Original Article

Global Spine Journal
2023, Vol. 13(1) 8–16
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DOI: 10.1177/2192568221989655
journals.sagepub.com/home/gsj

Association Between Deep Posterior Cervical Paraspinal Muscle Morphology and Clinical Features in Patients With Cervical Ossification of the Posterior Longitudinal Ligament

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Abstract

Study Design: A retrospective observational study.

Objective: To clarify the association of the paraspinal muscle area and composition with clinical features in patients with cervical ossification of the posterior longitudinal ligament (OPLL).

Methods: Consecutive patients with cervical OPLL who underwent cervical magnetic resonance imaging (MRI) before surgery were reviewed. The cross-sectional area (CSA) and fatty infiltration ratio (FI%) of deep posterior cervical paraspinal muscles (multifidus [MF] and semispinalis cervicis [SCer]) were examined. We assessed the association of paraspinal muscle measurements with the clinical characteristics and clinical outcomes, such as Neck Disability Index (NDI) score. Moreover, we divided the patients into 2 groups according to the extent of the ossified lesion (segmental and localized [OPLL-SL] and continuous and mixed [OPLL-CM] groups) and compared these variables between the 2 groups.

Results: 49 patients with cervical OPLL were enrolled in this study. The FI% of the paraspinal muscles was significantly associated with the number of vertebrae ($\rho = 0.283$, $p = 0.049$) or maximum occupancy ratio of OPLL ($\rho = 0.397$, $p = 0.005$). The comparative study results indicated that the NDI score was significantly worse (OPLL-SL, 22.9 $\pm$ 13.7 vs. OPLL-CM, 34.4 $\pm$ 13.7) and FI% of SCer higher (OPLL-SL, 9.1 $\pm$ 1.7% vs. OPLL-CM, 11.1 $\pm$ 3.7%) in the OPLL-CM group than those in the OPLL-SL group.

Conclusions: Our results suggest that OPLL severity may be associated with fatty infiltration of deep posterior cervical paraspinal muscles, which could affect neck disability in patients with cervical OPLL.

Keywords

cervical, fatty infiltration, multifidus, Neck Disability Index, neck pain, ossification of the posterior longitudinal ligament, paraspinal muscle, semispinalis cervicis

Introduction

Ossification of the posterior longitudinal ligament (OPLL) is an abnormal heterotopic bone formation in the posterior longitudinal ligament of the spine. Several epidemiological studies have reported that obesity and diabetes mellitus (DM) are independent risk factors for OPLL.[1,2] An OPLL mass often occupies the spinal canal and compresses the spinal cord, which

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results in various neurological deficits and reduced health-related quality of life.[3,4] In addition to neurological dysfunction, patients with cervical OPLL often have pain and stiffness around the neck.[5-7] Kaneko previously reported that 69% of patients with cervical OPLL presented with neck/nuchal pain at their first visit to a clinic.[7] A recent study reported that 61.2% of patients with OPLL (n = 263) had neck pain.[6] However, little is known about the factors associated with neck pain and disability in patients with cervical OPLL.

Paraspinal muscle degeneration has been widely investigated as a factor associated with low back pain in previous studies.[8-13] Pathological changes in paraspinal muscles with aging include muscle atrophy and muscle composition changes, such as fatty infiltration.[14-16] The association between fatty infiltration of paraspinal muscles and clinical symptoms in patients with lumbar spine disease has been previously well-investigated.[17,18] Furthermore, the relationship between cervical paraspinal muscle degeneration and clinical symptoms or clinical outcomes has been previously reported in patients with cervical spine disease.[19-29] Among cervical paraspinal muscles, the deep posterior cervical extensors, including the multifidus (MF) and semispinalis cervicis (SCer), attach vertebrae directly to other vertebrae and have an essential role in stabilizing cervical spine motion.[30] The fatty infiltration of deep cervical extensors has been previously reported to be associated with various cervical pathophysiological conditions in traumatic neck pain, degenerative cervical myelopathy, cervical radiculopathy, and cervical deformity.[19-24,28,29] However, we are not aware of any reports on the association between the morphology and composition of deep posterior cervical paraspinal muscles and clinical features in patients with cervical OPLL.

In this study, we identify which factor is associated with paraspinal muscle area or composition in patients with OPLL and elucidate whether paraspinal muscle fatty infiltration is associated with OPLL severity or cervical dysfunction in patients with OPLL. We hypothesized that greater fatty infiltration of deep posterior paraspinal muscle would be associated with worse cervical dysfunction or ossified lesion severity in patients with cervical OPLL. To test this hypothesis, we examined the total cross-sectional area (CSA) and fatty infiltration ratio (FI%) of the deep posterior cervical paraspinal muscles (MF and SCer) and clarified the associations of these muscle measurements with clinical characteristics and clinical outcomes in patients with cervical OPLL. Furthermore, paraspinal muscle measurements and clinical outcomes were compared between patients with a relatively small extent of OPLL (segmental and localized type) and patients with a relatively large extent of OPLL (continuous and mixed type).

Methods

Patient Selection

The study protocol was approved by the institutional review board of our hospital. A written informed consent for all procedures was obtained from all study participants. We retrospectively reviewed 124 consecutive patients who had been diagnosed with cervical OPLL based on neurological examination and radiographic assessment and had undergone cervical spine surgery (laminoplasty, posterior decompression and fusion, or anterior decompression and fusion) between April 2007 and September 2019 at our institution. Of these 124 patients, 73 had preoperative cervical magnetic resonance imaging (MRI) scans, cervical computed tomography (CT) scans, and cervical lateral radiographs in neutral, flexion, and extension positions within 3 months before surgery. We excluded 24 patients because of a history of cervical spine surgery and unavailability for paraspinal muscle measurements on a radiological workstation to evaluate the CSA and FI%, as previously described by Sasaki et al.[31] Consequently, 49 patients with cervical OPLL were enrolled in this study. MRI examinations were mainly performed on a 3 Tesla MRI system (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany) at our institution. The MRI protocol specified sagittal T2-weighted imaging (repetition time, 4000 ms/echo; echo time, 89 ms; field of view, 280 $\times$ 280 mm) and axial T2-weighted imaging (repetition time, 4000 ms/echo; echo time, 91 ms; field of view, 200 $\times$ 200 mm). Detailed information on some MRI protocols was unavailable because some patients who were referred from different healthcare centers underwent MRI examinations by different MRI systems. Sagittal images were obtained for the entire cervical spine and axial images were obtained for each cervical mid-disc level parallel to the vertebral endplates.

Measurements of Cervical Paraspinal Muscles, Ossified Lesion, and Radiographic Parameters

We used a radiological workstation specifically designed for measurement of paraspinal muscle to measure the total CSA (cm^2) and FI% (%) of the deep posterior cervical paraspinal muscles (MF and SCer) in the axial T2-weighted view (Figure 1).[31] The procedures are detailed as follows: We determined the CSA of the paraspinal muscles by manually constructing polygonal points around the outer edge of each muscle (Figure 1). All pixels in the region of interest were automatically sorted into 3 clusters (low, medium, and high intensity) by counting the number of pixels and measuring the signal intensity by the k-means method.[32] The high intensity area was defined as the fatty infiltration area. The FI% was calculated as the fatty infiltration area percentage (%, the fatty infiltration area / total CSA). The measurements of cervical paraspinal muscles were bilaterally obtained at mid-disc level of C4/5 and C5/6 because a previous study had reported that OPLL occurred more frequently at these spinal levels.[33] The measured values were expressed as the average of bilateral measurements. We evaluated inter- and intrarater reliabilities for the measurements of CSA and FI% of the deep posterior cervical paraspinal muscles by calculating the intraclass correlation coefficient (ICC). Two experienced spine surgeons (TD and NO) investigated the interrater reliability in a sample of 10 randomly selected subjects (a total of 40 paraspinal muscle

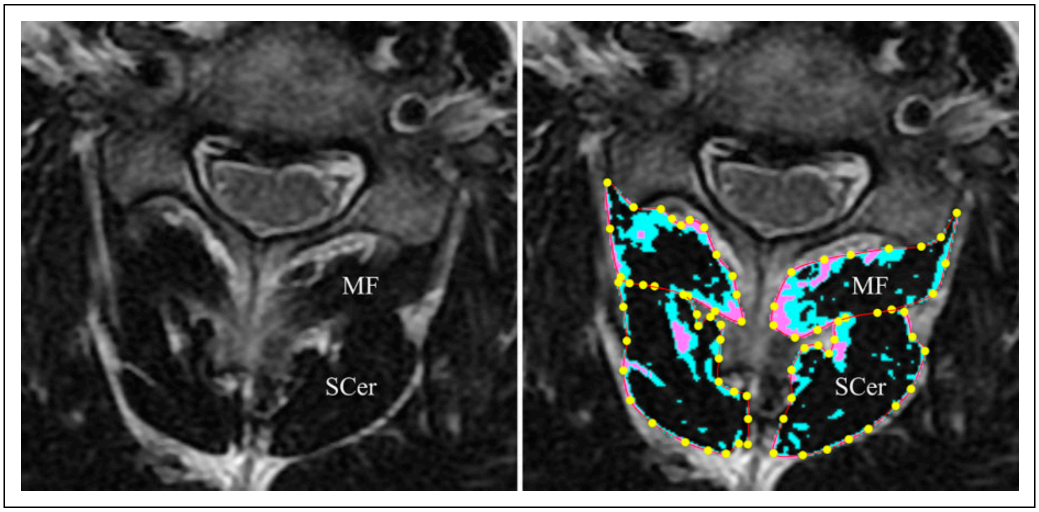

Figure 1. Measurement of the cross-sectional area (CSA) and fatty infiltration ratio (FI%) for the multifidus (MF) and semispinalis cervicis (SCer) at C4/5 level. Axial T2-weighted magnetic resonance imaging (MRI) was used to measure the CSA and FI% at mid-disc C4/5 level (left). Each region of interest was manually defined and automatically divided into 3 areas (low, medium, and high intensity areas) (right). The high intensity area was defined as the fatty infiltration area.

measurements). The intrarater reliability was evaluated in these 10 subjects by making duplicate measurements by the same observer (TD) with an interval of > 1 month. Values of 0.60-0.80 indicated good reliability and of > 0.80 indicated excellent reliability.[34] The respective ICCs of the CSA and FI% measurements for the interrater reliability were 0.868 and 0.755, indicating excellent and good reliability. The ICCs of the CSA and FI% measurements for the intrarater reliability were 0.966 and 0.884, indicating excellent reliability, respectively.

The maximum occupancy ratio of the OPLL mass was examined in the sagittal view of reconstructed CT images (%, anteroposterior OPLL thickness /anteroposterior spinal canal diameter). Furthermore, we assessed the number of vertebral levels involved in OPLL in the sagittal CT view. The OPLL was categorized into 4 types (continuous, segmental, mixed, and localized) according to the Investigation of Public Health and Welfare's classification.[35] Moreover, patients with OPLL were divided into 2 groups according to the extent of the ossified lesion; the segmental and localized (OPLL-SL) group with a relatively small extent of OPLL, and the continuous and mixed (OPLL-CM) group with a relatively large extent of OPLL.

Radiographic parameters included the C2-7 angle and the C2-7 range of motion (ROM) angle (°, degrees). The C2-7 angle, defined by tangential lines on the posterior edge of the C2 and C7 vertebral body, was measured on lateral radiographs in the neutral position. The C2-7 ROM angle was defined as the sum of the C2-7 angles seen during flexion and extension on lateral radiographs.[36]

Data Collection

We collected the following patients' characteristics and clinical data at the time of the preoperative MRI examination by examining the patients' medical records: age, sex, body mass index (BMI, kg/cm^2), symptom duration (month), and comorbid DM.

We assessed the patients' clinical outcomes within 7 days before surgery using the following clinical outcome measures: Numerical Rating Scale (NRS) score for neck pain, Neck Disability Index (NDI) score, the Japanese Orthopaedic Association (JOA) score, physical component summary (PCS) and mental component summary (MCS) of the Short Form-12 (SF-12) health survey, and EuroQol-5 Dimension (EQ-5D).

Statistical Analysis

Data are expressed as mean (standard deviation [SD]). Spearman's correlation coefficient (ρ) was used to assess the correlations between CSA and FI% of the paraspinal muscles with clinical characteristics (age, male, BMI, symptom duration, and DM), clinical outcomes (NRS score for neck pain, NDI score, JOA score, SF-12 PCS, MCS, and EQ-5D), and radiographic parameters (C2-7 angle and C2-7 ROM angle). The correlation coefficient was interpreted as follows: $0.1 \leq |\rho| < 0.3$ was considered weak, $0.3 \leq |\rho| < 0.5$ moderate, and $|\rho| \geq 0.5$ strong correlation.[37] We compared all variables between the OPLL-SL and OPLL-CM groups. We also performed a propensity score-matched analysis because a previous study reported that age and sex could affect fatty infiltration of cervical paraspinal muscles.[38] Clinical factors such as age and sex were included in the calculation of the propensity score. A one-to-one matching procedure between the 2 groups based on the estimated propensity score was used in a logistic regression model. Continuous data were compared by using the unpaired *t* test, whereas categorical data were compared by using Fisher's exact test. All data were analyzed by using IBM SPSS Statistics version 23 (IBM

Table 1. Patients' Characteristics.

Patient Characteristics (n = 49)		Mean (SD) or n (%)
Age, years		60.9 (12.5)
Male, n (%)		39 (79.6%)
BMI, kg/m^2		26.4 (4.9)
Symptom duration, months		25.0 (27.7)
DM, n (%)		16 (32.7%)
Type of OPLL		
Segmental, n (%)		18 (36.7%)
Continuous, n (%)		4 (8.2%)
Mixed, n (%)		18 (36.7%)
Localized, n (%)		9 (18.4%)
Clinical outcomes		
NRS score for neck pain		2.9 (2.6)
NDI score		27.7 (14.2)
JOA score		11.0 (2.0)
SF-12 PCS		24.7 (13.2)
SF-12 MCS		53.3 (10.0)
EQ-5D		0.58 (0.13)
Number of vertebrae with OPLL, n		3.6 (1.7)
Maximum occupancy ratio of OPLL, %		45.9 (13.9)
Radiographic measurements		
C2-7 angle, degrees		6.0 (9.4)
C2-7 ROM angle, degrees		28.7 (12.4)
CSA of paraspinal muscles		
CSA of MF, cm^2	C4/5	2.0 (0.5)
	C5/6	1.9 (0.5)
CSA of SCer, cm^2	C4/5	2.0 (0.5)
	C5/6	2.2 (0.6)
FI% of paraspinal muscles		
FI% of MF, %	C4/5	13.9 (4.3)
	C5/6	16.2 (5.1)
FI% of SCer, %	C4/5	10.3 (3.4)
	C5/6	9.3 (3.4)

BMI, body mass index; *CSA,* cross sectional area; *DM*, diabetes mellitus; *EQ-5D*, EuroQol 5 Dimension; *FI%,* fatty infiltration ratio; *JOA,* Japanese Orthopaedic Association; *MCS*, mental component summary; *MF*, multifidus muscle; *NDI*, Neck Disability Index; *NRS*, Numerical Rating Scale; *OPLL*, ossification of the posterior longitudinal ligament; *PCS*, physical component summary; *ROM*, range of motion; *SCer*, semispinalis cervicis muscle; *SD*, standard deviation; *SF-12*, Short Form-12.

Corp., Armonk, NY, USA). A p value of < 0.05 was considered statistically significant.

Results

Patients' Characteristics

Table 1 presents the characteristics of the 49 eligible patients in the study. The mean age was 60.9 (SD 12.5) years and 79.6% were males. The following completion rates of clinical outcomes were obtained: NRS score for neck pain, 95.9%; NDI score, 100.0%; JOA score, 100.0%; SF-12 PCS and MCS, 81.6%; and EQ-5D, 91.8%. Regarding the type of surgery, 38 patients (77.6%) underwent cervical laminoplasty, 8 (16.3%) underwent posterior decompression and fusion, and 3 (6.1%) underwent anterior decompression and fusion.

Correlations Between Paraspinal Muscle Measurements and Clinical Features

Table 2 presents the Spearman's correlation coefficients between the cervical paraspinal muscle measurements and other variables. Among the clinical characteristics in patients with OPLL, there were significant correlations between age and FI% and between male sex and CSA for both paraspinal muscles at C4/5 and C5/6 levels, respectively (Table 2). The BMI indicated a significant positive correlation with CSA of SCer at C4/5 (moderate, $\rho = 0.357$, $p = 0.012$) (Table 2). Among factors related to the ossified lesion, the number of vertebrae with OPLL was significantly associated with the FI% of MF at C5/6 (weak, $\rho = 0.283$, $p = 0.049$) (Table 2). The maximum occupancy ratio of OPLL was significantly associated with the FI% of SCer at C5/6 (moderate, $\rho = 0.397$, $p = 0.005$) (Table 2). With respect to clinical outcomes, none of clinical outcomes indicated a significant association with paraspinal muscle measurements.

Comparison of Paraspinal Muscle Measurements and Clinical Outcomes Between the OPLL-SL and the OPLL-CM Groups

Table 3 presents the results of a comparison data between the 2 groups (OPLL-SL group, 27 patients; OPLL-CM group, 22 patients). No significant differences were found in age, sex, BMI, symptom duration, and comorbid DM between the 2 groups. A significantly greater number of vertebrae with OPLL (OPLL-SL, 2.5 ± 0.9 vs. OPLL-CM, 5.0 ± 1.5, $p < 0.001$), greater maximum occupancy ratio of OPLL (OPLL-SL, 40.3 ± 12.2% vs. OPLL-CM, 52.8 ± 13.0%, $p = 0.001$), higher NDI score (OPLL-SL, 22.2 ± 12.7 *vs.* OPLL-CM, 34.5 ± 13.3, $p = 0.002$), and lower C2-7 ROM angle (OPLL-SL, 34.8 ± 10.4° vs. OPLL-CM, 21.3 ± 10.6°, $p < 0.001$) were observed in the OPLL-CM group compared with the OPLL-SL group (Table 3). No significant differences were found in the CSAs of the paraspinal muscles between the 2 groups (Table 3). For the FI% of the paraspinal muscles, the FI% of MF and SCer were relatively higher at both levels in the OPLL-CM group than in the OPLL-SL group. In particular, the FI% of SCer at C4/5 level was significantly higher in the OPLL-CM group than in the OPLL-SL group (OPLL-SL, 8.9 ± 2.3% vs. OPLL-CM, 11.9 ± 3.8%, $p = 0.002$) (Table 3).

Comparison of Paraspinal Muscle Measurements and Clinical Outcomes Between the OPLL-SL and OPLL-CM Groups Using a Propensity Score-Matched Analysis

After propensity score matching for age and sex, matched OPLL-SL (n = 17) and OPLL-CM (n = 17) groups were obtained (Table 4). Similar to the results in Table 3, a significantly higher NDI score (OPLL-SL, 22.9 ± 13.7 vs. OPLL-CM, 34.4 ± 13.7, $p = 0.020$), lower C2-7 ROM angle (OPLL-SL, 32.7 ± 11.0° vs. OPLL-CM, 20.5 ± 10.8°, $p = 0.003$), and higher FI% of SCer at C4/5 level (OPLL-SL, 9.1 ± 1.7% vs.

Table 2. Spearman's Correlation Coefficients Between the Posterior Cervical Paraspinal Muscle Measurements and Clinical Characteristics, Clinical Outcomes, or Radiographic Parameters.

Factors	CSA of NW		CSA of SCer		FI% of MF		FI% of SCer	
	C4/5	C5/6	C4/5	C5/6	C4/5	C5/6	C4/5	C5/6
Age	-0.055	-0.193	-0.097	-0.351 *	0.508 *	0.390 *	0.398 *	0.414 *
Male	0.344 *	0.444 *	0.423 *	0.405 *	0.014	-0.136	0.186	-0.201
BMI	0.108	0.26	0.357 *	0.269	-0.154	-0.170	-0.214	-0.11
Symptom duration	0.093	0.044	-0.247	0.161	0.113	0.141	-0.039	-0.324 *
DM	0.200	0.163	0.062	-0.046	-0.006	-0.074	-0.046	0.203
Number of vertebrae with OPLL	-0.016	-0.08	-0.069	-0.049	0.019	0.283 *	0.257	0.208
Maximum occupancy ratio of OPLL	0.043	-0.007	0.008	-0.037	0.139	0.182	0.12	0.397 *
NRS score for neck pain	-0.187	-0.257	-0.07	-0.16	-0.035	0.215	0.274	0.219
NDI score	0.052	-0.012	0.101	-0.015	-0.109	0.09	0.18	0.035
JOA score	0.123	0.185	-0.097	-0.105	0.216	-0.179	0.187	-0.036
SF-12 PCS	0.027	0.244	0.064	0.118	-0.009	0.235	0.024	-0.221
SF-12 MCS	0.132	-0.209	0.134	0.197	-0.016	0.053	-0.142	0.104
EQ-5D	-0.008	-0.08	-0.103	0.032	0.066	0.137	0.056	0.042
C2-7 angle	-0.145	0.209	-0.14	-0.041	0.166	0.142	0.195	-0.01
C2-7 ROM angle	-0.010	0.087	-0.021	-0.030	-0.109	-0.109	-0.186	-0.173

BMI, body mass index; *CSA*, cross sectional area; *DM*, diabetes mellitus; *EQ-5D*, EuroQol 5 Dimension; *FI%*, fatty infiltration ratio; *JOA*, Japanese Orthopaedic Association; *MCS*, mental component summary; *MF*, multifidus muscle; *NDI*, Neck Disability Index; *NRS*, Numerical Rating Scale; *OPLL*, ossification of the posterior longitudinal ligament; *PCS*, physical component summary; *ROM*, range of motion; *SCer*, semispinalis cervicis muscle; *SF-12*, Short Form-12.
* Statistically significant value ($p < 0.05$).

OPLL-CM, 11.1 $\pm$ 3.7%, $p = 0.049$) were observed in the matched OPLL-CM group than in the matched OPLL-SL group (Table 4). These results suggest that patients with a relatively large extent of OPLL, which may cause reduced cervical spine mobility, could have higher fatty infiltration of deep posterior paraspinal muscles, resulting in worse neck-associated symptoms.

Discussion

To the best of our knowledge, this is the first study to examine the morphology and composition of deep posterior cervical paraspinal muscles in patients with cervical OPLL. Our study yielded the following findings: 1) ossified lesion severity was positively associated with fatty infiltration of deep posterior paraspinal muscles; 2) a significantly worse NDI score, lower C2-7 ROM angle, and higher FI% of SCer were observed in the OPLL-CM patients than in the OPLL-SL patients; and 3) similar results were observed in a comparison between the propensity score-matched groups. These findings suggest that OPLL severity, as indicated by the number of vertebral levels or maximum occupancy ratio of OPLL, may affect the deep posterior cervical paraspinal muscle composition and cervical spine mobility, resulting in neck disability.

Decreased cervical spine mobility is one possible explanation for the association between OPLL severity and fatty infiltration of deep posterior paraspinal muscles. Our results indicated that patients with a large extent of OPLL (continuous and mixed type of OPLL) had a lower C2-7 ROM angle and higher FI% of SCer at C4/5 (Tables 3 and 4). Yuan et al. reported that active cervical ROM was lower in patients with OPLL than in the normal controls because multilevel vertebral fusion caused by OPLL would adversely affect intervertebral motion.[39] Decreased cervical spine mobility by multilevel ossified lesion may facilitate the paraspinal muscle degeneration owing to muscle disuse or unbalanced cervical spine motion. Spinal cord compression caused by OPLL is another possible reason for the association between OPLL severity and fatty infiltration of the deep posterior paraspinal muscles. Previous studies have suggested that fatty infiltration of paraspinal muscles was associated with spinal cord compression in degenerative cervical myelopathy.[20,23,24,29] Our results also indicated a significant correlation between the FI% of SCer at C5/6 and maximum occupancy ratio of OPLL in patients with cervical OPLL (Table 2), and the FI% of the paraspinal muscles was higher in the OPLL-CM group with a greater occupancy ratio of OPLL than in the OPLL-SL group. Muscle fatty infiltration is known to occur after skeletal muscle denervation, which is reportedly caused by spinal cord compression in cervical spondylotic myelopathy.[40] Further studies are needed to clarify the mechanisms of paraspinal muscle degeneration in patients with cervical OPLL.

Our study results suggest that the CSAs of deep posterior paraspinal muscles had no significant correlation with OPLL severity or clinical outcomes (Table 2), and the CSAs of paraspinal muscles were comparable between the groups with different extents of OPLL (Tables 3 and 4). These findings indicate that the deep posterior paraspinal muscle area may not be altered according to the severity of ossification in patients with cervical OPLL. Previous studies regarding posterior cervical paraspinal muscles had mostly focused on the relationship between paraspinal muscle fatty infiltration and clinical results and had not examined the CSA of each paraspinal muscle.[20,23,25,26] Tamai et al. reported that the paraspinal muscle

Table 3. Comparison of Demographic Data, Clinical Outcomes, Radiographic Measurements, and Cervical Paraspinal Muscle Measurements Between the OPLL-SL and the OPLL-CM Groups.

		OPLL-SL n = 27	OPLL-CM n = 22	p value
Age, years		58.6 (13.7)	63.7 (10.4)	0.150
Male, n (%)		24 (88.9%)	15 (68.2%)	0.090
BMI, kg/m^2		26.5 (5.0)	26.3 (4.8)	0.901
Symptom duration, months		24.1 (29.6)	26.0 (27.3)	0.549
DM, n (%)		10 (37.0%)	6 (30.4%)	0.767
Number of vertebrae with OPLL, n		2.5 (0.9)	5.0 (1.5)	< 0.001
Maximum occupancy ratio of OPLL, %		40.3 (12.2)	52.8 (13.0)	0.001
Clinical symptoms and outcomes				
NRS score for neck pain		2.5 (2.6)	3.4 (2.6)	0.244
NDI score		22.2 (12.7)	34.5 (13.3)	0.002
JOA score		11.3 (2.1)	10.6 (2.0)	0.243
SF-12 PCS		25.7 (13.7)	23.2 (12.9)	0.565
SF-12 MCS		53.2 (11.0)	53.6 (8.7)	0.888
EQ-5D		0.58 (0.14)	0.58 (0.13)	0.936
Radiographic measurements				
C2-7 angle, degrees		7.5 (9.9)	4.1 (8.7)	0.219
C2-7 ROM angle, degrees		34.8 (10.4)	21.3 (10.6)	< 0.001
CSA of paraspinal muscles				
CSA of MF, cm^2	C4/5	2.0 (0.4)	2.0 (0.6)	0.633
	C5/6	1.9 (0.5)	1.8 (0.6)	0.764
CSA of SCer, cm^2	C4/5	2.0 (0.4)	2.0 (0.7)	0.743
	C5/6	2.3 (0.4)	2.1 (0.7)	0.319
FI% of paraspinal muscles				
FI% of MF, %	C4/5	13.0 (4.2)	15.0 (4.2)	0.098
	C5/6	14.9 (4.9)	17.8 (5.0)	0.052
FI% of SCer, %	C4/5	8.9 (2.3)	11.9 (3.8)	0.002
	C5/6	8.5 (3.2)	10.3 (3.5)	0.070

BMI, body mass index; *CSA*, cross sectional area; *DM*, diabetes mellitus; *EQ-5D*, EuroQol 5 Dimension; *FI*, fatty infiltration; *JOA*, Japanese Orthopaedic Association; *MCS*, mental component summary; *MF*, multifidus muscle; *NDI*, Neck Disability Index; *NRS*, Numerical Rating Scale; *OPLL*, ossification of the posterior longitudinal ligament; *PCS*, physical component summary; *ROM*, range of motion; *SCer*, semispinalis cervicis muscle; *SF-12*, Short Form-12. Data are expressed as mean (standard deviation).

Table 4. Comparison of Demographic Data, Clinical Outcomes, Radiographic Measurements, and Cervical Paraspinal Muscle Measurements Between the OPLL-SL and the OPLL-CM Groups Using a Propensity Score Matched Analysis.

		matched OPLL-SL n = 17	matched OPLL-CM n = 17	p value
Age, years		61.2 (11.3)	63.1 (10.9)	0.625
Male, n (%)		14 (82.4%)	14 (82.4%)	1.000
BMI, kg/m^2		26.9 (5.1)	27.1 (4.9)	0.952
Symptom duration, months		16.0 (19.6)	25.2 (27.0)	0.265
DM, n (%)		8 (47.1%)	5 (29.4%)	0.481
Number of vertebrae with OPLL, n		2.5 (0.8)	5.2 (1.6)	< 0.001
Maximum occupancy ratio of OPLL, %		41.8 (10.8)	52.6 (14.3)	0.018
Clinical symptoms and outcomes				
NRS score for neck pain		2.3 (2.5)	3.4 (2.4)	0.202
NDI score		22.9 (13.7)	34.4 (13.7)	0.020
JOA score		11.1 (2.1)	10.4 (2.1)	0.297
SF-12 PCS		26.2 (10.7)	23.6 (13.9)	0.594
SF-12 MCS		50.7 (9.3)	54.3 (9.4)	0.317
EQ-5D		0.58 (0.10)	0.58 (0.14)	0.929
Radiographic measurements				
C2-7 angle, degrees		8.4 (8.9)	3.6 (9.5)	0.135
C2-7 ROM angle, degrees		32.7 (11.0)	20.5 (10.8)	0.003
CSA of paraspinal muscles				
CSA of MF, cm^2	C4/5	1.9 (0.5)	2.1 (0.6)	0.241
	C5/6	2.0 (0.5)	1.9 (0.6)	0.384
CSA of SCer, cm^2	C4/5	2.1 (0.4)	2.0 (0.7)	0.737
	C5/6	2.4 (0.4)	2.2 (0.8)	0.613
FI% of paraspinal muscles				
FI% of MF, %	C4/5	13.3 (4.3)	13.9 (2.9)	0.661
	C5/6	15.7 (4.6)	17.6 (5.3)	0.272
FI% of SCer, %	C4/5	9.1 (1.7)	11.1 (3.7)	0.049
	C5/6	8.7 (5.3)	10.2 (3.3)	0.134

BMI, body mass index; *CSA*, cross sectional area; *DM*, diabetes mellitus; *EQ-5D*, EuroQol 5 Dimension; *FI*, fatty infiltration; *JOA*, Japanese Orthopaedic Association; *MCS*, mental component summary; *MF*, multifidus muscle; *NDI*, Neck Disability Index; *NRS*, Numerical Rating Scale; *OPLL*, ossification of the posterior longitudinal ligament; *PCS*, physical component summary; *ROM*, range of motion; *SCer*, semispinalis cervicis muscle; *SF-12*, Short Form-12. Data are expressed as mean (standard deviation).

volume was significantly associated with the cervical balance parameters, such as the C2-7 angle or T1 slope, and disc degeneration by calculating the adjusted CSA ratio (the muscle CSA divided by the vertebral CSA) in patients with neck pain or radiculopathy.[28] In our study, no significant correlation was found between the CSA with cervical alignment (C2-7 angle) or cervical spine mobility (C2-7 ROM angle) (Table 2). The difference between our results and previous study results may be caused by differences in the methods for evaluating CSAs of paraspinal muscles or targeted patients. A detailed analysis regarding the CSAs of posterior paraspinal muscles may shed light on the association between paraspinal muscle area and clinical outcomes in cervical spine disease.

Our results revealed that the NDI score was worse and FI% of SCer higher for the OPLL-CM patients with a relatively large extent of OPLL than the OPLL-SL patients with a relatively small extent of OPLL (Tables 3 and 4). Many studies have previously reported the relationship between fatty infiltration of lumbar paraspinal muscles and low back pain.[8-13] In the field of the cervical spine, Elliot et al. reported that the NDI score was associated with fatty infiltration of posterior cervical muscles after whiplash injury.[41] Similarly, Kim et al. reported that fatty infiltration of cervical extensor muscles was significantly correlated with the visual analog scale score for neck pain and the NDI score in patients who had neck pain.[25] Our finding that neck disability could be associated with fatty infiltration of deep posterior paraspinal muscles according to the severity of OPLL, is consistent with these previous results.[25,41] Clinical manifestations, paraspinal muscle degeneration, and OPLL morphology may have a complex interaction with each other and lead to a cycle of repeated neck-associated clinical problems. A better understanding of the mechanisms underlying the development of clinical manifestations owing to paraspinal muscle degeneration could contribute toward better clinical management of patients with cervical OPLL.

The results of correlation analysis between paraspinal muscle measurements and clinical characteristics revealed that higher age was significantly associated with higher fatty infiltration and male sex was significantly associated with a higher CSA of paraspinal muscles. These results correspond to previous results.[31,38] Conversely, the BMI had no significant association with paraspinal muscle measurements except for the CSA of SCer at C4/5 (Table 2). Compositional variations in intramuscular adipose tissue at different body locations have been shown to be related to BMI as well as age and sex.[42-44] OPLL patients reportedly have been associated with several metabolic disorders, such as DM and obesity.[1,2] The compositional changes in intramuscular fat tissue may be different between patients with and without OPLL. Thus, future directions for investigation may include comparisons between OPLL patients and normal controls.

This study has several limitations. First, the number of patients studied was small because cervical OPLL is a relatively rare disease and this study was conducted in a single center, due to which it was not possible to fully examine the association between paraspinal muscle measurements and clinical features. Prospective large cohort studies are needed to further confirm and extend our findings. Second, the timing between the imaging examination (within 3 months before surgery) and clinical outcome investigation (within 7 days before surgery) varied. However, we believe that this inconsistent timing between the imaging study and clinical outcomes had only a small effect on our results because fatty infiltration of the paraspinal muscles may not be altered in such a short period. Third, this study did not examine postoperative clinical outcomes because the study participants underwent different surgical procedures, which inevitably had a large effect on postoperative paraspinal muscle morphology and clinical results. Further investigation regarding the effect of preoperative paraspinal muscle degeneration on postoperative outcomes is needed in cervical spine pathophysiology including cervical OPLL. Fourth, some clinical outcomes had not been completely administered, which may have affected the results of this study. Fifth, some of the MRI was generated on different MRI systems with potentially different protocols, which could have resulted in possible inaccurate MRI measurements. Future studies should use standardized MRI systems and protocols. Finally, other posterior cervical extensors, such as the semispinalis capitis or splenius capitis, and anterior cervical flexors were not investigated in this study. We focused on deep posterior cervical paraspinal muscles, such as the MF and SCer, because these muscles have a critical role in postural stability through their deep attachments to the cervical spine.[19] Further study is needed to achieve more reliable results. However, despite these limitations, this is the first study to clarify the associations of the paraspinal muscle degeneration with clinical manifestations or ossified lesion severity in patients with cervical OPLL. This may imply the potential benefit of physical therapy to avoid paraspinal muscle degeneration and alleviate cervical disability in patients with OPLL. Our findings would encourage clinicians to consider paraspinal muscle fatty infiltration and cervical manifestations in patients with cervical OPLL and to provide better patient instruction and clinical management including physical therapy.

Conclusions

Our results suggest that fatty infiltration of deep posterior cervical paraspinal muscles is associated with the severity of OPLL, such as the number of vertebrae with OPLL and occupancy ratio of OPLL, and could have effects on cervical disability in patients with cervical OPLL. Patients with a large extent of OPLL, which could cause reduced cervical spine mobility, were more likely to have worse neck-associated clinical manifestations owing to deep posterior paraspinal muscle degeneration.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article. YT reports personal fees from ZOZO, Inc, outside the submitted work. HO reports personal fees from AYUMI Pharmaceutical Corporation, personal fees from Nippon Zoki Pharmaceutical Co., Ltd., personal fees from Ono Pharmaceutical Co., Ltd., personal fees from Sompo Holdings, Inc, personal fees from NuVasive Japan, Inc, personal fees from Promotion of Practical Use of AI Medical Diagnosis Support Equipment, personal fees from MS&AD InterRisk Research & Consulting, Inc, personal fees from Inotech Corporation, personal fees from Chugai Pharmaceutical CO., LTD, personal fees from The Association for Preventive Medicine of Japan, grants from Pfizer Inc, personal fees from Shionogi & Co., Ltd., personal fees from MTG Co., Ltd., outside the submitted work. KM is a shareholder/an adviser of Trunk Solution CO., Ltd. and received the following support: a research grant from the Ministry of Health, Labour and Welfare; grant support from Sompo Holdings, Inc, MS&AD Inter-Risk Research & Consulting, Inc., Inotech Co., Ltd., NUVASIVE Japan MTG Co., Ltd. DeNA, Medical Data Scientist and Medical AI Device Development Organization, The Association for Preventive Medicine of Japan, Murata Manufacturing Co., Ltd. including personal fees from Nippon Zoki Pharmaceutical Co., Ltd., Ono Pharmaceutical Co. Ltd., Chugai Pharmaceutical Co., Ltd., AYUMI Pharmaceutical Corporation, Shionogi & Co., Ltd.; lecture fees from Eli Lilly Japan K.K., Pfizer Japan Inc., Hisamitsu Pharmaceutical Co., Inc., outside the submitted work. ST has received honoraria from Amgen inc., ASAHI KASEI PHARMA CORPORATION, Amgen Astellas BioPharma K.K., KYOCERA Medical Corporation, DAIICHI SANKYO COMPANY, LIMITED, TEIJIN PHARMA LIMITED., Eli Lilly Japan K.K., Pfizer Japan Inc., endowments from Astellas Pharma Inc., AYUMI Pharmaceutical Corporation, Bristol.Myers Squibb, Pfizer Japan inc, DAIICHI SANKYO COMPANY LIMITED, Chugai Pharmaceutical Co., Ltd, and grants from The Japan Agency for Medical Research and Development (AMED), Japan Society for the Promotion of Science (JSPS)/ Grant.in.Aid for Scientific Research (A), and the Japan Society for the Promotion of

Science (JSPS)/Grant.in.Aid for Exploratory Research., outside the submitted work.

Ethical Approval

The study approval was given by the institutional review board of the Clinical Research Support Center of the University of Tokyo Hospital (Approval no. 10 335).

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: YO reports grants from Depuy Synthes, grants from Medtronic Japan, grants from Olympus Terumo Biomaterials Corp., grants from Stryker Japan K.K., grants from Nuvasive Japan Inc., outside the submitted work.

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