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Complete Traumatic Spinal Cord Injury: Current Insights Regarding Timing of Surgery and Level of Injury

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Abstract

Study Design: A narrative literature review.

Objectives: To review the neurological recovery patterns in traumatic spinal cord injury (tSCI) patients with a complete lack of motor and sensory function below the level of injury (ie, ASIA A [American Spinal Injury Association scale]), as well as the impact of level of injury and timing of surgical intervention.

Results: Spontaneous neurological recovery in patients with complete tSCI differs per level of injury: patients with cervical and thoracolumbar tSCI recover ≥1 ASIA grade in 17.3% to 34.0% 1 year after injury, compared with 10.7% to 18.6% in thoracic tSCI. Surgical decompression within 24 hours has a beneficial effect on neurological recovery in patients with complete cervical tSCI, whereas this effect is less clear for thoracic and thoracolumbar tSCI. A 1- or 2-grade improvement in the ASIA scale does not necessarily result in functional recovery.

Conclusion: In complete tSCI, the level of injury as well as surgical timing affect neurological recovery. There appears to be a beneficial effect of early surgical decompression in patients with complete cervical tSCI, more so than for thoracic and thoracolumbar tSCI. Frequently, the effect of surgical intervention is evaluated by an improvement in ASIA grade, but it is unclear whether this scale is sensitive enough to evaluate meaningful effectiveness of the intervention and desired outcome for patients with tSCI.

Keywords

spinal cord injuries, surgical decompression, spinal fusion, outcome assessment, complete spinal cord injury

Introduction

Traumatic spinal cord injury (tSCI) is a devastating event that can lead to death or lifelong disability. Since it usually occurs in younger individuals, the loss of productive life years has an enormous economic and social impact. The annual incidence is estimated at 10.4 to 83 cases per million per year, with wide variations between regions and countries.[1,2] The cervical spinal cord is the most commonly affected level, followed by the thoracic and lumbar.[3] Around 30% to 55% of patients with tSCI will present with complete neurological injury.[1,3-6] In particular, younger individuals more often present with complete tSCI compared to older patients.[1]

Surgical intervention aims to restore the mechanical integrity of the spinal column, as well as to potentiate neurological recovery. The neurological outcome is affected by the initial severity, as well as the level, of neurological injury.[7-10] Nevertheless, current guidelines recommend performing surgical decompression in tSCI within 24 hours, regardless of the level and severity of injury.[11] Although these guidelines are based on

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Table 1. The Natural Neurological Recovery Patterns in Complete tSCI.[9,22,23,44]

		Percentage of ASIA Conversion 1 Year After Trauma				
	Baseline ASIA	A	B	C	D	E
Cervical tSCI	A	70.2-70.9	12.5-14.6	8.0-9.4	4.5-7.2	0
Thoracic tSCI	A	84.1-87.4	4.1-5.9	4.4-7.9	0-4.8	0
Thoracolumbar tSCI	A	70.8	15.3	5.6	6.3-8.3	0

Abbreviations: ASIA, American Spinal Injury Association; tSCI, traumatic spinal cord injury.

the results of studies including both patients with complete and incomplete tSCI,[12-15] in daily practice a distinction in surgical urgency is usually still made on the basis of the severity of initial neurological injury, such that patients with incomplete tSCI are treated more urgently than patients with complete tSCI.[16-24]

This study reviews the current body of evidence on level of injury and timing of surgical intervention in tSCI patients with a complete lack of motor and sensory function below the level of injury and no preservation of the sacral segments (ie, grade A on the ASIA [American Spinal Injury Association] Impairment Scale [AIS]).

Cervical tSCI

Natural History

Approximately 17.3% to 34.0% of patients with cervical tSCI will present with a complete injury.[20,21] In polytrauma patients with cervical spine injuries, the incidence of complete tSCI is much higher—65.4%.[3] After 1 year, patients with an initial ASIA A injury will remain ASIA A in 70.2% to 70.9% of the cases, implying that approximately 30% will show some signs of recovery. Around 12.5% to 14.6% will improve to ASIA B, 8.0% to 9.4% to ASIA C, 4.5% to 7.2% to ASIA D, and 0% to ASIA E (Table 1).[9,22,23] In contrast, patients with incomplete tSCI have a much higher spontaneous recovery compared with complete tSCI (Supplement 1, available online).[27] Motor recovery is evaluated for each muscle group below the level of injury and calculated into a motor score (ranging from 0 to 5 per muscle group) according to ASIA standards.[24] Patients with complete cervical tSCI show a mean recovery of 9.0 to 14 motor score points below the level of injury 1 year after injury.[9,22,25,26] Neurological recovery most commonly occurs within the first 3 months and will enter a plateau phase thereafter.[9] However, 9.1% of the patients who have not recovered the first year postinjury can still exhibit some neurological recovery even 5 years after injury.[27]

Impact of Timing of Surgical Intervention

The majority of studies in patients with cervical tSCI have investigated the effect of early surgery in cohorts with complete and incomplete tSCI (Table 2).[12,28-40] Two studies have investigated the effect of surgery in patients with complete tSCI.[41,42] Bourassa-Moreau et al addressed the effect of surgical timing in patients with complete tSCI and observed a significant ($P = .008$) benefit of surgical decompression within 24 hours on ≥1 ASIA grade improvement.[41] Nine (64.3%) out of 14 patients in the early group improved at least one grade, compared to none out of 6 in the late group. Another study by Hansebout and Hansebout in 20 complete tSCI patients evaluated the effect of early surgical decompression in combination with perioperative regional epidural cooling within 8 hours of injury.[42] Fourteen of these patients had cervical injuries. Nine (64.3%) out of 14 patients with complete cervical tSCI improved at least one ASIA grade.

A recent meta-analysis demonstrated a significant beneficial effect of early surgery within 24 hours in patients with complete cervical tSCI.[43] In 422 patients with complete cervical tSCI, the impact of surgical timing on neurological recovery was investigated. An increase of ≥2 ASIA grades was regarded as successful. Improvement in the early surgery group was 22.6% (95% confidence interval [CI] = 16.6% to 28.7% in 248 patients from 11 studies) compared to 10.4% (95% CI = 5.6% to 15.8% in 174 patients from 6 studies) in the late surgery group. The odds ratio for neurological improvement of early versus late surgery with complete cervical tSCI was 2.6 (95% CI = 1.4 to 5.1).[43] This result would indicate a paradigm shift in the surgical treatment of patients with traumatic cervical spinal cord injury in the sense that patients with complete tSCI should not be treated less urgently than patients with incomplete tSCI.

Thoracic tSCI

Natural History

Approximately 16.2% to 73.0% of patients with thoracic tSCI will present with complete neurological injury.[20,21] In polytrauma patients with thoracic injuries, the incidence of complete tSCI is much higher—69.4%.[3] Within 1 year (Table 1), 10.7% to 18.6% of the patients with an initial ASIA A injury will improve ≥1 ASIA grade compared with 84.6% in patients with an initial ASIA B injury.[9,23,44] The mean motor point recovery in thoracic tSCI is 0.1 to 4.5 one year after injury, which is substantially less than in cervical or thoracolumbar tSCI.[9,26,44] Patients with thoracic tSCI who remained ASIA A 1 year after injury can still show neurological recovery up till 5 years in 3.6%.[27]

Impact of Timing of Surgical Intervention

The impact of early surgery in patients with thoracic tSCI is less clear, and therefore, urgent surgery in patients with

Table 2. Neurological Recovery After Early (<24 Hours) or Late (>24 Hours) Surgery in Cervical tSCI.

	Follow-up Mean	Age Mean[a]		Number of Patients With Baseline ASIA A	Percentage of ASIA Conversion in Follow-up				
					A	B	C	D	E
Early and late studies									
Fehlings[12]	6 months[b]	45	Early	44	56.8	25.0	13.6	4.5	0
		50.7	Late	27	63.0	25.9	11.1	0	0
Levi[32]	11.4 months	25.5	Early	21	23.8	52.4	19.0	4.8	0
		27	Late	14	57.1	14.3	7.1	21.4	0
Umerani[39]	6 months[b]	37.5	Early	11	54.5	18.2	18.2	9.1	0
		40.1	Late	18	77.8	11.1	5.6	5.6	0
Newton[35]	3-6 months	22	Early	24	58.3	12.5	4.2	4.2	20.8
			Late	8	100	0	0	0	0
Randle[38]	10.8 months	28.9	Early	20	50.0	35.0	15.0	0	0
		29,4	Late	12	75.0	16.7	0	8.3	0
Bourassa[41]	163.2 days	37.3	Early	14	35.7	35.7	7.1	21.4	0
		47.1	Late	6	100	0	0	0	0
Cotler[29]	19.7 months	n.a.	Early	7	57.1	0	28.6	14.3	0
			Late	4	0	100	0	0	0
Late studies									
Liu[33]	24.9 months	41.9	Late	66	63.6	24.2	10.6	1.5	0
Benzel[28]	2-3 months[c]	n.a.	Late	35	100	0	0	0	0
Early studies									
Papadopoulos[36]	31.6 months	32	Early	38	44.7	34.2	13.2	7.9	0
Jug[31]	6 months	n.a.	Early	26	65.4	19.2	3.8	11.5	0
Shen[40]	3.1 years	39.9	Early	2	50	50	0	0	0
Mattiassich[34]	2.6 years	50	Early	20	50.0	25.0	15.0	10.0	0
Hansebout[42]	55.2 months	22.6	Early	14	35.7	35.7	21.4	7.1	0
Grassner[30]	12 months[d]	51.9	Early	14	28.6	35.7	7.1	28.6	0

Abbreviations: ASIA, American Spinal Injury Association; tSCI, traumatic spinal cord injury.
[a]Mean age for the cohort (including complete and incomplete tSCI patients).
[b]All patients had at least 6 months of follow-up.
[c]All patients had at least 2 to 3 months of follow-up.
[d]All patients had at least 12 months of follow-up.

complete thoracic tSCI is still a subject of debate.[41,45-50] Most studies on neurological outcome include patients with both complete and incomplete thoracic and thoracolumbar tSCI (Table 3).[13,16,41,51,52] Two studies evaluated the effect of surgical timing in thoracic tSCI specifically.[52,53] One study in 12 complete thoracic tSCI patients evaluated the efficacy of surgery.[53] Two patients had an undocumented surgical timing, one was decompressed in 1 day and 9 had surgical decompression between 2 to 36 days after injury. Only 2 (16.7%) patients improved neurologically. One patient who underwent surgery at 2 days improved to ASIA C, another patient underwent surgery at 25 days and improved to ASIA B. The second study evaluated the neurological recovery after surgery within 24 hours in 8 patients with thoracic tSCI (T4-T9).[52] After 1 year, 2 (37.5%) improved to ASIA B and 1 to ASIA D.

Thoracolumbar tSCI

Natural History

Isolated conus medullaris injury from thoracolumbar fractures without concomitant dysfunction of the cauda equina is rare.[54] There is a variance in the literature regarding the description of the level of spinal injury for conus medullaris and cauda equina injury.[55] Studies have described medullary injury from T8-L2 and cauda equina injury caudal from L1-L2.[55,56] Conus medullaris syndrome (CMS) and cauda equina syndrome (CES) may be difficult to distinguish. CMS is often defined by a symmetric sensory deficits, paralytic bladder incontinence, bowel incontinence, and mild lower extremity weakness. CES is often characterized by asymmetric sensory-motor deficits. Approximately 21.0% of patients will present with a complete lack of motor and sensory function below the level of injury.[21] The rate of neurological recovery in thoracolumbar tSCI is similar to the recovery in complete cervical tSCI (Table 1).[44] After 1 year, patients will have a median recovery of 3.6 to 5.3 motor score points below the level of injury.[26,44]

Impact of Timing of Surgical Intervention

There is paucity of literature concerning the surgical timing and neurological outcome in patients with conus medullaris (CM) and cauda equina (CE) injury (Table 3).[52,56-60] Although the natural course of conus medullaris injury differs considerably

Table 3. Neurological Recovery After Early (<24 Hours) or Late (>24 Hours) Surgery in Thoracic and Thoracolumbar tSCI.

	Follow-up Mean	Mean Age[a]		Level of Injury	Number of Patients With Baseline ASIA A	Percentage of ASIA Conversion in Follow-up				
						A	B	C	D	E
Thoracic										
Rahimi[53]	47.9 months	40.4	Early	T5-T11	1	100	0	0	0	0
			Late	T5-T11	9	77.8	11.1	11.1	0	0
Dobran[52]	12 months[b]	47.5	Early	T4-9	8	62.5	25.0	0	12.5	0
Rahimi[13]	12 months[b]	31.7	Early	T5-T12	7	80.0	20.0	0	0	0
		37.8	Late	T5-T12	9	88.9	11.1	0	0	0
Thoracic and thoracolumbar										
Wiberg[16]	8 months to 6 years	29	Early	T4-L1	2	0	50.0	50.0	0	0
			Late	T4-L1	4	100	0	0	0	0
Bourassa-Moreau[41]	145.8 days	40.9	Early	T2-L2	24	83.3	8.3	0	8.3	0
		51.2	Late	T2-L2	9	77.8	0	11.1	11.1	0
Ramirez-Villaescusa[51]	>2 years	36.8	Early	T1-L2	2	100	0	0	0	0
Thoracolumbar										
Cengiz[56]	14.5 months	39.7	Early	T8-L2	6	33.3	16.7	16.7	33.3	0
		41.4	Late	T8-L2	7	85.7	14.3	0		0
Rath[58]	14.2 months	44.3	Early	T10-L1	3	0	0	66.7	33.3	0
			Late	T12	3	100	0	0	0	0
Dobran[52]	12 months[b]	47.5	Early	T10-12	8	62.5	12.5	25.0	0	0
			Early	L1-S1	1	100	0	0	0	0
Rahimi[57]	32 months	32.3	Early	T12-L2	2	0	0	100	0	0
		23.6	Late	T12-L1	11	27.3	0	45.5	18.2	9.1
Payer[60]	24 months	36	Early	T11-L2	6	16.7	16.7	16.7	50	0
Clohisy[59]	42 months	36.3	Late	T12	1	0	0	0	100	0

Abbreviations: ASIA, American Spinal Injury Association; tSCI, traumatic spinal cord injury.
[a]Mean age for the cohort (including complete and incomplete tSCI patients).
[b]All patients had at least 12 months of follow-up.

from higher thoracic spinal cord injury, a large number of studies are based on cohorts containing both thoracic and thoracolumbar tSCI patients.[41,56,58,61] Evidence for optimal surgical timing in cauda equina injury is primarily based on lumbar disc herniation series.[62] However, 3 studies did specifically evaluate thoracolumbar tSCI.[52,57,60] One study in patients with thoracolumbar tSCI evaluated the effect of surgery within 8 hours.[60] Five (83.3%) of 6 patients with complete (ASIA A) thoracolumbar tSCI improved neurologically: 1 improved to ASIA B, 1 to ASIA C, and 3 to ASIA D. Another study in patients with thoracolumbar tSCI evaluated the efficacy of surgery.[57] There were 17 patients who had complete thoracolumbar tSCI, 4 of whom had undocumented surgical timing, 2 were decompressed within 24 hours, and 11 had surgical decompression after 24 hours. Both patients who underwent surgery within 24 hours improved from an ASIA A to an ASIA C at follow-up. Eight (72.7%) patients who underwent surgery after 24 hours improved neurologically: 5 improved to ASIA C, 2 to ASIA D, and 1 to ASIA E. The third study evaluated neurological recovery when patients underwent surgery within 24 hours.[52] Eight patients had thoracolumbar tSCI (T10-T12). Three (37.5%) patients with thoracolumbar tSCI improved neurologically after 1 year: 1 to an ASIA B and 2 to ASIA C.

Severity of Injury and Interpretation of Recovery

The severity of injury is generally categorized according to international standards for neurological classification of spinal cord injury of the American Spine Injury Association in conjunction with the International Spinal Cord Society: the ASIA Impairment Scale (AIS).[24] The consistency of the initial neurological assessment in patients with complete tSCI depends on numerous factors hampering its reliability.[63] Such factors include closed head injury, drug effects, language barriers, psychological disorders, or ventilator dependency. Burns et al assessed the consistency of the ASIA scale in the acute phase directly after injury and on reexamination within 7 days after injury. When an initial neurological examination was performed reliably, that is, without any of the aforementioned factors, and showed ASIA grade A, only 1 (2.6%) of 38 patients converted to ASIA B on reevaluation within 7 days. When there was concern regarding the reliability of the initial examination, 4 (9.3%) of 43 patients converted to ASIA B on reexamination within 7 days.[63] In contrast, 2 (15.4%) of 13 patients with an initially reliable ASIA B improved to ASIA C on reexamination within 7 days and 1 (7.7%) to ASIA D. In patients where the initial ASIA B was unreliable at first examination, none improved within the first week after injury. Thus 5 (6.2%) of all 81 patients with ASIA A at initial examination converted to ASIA B, whereas 3 (13.6%) of 22 patients with ASIA B at presentation improved ≥1 ASIA grade. When evaluating the effect of any intervention in patients with tSCI it is important to distinguish whether the initial neurological assessment was performed reliably, since this can affect the rate of spontaneous neurological improvement.

The effect of surgical timing is often evaluated with improvement by either 1 or 2 ASIA grades.[12,33,41,56,64] An improvement in ASIA grade is considered to be a clinically meaningful outcome in evaluating the effect of surgical interventions in patients with tSCI.[12,43] It is, however, unknown whether this improvement in ASIA grade translates to meaningful functional recovery and thus what this increase means in regard to a patient's quality of life.[65] Therefore, the question arises whether the ASIA classification is sensitive enough to capture the functional meaningful improvement for patients with tSCI. Several studies show that regaining the ability to walk is the greatest desirable outcome in patients with tSCI, followed by self-care, enhanced mobility, independent transfers, and sphincter management.[66-70] However, an improvement in ASIA grade does not ensure the ability to walk. One study in patients with cervical and thoracic tSCI evaluated the relation of ASIA conversion and the ability to walk.[71] From the 161 ASIA A patients, 23 improved to ASIA B, 9 to ASIA C, and 10 to ASIA D. Only 6 patients regained the ability to walk, all of which improved to ASIA D.[71] In addition, the priorities of neurological improvement differ for patients with tetraplegia and paraplegia. Patients with paraplegia have a higher priority of regaining locomotion and sexual function compared to patients with tetraplegia.[66,70] Conversely, patients with tetraplegia have a high priority of regaining hand function, which does not necessarily has to coincide with an improvement in ASIA grade but could also occur with a decrease in the level of injury. Future studies should not only focus on an improvement in ASIA scale but also on lowering of tSCI level and its perceived effect on meaningful recovery in tSCI patients.

Conclusion

There appear to be different patterns for spontaneous recovery in cervical, thoracic, and thoracolumbar tSCI. To promote neurological recovery, surgical decompression of the spinal cord within 24 hours seems particularly beneficial in patients with complete cervical tSCI. This effect is less clear for patients with thoracic and thoracolumbar tSCI. The efficacy of surgical timing in tSCI is often evaluated with an improvement in ASIA grade. It is important to evaluate the reliability of the first neurological examination, since this can affect the spontaneous neurological improvement within the first week after injury. The effect of ASIA grade improvement on meaningful neurological recovery remains unclear.

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Supplemental Material

The supplemental material is available in the online version of the article.

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