A narrative review of morphological features and prognosis factors for cervical spine injury in subaxial lesion

Tsunehiko Konomi^, Kanehiro Fujiyoshi, Yoshiyuki Yato

Department of Orthopaedic Surgery, Murayama Medical Center, National Hospital Organization, Musashimurayama, Tokyo, Japan

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Correspondence to: Tsunehiko Konomi. Department of Orthopaedic Surgery, Murayama Medical Center, National Hospital Organization, 2-37-1 Gakuen, Musashimurayama, Tokyo 208-0011, Japan. Email: konomitsunehiko@gmail.com.

Background and Objective: Spinal cord injury (SCI) causes a serious body damage that results in motor and sensory dysfunction and could be life-threatening. Although, there is diversity among traumatic SCIs, the incidence of SCI in a subaxial cervical lesion is high. Generally, surgery is the preferred treatment, however the optimal timing and the indication for a surgical treatment remains unclear. This review serves as a comprehensive update on the morphology of traumatic cervical spine injury in subaxial lesion and various factors affecting its prognosis to maximize the therapeutic potential.

Methods: We performed a literature search in PubMed for studies published in the English language using a predefined search strategy and reviewed recent advances on the morphology, prognosis and surgical management for the traumatic cervical SCI in subaxial lesion.

Key Content and Findings: We screened 619 studies and included 47 selected studies. The possible reason for differences between the functional prognosis following the injury is due not to the morphological features or the surgical timing, but to differences in the proportion of included study participants with recovery meaningful potential.

Conclusions: Although no single treatment has been able to cure the SCI completely, a combination of effective surgical treatment with rehabilitation might provide a potential advantage over conservative managements from the point of view of the prevention of following neurological aggravation. Therefore, it is important to figure out the injury morphology precisely and to determine the optimal therapeutic strategy comprehensively according to individual factors with a consideration of the overall condition.

Keywords: Cervical spine injury in subaxial lesion; surgical treatment; functional prognosis

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Introduction

Spinal cord injury (SCI) and related spine injury causes a serious physical issue that results in motor and sensory impairment and could be life-threatening. Although there is diversity among traumatic SCIs, the incidence of SCI in a subaxial cervical lesion is generally high. Patients with a cervical SCI are essentially paralyzed below the level of the injured spinal cord and experience abnormalities in autonomic and sensory nerve pathways, including bladder disturbance. It is important to diagnose the morphology of the injury and to decide the surgical strategy for introducing rehabilitation training immediately after injury.

^ ORCID: 0000-0001-6704-7573.

Table 1 The search strategy summary

Items	Specification
Date of search	01/12/2021
Databases and other sources searched	PubMed
Search terms used	"Subaxial cervical spine injury", "surgical treatment" and "functional prognosis"
Timeframe	Mar 1, 1979 to Dec 1, 2021
Inclusion and exclusion criteria	English literature including clinical trial, meta-analysis and review were collected for reviewing
Selection process	All authors searched the database independently, and discussed and selected the literature for this review

Generally, surgery is the preferred treatment in the acute phase, however the optimal timing and the indication for a surgical treatment remains unclear. The aim of this article was to review a comprehensive update on the morphology of traumatic subaxial cervical spine injury (SCSI) and clinical conditions that require surgical management. We also argue about the timing of intervention from an alternative viewpoint to maximize the therapeutic potential. We present the following article in accordance with the Narrative Review reporting checklist (available at https://jxym.amegroups.com/article/view/10.21037/jxym-22-8/rc).

Methods

We performed a literature search in PubMed for studies written in the English language and published before December 2021 using a predefined search strategy combining the following search terms: "subaxial cervical spine injury", "surgical treatment" and "functional prognosis" and reviewed recent advances on the morphology, prognosis and surgical management for SCSI (*Table 1*).

Discussion

Morphology of SCSI

The surgical strategy for SCSI in the acute phase includes three major concepts: (I) removal of factors inhibiting the recovery of neural function, e.g., cord compression, (II) minimization of secondary damage following cord injury, and (III) acquisition of spinal stability to enable early ambulation. Therefore, surgical treatment should be determined based on morphological features of the traumatic injury.

Holdsworth *et al.* reported the first comprehensive classification of the morphology of traumatic SCSI in 1963 (1). Following this, in 1982, Allen *et al.* proposed a classification system based on six injury mechanisms, i.e., compressive flexion, vertical compression, distractive compression, compressive extension, distractive extension, and lateral flexion (2). In 1986, Harris *et al.* published a classification system focusing on injury due to rotational force in addition to flexion and extension forces (3). Although these systems precisely and comprehensively describe various patterns of cervical trauma, difficulties in applying in clinical practice and low interobserver reliability remain to be resolved (4). In 2007, the Spine Trauma Study Group proposed a new classification system for cervical spine injury with a subaxial lesion, i.e., the subaxial cervical injury classification (SLIC) (5). The SLIC score consists of three types of injury morphology, i.e., vertebral body morphology, disc-ligamentous complex (DLC) damage, and neurological status, according to the degree of injury, and is a classification that determines treatment strategy based on the total score (*Table 2*). One of the advantages of the SLIC system is that DLC injury is evaluated in addition to morphology, so that SCSI without bone injury can be characterized. Furthermore, the SLIC system makes it easier to determine the appropriateness of surgical treatment by including neurological findings. The higher the score of the SLIC system, the worse a severity of the injury, implying the necessity for any surgical intervention. Conservative treatment is recommended for cases with 1–3 points, and surgical treatment is recommended for cases with 5 points or more. However, caution must be taken with this classification system, as van Middendorp

Table 2 Subaxial cervical injury classification scale (5)

Variable	Points
Morphology	
No abnormality	0
Compression	1
(Burst	+1=2)
Distraction (e.g., facet perch, hyperextension)	3
Rotation/translation (e.g., facet dislocation, unstable teardrop or advanced staged flexion compression injury)	4
Disco-ligamentous complex (DLC)	
Intact	0
Indeterminate (e.g., isolated interspinous widening, MRI signal change only)	1
Disrupted (e.g., widening of disc space, facet perch or dislocation)	2
Neurological status	
Intact	0
Root injury	1
Complete cord injury	2
Incomplete cord injury	3
[Continuous cord compression in setting of neurodeficit (neuromodifier)	+1]

et al. pointed out the necessity for modifying the morphological evaluation (6). Moreover, the SLIC score is easily underestimated with regard to a unilateral facet injury, which results in instability requiring stabilization of the cervical spine (7). While the classification has higher interobserver reliability scores than the previous Allen and Ferguson classification, no single classification has gained acceptance in clinical practice (8). To address these issues, the AO Spine classification system for the subaxial cervical spine has developed in 2015, which is demonstrated to be substantial reliability in initial assessment (9). It classifies SCSI according to facet injury (F1–F4), neurological status (N0–N4 and NX), and a case-specific modifier (M1–M4) in addition to the morphology of the injury (A: compression injury, B: tension band injury, and C: translation injury) (*Table 3*). Within the morphological subtypes, type A and type B injuries are further divided into 8 (A0–A4, B1–B3) subgroups. It is important to state that facet injuries (type F) are meaningful features to this system and are used to represent the stability condition in isolated facet fractures or indicate subluxation/ dislocation without a fracture. In the case-specific modifiers, M1 states hidden injury to the posterior capsuloligamentous complex without complete disruption, which indicates that the patient may have an unstable or a stable injury. M2 modifier denotes the presence of a critical disc herniation, an important distinction to make in the presence of a unilateral or bilateral facet dislocation that is going to be treated with closed reduction. The surgeon could communicate by this modifier that the disc herniation presenting anteriorly may shift posteriorly during the reduction maneuver and become a possible cause of a secondary cord injury. In such cases, the surgeon may decide to approach the injury anteriorly first before applying posterior fixation to avoid the herniation. M3 is used to note a bone abnormality such as stiffening or metabolic bone disease creating a rigid spinal column and long lever arm, which increases mechanical forces around the site of the injured cord. This is important to denote that these patients should be fixed to longer levels to prevent failure of instrumentation and further fracture. With the incorporation of case-specific modifiers, the surgeon communicates easily and could precisely distinguish between stable conditions that can be treated conservatively and unstable conditions that require surgical treatment.

The reliability of the AO Spine subaxial classification system was recently shown by a consensus process between

Table 3 AO Spine classification system and the score for the subaxial cervical spine injury (10)

Type	Subtype	Description	Points
Compression injuries	A0	Minor, nonstructural fractures	0
	A1	Wedge/impaction	1
	A2	Split/pincer	2
	A3	Incomplete burst	4
	A4	Complete burst	5
Tension band injuries	B1	Pure transosseous disruption	5
	B2	Osseoligamentous disruption	6
	B3	Hyperextension injury	6
Translation injuries	C	Translation injury	7
Facet injuries	F1	Non-displaced facet fracture	2
	F2	Facet fracture with potential for instability	4
	F3	Floating lateral mass	5
	F4	Pathologic subluxation or perched dislocated facet	7
Neurology	N0	Neurology intact	0
	N1	Transient neurologic deficit	1
	N2	Radicular symptom	2
	N3	Incomplete spinal cord injury or any degree of cauda equina injury	4
	N4	Complete spinal cord injury	4
	NX	Cannot be examined	3
Case-specific modifiers	M1	Posterior capsuloligamentous complex injury without complete disruption	2
	M2	Critical disk herniation	4
	M3	Stiffing/metabolic bone disease (i.e., DISH, AS, OPLL, OLF)	4
	M4	Vertebral artery abnormality	N/A

DISH, diffuse idiopathic skeletal hyperostosis; AS, ankylosing spondylitis; OPLL, ossification of posterior longitudinal ligament; OLF, ossification of ligamentum flavum.

expert spine surgeons with an average of interobserver reliability of 0.67 (κ) and an average intraobserver reliability of 0.75 (κ) among all subtypes (5,11). Furthermore, Mushlin *et al.* demonstrated that this classification system has higher association between certain morphology subtypes and American Spinal Injury Association (ASIA) impairment scales at the initial and follow-up, which could help communicating among clinicians and patients to discuss the severity and prognosis of the injury (12). Based on the knowledge of global spine surgeons the hierarchical score system was proposed and adopted as a universally accepted treatment algorithm for cervical spine injury in subaxial lesion (*Table 3*) (10).

Various factors affecting the prognosis following SCI

In general, SCSI without bone injury accounts for approximately 70% of all cervical SCI cases (13), and it is known that pre-existing cord compression does not impact on the severity or functional prognosis (14-19). The presence of ossification of the posterior longitudinal ligament (OPLL) also did not correlate with the severity of paralysis immediately after injury and subsequent functional recovery (17). Meanwhile, although the severity of paralysis after injury was not determined by static factors such as the extent of spinal cord compression or traumatic force, it was governed by the basis of a combination of both static factors and the traumatic force (14). Furthermore, the severity of paralysis became worse in patients with segmental instability with prevertebral hyperintensity in magnetic resonance sagittal images at the injured site (15). In cases with diffuse idiopathic skeletal hyperostosis (DISH), multilevel spinal body fusions produce long lever bony arms, creating a frail condition where even minor trauma can cause fractures with an increased risk of SCI (20).

Magnetic resonance imaging (MRI) findings of hemorrhage and degree of edema are reasonably associated with the motor functional potential post injury (21-23). Hemorrhagic changes are described as a hypointensity region surrounded by an area of hyperintensity on T2-weighted MRI (24). Previous studies showed that cord hemorrhage on early MRI was strongly associated with ASIA impairment scale (AIS) grade A people and thus indicating poorer recovery outcomes in motor function (21,25-27). Boldin *et al*. reported that the presence of intramedullary extensive hemorrhage (length of 10.5 mm or more) was associated with poorer prognosis at long-term follow-up (28). The patterns of MRI signal intensity changes were well correlated with the functional prognosis (23,29-31). We previously reported the presence of intramedullary hemorrhage and/or severe cord compression on initial MRI were closely associated with irreversible paralysis in persons with motor complete paralysis following SCSI (32). Apart from MRI characteristics, the serum zinc concentration in acute phase is a reliable biomarker that could predict the functional outcome following SCI (33) and a high level of serum C-reactive protein could predict the progression of intramedullary signal intensity change on MRI from acute to subacute phase, indicating the progression of secondary SCI (34).

In contrast, studies have described that over 50–60% of cord compression is a borderline as to deterioration of the motor function in patients with cervical spondylotic myelopathy and OPLL (35,36). However, the efficacy of decompression for SCSI with pre-existing stenosis remains unclear (37-40). Kawano *et al*. revealed that there was no difference in neurological recovery between surgical treatment and conservative management in SCSI patients with a cord compression (a compression rate >20% was defined as the presence of pre-existing cord compression) in their multi-center prospective study (16). On the contrary, we retrospectively investigated the clinical outcomes of decompression surgery for 78 consecutive SCSI cases without bone injury, but with pre-existing cord compression (41). As a result, we found that the improvement rate of the score of Spinal Cord Independence Measure and AIS grade in the surgical treatment group was better in cases with severe (40% or greater) pre-existing cord compression, while the surgical efficacy was not proved in cases without severe cord compression.

Kubota *et al*. demonstrated the effect of cord compression in an animal experiment SCI model (42). The mice with the existing cord compression group had undergone artificial cord compression at 6 weeks before injury, while in the other group, concurrent compression was applied immediately after injury to compare the effect of existing asymptomatic spinal cord compression with concurrent spinal cord compression. As a result, in the group with concurrent spinal cord compression, functional recovery was significantly poorer as compared with the group with existing spinal cord compression. The underlying mechanism was suggested to be restructuring of the spinal cord blood flow due to pre-exiting cord compression, which compensated for the adverse effects of spinal cord compression on SCI, indicating that early decompression of the concurrent compression could be a reasonable strategy. Whereas an early decompression might not be always necessary in cases with SCI with pre-existing cord compression.

The optimal timing for surgical intervention

The degree of paralysis after SCI could change dramatically especially in the acute phase (43), decisions of whether or when the surgery should be undertaken are challenging issues. Fehlings *et al*. conducted a multicenter prospective cohort study with 313 cases of cervical SCI, and reported that more than two grades improvement in AIS grade was significantly higher when the surgery was performed within 24 h compared with surgery performed after 24 h (44). However, the group that received surgery after 24 h contained many cases with AIS D, while the early surgery group contained more cases with AIS A and B. This imbalance between the groups gives rise to doubts about the strength of the conclusion. Conversely, it is obviously important that reduction surgery for cervical SCI with dislocation and instability should be performed as soon as possible after injury. According to Newton *et al*., when reduction surgery was performed within 4 h for cases of cervical dislocation fracture with complete paralysis caused by rugby, five out of the eight cases recovered to AIS E (45). In contrast, none of the 24 cases who received surgical reduction after 4 h recovered to AIS E, and only one case recovered to AIS D. This suggests that the effects of secondary damage following cervical SCI due to long-term ischemia or a perfusion abnormality might have a greater influence than appreciated in addition to the primary traumatic force. Furthermore, even in cervical fracture cases of DISH patients with complete paralysis, surgical treatment within 8 h following injury could ameliorate the neurological condition from complete to partial motor paralysis (20).

An experimental animal study regarding the surgical timing of decompression in an injured spinal cord with concurrent compression revealed differences in functional recovery potential following decompression surgery performed between at 72 h after injury and within 48 h, suggesting that the longer the ischemia lasts, an uncompensatable impairment could occur due to impeded blood flow (42). In the meanwhile, as it can be seen that there are cases with complete paralysis who do not show any improvement (46). Kawano *et al*. demonstrated that despite early surgical intervention, the recovery rates of persons with AIS grade A with bone injury was significantly worse than that of without bone injury (47). The possible reason for such differences is due not to the surgical timing and surgical treatment itself, but to differences in the proportion of included study participants with recovery potential, suggesting that consideration whether injured spinal cord has a negligible chance of recovering meaningful motor function before invasive treatment, is important for achieving maximum therapeutic benefits.

Conclusions

Although no single treatment has been able to cure SCI completely, a combination of effective surgical strategy with rehabilitation program could provide a potential advantage over conventional managements from the point of the view of the prevention of further SCI, subsequent neurological aggravation and related adverse events. Therefore, it is important to figure out the injury morphology precisely and to determine the optimal therapeutic strategy comprehensively according to various factors with consideration of individual condition. Many issues remain to be resolved on the finest surgical strategy for SCSI, although, a randomized prospective trial designed to evaluate the efficacy of surgical treatment from multiple viewpoints (surgical timing, cord compression, instability, soft-tissue damage, frailty and so on) is essential for a future development in this field.

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Footnote

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