshold to Define Early Versus Late Surgery Post SCI?

The literature, on the whole, seems to support the principle that "early" surgery results in improved clinical outcomes for SCI patients. However, the subsequent question becomes: What constitutes early? Over the years, various studies have examined the merits of a number of different post injury time thresholds in defining early versus late surgery. When issuing a recommendation supporting one of these thresholds over the others, 2 overriding principles must be considered: (1) efficacy (the extent to which performing surgery before the said threshold results in superior outcomes) and (2) feasibility (the extent to which it is possible to perform surgery before the said threshold given the practical realities of the prehospital and hospital environment).

What Threshold Has Been Shown to Be Most Efficacious?

In theory, with any neuroprotective therapy, the earlier the treatment is instituted postinjury, the greater the potential for preventing secondary injury and improving clinical outcomes. Below we consider the impact of early surgery relative to 3 commonly discussed time thresholds: (1) later threshold (48-72 hours post SCI), (2) earlier threshold (24 hours post SCI), and (3) ultra-early threshold (8-12 hours post SCI).

Later Threshold (48-72 Hours Post SCI). In 1997, Vaccaro et al[27] published an RCT in which 64 SCI patients were randomized to receive early (<72 hours post SCI) or late (>5 days post SCI) surgery. At a mean follow-up of 304 days postinjury, there was no difference in AIS grade conversion or motor score recovery between patients treated with early versus late surgery. Although there were several methodological limitations, including the loss of follow-up in approximately 40% of the study population, the authors rationed in the discussion section that the 72-hour threshold may have obscured the neuroprotective effect that earlier surgery could have conferred. An additional study by McKinley et al,[28] involving 779 patients within the Model SCI Systems database, found shorter length of hospital stay and reduced respiratory complications but no differences in neurological recovery among patients receiving early surgery versus late surgery as defined by a 72-hour threshold. In a study involving 20 patients with SCI secondary to injuries at the thoracolumbar junction, Clohisy et al[29] found that the 11 patients who underwent surgery before 48 hours experienced greater improvements in Frankel grade and motor scores at a mean of 3.5 year follow-up, however the late surgery group had surgery at a very late juncture (average 61 days postinjury).

Earlier Threshold (24 Hours Post SCI). Presently, 24 hours is likely the best studied threshold defining early versus late decompression post SCI. The results of these studies have largely been reviewed above. In summary, for cervical SCI, the STASCIS study associated surgery before 24 hours with a greater odds of neurological recovery as defined by a 2 AIS grade improvement at 6 months.[16] In thoracolumbar SCI, the small RCT by Rahimi-Movaghar et al,[30] although likely underpowered to show effect, did not find early surgery to result in improved neurological outcomes. In studies considering all neurological levels, Dvorak et al[13] showed early surgery to result in significantly greater motor recovery for patients with incomplete SCI (AIS grade B-D injuries) without a demonstrable effect in patients with complete SCI. Finally, in the smaller Ontario-based cohort study by Wilson et al,[20] early surgery was associated with a higher likelihood of a 2 AIS grade improvement and with a trend toward improved motor recovery (additional 5 points).

It should be acknowledged, however, when discussing the 24-hour, or any other timing to surgery threshold, that such cutoff points are biologically arbitrary; specifically, there is nothing magical occurring at 24 hours that makes surgery at 24.5 hours less effective than surgery at 23.5 hours. Rather, these thresholds have been proposed for practical purposes to facilitate group comparisons in the context of studies. When interpreting the results of this body of literature, it is important to keep in mind that the efficacy of surgery is likely to wane as time from injury increases, and that the arbitrary thresholds discussed are simply what authors have chosen to examine over time.

Ultra-Early Threshold (8-12 Hours Post SCI). Several more recently published studies have evaluated more aggressive time thresholds for surgery. Jug et al[31] compared neurological outcomes on patients who underwent surgery before 8 hours and 8 to 24 hours postinjury in 48 patients at a single center in Slovenia. At 6-month follow-up, patients in the <8-hour group demonstrated a greater median improvement in ASIA motor score and a greater likelihood of experiencing at least a 2 AIS grade improvement. With regard to functional outcomes, in a single center German study, Grassner et al[32] evaluated the impact of surgery prior to 8 hours on Spinal Cord Independence Measure (SCIM) scores in 70 patients at 1-year follow-up. When considering unadjusted and adjusted analyses (controlling for baseline injury severity, age, and basal SCIM scores), patients receiving surgery prior to 8 hours had superior SCIM scores at follow-up in addition to improved motor neurological outcomes. Finally, in analysis of 48 patients treated in a single US institution, patients were retrospectively categorized into 3 groups depending on the timing of surgery: ultra-early (<12 hours), early (12-24 hours), and late (>24 hours).[33] While the numbers involved were quite small, the authors found that patients who underwent ultra-early surgery experienced an average improvement in AIS grade of 1.3 as compared with 0.5 for the early surgery group at hospital discharge ($P < .05$). It is important to note that in this study, time to surgery was measured from the time of emergency department arrival, making it difficult to directly compare results to remaining studies recording time to surgery from the time of injury event.

It is worth noting that a large multicenter prospective cohort study (SCI-POEM), evaluating the <12-hour threshold, has currently completed enrollment of its target 300 patients, with reporting of results anticipated in the next year.[34]

In summary, while surgery before the late threshold (48-72 hours) does not seem to confer much advantage, select studies do demonstrate the efficacy of intervention before the early threshold (<24 hours). The results of ultra-early surgery (<8-12 hours) do appear promising based on the emerging preliminary literature; the results of the SCI-POEM study will help clarify the potential benefits of this more aggressive cutoff further.

What Threshold Is Feasible?

In spite of our desire to prioritize early medical and surgical treatment for SCI patients, the practical realities of trauma care at both the prehospital and hospital levels often pose barriers to expedited care. Several studies have attempted to quantify such delays and to investigate their underpinnings so as to identify opportunities to expedite care.

In a 1999 study, Tator et al[35] performed an in-depth analysis of 585 patients admitted to 36 North American centers with SCI over a 9-month period as a precursor to understand the potential feasibility of enrollment for the STASCIS study. In summary, because of several reasons, including transport and diagnostic delays, only 50% of patients would be eligible to undergo early surgery before 24 hours and hence be considered for enrollment in the clinical trial.

In an illuminating 2017 analysis of the Canadian Rick Hansen Spinal Cord Injury Registry, in only 39% of cervical SCI cases and 45% of thoracic SCI cases, were clinicians able to achieve surgery prior to 24 hours, in spite of believing this to be in the best interests of the patient.[36] It was suggested that improved strategies to identify and reduce barriers to early surgery were needed to optimize patient outcomes.

Several analyses have attempted to identify barriers to expedited care and surgery post SCI. In a 2015 study by Wilson et al,[37] examination of a population-based cohort of 1111 SCI patients within the province of Ontario revealed that the mean times to arrival at the site of definitive medical/surgical care and to surgery were 8.1 and 49 hours, respectively. While, 88% of patients arrived at the site of definitive care within 6 hours, only 53% of patients were able to undergo surgery within 24 hours. The authors found that older age and stops at intermediate health centers prior to arrival at the site of definitive care were independent factors associated with delays in surgery. Similarly, in an Australian study by Battistuzzo et al[38] involving 192 patients with cervical SCI, the authors found that increases in time spent at intermediate health centers prior to arrival at definitive care were a major cause of delay to timely surgical treatment. Finally, Furlan et al[39] showed that among 63 cervical SCI patients treated at a single Toronto center, those who received surgery prior to 24 hours spent less time at an intermediate hospital prior to arrival at definitive care, and a shorter time spent waiting for surgical decision at definitive care than did those patients who received late surgery.

As described in the section above, a number of articles have begun to report on the outcomes of ultra-early surgery performed prior to 8 or 12 hours postinjury. What is not clear from these articles, however, is the proportion of SCI patients presenting to these center that are actually eligible to undergo surgery at these time points. It would seem unlikely, based on the information presented above, that many hospitals could facilitate surgical treatment at such an early juncture postinjury in most cases; in fact, the existing literature demonstrates that there are challenges facilitating surgery within 24 hours for a substantial proportion of patients. With increasing support for the benefits of early, and potentially ultra-early surgery, there is need to examine prehospital and hospital logistics to help identify opportunities for improved efficiency with goals to further streamline the transport and care of SCI patients.

Evidence-Based Guidelines

In effort to distill the existing evidence into a practical and usable format for clinicians, timing of surgery was included as 1 of the 6 topics covered in the 2017 AOSpine Evidence Based Guidelines for the Management of Acute Spinal Cord Injury.[40] These guidelines were assembled using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) process and were overseen by a multidisciplinary guideline development committee. On the topic of surgical timing, based on extensive literature review[41] and subsequent rigorous structured assessment by the committee, the guideline reads, "we suggest that early surgery ($\leq$24 hours post SCI) be offered as an option for adult acute SCI patients regardless of level. (Grade: Weak Recommendation, Low Evidence)." The use of the word "suggest" instead of "recommend," coupled with "grade: weak recommendation" highlights the discussions above; although the evidence is generally supportive of early surgery, most of the evidence body is low quality, some of the literature is conflicting, and there remains a number of unanswered questions.

Summary

Existing international surgical opinion seems to support the principle of early surgery after traumatic SCI. While the best evidence for this practice involves patients with cervical SCI, there is insufficient evidence to support a differential effect for early surgery depending on neurological level of injury or injury severity. Further work is necessary to identify specific subgroups of patients who stand to derive particular benefit—specifically to develop more consistent and evidence-based approaches to manage central cord syndrome. When considering the various thresholds in the literature, it seems that there is increasing clinical evidence supporting previous preclinical work, that decompressing the spinal cord early after injury may confer clinical benefit. This is highlighted by studies showing improved neurological outcomes in those receiving early (<24 hours) and ultra-early surgery (<8-12 hours). At present, existing prehospital and hospital logistics seem to pose barriers to early surgery in a significant proportion of patients; as evidence continues to accumulate supporting this practice, modifications to transport and early care may be needed to ensure timely access to surgical decompression for SCI patients.

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