ORIGINAL ARTICLE

The potential for functional recovery of upper extremity function following cervical spinal cord injury without major bone injury

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Study Design: This was a retrospective observational study.

Objectives: The objectives were to describe the prognosis of upper extremity function following cervical spinal cord injury (CSCI), and to identify prognostic factors for functional recovery.

Setting: Spinal Injuries Center, Japan.

Methods: Sixty patients with C3–4 CSCI without major bone injury participated in the study. Patients were treated nonsurgically and evaluated using the American Spinal Injury Association (ASIA) scales for the upper and lower extremities, their residual cervical motor functions, the modified Frankel grade and an upper extremity function scale. We compared the findings for the upper extremity function scale at 6 months with those for the residual cervical motor functions and modified Frankel grade obtained 3 days after injury.

Results: Most patients with CSCI who could flex their hip and knee from a supine position (95%) or who showed some active elbow extension (86%) 3 days after their injury could use a spoon at 6 months. We compared patients who used their fingers at 6 months to those who could not, and observed significant differences in age and ASIA scores for the upper and lower extremities obtained 3 days after injury. A strong correlation was observed between the initial motor scores and the extent of functional recovery at 6 months.

Conclusion: Hip and knee flexion from the supine position and elbow extension 3 days after injury significantly predicted a positive prognosis for upper extremity function. Younger age and higher ASIA motor scores obtained 3 days after injury were factors associated with neurological recovery.

Spinal Cord (2013) **51**, 819–822; doi:10.1038/sc.2013.90; published online 17 September 2013

Keywords: cervical spinal cord injury; upper extremity; prognosis; paralysis; nonsurgical treatment

INTRODUCTION

The incidence of cervical spinal cord injury (CSCI) without major bone injury¹ has increased dramatically in developed countries because of the increasing elderly population.² Most patients with CSCI are elderly and present with spinal hyperextension predominantly at the C3–4 level, and with spinal cord compression resulting from spinal stenosis.^{3–6} CSCI can cause sensory deficits, paresis or paralysis throughout the body, which often includes the upper limbs. The consequences of CSCI can be permanent and typically impair the patient's quality of life, particularly when they involve the upper limbs. Anderson⁷ analyzed 681 responses from patients with spinal cord injury and found that regaining arm and hand function was most important to patients with quadriplegia. Thus, the recovery of upper-limb function after CSCI is important, as the upper limbs are a primary factor in enabling functional independence.^{7,8}

The prognosis for patients with CSCI should be known in order to standardize and to determine the goals of a rehabilitation program. The time course profiles and prognostic factors of upper extremity function recovery, however, remain unclear. Depending on the spinal

level at which the injury occurs, CSCI can cause various degrees of paralysis. In addition, surgical intervention may affect the prognosis of paralysis. Previous studies that report the prognosis for upper extremity recovery, and data on the prognosis of participants with different injury levels, diagnosis or treatments were pooled and analyzed as a group.^{9,10} Nevertheless, it is difficult to investigate the prognosis of paralysis in the upper extremities with different injury levels because the extent of paralysis can differ, depending on the level injured. Therefore, when evaluating paralysis in the upper extremities following CSCI, the injury level, type of injury and treatment should be uniform to allow meaningful analysis. To our knowledge, no study has used such an approach to investigate the prognosis of upper extremity paralysis in patients with CSCI at a specific spinal level. Here, we describe the prognosis of upper extremity function and identify the prognostic factors for functional recovery in the upper extremities following CSCI.

MATERIALS AND METHODS

A total of 526 patients with acute spinal injury were treated at the Spinal Injury Center in Fukuoka, Japan, between July 2005 and April 2011. All patients

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Received 18 February 2013; revised 25 July 2013; accepted 28 July 2013; published online 17 September 2013

underwent dynamic cervical radiographs, computed tomography, magnetic resonance imaging and neurologic examination on admission. Because the purpose of this study was to assess functional recovery under similar pathological conditions, we selected patients with similar diagnoses and injury levels. Therefore, we retrospectively selected 60 of the 526 patients based on the following criteria: (1) admission within 3 days following injury, (2) observation for >6 months, (3) CSCI without major bone injury, (4) evidence of C3–4 cord injury with T2-weighted magnetic resonance images and (5) nonsurgical treatment. Minor bone injuries were considered a small avulsion fracture of the vertebral body, spinous process fracture or bone bruise in the vertebral body without noticeable vertebral collapse.¹ Patients were excluded from the study if they experienced complications that required their transfer to another unit or hospital for treatment (for example, respiratory or heart failure). Evidence of preinjury cervical myelopathy was also an exclusion criterion. The 60 patients selected for the study included 54 men and 6 women, with a mean age of 63.2 ± 10.7 years (median, 65 years; range, 34–82 years) at the time of injury.

For each patient, we documented both the upper extremity motor score (UEMS; range, 0–50) and lower extremity motor score (LEMS; range, 0–50) from the American Spinal Injury Association (ASIA) motor score system.¹¹ In addition, we documented the modified Frankel grade,^{12–14} and the lowest level of residual cervical motor function based on the ASIA key muscle groups (C5, elbow flexors; C6, wrist extensors; C7, elbow extensors; C8, finger flexors; T1, finger abductors; Table 1).¹¹ The lowest level of residual cervical motor function was defined as the most caudal level to which any observable movement with gravity eliminated could be attributed. In addition, we used our own upper extremity function scale that evaluated the ability to eat a meal independently (Table 2 and Figure 1). Patients were assigned to one of two groups based on their ratings in this scale and finger movement ability (A and B: unable to use their fingers; C–E: able to use their fingers). In the analysis, we performed further comparisons between these two groups. A spine surgeon and a physiotherapist, each with over 5 years of experience in practice, performed the neurological evaluations at 3 days and 6 months after the injury. The average follow-up period was 24.2 months (range, 7–60 months) after the injury. Our institutional review board approved this research project, and all

subjects provided written informed consent before they were included in this retrospective study.

Statistical analysis

The relationships between the modified Frankel grade and the upper extremity function scale, and between the lowest level of residual cervical motor function and the upper extremity function scale, were assessed using χ^2 tests. The relationship between age and the upper extremity function scale were assessed using Student's *t*-test. The relationship between the ASIA motor score (UEMS and LEMS) and the upper extremity function scale were assessed using the Mann–Whitney test. Spearman's correlation coefficients were used to assess the relationships between age, UEMS and LEMS at 3 days after injury, and to assess the relationship between age, UEMS, LEMS and the upper extremity function scale at 6 months. All statistical analyses were conducted using JMP software (version 8; SAS Institute, Cary, NC, USA); *P*-values of <0.05 were considered significant.

RESULTS

The means for ASIA motor scores, UEMS and LEMS for all patients at 3 days after injury were 37.6 ± 29.8 , 13.3 ± 12.0 and 24.3 ± 19.8 , respectively. The relationship between the modified Frankel grade at 3 days and the upper extremity function scale at 6 months is shown in Table 3. Out of 12 patients, 7 (58%) who were Frankel grade A, B1 or B2 at 3 days after injury were unable to bring their hand to their mouth (grade A) at 6 months. Only 4 out of 14 patients (29%) who were Frankel grade C1 at 3 days after injury were able to use their fingers (grades C and D) at 6 months, whereas 21 out of 22 patients (95%) who were Frankel grade C2 at 3 days were able to use their fingers (grades C and D) at 6 months. Thus, most of these patients with CSCI (95%) were able to use a spoon at 6 months if they were

Table 1 The modified Frankel grading system

Grade	Neurological status
A	Complete: no motor or sensory function
B	Sensory only: some sensation preserved, no motor function
B1	Touch sensation remains in only sacral lesion
B2	Touch sensation remains in L/E
B3	Pain sensation remains in sacral lesion or L/E
C	Motor useless: some sensory and motor function, but motor function not useful
C1	Unable to flex the hip and knee from supine (Hip flexors 0–2)
C2	Able to flex the hip and knee from supine (Hip flexors 3–5)
D	Motor useful: sensory function preserved, motor function weak but useful
D0	MMTs of L/E are 4–5, but because of an acute phase, it is impossible to test the walking ability
D1	Able to walk with a walker, but not practiced, usually use a wheel chair
D2	Independent gait with a cane
D3	Independent gait without a cane
E	Normal: normal sensory and motor function (hyperreflexia and numbness are permitted)

Table 2 The upper extremity function scale

Grade A	Require full support (unable to raise hand to mouth)
Grade B	Unable to use a spoon/fork without a brace
Grade C	Able to use a thick-handled spoon/fork
Grade D	Able to use a normal spoon/fork
Grade E	Normal

Grades A and B: unable to use fingers.
Grades C–E: able to use fingers.

Figure 1 A brace used by patients with grade B (a), and a thick-handled fork used in patients with grade C (b). Scores were determined by the upper extremity function scale.

Table 3 Relationship between the modified Frankel grade at 3 days and upper extremity function at 6 months

Modified Frankel grade at 3 days	Number of patients	Upper extremity function scale at 6 months				
		A	B	C	D	E
A	3	2	1	0	0	0
B1	1	1	0	0	0	0
B2	8	4	3	1	0	0
B3	3	0	3	0	0	0
C1	14	0	10	2	2	0
C2	22	0	1	2	19	0
D1	6	0	0	0	6	0
D2	3	0	0	0	2	1
Total	60	7	18	5	29	1

able to flex their hip and knee from a supine position 3 days after injury. Significant differences were found between those with Frankel grades C1 and C2 in their ability to use their fingers ($P<0.001$), which indicated that the ability to perform hip and knee flexion from a supine position at 3 days is an important factor for an important prognostic factor.

The relationship between the lowest level of residual cervical motor function at 3 days and the upper extremity function scale at 6 months is shown in Table 4. Only 7 out of 24 patients (29%) with residual C5 level functions at 3 days were able to use their fingers at 6 months, whereas 6 out of 7 patients (86%) with residual C7 level functions, and 18 out of 19 patients (95%) with residual C8 level functions, were able to use their fingers. Therefore, most of these patients (86%) could use a spoon at 6 months if they had some active elbow extension range at 3 days. By comparing finger movement ability, we observed a significant difference between the residual level of cervical motor functions at the C6 level or higher and at the C7 level or lower ($P<0.001$), indicating that elbow extension at 3 days after injury is an important prognostic factor.

Factors affecting upper extremity functional recovery are shown in Table 5. We observed significant differences for the age at injury, the UEMS and the LEMS determined 3 days after injury between patients who were unable (grades A and B) or able to use their fingers (grades C–E) at 6 months after injury. This indicates that younger patients and patients with higher UEMS and LEMS at 3 days significantly improved their finger movement ability. Spearman's rank correlation coefficients revealed a weak correlation ($\rho = -0.25$) between age at 3 days and the upper extremity function scale at 6 months (Figure 2a), a strong correlation ($\rho = 0.74$) between UEMS at 3 days and the upper extremity function scale at 6 months (Figure 2b) and a strong correlation ($\rho = 0.81$) between LEMS at 3 days and the upper extremity function scale at 6 months (Figure 2c).

Table 4 Relationship between the lowest level of residual cervical motor function at 3 days and the upper extremity function at 6 months

Lowest level of RCMF at 3 days	Number of patients	Upper extremity function scale at 6 months				
		A	B	C	D	E
C4	5	3	1	1	0	0
C5	24	4	13	3	4	0
C6	2	0	2	0	0	0
C7	7	0	1	0	6	0
C8	19	0	1	1	17	0
T1	3	0	0	0	2	1

Abbreviation: RCMF, residual cervical motor function.

Table 5 Factors affecting functional recovery for the upper extremities

	Unusable (A, B)	Usable (C, D, E)	P-value
Age (years)	66.6 ± 9.2	60.8 ± 11.3	0.039
UEMS at 3 days	5.4 ± 3.1	18.9 ± 12.7	<0.001
LEMS at 3 days	6.6 ± 9.3	36.9 ± 15.0	<0.001

Abbreviations: LEMS, lower extremity motor score; UEMS, upper extremity motor score.

Seven patients were unable to raise their hands to their mouth (grade A) at 6 months. These patients required full support to perform this movement because they had severe paralysis (four patients), severe contracture with pain at the shoulder (three patients) or dementia (two patients). One of the patients had a combination of severe paralysis, severe contracture with pain and dementia.

DISCUSSION

We observed the potential for functional recovery in patients with CSCI without major bone injury following nonsurgical treatment.^{2,6} Nevertheless, few studies document the prognosis for paralysis, especially for the upper extremities.^{9,10} Ishida and Tominaga⁹

Figure 2 The correlation between age at injury and the upper extremity function scale (a), between UEMS at 3 days and the upper extremity function scale (b) and between LEMS at 3 days and the upper extremity function scale (c).

reported that a favorable prognosis for upper extremity recovery can be predicted following nonsurgical treatment in patients with acute central cervical cord injury. Our study demonstrated that >95% of patients with CSCI who were able to flex their hip and knee from a supine position at 3 days after injury were able to use a spoon at 6 months. Furthermore, >86% of our patients with CSCI who had some active elbow extension range at 3 days could use a spoon at 6 months. We suggest that these results can aid physicians and therapists in setting rehabilitation goals for patients with CSCI.

Many studies report positive predictors for lower extremity functional recovery in patients with CSCI, but not for upper extremity functional recovery.^{10,15} In previous studies, severe initial neurological damage and an older age were associated with a poor functional outcome.^{9,16,17} Our study showed that a younger age and a high UEMS and LEMS at 3 days after injury predicted improved upper extremity functions. Our findings are similar to those from other studies in that the total ASIA motor score was predictive of outcomes.^{9,16,17} We, however, extend the previous findings and report that both initial UEMS and LEMS can predict upper extremity function. These results are of interest because, to our knowledge, no previous study reports a relationship between initial upper extremity paralysis and its functional recovery. We found a strong correlation between UEMS at 3 days and functional recovery of upper extremities at 6 months. Our results indicate that upper extremity motor recovery might be similar to that for the lower extremities with regard to the recovery from pyramidal tract injury.

We included only patients with C3–4 CSCI without major bone injury in the present study for three reasons. First, these patients were not treated surgically.^{2,6} Second, these patients allowed a more simple assessment of finger function as only paralysis resulting from spinal cord damage was considered, rather than the injured nerve root. Finally, because CSCI without major bone injury occurs predominantly at C3–4, this CSCI patient subgroup is larger than the other subgroups with injuries at other spinal levels. Thus, CSCI without major bone injury at C3–4 was considered an appropriate criterion for evaluating upper extremity function.

Patients with CSCI with C3–4 injury would be expected to be able to raise their hand to their mouth because deltoid and bicep muscle functions are usually preserved, at least to some extent. We observed, however, that 7 out of 60 patients were unable to raise their hand to their mouth at 6 months, and these patients required full support during the movement. Although rehabilitation for these patients began as soon as possible following injury, three patients with a grade A had severe contracture in their shoulders that was accompanied by pain. Diong *et al.*¹⁸ reported that the incidence of shoulder contracture 1 year after spinal cord injury was 43%. This type of contracture is associated with CSCI, and injury at C3–4 might result in shoulder pain, as well as muscle weakness.

The present study has some limitations. First, this was a retrospective study and was based on a small number of patients. Second, the degree of paralysis differs according to the spinal level of the injury, and we did not examine all levels of CSCI. Therefore, further study is needed to evaluate injury at other spinal levels.

CONCLUSIONS

We observed upper extremity functional recovery in patients with CSCI without major bone injury, and without surgical treatment. Our study demonstrates that hip and knee flexion from a supine position, and some observable elbow extension at 3 days after the injury, predicted a positive prognosis for upper extremity function at 6 months after injury. A younger age and higher UEMS and LEMS scores at 3 days were also factors affecting functional recovery.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We thank Mr R Watanabe, OT, and Mr K Iwahashi, OT, for their suggestions with regard to rehabilitation of the upper extremities.

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