Prevalence of Cervical Canal Stenosis in Patients with Femoral Fracture: A Retrospective Single-Center Study

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Abstract:

Introduction: Cervical spine surgery reduces falls and subsequent femoral fractures. Nonetheless, current evidence on the prevalence of cervical cord compression (CCC) and increased signal intensity (ISI) in patients with femoral fractures is limited. We aimed to determine the prevalence of CCC and ISI and characterize the physical status and imaging findings using cervical spine magnetic resonance imaging (MRI) and brain computed tomography (CT) in patients with femoral fractures.

Methods: This study included 173 patients (140 women, 33 men) with femoral fractures caused by falling, who underwent both cervical spine MRI and brain CT. CCC cases classified as grade 2 (compression of less than one-third of the spinal cord) or higher were investigated. The ISI of the severely affected intervertebral disc level was evaluated using T2-weighted MRI. Hand grip strength and myelopathic signs were also evaluated. Data analysis was performed using the χ^2 test, Fisher's exact test, and Student's *t*-test.

Results: Among the 173 patients, 83 (48.0%) had CCC, 29 (16.8%) had ISI, and 68 (39.3%) had abnormal brain CT findings. There was no ISI in patients in the non-CCC group. The patients' average age in the CCC group was significantly higher than that in the non-CCC group. There was no significant difference in the proportion of myelopathic sign and abnormal brain CT findings between the CCC and non-CCC groups or between the ISI and non-ISI groups. Bilateral hand grip strength was significantly negatively correlated with the stenosis rate (right, p=0.047; left, p=0.0018).

Conclusions: In conclusion, our study showed that patients with femoral fractures had a high frequency of cervical canal stenosis and intracranial lesions using cervical spine MRI and brain CT.

Keywords:

cervical cord compression, hip fracture, cognitive impairment, magnetic resonance imaging, computed tomography, silent brain infarction, hand grip strength

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Introduction

Cervical myelopathy is a disabling syndrome associated with symptomatic spinal cord compression caused by cervical degenerative disease. Patients often present with various symptoms, such as hand clumsiness, worsening handwriting, difficulty in grasping objects, numbness in the hands, and increasing difficulty with balance and ambulation[1)]. A Japanese population-based study further reported a prevalence of 24.4% for cervical cord compression (CCC)[2)]. Nonetheless, the subtle and varied presentations of cervical myelopathy can result in a delayed diagnosis or misdiagnosis of cervical myelopathy[3)].

Recent reports have shown that the progression of cervical myelopathy, including gait imbalances, can lead to falls and subsequent fragility fractures[4,5)]. In particular, hip fractures are serious injuries that can worsen the mortality rate[6,7)]. This can result in subsequent fractures[8,9)] and an increase in the medical cost[10)]. Some authors have demonstrated that cervical surgery reduces falls and therefore recommend it[11)]. However, there is a paucity of information on CCC and increased signal intensity (ISI) in the cervical spi-

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nal cord of patients with femoral fractures, including muscle strength and myelopathic signs, which may be factors for surgical decision-making. Additionally, brain lesions and cognitive impairment may deteriorate an individual's physical capacity. The present study aimed to determine the prevalence of CCC and ISI in patients with femoral fractures and to characterize the physical status and imaging findings of these patients using cervical spine magnetic resonance imaging (MRI) and brain computed tomography (CT).

Materials and Methods

This research has been approved by the Institutional Review Board of the authors' affiliated institution, and written informed consent was obtained from all the patients or their families.

From July 2009 to May 2013, 192 patients with femoral fractures caused by falls were admitted to the authors' affiliated institution. Patients who underwent both cervical spine MRI and brain CT were included in our study.

Physical and mental examinations

Deep tendon reflexes, including those of the biceps, triceps, patella, and Achilles tendon, were examined. Pathologic reflexes, including the Hoffmann's, Wartenberg's, and Babinski's reflexes and ankle clonus, were examined in each patient. Patients with hyperreflexia at levels below the segment of canal stenosis or any positive pathologic reflex were determined to have myelopathic signs according to the report by Seichi et al[12]. The grip strength of each hand was measured using a Jamar hydraulic hand dynamometer (Lafayette Instrument Co., Lafayette, IN, USA). Additionally, patients were asked simple questions such as their current location as well as the date and time; if they could not answer, they were deemed to have cognitive impairment.

Imaging examinations

All the patients underwent cervical spine MRI (EXCITE HD 1.5 Tesla; GE Healthcare, Chicago, IL, USA), and T2-weighted images (repetition time: 3000, echo time: 0.0, flip angle: 90.0°) in the sagittal plane were acquired with a section thickness of 4 mm. The cervical canal stenosis rate was calculated by dividing the anteroposterior diameter of the spinal cord at the compressed disk level by that at the caudal normal disk level. Following the Wakayama Spine Study[2], one spine surgeon assessed from the C2-C3 to C7-Th1 levels and divided the patients into five groups according to the grades of the canal stenosis on T2-weighted image, as follows: grade 0 (normal), grade 1 (disappearance of the subarachnoid space without cord compression), grade 2 (compression of less than one-third of the spinal cord), grade 3 (compression of more than one-third but less than two-thirds of the spinal cord), and grade 4 (compression of more than two-thirds of the spinal cord). The severity of CCC was defined as grade 2 or more at the most severely affected intervertebral disc level. The ISI of the most severely affected intervertebral disc level was evaluated using T2-weighted MRI[13].

All patients underwent brain CT (Hi Speed NX/i-s or Light Speed VCT; GE Healthcare), and images in the axial plane were acquired with a section thickness of 5 mm. The brain CT scans were read by radiologists and any abnormal findings—including low-density areas representing old brain infarction or brain hemorrhage, chronic subdural hematoma, or clipping for subarachnoid hemorrhage—were determined to be abnormal brain CT findings.

Statistical analysis

The prevalence of sex, cognitive impairment, abnormal brain CT finding, fracture type, and fracture side was compared between the CCC and non-CCC groups and between the ISI and non-ISI groups using the χ^2 and Fisher's exact tests. The data, including age and hand grip strength, were compared between the CCC and non-CCC groups and between the ISI and non-ISI groups using the Student's *t*-test. The prevalence of cognitive impairment was compared between the patients with normal brain CT findings and those with abnormal brain CT findings using the χ^2 test. A correlation coefficient between bilateral hand grip strength and cervical canal stenosis rate was determined. Statistical analysis was performed using Bell Curve for Excel (Social Survey Research Information Co., Ltd., Tokyo, Japan). All the statistical tests were performed at a two-sided significance level of 0.05.

Results

Baseline characteristics

The study included 173 patients (140 women and 33 men) with an average age of 81.9 years (range, 46-100 years). Regarding history of brain disease, 5 patients had cerebral hemorrhage, 4 had brain infarction, 1 had brain tumor resection, 1 had subdural hematoma, 1 had subarachnoid hemorrhage, and 1 had spinocerebellar degeneration. Eighty-two patients had right femoral fractures, 91 had left femoral fractures, and none had bilateral femoral fractures (Table 1). Femoral fractures were located at the femoral neck in 45 patients, trochanter in 109, sub-trochanter in 6, diaphysis in 9, and supracondylar femur in 3. The treatment included proximal femoral intramedullary nailing in 110 patients, multiple pinning in 6, plating in 7, bipolar hip arthroplasty in 34, intramedullary nailing in 5, and conservative treatment in 11 (Table 2).

Physical and mental examinations

Among the 173 patients included in the study, 107 (61.8%) exhibited some myelopathic signs and 84 (48.6%) had cognitive impairment. The average right hand grip strength of 171 patients (2 patients could not be examined because of cognitive impairment) was 8.9±7.7 kg, and there was a significant negative correlation with the stenosis rate

Table 1. Patient Characteristics and Baseline Functions.

Characteristic/Function	Value
Sex	
Female, n	140
Male, n	33
Age, years	81.9 (46–100)
Cognitive impairment, n	84 (48.6%)
Hand grip strength, kg	
Right	8.9±7.7
Left	8.8±7.4
Fracture side, n	
Right	82
Left	91
Brain CT evaluation, n	
Normal	105
Low-density area	61
Subdural hemorrhage	5
Clipping	2

CT: computed tomography

Table 2. Fracture Locations and Treatments.

Location	Treatment method					
	PFN	BHA	Plate	MP	IN	Cons.
Neck, n	4	32		6		3
Trochanteric, n	103	2				4
Subtrochanteric, n	3		1		1	1
Diaphyseal, n			4		4	1
Supracondylar, n			2			1
Total, n	110	34	7	6	5	11

PFN: proximal femoral intramedullary nail; BHA: bipolar hip arthroplasty; MP: multiple pinning; IN: intramedullary nail; Cons.: Conservative

(r=−0.15, p=0.047). The average left hand grip strength of 171 patients (2 patients could not be examined because of cognitive impairment) was 8.8±7.4 kg, and there was a significant negative correlation with the stenosis rate (r=−0.23, p=0.0018).

Image findings

On cervical spine MRI, cervical compression was graded 0 in 53 patients, 1 in 37, 2 in 59, 3 in 22, and 4 in 2, and the grade was ≥2 in 83 patients (47.9%) (Table 3). As seen in Fig. 1, the prevalence of CCC (≥grade 2) by age group for patients aged 69 years and younger, 70-79 years, 80-89 years, and 90 years and older were 25%, 32%, 51%, and 73%, respectively. As seen in Table 3, 29 of the 173 patients (16.8%) had ISI in total; 14 of the 59 patients in grade 2 had ISI; 13 of the 22 in grade 3 had ISI; and 2 of the 2 patients in grade 4 had ISI. There was no ISI in patients with grades 0 and 1.

Based on brain CT evaluation, 68 patients (39.3%) had abnormal brain CT findings (low-density area in 61, subdural hematomas in 5, and clipping for subarachnoid hemorrhage in 2). The proportion of those with cognitive impairment was higher among patients with abnormal brain CT findings than among those with normal brain CT findings (χ^2 test, p=0.033).

CCC vs. non-CCC groups

The CCC group consisted of 72 women and 11 men, whereas the non-CCC group comprised 71 women and 19 men; the sex proportion was not significantly different between the groups (χ^2 test, p=0.17). The average age of the patients in the CCC group was 84.4±8.5 years, and that of the patients in the non-CCC group was 79.5±9.3 years; the age was significantly different between the groups (Student's *t*-test, p=0.0004). Forty-nine patients in the CCC group and 59 in the non-CCC group had myelopathic sign; there was no significant difference in the ratio of myelopathic sign between the groups (χ^2 test, p=0.37). There was no significant difference in the ratio of abnormal brain CT (χ^2 test, p=0.46) as well as in the ratio of cognitive impairment between the CCC and non-CCC groups (χ^2 test, p=0.57). The average right hand grip strength of the CCC group was 7.7±6.8 kg, and that of the non-CCC group was 9.9±8.4 kg, which was not significantly different (Student's *t*-test, p=0.06). The average left hand grip strength of the CCC group was 7.1±6.9 kg, and that of the non-CCC group was 10.3±7.6 kg, which was significantly different (Student's *t*-test, p=0.006) (Table 4).

ISI vs. non-ISI groups

The ISI group comprised 25 women and 4 men, whereas the non-ISI group comprised 118 women and 26 men; the sex proportion was not significantly different between the two groups (χ^2 test, p=0.58). The average age of the patients in the ISI group was 84.3±8.3 years, and that of the patients in the non-ISI group was 81.4±9.4 years; the age was not significantly different between the groups (Student's *t*-test, p=0.13). Nineteen patients in the ISI group and 89 in the non-ISI group showed myelopathic sign; there was no significant difference in the ratio of myelopathic sign between the groups (χ^2 test, p=0.17). There was no significant difference in the ratio of abnormal finding on brain CT (χ^2 test, p=0.8) as well as in the ratio of cognitive impairment between the ISI and non-ISI groups (χ^2 test, p=0.29). The average right hand grip strength of the ISI group was 6.2±6.3 kg, and that of the non-ISI group was 9.4±7.9 kg, which was significantly different (Student's *t*-test, p=0.041). The average left hand grip strength of the ISI group was 6.4±6.5 kg, and that of the non-ISI group was 9.3±7.5 kg, which was not significantly different (Student's *t*-test, p=0.056) (Table 5).

Discussion

The strength of our study is that we obtained the exact frequency of cervical canal stenosis and intracranial lesions in patients with femoral fracture using cervical MRI and

Table 3. Stenosis Grade, Disc Level, and Increased Signal Intensity.

CCC	Site	Grade 0	1	2	3	4	Total
+	C2/3						0
	C3/4			10 (2)	8 (4)	1 (1)	19 (7)
	C4/5			22 (4)	8 (5)		31 (9)
	C5/6			24 (8)	6 (4)	1 (1)	32 (13)
	C6/7			3 (0)			3 (0)
	C7/Th1						0
−		53 (0)	37 (0)				
	Total	53 (0)	37 (0)	59 (14)	22 (13)	2 (2)	173 (29)

All numbers within parentheses "( )" indicate the numbers of patients with increased signal intensity on magnetic resonance imaging.
Grade 0: normal; grade 1: disappearance of the subarachnoid space without spinal cord compression; grade 2: stenosis <1/3; grade 3: ≥1/3 stenosis <2/3; grade 4: stenosis ≥2/3.
CCC: cervical cord compression

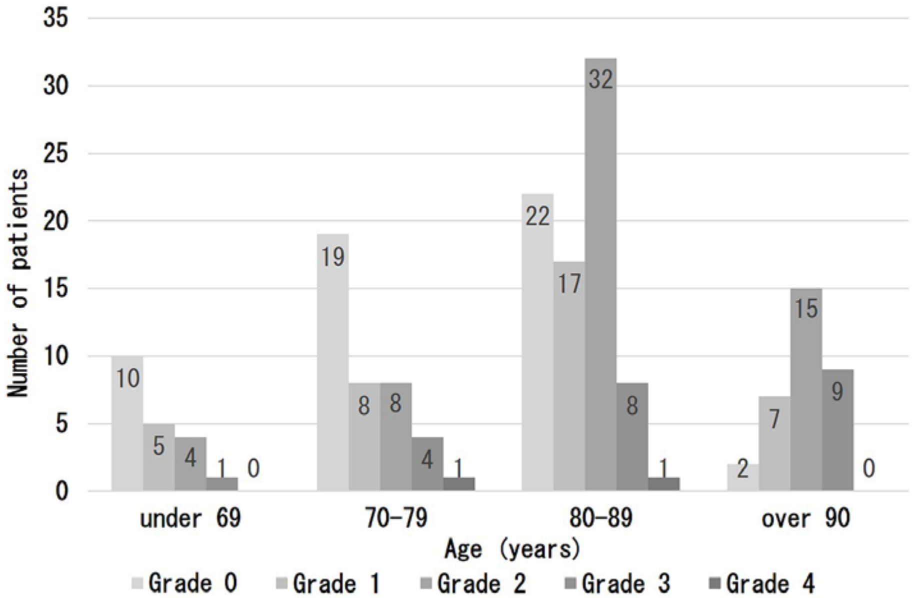

Figure 1. Frequency of the Cervical Canal Stenosis Grades by Ages.
Grade 0: normal; grade 1: disappearance of the subarachnoid space without spinal cord compression; grade 2: stenosis <1/3; grade 3: ≥1/3 stenosis <2/3; grade 4: stenosis ≥2/3.

brain CT for the first time. Previous studies on cervical myelopathy in patients with femoral fractures did not perform any imaging examination[4,5]. Our study showed that the prevalence of CCC and ISI in patients with femoral fracture was 47.9% (83 of 173 patients) and 16.8% (29 of 173 patients), respectively. The prevalence of CCC and ISI is higher than those of past reports on Japanese residents. For example, the CCC rate in 70-79-year-old patients was as high as 32.5% in our study, while it was 22.9% in the Wakayama Spine Study[2]. The prevalence of ISI among patients aged 70-79 years was as high as 12.5% in our study, while it was 6.5% among healthy volunteers without symptoms related to sensory or motor disorders, or severe neck pain[14]. The higher prevalence of CCC and ISI in our patients supports the idea that cervical myelopathy is a risk factor for falls and subsequent femoral fractures.

Based on the previously reported positive predictive value of ISI of 88.9%[15], it can be inferred that at least 14.9% patients had cervical myelopathy in this study. This frequency is reasonable because it was close to that previously reported by Radcliffe et al. (18%)[4], indicating that treating these patients may prevent several femoral fractures. Kimura et al. reported that surgical intervention for degenerative cervical myelopathy was effective in reducing the frequency of falls in a prospective study[11]. Horowitz et al. revealed that the surgical management of cervical spondylotic myelopathy may be protective against the risk of fragility fracture[5]; however, the authors also reported that 58 cervical decompression surgeries are needed to prevent only one fragility fracture. If femoral fractures are most efficiently prevented

Table 4. Characteristics of the Cervical Cord Compression and Non-Cervical Canal Compression Groups.

Characteristic	CCC Group (n=83)	Non-CCC Group (n=90)	p-value
Sex, n			0.17
Female	72	71	
Male	11	19	
Age, years	84.4±8.5	79.5±9.3	0.0004
Myelopathic sign, n	49	59	0.37
Abnormal brain CT finding	35	33	0.46
Cognitive impairment, n	46	46	0.57
Right hand grip strength, kg	7.7±6.8	9.9±8.4	0.06
Left hand grip strength, kg	7.1±6.9	10.3±7.6	0.006
Fracture type, n			0.42
Neck	8	21	
Trochanteric	53	56	
Subtrochanteric	1	5	
Diaphyseal	3	6	
Supracondylar	2	1	
Periprosthetic	0	1	
Fracture side, n			0.9
Right	39	43	
Left	44	47	

Table 5. Characteristics of the Increased Signal Intensity and Non-Increased Signal Intensity Groups.

Characteristic	ISI Group (n=29)	Non-ISI Group (n=144)	p-value
Sex, n			0.58
Female	25	118	
Male	4	26	
Age, years	84.3±8.3	81.4±9.4	0.13
Myelopathic sign, n	19	89	0.17
Abnormal brain CT finding	12	56	0.8
Cognitive impairment, n	18	74	0.29
Right hand grip strength, kg	6.2±6.3	9.4±7.9	0.041
Left hand grip strength, kg	6.4±6.5	9.3±7.5	0.056
Fracture type, n			0.29
Neck	5	40	
Trochanteric	23	86	
Subtrochanteric	0	6	
Diaphyseal	0	9	
Supracondylar	1	2	
Periprosthetic	0	1	
Fracture side, n			0.76
Right	13	69	
Left	16	75	

by spine surgery, screening methods should be considered to select the most suitable patients.

Our study showed a strong relationship between hand grip strength and cervical canal stenosis. Low hand grip strength was found to be a significant predictor of reduced gait ability in patients with hip fracture in recent reports[16-18]. Our new findings indicate that CCC is involved in the mechanism between hand grip strength and gait ability. Therefore, CCC may decrease hand grip strength and increase susceptibility to falls. Grip strength measurement can be an important test not only for predicting walking ability but also for screening for cervical myelopathy. The myelopathic sign is not related to CCC or ISI, and it is thought that common diseases of the elderly, such as brain lesions, spinocerebellar degeneration, and lumbar spinal canal stenosis, may modify the myelopathic sign[19-21]. Therefore, the assessment of myelopathic signs alone is not useful for screening for cervical spinal canal stenosis.

Sixty-eight of the 173 patients (39%) had abnormal brain CT findings, and most of the findings (61/68) were low-density areas representing old brain infarctions or brain hemorrhages. Considering that there were only 13 patients with a known history of brain disease, most of them may have had silent brain infarction based on a past brain MRI study[22]. Silent brain infarction has been reported to increase the risk of cognitive impairment, which decreases psychomotor speed and memory performance[23]. Similar results were obtained in our study; patients with abnormal brain CT findings were significantly more likely to have cognitive impairment than those without. Therefore, brain disease may be an important risk factor for falls as well as cognitive impairment.

In the present study, the prevalence of cognitive impairment was 48.6%, which is higher than the reported rate of 10%-20% among 80-84-year-old adults without femoral fracture in Japan[24]. The high cognitive impairment rate in our study indicates that this impairment may be a risk factor for falls and subsequent fractures; this is consistent with the findings of previous studies showing that cognitive impairment leads to gait function deterioration[25,26]. We found that the prevalence of CCC and ISI was not related to the prevalence of cognitive impairment. From this result, we hypothesized that cervical myelopathy and cognitive impairment may independently contribute to the tendency toward falls. The high prevalence of cognitive impairment suggests that improving mental aspects of patients is the key for treating cervical myelopathy and hip fracture.

One of the limitations of this study is that the patients were not interviewed about the symptoms of cervical myelopathy, such as the numbness of fingers or gait disturbance, due to severe cognitive impairment. If these symptoms were determined, the frequency of cervical myelopathy could have been calculated. Another study limitation was that the imaging examinations, i.e., cervical radiography or cervical CT, could not be used to evaluate the prevalence of cervical ossification of the posterior longitudinal ligament. Finally, the diagnosis of cognitive impairment in this study might not be accurate, as the diagnosis was not made by a psychiatrist based on brain MRI findings or a questionnaire. Furthermore, it is possible that the diagnosis of cognitive impairment may have been affected by delirium in the acute phase of trauma.

In conclusion, our study showed that of 173 patients with femoral fracture, 83 (48.0%) had CCC, 29 (16.8%) had ISI, and 68 (39.3%) had abnormal brain CT findings. This study showed the prevalence of cervical spinal stenosis using MRI. Further research is required to determine the prevalence of cervical myelopathy.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: Toru Yokoyama designed the study.

Hirotsugu Omi, Toru Yokoyama, Kazunari Takeuchi, and Takuya Naraoka performed the medical examinations.

Sanae Omi wrote about brain CT.

Hirotsugu Omi evaluated cervical spine MRI and wrote the manuscript.

Ethical Approval: This study was approved by the institutional review board of the Odate Municipal General Hospital (approval number: 02-21).

Informed Consent: Written informed consent was obtained from all patients or their families.

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