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Original Article

Recovery of Motor Function in Patients with Subaxial Cervical Spine Injury Relevant to the Fracture Pattern

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In this study, we studied the relationship between fracture patterns and motor function recovery in 70 consecutive patients with cervical spinal cord injury. Fractures were categorized into 6 fracture types and subdivided into stages according to the Allen-Ferguson classification system: compressive flexion (CF), distractive flexion (DF), compressive extension (CE), distractive extension (DE), vertical compression (VC) and lateral flexion (LF). Paralysis was evaluated using the American Spinal Injury Association (ASIA) impairment scale at the time of injury and 3 months afterwards. The residual rate of complete motor palsy (ASIA grade A or B) at the final examination was higher in those patients with DE fractures than those with CF, DF or CE. The final outcomes were as follows. Of the 14 patients who were classified with CF fractures, residual palsy was frequently seen in patients who had stage 5 injury. Of the 27 patients with DF fractures, residual palsy occurred in about half of the patients who had stage 4 or 5 injury. Of the 18 patients with CE fractures, residual palsy occurred in half of the patients with stage 3 injury or higher. Finally, of the 7 patients with DE fractures, the rate of residual palsy was high even for the stage 1 and 2 cases; indeed, all DE patients who had complete motor palsy at the first examination had residual palsy at the final examination. Accordingly, we conclude that motor recovery may be related to fracture pattern.

Key words: cervical spinal cord injury, motor function recovery, fracture patterns

The epidemiology, anatomy, biomechanics, and classification of subaxial cervical injuries are important for their appropriate diagnosis and treatment [1]. Despite extensive documented clinical experience of subaxial cervical spine injuries, their classification and treatment remains controversial. The Allen-Ferguson classification [2, 3] has been the most widely used by spine surgeons as it takes into account not only injury severity but also the mechanism by which the cervical spine damage occurred, which is prerequisite information for establishing the most appropriate plan for stabilization [4, 5].

The relationship between the cervical spine fracture pattern and motor recovery has been discussed in a few studies [6, 7]; here, we further examined this relationship in patients with cervical spinal cord injury.

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Patients and Methods

We retrospectively examined 70 consecutive patients with subaxial cervical fracture or dislocations who underwent surgery between July 2006 and December 2010 at Kobe Red Cross Hospital. There were 57 male and 13 female patients, and the average age at injury was 55 years old (ranging from 19 to 87 years old). The causes of injury were traffic accidents in 27 patients, falls in 38 and others causes in 5. After an average 4-day waiting period, these patients underwent surgical treatment. Posterior fusion was performed in 39 patients (with additional posterior decompression in 5 patients), anterior fusion in 11 patients and anterior and posterior fusion in 20 patients (with additional posterior decompression in 2 patients). Methylprednisolone sodium succinate was used in 21 of the 70 patients according to the National Acute Spinal Cord Injury Study II protocol [8].

Cervical radiographs and CT scans were performed on patients when they arrived at the emergency room. These images were used to were categorize casesd into 6 fracture types according to the Allen-Ferguson classification system [4]: compressive flexion (CF), distractive flexion (DF), compressive extension (CE), distractive extension (DE), vertical compression (VC) and lateral flexion (LF). There were 14 patients with CF fractures (stage 1: 1, stage 2: 2, stage 3: 2, stage 4: 5, stage 5: 4), 27 with DF (stage 1: 1, stage 2: 11, stage 3: 11, stage 4: 4), 18 with CE (stage 1: 4, stage 2: 5, stage 3: 4, stage 4: 4, stage 5: 1), 7 with DE (stage 1: 2, stage 2: 5), 4 with VC (stage 2: 1, stage 3: 3), and none with LF. Assessment was performed following discussions between three experienced spine surgeons (Table 1).

Paralysis was evaluated using the American Spinal Injury Association (ASIA) impairment scale, running from A to E, at the time of injury and 3 months afterwards [9]: ASIA-A (no motor or sensory function is preserved in the sacral segments S4-S5), ASIA- B (sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5), ASIA-C, (motor function is preserved below the neurological level, and more than half of the key muscles below the neurological level have a muscle grade less than 3), ASIA-D, (motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more), and ASIA-E, (motor and sensory functions are normal). ASIA grades of A or B means indicated that the patients had complete motor palsy.

Table 1 The Allen-Ferguson classification

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
compressive flexion	1	2	2	5	4
distractive flexion	1	11	11	4	
compressive extension	4	5	4	4	1
distractive extension	2	5			
vertical compression		1	3		

Results

There were 29 patients with ASIA grade A, 13 with grade B, 12 with grade C, 7 with grade D and 9 with grade E at the injury. At the final examination, there were 24 patients with grade, 1 with grade B, 14 with grade C, 20 with grade D and 11 with grade E. Neurologic improvement of an increase in at least 1 grade was observed in 26 of 70 (37%) patients. The residual rate of complete motor palsy (grade A or B) at the final examination was higher in patients with DE fractures than those with CF, DF and CE (Fig. 1).

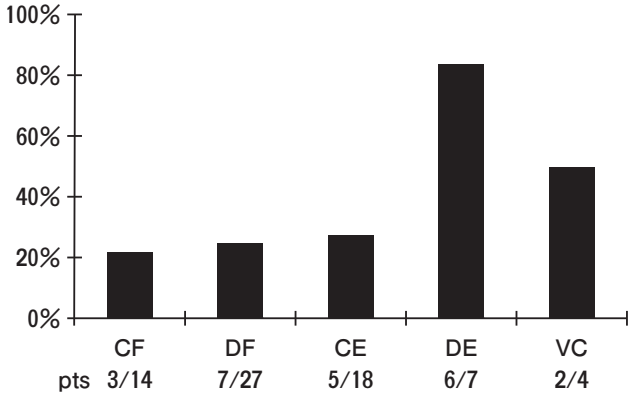

Fig. 1 Residual rate of motor complete palsy at final examination. The residual rate of complete motor palsy at the final examination was higher in DE cases than in CF, DF and CE cases; CF, compressive flexion; DF, distractive flexion; CE, compressive extension; DE, distractive extension; VC, vertical compression; pts, patients.

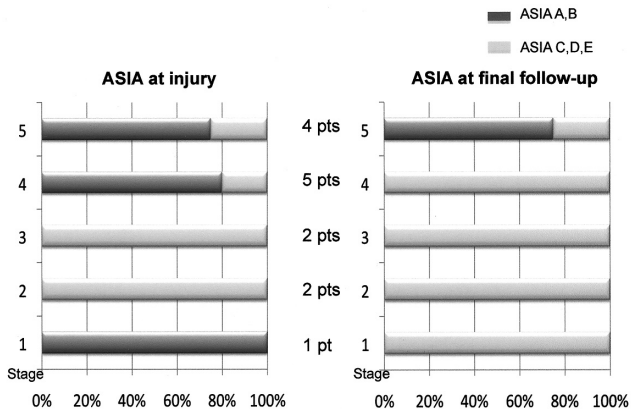

Fig. 2 Compressive flexion. There were 7 (4 stage-4, 3 stage-5) patients with ASIA-A or-B classification at the time of injury. At the final follow up, the 4 stage-4 patients had recovered.

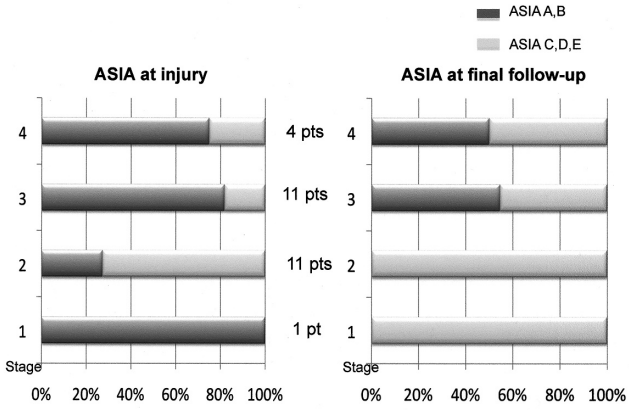

Fig. 3 Distractive flexion. There were 14 (1 stage-1, 2 stage-2, 8 stage-3, 3 stage-4) patients with ASIA-A or-B classification at the time of injury. At the final follow up, residual palsy was observed in half of patients who had DF stage-4 or-5 injury.

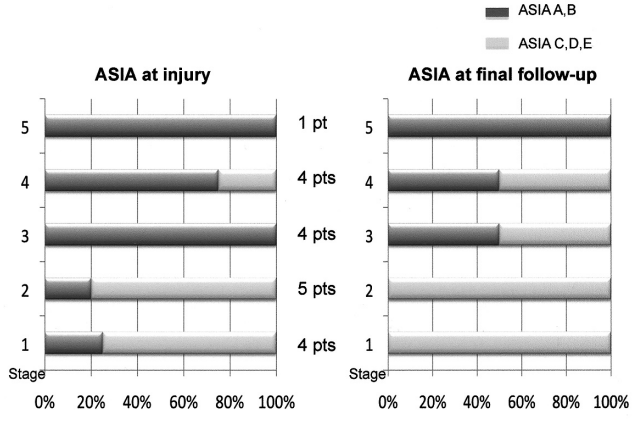

Fig. 4 Compressive extension. There were 10 (1 stage-1, 1 stage-2, 4 stage-3, 3 stage-4, and 1 stage-5) patients with ASIA-A or-B classification at the time of injury. At final follow up, residual palsy was observed in half of the patients who had CE stage-3 or higher injury.

It has been suggested that neurological recovery correlates with the type of fracture and its stage. Of 14 patients who were classified with CF fractures at final examination, residual palsy was frequent at stage 5 CF. Some patients with stage 4 or lower had complete motor palsy at the injury; however these patients had recovered at the final examination (Fig. 2).

Of 27 patients who were classified with DF fractures at final examination, residual palsy frequently occurred in half of patients who had stage 4 or 5 DF. Some patients in stage 1 or 2 had complete motor palsy at the first examination but these patients had recovered at the final examination (Fig. 3).

Of 18 patients who were classified with CE fractures at the final examination, residual palsy occurred in half of patients who had stage 3 or higher CE. Some patients in stage 1 or 2 had complete motor palsy at the first examination but these patients had recovered at the final examination (Fig. 4).

Of 7 patients who were classified with DE fractures at final examination, residual palsy was frequent at stage 1 or 2 DE. All patients who had complete motor palsy at the first examination had residual palsy at the final examination (Fig. 5A).

Of 4 patients who were classified with VC fractures at the final examination, residual palsy was frequent at stage 3 VC. All patients who had complete motor palsy at the first examination had residual palsy at the final examination (Fig. 5B).

Discussion

The relationship between fracture pattern and motor recovery has been discussed in a few studies. Pollard *et al.* reported that neurological recovery was not related to the type of fracture or mechanism of injury [6], but other authors have shown that the type of fracture does affect neurological recovery [7, 10]. Furthermore, Albrecht *et al.* reported that the type of fracture was an independent risk factor for mortality [11]. In addition, fracture of the lamina

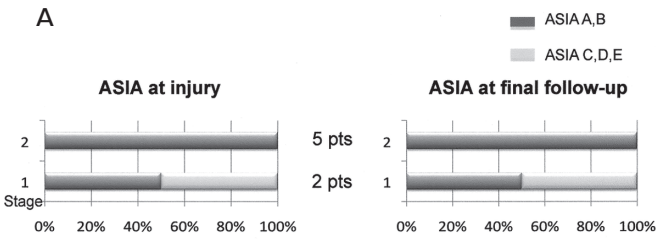

Fig. 5A Distractive extension. There were 6 (1 stage-1, 5 stage-2) DE patients with ASIA-A or-B classification at the time of injury. All patients who had complete motor palsy at the first examination had residual palsy at the final examination.

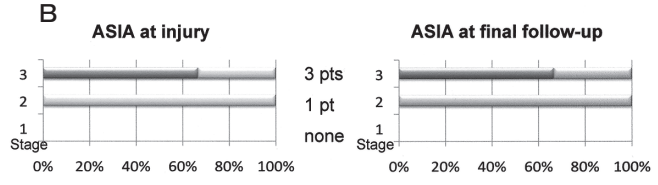

Fig. 5B Vertical compression. There were 2 (2 stage-2) VC patients with ASIA-A or-B classification at the time of injury. Both patients who had complete motor palsy at the first examination had residual palsy at the final examination.

and facet were each identified as markers of high-risk fracture, and extension injuries were found to increase the risk of spinal cord injury [7].

Here, the rate of complete motor palsy at the final examination was higher in patients with DE fractures than those with CF, DF and CE fractures. McLain *et al.* conducted a biomechanical study of DF and DE fractures in order to compare the elongation of the space between vertebral bodies before the rupture of the posterior longitudinal ligament (PLL), and found that DE fractures had shorter elongation [12]. Thus, the PLL is thought to be more easily ruptured in DE-type than in DF-type fractures. In another study, soft tissue injuries in DE fractures were evaluated by MRI and examined along with the severity of neurological symptoms: spinal cord injuries were confirmed in those cases with ruptured PLLs [13]. According to studies on the quantitative contributions made by individual ligaments to spinal stability, the PLL was not only wider anatomically than the anterior longitudinal ligament (ALL) but also substantially stronger dynamically; accordingly, PLL injuries caused more instability than ALL injuries [14-17]. Thus, PLL injury is likely to be a good predictor of spinal cord injury. Therefore, we speculated that the rate of persistent severe motor paralysis (ASIA grade A and B) was high in patients with DE-type fractures because this type of injury easily damages the spinal cord.

Neurological recovery may be suggested to correlate with the type of fracture and stage. Severe motor paralysis persists in higher-stage cases. In cases with DF fractures, patients with bilateral facet joint dislocations had a higher percentage of complete paralysis compared to patients with unilateral facet joint dislocations [18]. In cases with CF fractures, Allen reported that the severity of the stage and neurological damage correlated with the CF pattern [4]. CE fractures have proven controversial; Allen reported that the severity of spinal column damage did not correlate with the severity of the neurological damage; on the other hand, Nakashima *et al.* observed a correlation between spinal column damage and the degree of neurological damage [19]. Since the numbers of our cases with DE and VC fractures were few, it is difficult to correlate our data with others' or add to existing discussions. In terms of types and stages, severe motor paralysis was observed in higher-stage fractures. It is not surprising that persistent severe paralysis correlated with higher-stage fractures as spinal trauma tends to be more severe and cause more severe spinal cord injuries. Severe motor paralysis was observed at the time of the injury in 42 patients but patients with lower-stage fractures were more likely to recover from paralysis.

It is important to note 2 limitations of this study, apart from limited numbers: namely, the short follow-up period and the fact that patients who were treated with conservative treatments were excluded from the study.

In conclusion, we conclude that motor recovery may be related to fracture pattern. The residual rate of complete motor palsy at the final examination was higher in patients with DE fractures than those with CF, DF and CE. Residual motor palsy was severe in those patients with higher DF and CF fracture stages.

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