ORIGINAL ARTICLE

The pincers effect on cervical spinal cord in the development of traumatic cervical spinal cord injury without major fracture or dislocation

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Study Design: Retrospective radiographic study.

Objective: To investigate the pincers effect on cervical spinal cord in the development of traumatic cervical spinal cord injury (CSCI) without major fracture or dislocation.

Setting: The Japan LHWO Spinal Injuries Center

Methods: Two hundred and twenty cases of traumatic CSCI without major fracture or dislocation were examined. The pinched diameters of the cervical spinal cord for 70 patients who complained of neck pain without neurological deficits were measured using sagittal-plane neutral and extension radiographs at 5 segments. These 70 patients were divided into 2 groups: group A patients were less than 40 years old and group B patients were 41 or more. We defined the pinched ratio of the cervical spinal cord during extension as ((sagittal diameter in the neutral image)–(sagittal diameter in the extension image))/(sagittal diameter in the neutral image)*100.

Results: The incidence of traumatic CSCI without major fracture or dislocation at the C3–4, C4–5, C5–6 and C6–7 was 59.5, 25, 11.4 and 4.1%, respectively. Further, the pinched ratio of the cervical spinal cord at the C3–4 segment was significantly higher than that at the other segments.

Conclusion: We concluded that the cervical spinal cord at the C3–4 segment might receive the highest bony impingement load during acute hyperextension of the cervical spine. The extreme pincers load on the cervical spinal cord at the C3–4 segment may have one of the important roles in the development of traumatic CSCI at the C3–4 segment.

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Keywords: traumatic cervical spinal cord injury without major fracture or dislocation; pincers effect; cervical spinal cord pinched diameter; cervical spinal cord pinched ratio

INTRODUCTION

Traumatic cervical spinal canal injury (CSCI) was originally described in 1954 by Schneider *et al.*¹ Although it is usually associated with bony injuries of the spinal column, namely, a fracture or dislocation, it also often occurs without these concomitant injuries. Most patients with traumatic CSCI without major fracture or dislocation have pre-existing cervical spondylotic changes or cervical ossification of the posterior longitudinal ligament, which results in narrowing of the cervical spinal canal.² Further, hyperextension of the cervical spine has been postulated to be an important mechanism of CSCI in the absence of major bony injuries.^{1–7} Traumatic CSCI is usually examined using magnetic resonance imaging, which has been found to be superior to computed tomography for detection of minor bony injuries (for example, anterior vertebral body bony tip fracture or spinous process fracture), intervertebral disc injury, ligamentous injury or cervical cord intramedullary pathology.^{3,8}

Several studies have reported the frequent incidence of traumatic CSCI at the level of C3–4 segment in the Japanese population.^{6,7,9} However, to the best of our knowledge, few reports have described the

biomechanical etiology of traumatic CSCI without major fracture or dislocation, and this remains a matter of debate.

In this study, we measured the pinched diameter of the cervical spinal cord during cervical spine extension in the sagittal plane and evaluated the effect of pincers load on each segment of the cervical spinal cord. The aim of the current study is to investigate the pincers effect on cervical spinal cord in the development of traumatic CSCI without major fracture or dislocation.

MATERIALS AND METHODS

Patients with traumatic CSCI

From January 2000 to May 2012, a total of 220 inpatients (188 men and 32 women; average age, 65.2 years; age range, 16–90 years) with traumatic CSCI without major fracture or dislocation were treated at our facility. All the patients showed intramedullary cervical spinal cord intensity changes on MR images of the injured segment (Figure 1). Patients with the following conditions were excluded from the study: multiple segmental cervical cord injury, cervical myelopathy before trauma, apparent herniated disc at the injured segment, severe sagittal instability as detected on functional radiographs or ankylosing spondylitis.

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Figure 1 The MR images in patients with CSCI at 3 months post injury. The images demonstrated intramedullary cervical cord intensity changes at the level of C3-4 (T1-weighted image; low intensity, T2-weighted image; high intensity).

Of the 220 patients, 131 had the injury at C3-4, 55 at C4-5, 25 at C5-6 and 9 at C6-7.

Patients with neck pain without neurological deficits

From January 2011 to December 2011, 70 outpatients (35 men and 35 women; average age, 44.9 years; age range, 10–79 years) with neck pain underwent functional plain radiographic examination and neurological examination by a spinal surgeon. No patient showed neurological deficits or dynamic instability on the plain radiographs. On the basis of age, the patients were divided into 2 groups: group A comprised those less than 40 years of age (31 subjects; average age, 31.7 years) and group B, those who were 41 years old or more (39 subjects; average age, 55.4 years).

This study was approved by our institution's review board, and informed consent was obtained from all patients.

Measurement of the pinched diameter of the spinal cord in the sagittal plane

Using functional plain radiographs in the sagittal plane, three independent blinded observers measured the pinched diameter between the posteroinferior margin of the superior vertebral body and the anterosuperior margin of the lamina of the inferior vertebra for the 70 outpatients without neurological abnormalities at 5 segments (C2-3, C3-4, C4-5, C5-6 and C6-7) in the neutral and extension positions (Figure 2a, b).

The pinched diameter of the cervical spinal cord was defined as the distance between the posteroinferior margin of the superior vertebral body and the anterosuperior margin of the lamina of the inferior vertebra.¹⁰ From this definition, the pinched ratio of the cervical spinal cord during extension was defined as ((sagittal diameter in the neutral image)–(sagittal diameter in the extension image))/(sagittal diameter in the neutral image)*100.

Statistical analysis

The Mann–Whitney *U* test administered using the computer software package StatMate III (ATMS Co., Ltd, Tokyo, Japan) was used for statistical

Figure 2 The functional plain radiographs with cervical spine neutral (a) and extension (b) in the sagittal plane. The pinched diameter of the cervical spinal cord was measured at the distance between the posteroinferior margin of the superior vertebral body and the anterosuperior margin of the lamina of the inferior vertebra.

analysis. A *P* value of less than 0.05 was considered statistically significant. Kappa (*k*) statistics was calculated as a measure of the inter observer reliability of the pinched diameter of the cervical spinal cord.

RESULTS

In the present series, the incidence of traumatic CSCI without major fracture or dislocation at the C3-4, C4-5, C5-6 and C6-7 segments was 59.5, 25, 11.4 and 4.1%, respectively.

A high level of agreement ($k = 0.674$) was noted among the 3 independent observers who measured the pinched diameter of the cervical spinal cord. The average values of this diameter in the neutral and extension positions at the 5 segments are shown in Table 1. For all segments, except C6-7, the pinched diameter was significantly narrower in the extension position than the neutral position.

The average pinched ratios during cervical spine extension at the 5 segments are shown in Table 2. Comparisons for the total outpatient population and group A showed that the pinched ratio at the C3-4 segment was significantly higher than that at the other segments. In the case of group B, only the pinched ratio at the C4-5 segment was not significantly different from that at the C3-4 segment ($P = 0.0506$).

DISCUSSION

Koyanagi *et al.*⁴ explained the predominance of CSCI at the middle to the upper cervical segments on the basis of the characteristics of spondylotic changes in the cervical spine. They hypothesized that the restricted intervertebral movement of the lower cervical segments due to degenerative changes might in fact protect the spinal cord at these segments from traumatic injury. The upper segments (C3-4 or C4-5) rostral to the fixed segments, however, might be damaged with cervical spine hyperextension.

In our series, a high incidence of traumatic CSCI was observed at the upper segments (C3-4, 59.5; C4-5, 25.0%) even in relatively younger population with less cervical spondylotic changes. We believe that morphological differences among the segments may contribute to the development of traumatic CSCI. According to our results, the sagittal pinched diameters of the cervical spinal cord at all segments, except C6-7, significantly reduced during extension. Moreover, the pinched ratio at the C3-4 segment was significantly higher than that at the other segments even in younger subjects, who had fewer

Table 1 The sagittal cervical spinal cord pinched diameters at 5 segments

	Cervical spinal cord pinched diameter (mm)				
	C2-3	C3-4	C4-5	C5-6	C6-7
Neutral	18.16 ± 1.77**	16.47 ± 1.74***	15.7 ± 1.85**	14.84 ± 1.93*	15.73 ± 1.65 ^{ns}
Extension	17.41 ± 1.7	15.01 ± 1.71	14.81 ± 1.78	14.2 ± 1.85	15.49 ± 1.71

Compared with neutral and extension posture * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 2 The cervical spinal cord pinched ratio during cervical spine extension

	Cervical spinal cord pinched ratio (%)				
	C2-3	C3-4	C4-5	C5-6	C6-7
Total (n = 70)	4.03 ± 4.54***	8.81 ± 4.97	5.58 ± 4.48***	4.13 ± 4.99***	1.51 ± 4.07***
Group A (n = 31)	4.82 ± 5.26***	10.19 ± 4.82	5.23 ± 4.33***	4.44 ± 5.38***	0.87 ± 4.15***
Group B (n = 39)	3.41 ± 3.82***	7.71 ± 4.83	5.86 ± 4.63 ^{ns} ($P = 0.0506$)	3.88 ± 4.71**	2.02 ± 3.98***

Compared with C3-4 segment * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

spondylotic changes in the cervical spine. Therefore, the degree of degenerative changes in the cervical spine may not affect the pincer mechanism at the upper cervical segments. We hypothesized that the cervical spinal cord at the C3-4 segment might receive the highest bony impingement load during acute hyperextension of the cervical spine. This acute pincers load at the C3-4 segment may play one of the important roles in the development of traumatic CSCI at the C3-4 segment.

Some issues remain unaddressed in the current study. As the cervical kinematics may change after trauma owing to soft tissue injury, we did not evaluate the pincers effect with actual traumatic CSCI patients. Moreover, we did not evaluate the dynamic loading on the cervical spine during hyperextension. Using the current investigation as the pilot study, further research using anatomical analysis of the cervical spinal column, including the cervical facet angle, with a larger patient population may help shed light on these issues. Moreover, the biomechanical etiology of traumatic CSCI without major fracture or dislocation should be clarified in greater detail.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

- Schneider RC, Cherry G, Pantek H. The syndrome of acute central cervical spinal cord injury, with special reference to the mechanisms involved in hyperextension injuries of cervical spine. *J Neurosurg* 1954; **11**: 546–577.
- Gupta SK, Rajeev K, Khosla VK, Sharma BS, Paramjit, Mathsriya SN *et al*. Spinal cord injury without radiographic abnormality in adults. *Spinal Cord* 1999; **37**: 726–729.
- Tewari MK, Gifti DS, Singh P, Khosla VK, Mathuriya SN, Gupta SK *et al*. Diagnosis and prognostication of adult spinal cord injury without radiographic abnormality using magnetic resonance imaging: analysis of 40 patients. *Surg Neurol* 2005; **63**: 204–209.
- Koyanagi I, Iwasaki Y, Hida K, Akino M, Imamura H, Abe H *et al*. Acute cervical cord injury without fracture or dislocation of the spinal column. *J Neurosurg* 2000; **93**: 15–20.
- Harrop JS, Sharan A, Ratliff J. Central cord injury: pathophysiology, management, and outcomes. *Spine J* 2006; **6**: 198S–206S.
- Shimada K, Tokioka T. Sequential MR studies of cervical cord injury: correlation with neurological damage and clinical outcome. *Spinal Cord* 1999; **37**: 410–415.
- Shimada K, Tokioka T. Sequential MRI studies in patients with cervical cord injury but without bony injury. *Paraplegia* 1995; **33**: 573–578.
- Miyanji F, Furian JC, Aarabi B, Arnold PM, Fehlings MG. Acute cervical traumatic spinal cord injury: MR imaging Findings correlated with neurologic outcome-prospective study with 100 consecutive patients. *Radiology* 2007; **243**: 820–827.
- Takahashi M, Harada Y, Inoue H, Shimada K. Traumatic cervical cord injury at C3-4 without radiographic abnormalities: correlation of magnetic resonance findings with clinical feature and outcome. *J Orthop Surg (Hong Kong)* 2002; **10**: 129–135.
- Penning L. Some aspects of plain radiography of the cervical spine in chronic myelopathy. *Neurology* 1962; **12**: 513–519.