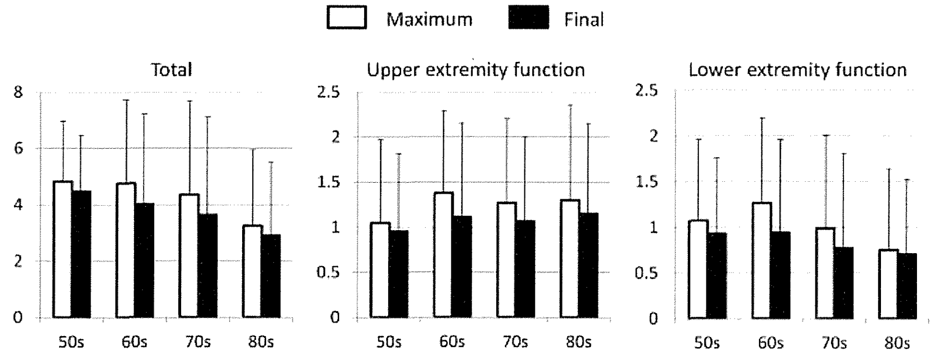

Fig. 3 Acquired points (p = not significant).

maximum and final assessments were 1.1 and 0.9 in group 50s, 1.3 and 0.9 in group 60s, 1.0 and 0.8 in group 70s, and 0.8 and 0.7 in group 80s, respectively (►**Fig. 3**). Although there were no significant differences in acquired points between the groups in each category through all the periods, the acquired points of the lower extremities tended to be low in groups 70s and 80s.

Preoperative Comorbidities and Postoperative Complications

In terms of the preoperative comorbidities, hypertension was observed in 5 patients (24%) in group 50s, 11 (34%) in group 60s, 20 (54%) in group 70s, and 8 (80%) in group 80s, and diabetes mellitus was detected in 3 patients (14%) in group 50s, 7 (22%) in group 60s, 12 (32%) in group 70s, and 5 (50%) in group 80s (►**Table 1**). In the patients with hypertension (HT +), the average JOA scores at the preoperative, postoperative maximum, and final assessments were 7.9, 12.5, and 11.8 points, respectively. And in the patients without hypertension (HT−), they were 9.3, 13.7, and 13.1 points, respectively. The average acquired points at the postoperative maximum and final assessments were 4.6 and 4.0 in HT+ patients and 4.3 and 3.7 in HT− patients, respectively. Although the average JOA scores at the preoperative, postoperative maximum, and final assessments were significantly lower for HT+ patients than for HT− patients, no significant difference was detected in the average acquired points at the postoperative maximum and final assessments. In the patients with diabetes mellitus (DM +), the average JOA scores at the preoperative, postoperative maximum, and final assessments were 7.9, 11.7, and 11 points, respectively. And in the patients without diabetes mellitus (DM −), they were 9.0, 13.1, and 13.7 points, respectively. The average acquired points at the postoperative maximum and final assessments were 3.8 and 3.1 in DM+ patients and 4.7 and 4.1 in DM− patients, respectively. Although the average JOA scores at the postoperative maximum and final assessments were significantly lower for DM+ patients than for DM− patients, no significant differences were detected in the average preoperative JOA score or average acquired points at the postoperative maximum and final assessments.

Regarding the postoperative complications, C5 nerve palsy was observed in 1 patient each in groups 50s (4.8%), 70s (2.7%), and 80s (10%) and 2 in group 60s (6.3%). Delirium was observed 3 (8%) in group 70s and 2 (20%) in group 80s. One patient in group 60s had a cerebral infarction (3.1%). There were no surgical site infections in this series (►**Table 2**).

Discussion

Cervical laminoplasty is a well-reported surgical treatment for cervical myelopathy with CSM, OPLL, and CDH. The long-term clinical and radiologic results of laminoplasty have been investigated, and the risk factors for poor outcomes (age at the time of operation, symptom duration, signal changes in the spinal cord on magnetic resonance imaging, transverse area of the spinal cord at the site of maximum compression, and kyphotic alignment) have been identified.[19–21,25]

In terms of age-related effects on laminoplasty, many authors have reported comparative studies of the surgical outcomes in elderly patients, but their conclusions were controversial because their definitions of *elderly* varied from 65 to 80 years.[7,14,21–26] Therefore, in the present study, the surgical outcomes of laminoplasty were examined in two

Table 2 Postoperative complications

	Group 50s	Group 60s	Group 70s	Group 80s
C5 palsy (%)	1 (4.8)	2 (6.3)	1 (2.7)	1 (10)
Delirium (%)	0	0	3 (8.1)	2 (20)
Cerebral infarction (%)	0	1 (3.1)	0	0
SSI	0	0	0	0

Abbreviation: SSI, surgical site infection.

ways: (1) the Spearman rank correlation coefficient between age and clinical outcome; and (2) the surgical outcomes by decade without a definition of *elderly*.

In the present study, a negative correlation was detected between age and preoperative JOA scores, but the decade classification did not show a significant difference. Furthermore, the postoperative JOA scores decreased significantly with aging. Symptom duration has often been discussed as one of the causes of the poor preoperative condition in elderly patients. Several authors have reported that long symptom duration contributed to the poor surgical outcomes of laminoplasty, especially in elderly patients.[19,21,25] Generally, surgeons hesitate to operate on elderly patients due to their comorbidities; however, in the acquired points, there were no significant difference between the patients with or without comorbidities in the present study. Delaying surgical treatment for elderly patients causes prolonged symptom duration, and severe myelopathy may develop. Nagata et al recommended that the surgical treatment be done as soon as possible after onset of progressive myelopathy in elderly patients.[19] Moreover, Matsunaga et al reported that the neurologic function deteriorated with increasing age in healthy volunteers.[27] The age-related degeneration of the spinal cord, such as a decrease in the number of anterior horn cells and myelinated fibers in the corticospinal tracts and posterior funiculus, might contribute to the preoperative and postoperative status.[28–30] For these reasons, we chose to operate on elderly patients as soon as possible, and there were no significant differences in symptom duration among the decades in the present series.

On the other hand, no correlation was seen between age and acquired points in each category through all periods. Similarly, the analysis by decade showed the same results. In the present study, the acquired points of the lower extremity tended to be low in groups 70s and 80s, and those of the upper extremity did not show any difference among the decades.

Machino et al pointed out one limitation of the recovery rate of the JOA score: the actual surgical outcomes in patients with the same recovery rate might differ according to the preoperative JOA score.[24] Patients with low preoperative JOA scores had poorer surgical outcomes than patients with high preoperative JOA scores, though both of them achieved the same JOA score. They recommended that acquired points should be used for evaluation of elderly patients rather than the recovery rate. Therefore, in the present study, the recovery rate was not calculated, and acquired points were considered for evaluation of surgical outcomes.

One limitation of this study was that the radiologic examinations were not evaluated. Further studies will be necessary to clarify the relationship between the age-related radiologic features and the clinical outcomes. However, to the best of our knowledge, this is the first report of an age-related decline of pre- and postoperative clinical status without defining *elderly*.

In conclusion, although an age-related decline of JOA scores was detected in all periods, there were no severe sequelae and no differences in the acquired points related to age. These results suggest that laminoplasty for cervical myelopathy is useful in elderly patients.

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CERVICAL SPINE

Ossification of the Posterior Longitudinal Ligament of the Cervical Spine in 3161 Patients

A CT-Based Study

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Study Design. A cross-sectional study.

Objective. To examine the prevalence of ossification of the posterior longitudinal ligament (OPLL) and ossification of the nuchal ligament (ONL) of the cervical spine in the San Francisco area.

Summary of Background Data. The prevalence of OPLL and ONL is unknown in the non-Asian population.

Methods. This computed tomography–based cross-sectional study assessed the prevalence of OPLL and ONL within the cervical spine of patients treated at a level 1 trauma center between 2009 and 2012. The prevalence of both OPLL and ONL was compared between racial groups.

Results. Of the 3161 patients (mean age, 51.2 ± 21.6 yr; 66.1% male), there were 1593 Caucasians (50.4%), 624 Asians (19.7%), 472 Hispanics (14.9%), 326 African Americans (10.3%), 62 Native Americans (2.0%), and 84 Others (2.7%). The prevalence of cervical OPLL was 2.2% (95% confidence interval [CI]: 1.7–2.8). The adjusted prevalence was 1.3% in Caucasian Americans (95% CI: 0.7–2.3), 4.8% in Asian Americans (95% CI: 2.8–8.1), 1.9% in Hispanic Americans (95% CI: 0.9–4.0), 2.1% in African Americans (95% CI: 0.9–4.8), and 3.2% in Native Americans (95% CI: 0.8–12.3). The prevalence of OPLL in Asian Americans was significantly higher than that in Caucasian Americans (P = 0.005). ONL was detected in 346 patients and the prevalence was 10.9% (95% CI: 10.0–12.0). The adjusted prevalence of ONL was 7.3% in Caucasian Americans (95% CI: 5.8–9.3), 26.4% in Asian Americans (95% CI: 21.9–31.5), 7.4% in Hispanic Americans (95% CI: 5.2–10.5), 2.5% in African Americans (95% CI: 1.2–4.9), and 25.8% in Native Americans (95% CI: 16.5–37.5). ONL was significantly more common in Asian Americans than in Caucasian Americans, Hispanic Americans, and African Americans (P = 0.001).

Conclusion. This study also demonstrated that OPLL and ONL were significantly more common in Asian Americans than in Caucasian Americans.

Key words: CT, ossification, posterior longitudinal ligament, cervical spine, race.

Level of Evidence: 3

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Ossification of the posterior longitudinal ligament (OPLL) is a condition of ectopic bone formation within the posterior longitudinal ligament. OPLL is regarded as a rare disease in Western countries. However, in the Japanese,[1] OPLL is one of the major entities causing cervical myelopathy and was once called "Japanese disease."[2] According to previous reports, the prevalence of OPLL in the Japanese ranged from 1.9% to 4.3%.[3]

The relatively low prevalence of OPLL (from 0.1% to 1.7%) in Europeans or North Americans[3–6] is thought to be associated with genetic background[7]; however, a lack of familiarity with OPLL might contribute to the low detection rate.

With widespread availability of multislice computed tomography (CT) and growing recognition of OPLL, globally, an increasing number of reports have been published concerning OPLL.[8–10] The increased use of multislice CT has resulted in a higher reported prevalence of OPLL than previously reported using conventional plain radiographs.[11,12] As most previous reports regarding the prevalence of OPLL in western countries were based on plain radiographs, the prevalence of OPLL in the United States is uncertain.

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This study aimed to examine the prevalence of cervical OPLL in various racial groups within the United States and to compare the prevalence of cervical OPLL between racial groups. We hypothesized that Asian Americans would demonstrate a significantly higher prevalence of cervical OPLL and ONL than Caucasian Americans.

MATERIALS AND METHODS

Study Participants

This study was approved by our institutional review board. All patients gave their written informed consent prior to participation in this study.

From January 1, 2009, to September 30, 2012, a cross-sectional review of a prospectively registered database at a level 1 trauma center in San Francisco was performed. All patients who underwent head and neck CT for the purpose of trauma screening were evaluated. Demographic data, including age, sex, race, body mass index (BMI), and coexistence of diabetes mellitus (DM), were recorded. These data were based on a questionnaire completed at the initial visit to the trauma center.

Race was classified as Caucasian American (white on the questionnaire), Asian American, Hispanic American, African American (black on the questionnaire), Native American, and Others in accordance with the classification of the institution. A detailed chart review was performed to examine the incidence of neurological symptoms.

Image Assessment

Cervical OPLL was defined as ectopic OPLL of more than 2 mm in thickness (Figure 1).[13] Osteophytes located near the uncovertebral joint or at the corners of the vertebrae were assumed to be degenerative in nature and were not considered OPLL. Types of OPLL were classified on the basis of the criteria reported by Tsuyama.[13]

Barsony[14] first reported ossification of the nuchal ligament (ONL) within the cervical spine. This disease was examined as one of somatic conditions related to ossification of the spinal ligament.[15,16] Thus, the prevalence of ONL (along with OPLL) was examined as part of the current study (Figure 2).

All computed tomographic scans were acquired using multidetector CT (LightSpeed, GE Healthcare, Milwaukee, WI) with the following parameters: slice thickness, 1.25 mm; pixel size, 0.352 mm; tube rotation speed, 0.5 seconds; beam collimation, 40 mm; beam pitch, 0.9; tube current, 200 mA; and voltage, 120 kV. Both axial images and reconstructed sagittal images were examined with a Picture Archiving and Communication System viewer.

Images were reviewed in 3 steps. An experienced orthopedic spine surgeon (T.F.), who was familiar with OPLL, initially screened all images with identifiers removed. Then, the original reports by radiologists were reviewed. When there was an agreement between the orthopedic surgeon and the radiological report, a definite diagnosis was achieved (κ: 0.70). When there was a disagreement, a final consensus was achieved after discussion with 2 other orthopedic spine surgeons (M.I. and S.H.) and another neuroradiologist (C.C.).

Statistical Analysis

An *a priori* sample size calculation was performed. According to previous reports, which were all based on plain radiographs, the prevalence of OPLL ranged from 1.9% to 4.3% in Japanese,[3] 0.4% to 3.0% in Asians,[3] and 0.1% to 1.7% in Europeans or North Americans.[3-6] There have been many

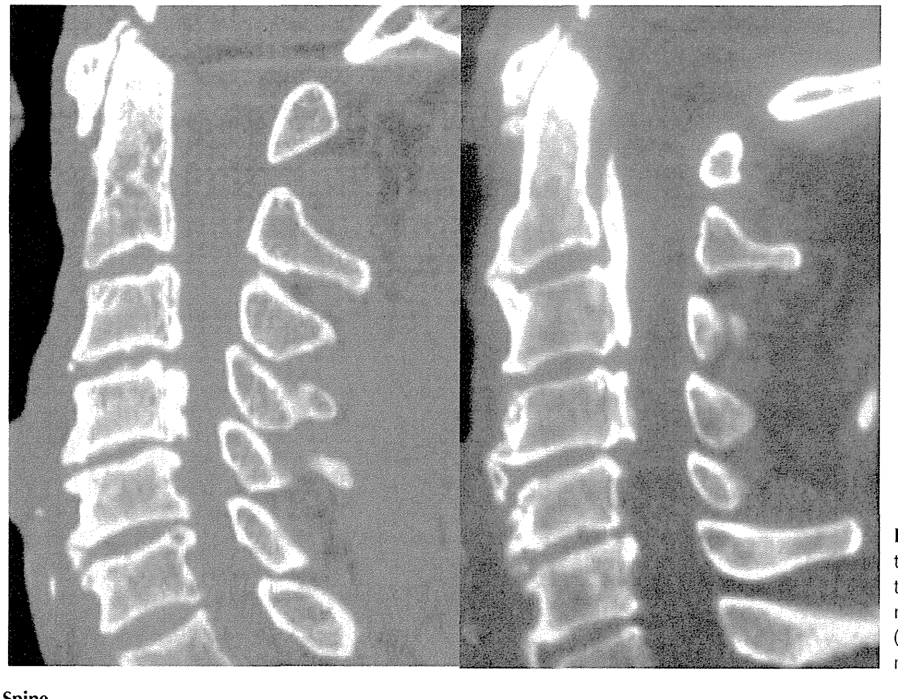

Figure 1. Computed tomographic scan of the cervical spine showing ossification of the posterior longitudinal ligament. A segmental type of ossification is shown at C4 (*left*). A continuous type of ossification is noted at C3 (*right*).

Figure 2. Cervical computed tomographic scan of ossification of the nuchal ligament.

studies supporting a higher sensitivity of CT for identification of ossification of the spinal ligament.[11,12]

We projected that the prevalence of OPLL would be 1% in the current study. A sample size (N) was calculated using the following formula,[17]

$$N = \frac{(Z^2)P(1-P)}{d^2}$$

where z = statistic for the level of confidence (1.96), P = expected prevalence (0.01), and d = allowable error (0.005). A sample size of at least 1521 participants was estimated to be necessary to examine the prevalence of OPLL.

The prevalence of OPLL and ONL was compared among 6 races using Tukey-Kramer procedure for all-possible pairwise comparison using a logistic regression model. Both unadjusted and adjusted analyses were performed to identify potential confounders. Age, sex, and coexistence of DM were included as potential confounders. Prevalence and its 95% confidence interval (CI) were calculated by the direct method of standardization to the 2010 US Census population using the age groups per decade.[18] A P value of less than 0.05 was considered statistically significant. All P values were based on 2-sided tests. Statistical analysis was performed using SAS (SAS Institute, Cary, NC).

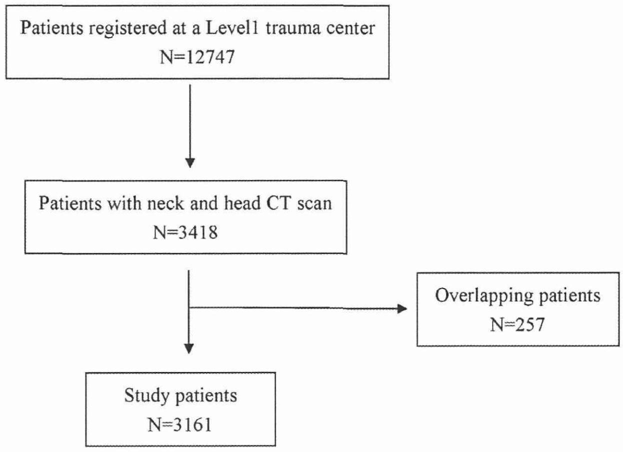

Figure 3. Flow diagram of participants. CT indicates computed tomographic.

RESULTS

Demographic Data

During the study period, 12,747 patients were registered in the trauma database. Of these, 3418 patients underwent head and neck CT. A total of 257 patients underwent CT more than once and these duplicative data were excluded. Finally, 3161 patients were included in the analysis (Figure 3).

The demographic data for the 3161 patients are shown in Table 1. The mean age of the study patients was 51.2 ± 21.6 years. Based on the interview sheets, 251 patients (7.9%) had DM. BMI data were available for 65% of the patients. Mean BMI was 25.5 ± 5.7 kg/m^2.

The racial composition of the study patients corresponded to the population statistics for the San Francisco Bay Area.[18] There were 2089 males (66.1%) and 1072 females (33.9%). Of the 3161 patients, 1593 were Caucasian Americans (50.4%), 624 were Asian Americans (19.7%), 472 were Hispanic Americans (14.9%), 326 were African Americans (10.3%), 62 were Native Americans (2.0%), and 84 subjects were classified as Others (2.7%).

Prevalence of Cervical OPLL

Of the 3161 patients, there were 70 patients with cervical OPLL (48 males and 22 females) (Tables 2 and 3). The overall prevalence of OPLL was 2.2% (95% CI: 1.7–2.8).

With regard to the type of OPLL, 5 patients had continuous type (7.1%), 4 were mixed type (5.7%), 44 were classified as segmental type (62.9%), and 17 were localized type (circumscribed type) (24.3%) (Table 4). OPLL was found primarily at the C5 vertebral body (26.1%), followed by C4 (17.0%), and C6 vertebral bodies (13.3%).

Regarding age, the highest prevalence was observed in patients between 75 and 85 years of age (5.0%), followed by those between 65 and 75 years of age (4.7%), and those between 55 and 65 years of age (3.8%). The mean age of patients with OPLL was significantly higher (65.8 ± 15.0 yr) than those without OPLL (50.9 ± 21.6 yr); P value of less

TABLE 1. Demographic Data of the Study Patients

Race	All	Caucasian	Asian	Hispanic	African American	Native American	Others
N (%)	3161 (100)	1593 (50.4)	624 (19.7)	472 (14.9)	326 (10.3)	62 (2.0)	84 (2.7)
Sex							
Male	2089	1078	345	343	227	36	60
Female	1072	515	279	129	99	26	24
Mean ± SD	51.2 ± 21.6	51.2 ± 20.9	60.5 ± 22.4	43.1 ± 20.2	45.5 ± 18.3	55.8 ± 22.3	45.4 ± 19.8
Age (yr)							
15–25	371	155	52	88	56	6	14
25–35	522	276	63	114	47	9	13
35–45	450	235	60	84	48	6	17
45–55	497	271	58	63	82	5	18
55–65	424	228	83	46	46	10	11
65–75	299	154	83	25	24	10	3
75–85	301	122	129	26	12	10	2
>85	297	152	96	26	11	6	6
BMI (kg/m^2)*							
Mean ± SD	25.5 ± 5.7	25.5 ± 5.5	24.0 ± 5.5	27.2± 6.1	26.1 ± 6.0	24.3 ±4.4	25.9 ± 4.9
Median	25.0	25.0	23.7	26.8	25.0	24.0	25.2
DM (%)	251(7.9)	87 (5.5)	95 (15.2)	32 (6.8)	25 (7.7)	7 (11.3)	5 (6.0)

*Available for 65% of the patients.
BMI indicates body mass index; DM, diabetes mellitus.

than 0.001. Patients with DM had a significantly higher prevalence of OPLL (5.6%) than those without DM (1.9%; odds ratio = 3.0, $P < 0.001$). The prevalence of OPLL in male patients was higher than that in female patients; however, the difference was not significant (2.3% *vs.* 2.1%; $P = 0.7$). The mean BMI of patients with OPLL was significantly higher (27.2 ± 5.3 kg/m^2) than that of those without OPLL (25.6 ± 5.4 kg/m^2); P value of less than 0.047.

Adjusted prevalence of OPLL by age, sex, and DM was 1.3% in Caucasian Americans (95% CI: 0.7–2.3), 4.8% in Asian Americans (95% CI: 2.8–8.1), 1.9% in Hispanic Americans (95% CI: 0.9–4.0), 2.1% in African Americans (95% CI: 0.9–4.8), and 3.2% in Native Americans (95% CI: 0.8–12.3) (Figure 4). The prevalence of OPLL in Asian Americans was significantly higher than that in Caucasian Americans ($P = 0.005$).

Prevalence of Cervical ONL

There were 346 patients with ONL (250 males and 96 females) (Tables 5 and 6). The overall prevalence of ONL was 10.9% (95% CI: 10.0–12.0). Patients with ONL were more likely to have OPLL than those without ONL (7.2% *vs.* 1.6%, odds ratio = 4.8, $P < 0.001$).

Regarding age, the highest prevalence was observed in patients older than 85 years (23.6%), followed by those between 75 and 85 years of age (22.9%) and those between 65 and 75 years of age (20.7%). The mean age of patients with ONL was significantly higher than that of those without ONL (67.9 ± 15.9 yr *vs.* 49.1 ± 21.3 yr; $P < 0.001$). Patients with DM had a significantly higher prevalence of ONL than those without DM (26.7% *vs.* 9.6%, odds ratio = 3.4, $P < 0.001$). The prevalence of ONL in male patients was significantly higher than that in female patients (12.0% *vs.* 9.0%, odds ratio = 1.4, $P = 0.01$). Mean BMI of patients with ONL was not significantly different from that of those without ONL (25.6 ± 5.5 kg/m^2 *vs.* 25.7 ± 5.2 kg/m^2; $P = 0.8$).

Adjusted prevalence of ONL by age, sex, and DM was 7.3% in Caucasian Americans (95% CI: 5.8–9.3), 26.4% in Asian Americans (95% CI: 21.9–31.5), 7.4% in Hispanic Americans (95% CI: 5.2–10.5), 2.5% in African Americans (95% CI: 1.2–4.9), and 25.8% in Native Americans (95% CI: 16.5–37.5) (Figure 5). The adjusted prevalence of ONL in Asian Americans was significantly higher than that in Caucasian Americans ($P = 0.001$), Hispanic Americans ($P = 0.001$), and African Americans ($P = 0.001$). The prevalence of ONL in Native Americans was significantly higher than that in Caucasian Americans ($P = 0.02$) and African Americans ($P = 0.004$).

Incidence of Neurological Symptoms

One patient (0.03%) became completely tetraplegic because of spinal cord injury caused by narrowing of the spinal canal

TABLE 2. Prevalence of Cervical Ossification of the Posterior Longitudinal Ligament Among Races Per Decade

	All			White			Asian			Hispanic		
Race	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**
Total	70	2.2	1.7–2.8	21	1.3	0.8–2.0	30	4.8	3.3–6.8	9	1.9	0.9–3.6
Sex												
Male	48	2.3	1.7–3.0	17	1.6	0.9–2.5	20	5.8	3.6–8.8	5	1.5	0.5–3.4
Female	22	2.1	1.3–3.1	4	0.8	0.2–2.0	10	3.6	1.7–6.5	4	3.1	0.9–7.8
Age (yr)												
15–25	0	0.0		0	0.0		0	0.0		0	0.0	
25–35	0	0.0		0	0.0		0	0.0		0	0.0	
35–45	7	1.6		4	1.7		2	3.3		1	1.2	
45–55	10	2.0		2	0.7		3	5.2		3	4.8	
55–65	16	3.8		6	2.6		7	8.4		0	0.0	
65–75	14	4.7		4	2.6		6	7.2		2	8.0	
75–85	15	5.0		3	2.5		8	6.2		2	7.7	
>85	8	2.7		2	1.3		4	4.1		1	3.8	
DM												
+	14	5.6	3.1–9.2	3	3.4	0.7–9.8	6	6.3		3	9.4	2.0–25.0
−	56	1.9	1.5–2.5	18	1.2	0.7–1.9	24	4.5		6	1.4	0.5–2.9

CI indicates confidence interval; DM; diabetes mellitus.

TABLE 3. Prevalence of Cervical Ossification of the Posterior Longitudinal Ligament in Each Decade Between Races

	African American			Native American			Other		
Race	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**
Total	7	2.1	0.9–4.4	2	3.2	0.4–11.2	1	1.2	0.0–6.3
Sex									
Male	5	2.2	0.7–5.1	1	2.8	0.1–14.5	0	0.0	0.0–6.0
Female	2	2.0	0.3–7.1	1	3.8	0.1–19.6	1	4.2	0.1–21.1
Age (yr)									
15–25	0	0.0		0	0.0		0	0.0	
25–35	0	0.0		0	0.0		0	0.0	
35–45	0	0.0		0	0.0		0	0.0	
45–55	2	2.4		0	0.0		0	0.0	
55–65	2	4.3		0	0.0		0	9.1	
65–75	1	4.2		1	10.0		1	20.0	
75–85	2	16.7		0	0.0		0	0.0	
>85	0	0.0		1	16.7		0	0.0	
DM									
+	0	0.0	0.0–13.7	1	1.3	0.4–57.9	1	20.0	0.5–71.6
−	7	2.3	0.0–4.7	2	1.8	0.1–9.7	0	0.0	0.0–4.6

CI indicates confidence interval; DM, diabetes mellitus.

TABLE 4. Number of Cases (%) Representing Each Type of Ossification of the Posterior Longitudinal Ligament Among Races

	White	Asian	Hispanic	African American	Native American	Others	Total
Continuous	1 (5)	3 (10)	1 (11)	0	0	0	5 (7)
Mixed	2 (10)	2 (7)	0	0	0	0	4 (5.7)
Segmental	10 (48)	18 (60)	8 (89)	6 (86)	2 (100)	0	44 (62.9)
Localized	8 (38)	7 (23)	0	1 (14)	0	1 (100)	17 (24.3)
Total	21	30	9	7	2	1	70

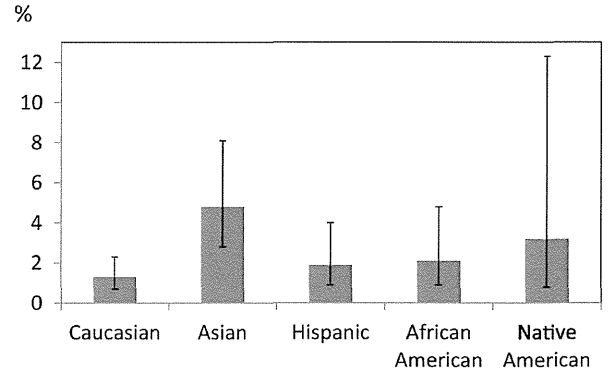

Figure 4. Prevalence of cervical ossification of the posterior longitudinal ligament by race. Error bars indicate 95% confidence interval.

induced by massive OPLL. This Chinese American male patient had an 88% OPLL-occupying ratio within the spinal canal (Figure 6). Although emergent surgery with laminectomy and fusion was performed on this patient, little change in his neurological deficit was noted.

DISCUSSION

To the best of our knowledge, this is the first study to examine the prevalence of OPLL, using CT, in a large cohort of Americans of various racial groups. In the San Francisco Bay area, based on CT, the overall prevalence of cervical OPLL was 2.2% and the prevalence of ONL was 10.9%. Asian Americans demonstrated a significantly higher prevalence of cervical OPLL and ONL than Caucasian Americans.

TABLE 5. Prevalence of Ossification of the Nuchal Ligament Among Races Per Decade

	All			White			Asian			Hispanic		
Race	n	Rate	95% CI	n	Rate	95% CI	n	Rate	95% CI	n	Rate	95% CI
Total	346	10.9	10.0–12.0	117	7.3	6.1–8.7	165	26.4	23.0–30.1	35	7.4	5.2–10.2
Sex												
Male	250	12.0	11–13.0	94	8.7	7.1–10.6	107	31.0	26.2–36.2	27	7.9	5.3–11.3
Female	96	9.0	7.0–11.0	23	4.5	2.9–6.6	58	20.8	16.2–26.0	8	6.2	2.7–11.9
Age (yr)												
15–25	0	0.0		0	0.0		0	0.0		0	0.0	
25–35	4	0.8		2	0.7		2	3.0		0	0.0	
35–45	27	5.8		12	5.1		6	10.0		5	6.0	
45–55	47	9.3		13	4.8		18	31.0		6	9.5	
55–65	71	16.3		22	9.6		31	37.3		8	17.4	
65–75	71	20.7		28	18.2		26	28.9		5	20.0	
75–85	76	22.9		16	10.7		51	36.4		7	26.9	
>85	76	23.6		31	17.8		39	38.5		4	15.4	
DM												
+	67	26.7	21.3–32.6	20	18.4	10.9–28.1	42	44.2	34.0–54.8	6	18.8	7.2–36.4
−	279	9.6	8.5–10.7	101	6.7	5.5–8.1	123	23.3	19.7–27.1	29	6.6	4.5–9.3

CI indicates confidence interval; DM, diabetes mellitus.

TABLE 6. Prevalence of Ossification of the Nuchal Ligament in Each Decade Between Races

	African American			Native American			Other Races		
Race	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**	**n**	**Rate**	**95% CI**
Total	8	2.5	1.1–4.8	16	25.8	15.5–38.5	5	6.0	2.0–13.4
Sex									
Male	8	3.5	1.5–6.8	12	30.6	16.4–48.1	3	5.0	1.0–13.9
Female	0	0.9	0.0–3.7	4	19.2	6.6–39.4	2	8.3	1.0–27.0
Age (yr)									
15–25	0	0.0		0	0.0		0	0.0	
25–35	0	0.0		0	0.0		0	0.0	
35–45	1	2.1		1	16.7		1	5.9	
45–55	4	4.9		2	40.0		3	16.7	
55–65	3	6.5		4	40.0		1	9.1	
65–75	0	0.0		5	50.0		0	0.0	
75–85	0	0.0		2	20.0		0	0.0	
>85	0	0.0		2	33.3		0	0.0	
DM									
+	1	4.0	0.1–20.4	2	28.6	3.7–71.0	0	0.0	0.0–52.2
–	7	2.3	0.9–4.7	14	25.5	14.7–39.0	5	6.3	2.1–14.2

CI indicates confidence interval; DM, diabetes mellitus.

OPLL was first reported in the English literature in the 19th century.[19] In 1838, Key[19] reported 2 cases of paraplegia due to ossification of the spinal ligament in the thoracolumbar region. However, this entity went almost completely unrecognized for more than 120 years, until Tsukimoto,[20] a Japanese orthopedic surgeon, reported an autopsy-documented case of narrowing of the cervical spinal canal with cord compression in 1960. Since then, OPLL has become widely recognized in Japan, and a large number of cases have been reported.[21] In 1969, Minagi and Gronner[10] reported 2 cases of OPLL in Caucasians.

Other researchers have reported the presence of OPLL in non-Asians.[22,23] Firooznia *et al*[4,24] reported 7 cases of OPLL

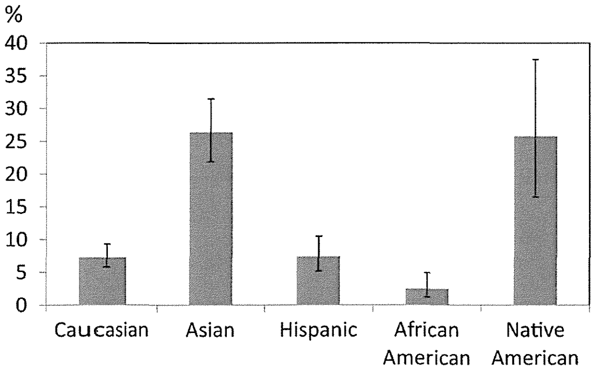

Figure 5. Prevalence of cervical ossification of the nuchal ligament by race. Error bars indicate 95% confidence interval.

in 1000 patients in New York. Epstein[23] reported that OPLL might contribute to 20% of cervical myelopathy in North Americans. The authors emphasized the usefulness of CT for the diagnosis of OPLL as CT is more sensitive regarding the diagnosis of ossification of the spinal ligament.[25–29] According to previous reports, the prevalence of cervical OPLL was 1.7% in Italians,[6] 0.1% to 1.3% in North Americans,[3,4] 1.9% to 4.3% in Japanese,[3,30] and 0.4% to 3.0% in other Asians[3,31,32] (Table 7).

Our CT-based study demonstrated that the prevalence of cervical OPLL (2.2%) was higher than that was reported previously in both Asians and Caucasians. The reason for this discrepancy may be related to the inability of plain radiographs to detect small ossifications that are currently detected by CT. Thus, the percentages of segmental and localized types of OPLL in the present study were greater than those previously reported.[33]

Jeon *et al*[34] reported that the distribution of OPLL, by type, was different when analyzed using CT. They found that the prevalence of the continuous type decreased, and the prevalence of the segmental type increased, upon CT analysis. Sohn *et al*[12] used CT to examine the prevalence of OPLL in Koreans. They reported that CT revealed an earlier stage of OPLL located at 1 segment.

Similar results were reported regarding the prevalence of thoracic OPLL. Ohtsuka *et al*[31] studied the prevalence of ossification of the spinal ligament in 1058 individuals older than 50 years in the general Japanese population.[35] They reported that the prevalence of thoracic OPLL, based on chest

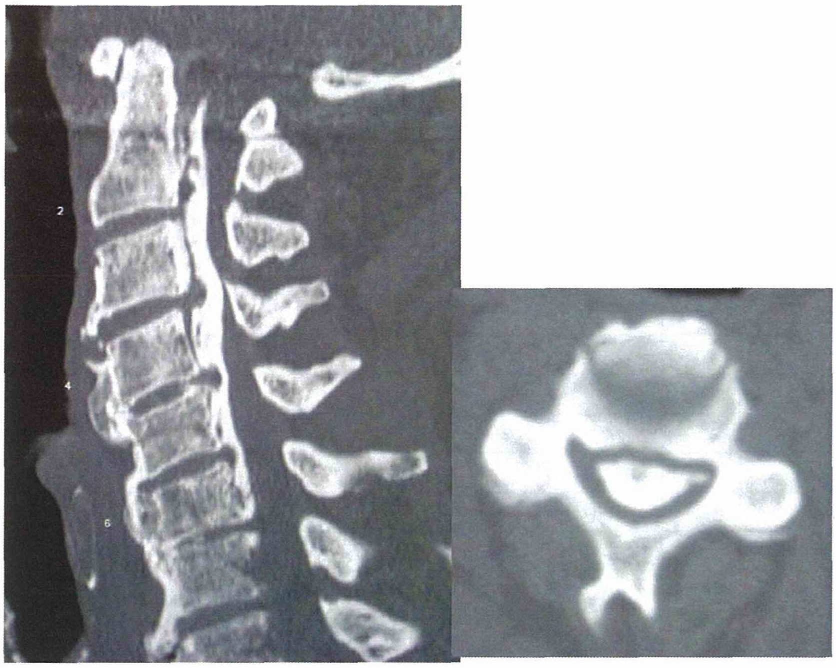

Figure 6. Computed tomographic scan of the cervical spine showing ossification of the posterior longitudinal ligament in an 87-year-old Chinese America male. The continuous type of ossification of the posterior longitudinal ligament occupies 88% of the spinal canal.

radiographs, in the Japanese was 0.8%.[35] Recently, Mori *et al*[11] reported a higher prevalence of thoracic OPLL (1.9%) in a larger Japanese cohort, based on chest CT.

According to the demographics obtained from the San Francisco census and the information regarding the spoken language on the interview sheet, most of the Asian American population in the present study was of Chinese origin. As many recent studies have reported, OPLL is present in the Chinese population.[8,36,37] However, it is unclear whether OPLL is as equally common in the Chinese as it is in the Japanese because there has been no CT-based study, to date, concerning the prevalence of cervical OPLL in the Japanese.

With regard to the Koreans, Sohn *et al*[12] examined 3240 patients who underwent thyroid CT. They reported that the prevalence of cervical OPLL was 4.6%, close to the prevalence of OPLL in Asian Americans noted in the present study. Future epidemiological studies are advocated to compare the prevalence of OPLL between races in East Asia.

In the present study, Native Americans showed as high a prevalence of OPLL and ONL as Asian Americans. In a study of 600 Native Americans in Arizona, Henrard and Bennett[38] reported that the prevalence of ossification of the spinal ligament was 25% in males and 4.7% in females. These findings

TABLE 7. Prevalence of Cervical OPLL

Authors	Country	Race	Modality	Prevalence (%)	Subjects (Male)	OPLL Case	Mean Age (yr)
Ohtsuka *et al*[31]	Japan	Asian	Cervical x-ray	3.2	1058 (440)	34	62.8
Shingyouchi *et al*[15]	Japan	Asian	Cervical x-ray	4.1	4802 (4802)	198	51.4
Yoshimura *et al*[30]	Japan	Asian	Cervical x-ray	1.9	1562 (524)	30	70.3 ± 11
Firooznia *et al*[4]	New York, US	White	Cervical x-ray	0.7	1000 (NA)	7	NA
Sohn *et al*[12]	Korea	Asian	Thyroid CT	5.7	3240 (1084)	185	50.7
Present study	San Francisco, US	White	Cervical CT	1.3	1593 (1078)	21	51.2 ± 20.9
		Asian		4.8	624 (345)	30	60.5 ± 22.4
		Hispanic		1.9	472 (343)	9	43.1 ± 20.2
		African American		2.1	326 (227)	7	45.5 ± 18.3
		Native American		3.2	62 (36)	2	55.8 ± 22.3

OPLL indicates ossification of the posterior longitudinal ligament; NA, not available; CT, computed tomography.

may be related to the fact that the origin of Native Americans is mongoloid.[39]

It has been reported that genetic factors are closely related to the pathogenesis of OPLL. Tsukahara *et al*[7] reported that collagen 6A1 (COL6A1) was the candidate gene for OPLL.

In the present study, the overall prevalence of cervical ONL was 10.9% (95% CI: 10.0–12.0). The prevalence of ONL was also highest in Asian Americans (26.4%), followed by Native Americans (25.8%), Hispanic Americans (7.4%), and Caucasian Americans (7.3%). Patients with ONL were more likely to have OPLL than those without ONL (7.2% *vs.* 1.6%, odds ratio = 4.8, $P < 0.001$).

Ohtsuka and Yanagihara[35] reported that the prevalence of cervical ONL in the Japanese, based on plain radiographs, was 17.2%. Shingyouchi *et al*[15] studied the cervical spine radiographs of 4802 middle-aged males in the Japanese military. They reported that the prevalence of OPLL was 4.1%, and that of ONL was 23.3%. Wang *et al*[16] reported that the prevalence of ONL was 49.7% (185/372) in Chinese patients who underwent surgery for cervical spondylosis. They reported that ONL was associated with the presence of OPLL. These findings suggest that OPLL and ONL are associated with a systemic tendency for ossification.

Our study had several limitations. The participants in this study may not represent the general population. However, because it is unethical to obtain computed tomographic scans of normal volunteers, we think that our study may represent the best possible racial sampling for a CT-based study. In addition, the small sample sizes of the minor races contributed toward a wide variation in the CIs of the prevalence. Finally, the rate of cervical myelopathy caused by OPLL was unclear. Thus, future studies are needed to extend our results.

Despite these limitations, we think that our data are invaluable because of the difficulty in obtaining CT data on a large cohort of participants composed of different racial groups. The San Francisco Bay area is unique in that individuals of varying races can be recruited for a single study.

CONCLUSION

This CT-based study clarified the prevalence of cervical OPLL and ONL within various racial groups in San Francisco area. Asian Americans demonstrated a significantly higher prevalence of cervical OPLL and ONL than Caucasian Americans. The presence of ONL was associated with OPLL.

➢ Key Points

- ❑ In the San Francisco area, based on CT, overall prevalence of cervical OPLL was 2.2% (95% CI: 1.7–2.8) and the prevalence of ONL was 10.9% (95% CI: 10.0–12.0).
- ❑ The presence of ONL was associated with OPLL.
- ❑ Asian Americans demonstrated a significantly higher prevalence of cervical OPLL and ONL than Caucasian Americans.

Acknowledgments

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Shuai Ye, MS, and Jong-Han Yim, MD, equally contributed to this work.

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BMC Research Notes

CASE REPORT Open Access

Neurological deterioration induced by sitting in patients after cervicothoracic posterior decompression with instrumented fusion surgery for ossification of the longitudinal ligament: two cases reports

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Abstract

Background: We report on Japanese patients who showed neurological deterioration induced by sitting after cervicothoracic posterior decompression with instrumented fusion, but showed immediate neurological recovery after bed rest.

Case Presentation: Patients showed incomplete paraparesis caused by the ossification of the posterior longitudinal ligament at uppermost thoracic spine. Cervicothoracic posterior decompression with instrumented fusion was performed. Postoperatively, the patients showed partial paraparesis when they were sitting. They showed rapid recovery from lower extremity paralysis upon lying down. After strict bed rest for one month, those patients showed no apparent development of paralysis during sitting.

Conclusion: In patients with postoperative residual anterior spinal cord compression, micromotion might exacerbate neurological symptoms.

Keywords: Ossification of the posterior longitudinal ligament, Posterior surgery, Instrumented fusion, Postoperative complication

Background

Ossification of the longitudinal ligament (OPLL) is one of anterior spinal cord compressive lesions at the uppermost thoracic spine, and is often treated using a posterior approach to decompression because of the anatomical complexity of the upper mediastinum [1]. OPLL patients showing local kyphosis often have a poor surgical outcome after posterior decompression surgery alone [2]. Concurrent instrumented posterior fusion is usually adopted as a stabilization procedure. The rationale for posterior decompression with instrumented fusion surgery (PDF) is to obtain neurological recovery by immediate stabilization of the spine, even if there is residual anterior compression following the procedure [3-6]. Here we report two cases that showed neurological deterioration induced by sitting after cervicothoracic PDF for OPLL, but showed immediate neurological recovery after bed rest.

Case presentations

Case 1

A 71-year-old Japanese woman complained of difficulty walking caused by OPLL at T2-3. C7–T5 PDF surgery was performed (Figure 1A, B, C). Three days after surgery, the patient showed partial paraparesis when she was sitting. Emergent CT and MRI showed no apparent abnormalities (Figure 1D). During those examinations, the patient gradually recovered from lower extremity paralysis. We ordered

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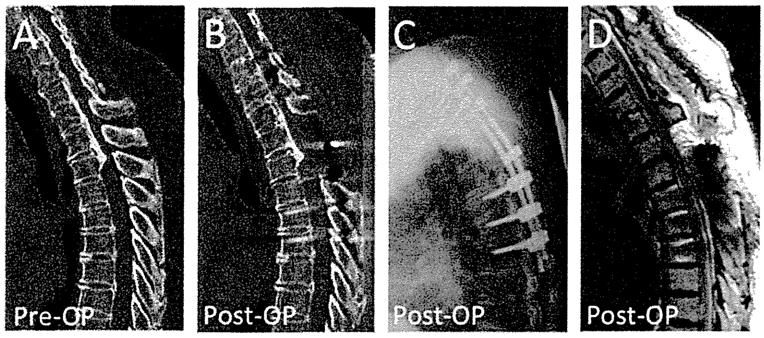

Figure 1 Pre- and postoperative images of Case 1. Pre-operative computed tomography image showed beak-shaped ossification of the posterior longitudinal ligament at T2/3 vertebral level **(A)**. Posterior decompression with instrumented fusion surgery at C7-T5 level was performed **(B-D)**. This patient showed partial paraparesis when she was sitting, but showed immediate neurological recovery after bed rest.

strict bed rest without sitting up for one month. Subsequently, the patient showed no apparent development of paralysis during sitting or using a wheelchair.

Case 2

A 37-year-old Japanese man showed partial paraparesis because of OPLL at C3–T3 (worst at T1-2, Figure 2A). The patient underwent PDF surgery at C3–T5. The patient showed incomplete paralysis on sitting, but rapidly recovered after bed rest. An emergent CT-myelogram revealed no apparent abnormalities (Figure 2B). X-ray images obtained when the patient was sitting and lying showed no apparent motion between fused segments (C7-T4 angle was 4° in both lying and in sitting position, Figure 2C and D). We ordered strict bed rest for 3 weeks. Subsequently, the patient showed no apparent development of paralysis during sitting.

Discussion

Points in common between the present patients were that there was an anterior spinal cord compressive lesion at the upper thoracic level, that there was residual anterior spinal cord compression after surgery and the cervical 3.5 mm diameter rods were used at the cervicothoracic region. Previous Japanese reports describing neurological deterioration induced by sitting after cervicothoracic posterior decompression with instrumented fusion for OPLL showed similarities with the present patients [7,8]. Both of the present cases showed rapid neurological deterioration with sitting, followed by rapid recovery on lying down. These lines of indirect evidence lead us to suggest that, even after PDF surgery, there is micromotion at the fused segments. In contrast, no mid- to lower-thoracic OPLL patients showed neurological deterioration at sitting after PDF surgery in our previous series [5,6].

The possible differences between the previous mid- to lower-thoracic OPLL series and the present cases are the difference in the region and the difference of rod diameter, tapered rod (4.5 mm thoracic and 3.5 cervical) for case 1 and 3.5 mm cervical rod for case 2. Upper thoracic spinal cord might be vulnerable for external force because of its specific blood supply [9]; therefore in patients with postoperative residual anterior

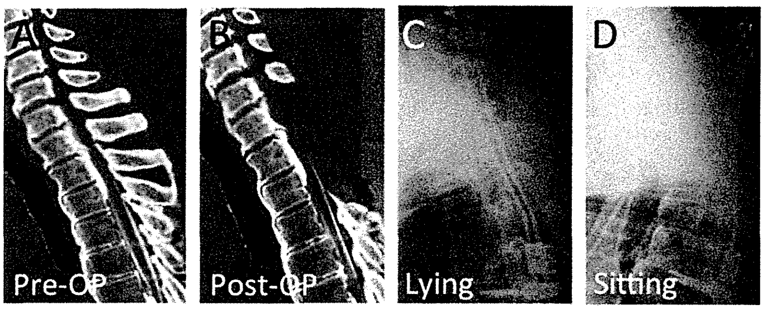

Figure 2 Pre- and postoperative images of Case 2. Pre-operative computed tomography image showed peak of ossification of the posterior longitudinal ligament at T1/2 vertebral level **(A)**. C3-T5 posterior decompression with instrumented fusion surgery was performed. The patient showed incomplete paralysis on sitting, but rapidly recovered after bed rest. An emergent computed tomographic-myelogram revealed no apparent abnormalities **(B)**. X-ray images obtained when the patient was lying **(C)** and sitting **(D)** showed no apparent motion between fused segments.

spinal cord compression at upper thoracic region, the spinal cord might be more vulnerable for micromotion than in the patients of mid- to lower thoracic spinal level.

Conclusion

In conclusion, we recommend surgeons be alert to the possibility of micromotion after cervicothoracic PDF surgery for OPLL. Thicker or more rigid rods for the PDF surgery may suppress this micromotion.

Consent

Written informed consent was obtained from both of the patients for publication of this Case Report and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

Abbreviations

OPLL: Ossification of the posterior longitudinal ligament; PDF: Ossification of the longitudinal ligament; CT: Computed tomography; MR: Magnetic resonance.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MK, CM, TI, KK, MO and SM analyzed and interpreted the patient data. KT, MY, MA, OI and TF were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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Reduced Field-of-View Diffusion Tensor Imaging of the Spinal Cord Shows Motor Dysfunction of the Lower Extremities in Patients with Cervical Compression Myelopathy

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Study Design. Cross-sectional study.

Objective. To quantify spinal cord dysfunction at the tract level in patients with cervical compressive myelopathy (CCM) using reduced field-of-view (rFOV) diffusion tensor imaging (DTI).

Summary of Background Data. Although magnetic resonance imaging (MRI) is the standard used for radiological evaluation of CCM, information acquired by MRI does not necessarily reflect the severity of spinal cord disorder. There is a growing interest in developing imaging methods to quantify spinal cord dysfunction. To acquire high-resolution DTI, a new scheme using rFOV has been proposed.

Methods. We enrolled 10 healthy volunteers and 20 patients with CCM in this study. The participants were studied using a 3.0 T MRI system. For DTI acquisitions, diffusion-weighted spin-echo rFOV single-shot echo-planar imaging was used. Regions-of-interest (ROI) for the lateral column (LC) and posterior column (PC) tracts were determined based on a map of fractional anisotropy (FA) of the spinal cord and FA values were measured. The FA of patients with CCM was compared with that of healthy controls and correlated with Japanese Orthopaedic Association (JOA) score.

Results. In LC and PC tracts, FA values in patients with CCM were significantly lower than in healthy volunteers. Total JOA scores correlated moderately with FA in LC and PC tracts. JOA subscores for motor dysfunction of the lower extremities correlated strongly with FA in LC and PC tracts.

Conclusions. It is feasible to evaluate the cervical spinal cord at the tract level using rFOV DTI. Although FA values at the maximum compression level were not well correlated with total JOA scores, they were strongly correlated with JOA subscores for motor dysfunction of the lower

extremities. Our findings suggest that FA reflects white matter dysfunction below the maximum compression level and FA can be used as an imaging biomarker of spinal cord dysfunction.

Key Words: diffusion tensor imaging; reduced field-of-view; magnetic resonance imaging; cervical spondylotic myelopathy; ossification of the posterior longitudinal ligament; fractional anisotropy; cervical disc herniation; atlantoaxial dislocation; spinal cord; corticospinal tract

Level of Evidence: 4

Mini Abstract

We evaluated functional disturbance in patients with cervical compressive myelopathy (CCM) using reduced field-of-view diffusion tensor imaging. Fractional anisotropy correlated strongly with gait disturbance in patients with CCM. Fractional anisotropy reflects white matter dysfunction and can be used as a biomarker of spinal cord dysfunction at the tract level.

Key Points

- It was feasible to evaluate the cervical spinal cord at the tract level using reduced field-of-view diffusion tensor imaging.
- Fractional anisotropy correlated strongly with gait disturbance in patients with cervical compressive myelopathy.
- Fractional anisotropy reflects white matter dysfunction below the level of maximum compression and can be used as an imaging biomarker of spinal cord dysfunction.

INTRODUCTION

Cervical compression myelopathy (CCM), including cervical spondylotic myelopathy, ossification of longitudinal ligament, and cervical disc herniation is a major cause of spinal cord disorder. Primarily, physical examination and imaging modalities including plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) are used to evaluate CCM clinically. MRI is the standard radiological evaluation of CCM, because it can reveal the degree of spinal cord compression and signal intensity changes in the spinal cord, neither of which can be obtained by plain radiographs or CT.[1–2] However, the information acquired by MRI does not necessarily reflect the severity of spinal cord disorder.[3] For example, it remains controversial whether there is significant correlation between intramedullary intensity changes obtained by T2-weighted MRI and severity of myelopathy symptoms. Therefore development of new imaging methods that can indicate the degree of spinal cord damage is under intense exploration.

Diffusion Tensor Imaging (DTI) can provide microstructural information about the spinal cord. Fractional anisotropy (FA) is derived from the diffusion matrix and represents the degree of anisotropy of a diffusion process. DTI has been used to evaluate patients with cervical spondylotic myelopathy.[4–12] DTI provides quantitative diffusion parameters. However, DTI has not been extensively used to evaluate specific spinal tract damage in patients with cervical spondylotic myelopathy because of the relatively lower spatial resolution limited by the achievable signal-to-noise ratio in previous studies.[4–8] A new method for reduced field-of-view (rFOV) has been proposed. The new rFOV diffusion method uses a spatially selective 2D echo-planar RF excitation pulse and a 180° refocusing pulse to reduce the FOV in the phase-encode direction, while simultaneously suppressing the signal from fat. This method allows the acquisition of high-resolution diffusion-weighted images and reduces susceptibility