Trauma Sites and Clinical Features Associated With Acute Hyperextension Spinal Cord Injury Without Bone Damage

—Relationship Between Trauma Site and Severity—

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Abstract

To elucidate whether a relationship exists between the site of trauma and severity of acute hyperextension spinal cord injury without bone damage, we examined the clinical features of 25 male and 10 female patients aged 13 to 88 years. None of the patients had vertebral damage such as fracture and dislocation. The site of impact was classified as the buccal, forehead, or mandibular region. The neurological findings were assessed according to Frankel's classification at admission and at follow up after 3 months or more to assess outcome. Eleven patients suffered trauma in the buccal region, one patient in Frankel's grade B, three in grade C, and seven in grade D at admission. All 11 of these patients showed an improvement of one grade or more to an outcome of C in one patient, D in one, and E in nine. Trauma occurred at the forehead region in 18 patients, four in grade B, 10 in grade C, and four in grade D. Improvement was seen at follow up by one grade or more to C in one patient, D in 10, and E in seven. Trauma occurred at the mandibular region in six patients, four in grade B and two in grade C. Four of these patients showed improvement of one grade or more to grade B in one, grade C in four, and grade E in one. Overall, seven patients had poor outcomes, five of whom suffered trauma to the mandibular region, indicating that impact to the mandibular region tends to have an unfavorable clinical outcome. Our findings indicate that the site of trauma greatly influences the severity of hyperextension spinal cord injury.

Key words: hyperextension, spinal cord injury, clinical feature, outcome

Introduction

The anatomical properties of the cervical vertebrae allow various movements including extension, flexion, and rotation.^{1,2,4,8)} When an excessive load is applied during such movements, the cervical vertebrae and spinal cord tend to be injured.^{3,21,22)} Patients with spinal cord injury often present with spondylosis-like changes and/or ossification of the posterior longitudinal ligament (OPLL), sometimes leading to narrow spinal canal.^{3,6,9,12,19,20)} These changes may precede the injury, but the spinal cord with such a preexisting anomaly tends to suffer injury even from

only mild trauma. Therefore, the site of trauma has been proposed as another factor that determines the severity of hyperextension spinal cord injury without bone damage.^{11,15)} The present study investigated the possible relationship between the trauma site and clinical features associated with acute hyperextension spinal cord injury without bone damage.

Subjects and Methods

Thirty-five patients (25 males and 10 females aged 13 to 88 years, mean 60.4 years) with hyperextension

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Fig. 1 Impact sites associated with traumatic cervical hyperextension spinal cord injury.

Fig. 2 Case 3. T₁- (left) and T₂-weighted (right) magnetic resonance images showing no spinal cord injuries.

spinal cord injury but without bone damage, who were emergently transferred to our hospital from October 1995 to January 1999, participated in this study. All patients were healthy before injury and had no history of cervical spinal cord disease. Immediately after transfer, the trauma site in individual patients was identified and classified as occurring in one of the buccal, forehead, or mandibular regions (Fig. 1).

Cervical radiography, computed tomography (CT), and magnetic resonance (MR) imaging were performed on all patients to evaluate the presence or absence of preexisting spinal cord disease (OPLL, spondylosis deformans, etc.).^{5,18,19} The level of consciousness was clear in 34 of 35 patients. Furthermore, trauma was due to a strong blow in only one case, but the patient's consciousness was relatively

clear and the site was accurately identified from the external wound.

Neurological findings at admission and at follow up (clinical outcome) 3 months or more later were evaluated using Frankel's classification in all cases.¹⁷ All patients were treated with bed rest and cervical immobilization using a neck collar. Surgical intervention was performed at 3 months or more after injury for two patients at the family's request. Therefore, differences due to surgical intervention were not included in the evaluation of outcome.

Statistical analysis was performed using an analysis of variance, followed by Scheffe's method. Statistical significance was established at the $p < 0.05$ level.

Results

The clinical characteristics of the 35 patients are shown in Table 1, and the neurological findings at admission and at follow up are summarized in Table 2. Patients with trauma in the buccal region showed improvement of one grade or more at follow up in all cases. Patients with trauma in the forehead region also showed improvement in all cases. Patients with trauma in the mandibular region showed improvement of one grade or more in four cases, but no change in the other two. Nine patients were graded as B at initial examination, and four had trauma in the mandibular region. Five of seven patients whose outcome was assessed as grade B or C had trauma in the mandibular region. Twenty-nine of the total 35 patients had preexisting cervical disease such as OPLL. Outcome differed significantly between patients who had suffered trauma to the mandibular region and to the other two sites ($p < 0.05$). The specific sites of injuries identified at admission are shown in Table 3. No significant difference was found between the affected levels.

Representative Cases

Case 3: A 24-year-old female was emergently transferred to our hospital after falling off her bicycle and suffering a severe blow to her mandibular region. At admission, her neurological condition was assessed as grade B according to Frankel's classification. Radiography of the cervical vertebrae revealed no preexisting spinal cord disease. MR imaging showed no abnormality of the spinal cord (Fig. 2). Her outcome was assessed as grade C at follow up.

Case 11: A 52-year-old female suffered a severe blow to her buccal region when hit by a car while crossing the road. The patient was emergently transferred to our hospital. The patient's neurological findings

Table 1 Clinical characteristics of the 35 patients with hyperextension spinal cord injury without bone damage

Case No.	Age	Sex	Site of blow	Spondylosis deformans	OPLL	Canal stenosis	Therapy	Frankel's classification		Clinical syndrome
								At admission	Outcome	
1	13	M	mandibular	—	—	—	resting	C	E	central cord
2	18	M	buccal	—	—	—	resting	C	E	central cord
3	24	F	mandibular	—	—	—	resting	B	C	Brown-Sequard
4	27	M	buccal	—	—	—	resting	D	E	central cord
5	34	M	forehead	—	—	—	resting	B	D	transverse
6	40	M	forehead	—	—	—	resting	D	E	central cord
7	43	M	forehead	+	+	+	resting	D	E	central cord
8	44	M	forehead	+	—	+	resting	C	D	central cord
9	44	M	forehead	+	—	+	resting	D	E	central cord
10	51	M	forehead	+	+	+	resting	D	E	central cord
11	52	F	buccal	+	—	+	resting	D	E	central cord
12	55	M	forehead	+	—	+	resting	C	D	central cord
13	57	M	forehead	+	—	—	laminoplasty	C	D	central cord
14	57	M	buccal	+	—	+	resting	D	E	central cord
15	58	M	forehead	+	—	—	resting	C	D	central cord
16	59	M	forehead	+	—	+	resting	C	E	central cord
17	61	M	forehead	+	—	—	resting	C	E	central cord
18	64	F	buccal	+	—	—	resting	D	E	central cord
19	66	M	mandibular	+	—	+	laminoplasty	C	C	central cord
20	66	M	mandibular	+	—	+	resting	B	C	central cord
21	68	F	buccal	+	—	+	resting	D	E	central cord
22	69	M	forehead	+	+	+	resting	B	D	central cord
23	70	M	buccal	+	+	+	resting	C	E	central cord
24	74	F	mandibular	+	—	+	resting	B	C	central cord
25	77	F	forehead	+	—	+	resting	B	E	central cord
26	77	M	forehead	+	—	+	resting	C	D	central cord
27	79	M	buccal	+	—	+	resting	D	E	central cord
28	79	M	forehead	+	—	+	resting	C	D	Brown-Sequard
29	80	M	forehead	+	+	+	resting	B	C	Brown-Sequard
30	80	F	buccal	+	—	+	resting	D	E	Brown-Sequard
31	83	F	buccal	+	+	+	resting	C	D	central cord
32	85	M	forehead	+	—	+	resting	C	D	central cord
33	86	M	mandibular	+	—	+	resting	B	B	central cord
34	87	F	buccal	+	—	+	resting	B	C	central cord
35	88	F	forehead	+	—	—	resting	C	D	central cord

OPLL: ossification of the posterior longitudinal ligament.

Table 2 Neurological findings at admission and outcome at follow up after 3 months or more

Trauma site	Frankel's classification			
	B	C	D	E
Buccal				
at admission	1	3	7	0
outcome	0	1	1	9
Forehead				
at admission	4	10	4	0
outcome	0	1	10	7
Mandibular				
at admission	4	2	0	0
outcome	1	4	0	1

Table 3 Affected levels of spinal cord at admission

	Trauma site		
	Forehead	Buccal	Mandibular
C-4	1	0	0
C-5	6	3	2
C-6	5	4	4
C-7	5	4	0
C-8	1	0	0

Fig. 3 Case 11. T₂-weighted magnetic resonance images (*left*) showing narrowed spinal canal but no lesion of the spinal cord. Bone target computed tomography scan (*right*) demonstrating fracture of the right maxillary sinus.

Fig. 4 Case 10. Computed tomography (CT) scan of the head (*left*) showing traumatic subarachnoid hemorrhage. Axial bone target CT scan through the C3-6 levels (*right*) showing ossification of the posterior longitudinal ligament.

were classified as grade D at admission. Radiography of the cervical vertebrae revealed a narrow spinal canal associated with spondylosis deformans. MR imaging showed no abnormality. Facial CT and radiography revealed a fracture of the right maxillary sinus (Fig. 3). Her clinical outcome was determined to be grade E at follow up.

Case 10: A 51-year-old male fell down on a snow-covered road and suffered a severe blow to his forehead region. Following emergent admission, his

neurological findings were graded as D. Head CT revealed a marked traumatic subarachnoid hemorrhage. Radiography of the cervical vertebrae revealed OPLL covering the 3rd to 6th vertebrae (Fig. 4). MR imaging showed no trauma of the spinal cord. At follow up his outcome was assessed as grade E.¹⁹⁾

Discussion

The present study revealed that trauma to the mandibular region tended to indicate more severe spinal cord injury in patients with hyperextension injury. Clinical outcome was determined as Frankel's grade B or C in seven patients, five of whom had suffered trauma to the mandibular region. Representative Cases 10 and 11 had only mild spinal cord injuries despite the presence of severe trauma concomitant with facial bone fracture or traumatic subarachnoid hemorrhage. Conversely, Case 3 was young and had no narrow spinal canal, but the neurological findings at admission and at follow up were extremely poor. In this patient, only an abrasion was observed on the mandibular region.

The tissue in the mandibular region consists of a so-called elastic body, implying a "spring" in the one-dimensional sense. The severity of damage can be deduced by the size of the distortion of the "spring," and can be expressed as $f = kx$ for an elastic body according to Hooke's law, where f : magnitude of force exerted (N), x : distortion (m), and k : spring coefficient (elastic coefficient) (N/m).¹³⁾ As shown in Fig. 5 *left column*, the tissue of the neck can be replaced by the three spring models. When the force of impact is added to this model, as expressed by A, B, and C, force is exerted in the direction of A and B by impact to the forehead (Fig. 5 *center column*). Similarly, force is exerted in the direction of A by buccal impact and in the direction of C by mandibular impact. In addition, the body as a whole may absorb the force in the case of forehead and buccal impacts. In practice, whether k_A , k_B , or k_C is the greatest spring coefficient remains unclear (Fig. 5 *left column*). Assuming that k_A and k_B cancel each other to some extent in the case of forehead impact, and that the force is absorbed by the body as a whole in the cases of forehead and buccal impacts (Fig. 5 *right column*), then mandibular impact would involve the most extreme distortion.

Individual injuries in our 35 patients were accidental, but any impact force applied to the cervical region may be reduced through instinctive defensive reactions in the cases of forehead and buccal trauma. However, trauma to the mandibular region is

Fig. 5 Schemas showing the three spring models (left column), forces exerted at each impact site (center column), and absorption of impact by the body (right column).

often not recognized beforehand so strong vector force is exerted on the hyperextended spinal cord, which probably results in severe injury due to the delayed defensive reaction.^{7,10,14,16,23)}

The present study, although limited to 35 cases, indicates that an impact at the mandibular region tends to cause severe neurological consequences. We recommend that this observation should be further investigated in a larger study.²⁴⁾

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Commentary

The authors attract our attention in a convincing fashion to the fact that in whiplash injury without bone damage, the highest degree of clinically significant hyperextension is caused by trauma to the mandibular region. It is recommended to further investigate the correlation between the mandibular site of injury and the most severe neurological consequences in a larger study. Indeed, the evidence of this correlation may be of great predictive value in patients with hyperextension spinal cord injury. On the other hand, future investigations on a larger scale should include, if possible, therapeutical recommendations as well, particularly with respect to surgical intervention.

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The authors tried to define the relationship between three sites of blow in the face; forehead, buccal and mandibular region, and severity of hyperextension cervical cord damage without bone pathology by using Frankel's classification in evaluating the clinical outcome of the patients.

Pathomechanism of hyperextension cervical cord injury syndrome has certainly known to be multifactorial and complex. And yet the authors made an attempt to come to some conclusion by analyzing only one factor, the site of blow in the face. They failed to provide us any data regarding the velocity of impacting vehicles or objects, the severity of the preexisting degenerative disease in the jeopardized spinal canal if such pathology be present, positive rate of intramedullary changes upon MR imaging in each groups, how soon after the injury the patient started having been treated with mega dose methylprednisolone, how strong the paraspinal muscles were, bull neck v.s. normal looking neck in shape? Any alcohol intoxicated patients be excluded or included in three subdivided groups. The effect of extension-rotation vectors in cervical cord injury which would be more frequently experienced in daily neurosurgical practice than pure hyperextension injury escaped from discussion.

Without hard core evidence based on research work with certain experimental models or relevant factors cited above to be discussed, it is fair to say that the authors showed us some tendency of the injury in their limited clinical experience. Generalization of mandibular blow could cause much severer neurological damage to the cervical cord, sounds to be too premature.

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This paper is a very interesting and unique paper. The authors analyzed their series of hyperextension spinal cord injury without bone destruction. In particular, they studied the relationship between trauma site and severity of spinal cord injury in each patient. Their results indicated that an impact at the mandible region tend to cause severe neurological deficit. The authors explained the mechanism using "three spring model." This reminds me a damage of boxing. In that

meaning, impact for the mandible region is an upper-cut, which cause a severe damage in boxing. I am still doubted whether trauma sites were really so clear, and also skeptical the injury was always not complexes but single. However, the authors' attitude to find a relationship between the trauma site and its severity of spinal cord injury is admirable as a clinician. Further investigation has to testify their hypothesis in a future.

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