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ORIGINAL ARTICLE

Cervical curvature, spinal cord MRIT2 signal, and occupying ratio impact surgical approach selection in patients with ossification of the posterior longitudinal ligament

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Abstract

Objective Factors impacting surgical options and outcomes in patients with cervical ossification of the posterior longitudinal ligament (OPLL) were explored.

Methods A retrospective analysis was conducted of 127 eligible cervical OPLL patients (61 males, 66 females) aged 41–70 years (mean 55.2 years) selected from 152 total OPLL patients treated from 2002 to 2006, with 5–10-year (mean 6.8 years) follow-up. Patients underwent anterior subtotal corpectomy with ossification ligament resection (anterior surgery, $n = 68$) or posterior cervical double-door laminoplasty (posterior surgery, $n = 59$). Radiographic assessments of cervical curvature, T2-weighted MRI (MRIT2) signal, and OPLL occupying ratio were correlated with surgical strategy before surgery and at 1, 5 weeks, and 5 years.

Results Lordosis increased following anterior surgery, though kyphosis improved by 10.3 %. The canal stenosis occupying ratio was >50 %, and short-term improvement following anterior surgery was significantly higher than posterior surgery ($P > 0.0001$). Superior neurological function was observed in patients with unchanged versus high spinal MRIT2 signals ($P = 0.0434$). No significant differences were observed in short-term outcomes between anterior and posterior surgeries in high spinal MRIT2 signal patients, but anterior surgery produced significantly better long-term outcomes at 1 week ($P = 0.7564$) and 1 year ($P = 0.0071$). Complications occurred in five anterior and three posterior surgeries.

Conclusion Preoperative assessment of cervical curvature, MRIT2 signal, and occupying ratio can be used to guide clinical surgical approach selection to potentially produce better long-term outcomes in patients with OPLL.

Keywords Ossification · Posterior longitudinal ligament · Occupying ratio · Cervical curvature · Anterior surgery · Posterior surgery

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Introduction

Ossification of the cervical posterior longitudinal ligament (OPLL) is characterized by progressive heterotopic coalescence of centers for chondrification and ossification that may mimic the symptoms of disc disease or spinal cord compression [1]. Cervical OPLL occurs commonly in East Asian populations, most often affecting the spinal centrum (body) 5 (C5) or, less frequently, the C4 and C6 [1, 2]. Partial lesions may begin from the trailing edge of the C2 odontoid process and extend to the posterior edge of the C7, sometimes reaching the upper thoracic centrum [2]. Unfortunately, effective prevention and treatment for OPLL is still not available.

Contemporary strategies primarily involve treatment of OPLL symptoms, with asymptomatic cases often left untreated until obvious spinal cord compression appears, which may result in severe neurological damage. At symptom onset, conservative treatment is often ineffective, necessitating surgery [2]. Surgical intervention is generally recommended when computer tomography (CT) or magnetic resonance imaging (MRI) reveals severe ligament ossification, high signal changes in spinal T2-weighted MRI (MRIT2) images, or abnormal somatosensory potentials [1, 2]. Optimal surgical time and type, however, remain controversial [3, 4]. Because OPLL ossification lesions are located at the anterior wall of the spinal canal, some researchers have suggested that the ideal surgical approach is anterior decompression followed by strong fixation after bone grafting, thus removing ossification and relieving spinal cord compression [5, 6].

Ossification of the posterior longitudinal ligament treatment, however, requires careful consideration of ossification location, extent, and thickness, however, each of which may directly affect surgical safety and postoperative patient outcomes. Compared to the anterior surgical approach, indirect decompression by posterior surgery is considered relatively simple, carrying lower risks and generally producing better therapeutic outcomes [7–9]. Backwards shifting of the postoperative spinal cord may, however, result in frontal ossification, further compressing the spinal cord and resulting in poor patient outcomes. Ossification can thus continue after surgery, with scar tissues forming in the spinal canal to produce secondary instability and kyphosis of the cervical spine [1, 2]. Additionally, a variety of parameters have been demonstrated to influence surgical outcomes, including age, type, ossification location, and OPLL occupying ratio [1, 2, 10].

Surgical approach selection was examined retrospectively in 127 OPLL patients treated with anterior or posterior surgery in order to identify the parameters associated with patient outcomes and to potentially propose an improved method for surgical determination. OPLL occupying ratio, changes in cervical curvature, and spinal MRIT2 signal were considered in order to potentially provide useful assessment indicators for surgical approach evaluation and selection applicable to clinical treatment selection for OPLL patients.

Materials and methods

Patient selection

Between 2002 and 2006, a total of 152 patients with cervical OPLL underwent surgical intervention at the Spine Surgery Center of Shandong University Qilu Hospital (Jinan, China). Patients were included that (1) had a confirmed diagnosis of cervical OPLL; (2) received surgical treatment with either anterior subtotal corpectomy with ossification ligament resection (anterior surgery) or posterior cervical double-door laminoplasty (posterior surgery); (3) were of adult age (>18 years); and (4) had complete medical records, including pre- and postoperative radiographic assessments of cervical curvature, T2-weighted MRI (MRIT2) signal, and OPLL occupying ratio for the primary surgery. Notably, some patients were included that thereafter underwent later secondary surgery for various reasons.

Patients were excluded that (1) did not complete a minimum of 5 years of follow-up; (2) presented with severe complications, including cerebral vascular embolism, secondary thoracolumbar spinal stenosis, or peripheral neuropathy; or (3) could not undergo precise neurological function assessment for any other reason. This study was approved by the Institutional Review Board of Shandong University Qilu Hospital, and written informed consent was obtained from all participants (Approval No: Sduqilu 2181).

Surgical treatment

Surgical modalities were selected based on the individual patient. Patients with cervical OPLL involving less than 3–4 vertebrae below the C3 level with thicknesses less than 5–6 mm and spinal stenosis less than 50 % were treated with anterior surgery. Patients with OPLL involving more than four segments, C1/C2 vertebrae, or cervical vertebrae lower than C6/C7, often resulting in poor surgical vision, were treated with posterior surgery. Additionally, posterior surgery was selected to avoid damage to the spinal cord and potential paralysis when the sagittal diameter was <3 mm.

Anterior surgery

Anesthesia was administered through the cervical plexus, and intensive anesthesia was administered according to standard protocols. Abnormal intervertebral discs and bone spurs were excised by anterior surgery concurrent with bone grafting of the intervertebral disc. After positioning, the edge of the uncinate process or the disc was considered the width for the purpose of spinal decompression by ossification removal (20–25 mm). The total resection of the corresponding vertebral body and ligament ossification was determined by ossification scope. For ligament ossifications adhering to the dural sac or non-completely removed dural ossification adhesions, ossifications were removed by the previously described floating method [11]. Following decompression, intervertebral bone graft was conducted using a titanium mesh filled with bone particles, and a titanium plate was used to reconstruct cervical stability.

Posterior surgery

Cervical canal expansion was performed by posterior surgery, removing multi-segment OPLL and cervical yellow ligament hypertrophy or ossification and thus relieving spinal cord compression. Local or general anesthesia was applied, and patients were positioned laterally during standard double-door laminoplasty [12]. Segmental instability was treated with titanium lateral mass screws or spinal pedicle screw fixation concurrent with bone graft fusion. If posterior longitudinal ligament ossification extended to the rear of the C2 vertebral body, C2 laminectomy was also conducted.

Postoperative treatment

For resection of 1–2 cervical segments by the anterior surgical approach, a cervical collar was recommended for 2 months after surgery; for resection of three or more cervical segments a neck-thoracic was recommended for 2 months after surgery, followed by a cervical collar for 1 month. For all posterior surgeries, a cervical collar was recommended for 1 month after surgery. All patients were advised to strictly limit neck activity.

Evaluation

X-ray, CT, and MRI imaging

Routine preoperative examinations of the lateral cervical spine by X-ray, CT, or MRI were available for all included patients, allowing determination of the type, shape, vertical range, and horizontal range of posterior longitudinal ligament ossification. Postoperative follow-up assessments were conducted at 1 month and subsequently every 12 months. Bone grafts were evaluated by X-ray and CT scanning to evaluate healing. Additionally, preoperative signal changes in the cervical spinal cord and ossification range were examined by MRI.

Cervical curvature, spinal canal diameter, and occupying ratio evaluation

Pre- and postoperative X-ray measurements of C2–C7 region spinal lordosis curvature (α), the angle formed by the lower edges of the C2 and C7 vertebral bodies, were used to indicate kyphosis ($\alpha \leq -5°$), straight spine ($-5° < \alpha < 10°$), and lordosis ($\alpha \geq 10°$). Changes in cervical centrum sequence were also observed. Anterior and posterior spinal canal diameters and ossification thicknesses were measured by CT scanning, and the smallest OPLL occupying ratios were calculated, as follows: spinal stenosis extent = (ossification thickness/osseous spinal canal anterior and posterior diameter) × 100 %. Patients were divided into three groups according to extent of the OPLL, namely the OPLL occupying ratio groups of <50 % (low), 50–60 % (moderate), and >60 % (high).

Neurological function assessment

Neurological function was assessed preoperatively and postoperatively at 1 week, 1 and 5 years using the Japanese Orthopedic Association JOA scoring system [13], allowing for calculation of improvement rate (IR) for nerve function, as follows: IR = (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100 %.

Statistical analysis

All data were analyzed using SPSS version 13.0 (IBM, Chicago, IL, USA) and expressed as mean ± standard deviation (SD). The effects of various factors and their interactions were analyzed using the mixed effects model [7], based on the patient scoring data (4×) and improvement rate measurement (2×). Surgical method efficacies, follow-up times, and count data were analyzed for both groups using a Student's *t* test. All categorical data were analyzed using a χ^2 test. *P* values of <0.05 were considered statistically significant ($P < 0.05$).

Results

Clinical and demographic parameters for included patients

Of the total 152 treated OPLL patients, 127 patients, including 61 males and 66 females aged 41–70 years (mean 55.2 years), were included in the present study. Of the total 152 patients, 25 patients were rejected due incomplete follow-up data ($n = 9$) or the presence of severe complication(s) ($n = 16$), including cerebral vascular embolism ($n = 7$), secondary thoracolumbar spinal stenosis ($n = 6$), and peripheral neuropathy ($n = 3$) that prevented precise measurement of neurological function. The preoperative duration of clinical symptoms ranged 12 months to 8 years (mean 3.5 years), manifesting as radiating upper limb pain, numbness, muscle atrophy, decreased muscle strength, and upper motor neuron dysfunction (e.g. sensory loss, decreased muscle strength, and increased muscle tone below the damaged nerve root level). In severe cases, rectal and bladder dysfunction were also observed. Clinical and demographic information by treatment group is shown in Table 1, indicating no significant differences in any of these parameters between the two groups ($P > 0.05$).

Table 1 Demographic and clinical information for the study cohort by surgical approach

	Anterior approach	Posterior approach	χ^2/t	P
Male/female	36/32	25/34	1.414	0.235
Age (years)	37–62 (54.4 ± 12.8)	40–67 (57.9 ± 9.5)	1.727	0.086
Symptom duration (years)	0.2–16 (3.1 ± 1.5)	0.3–19 (3.7 ± 2.1)	1.870	0.064

Surgical approach and outcomes of follow-up

Included patients were treated with either anterior subtotal corpectomy and ossification ligament resection ($n = 68$) or posterior cervical double-door laminoplasty ($n = 59$). Of the 59 patients treated with posterior surgery, laminoplasty of the neck at C3–C7 was conducted in 44 cases, and laminoplasty at C2–C7 was conducted in 13 cases. The mean operative time was 160 min (120–210 min), and mean blood loss was 330 ml (220–430 ml). For the 68 patients treated with anterior surgery, a single corpectomy was reported in 33 patients, resection of double vertebral bodies was reported in 17 cases, and subtotal resection with three vertebrae was reported in 18 patients. The mean operative time was 190 min (120–290 min), and mean blood loss was 460 ml (140–1,100 ml).

Follow-up was conducted for 5–10 years (mean 6.8 years) for each included patient. Titanium mesh sedimentation occurred in two patients treated with anterior subtotal corpectomy of three vertebral bodies after 1-year follow-up, but no obvious light regions were observed between the vertebral interface and titanium mesh. The activity of the titanium mesh in dynamic status was thus determined to be normal. Bone grafts did not heal in three patients, though no fracture or displacement of internal fixation occurred. In patients that underwent C1–C2 subtotal resection, no unhealed bone grafts were observed.

Surgical complications

Anterior surgery resulted in cerebrospinal fluid leakage in five patients, C5 bilateral nerve root palsy in one patient, and postoperative central neurological dysfunction in six patients (e.g. sensory loss and decreased muscle strength). Notably, all complications occurred in patients with high (>60 %) OPLL occupying ratios and high MRIT2 signals. These conditions progressively improved between 3 months and 1 year after occurrence in all patients. Immediately following surgery, 12 patients reported transient hoarseness, choking, and swallowing difficulties, alleviated spontaneously within 1–3 months. No cases of esophageal or tracheal injury were reported following anterior surgery.

Posterior surgery resulted in C5 nerve root palsy in three patients (1 bilateral case, 2 unilateral cases), C6 nerve root palsy in one patients associated with cervical lordosis, and neck-shoulder axial pain in seven patients associated with postoperative cervical straightness and kyphosis. No central neurological dysfunctions were observed following posterior surgery. In both surgical approaches, no complications due to wound infection, respiratory distress, or circulatory dysfunction were observed. Notably, early and terminal improvement rates of patients treated with anterior surgery were significantly better than patients treated with posterior surgery ($P < 0.01$).

Cervical curvature is affected by surgical approach

X-ray measurement of angle α (C2–C7) revealed that lordosis increased from 27.9 to 73.5 % following anterior surgery, though no change was observed following posterior surgery. No curvature (straight) was observed in 41.2 % of anterior surgery patients preoperatively, though this number was reduce to 16.2 % following surgery. The number of patients exhibiting kyphosis patients dropped to 10.3 % postoperatively following anterior surgery and rose to 33.9 % following posterior surgery (Table 2). Notably, restoration of kyphosis occurred in some patients following posterior surgery.

Pre- and postoperative improvement rates in cervical curvature were assessed by JOA scores. For patients with kyphosis, early improvement rates for cervical spine curvature in patients treated with anterior surgery was significantly better than that observed in patients treated with posterior surgery ($P > 0.0001$). Similarly, the terminal improvement rate increased significantly in patients treated with anterior surgery compared to those treated with posterior surgery ($P > 0.0001$) (Table 3).

In patients treated with posterior surgery, the recovery rate was <50 %. At the end of follow-up, 12 patients exhibited significant cervical curvature change, with 7 patients changing from lordosis to straight, and 5 patients changing from lordosis to kyphosis (data not shown).

OPLL occupying ratio is affected by surgical approach

In patients with low spinal stenosis (<50 %), both surgical approaches resulted in early improvement in spinal stenosis, though anterior surgery produced greater terminal improvement rates. For patients moderate (50–60 %) and high (>60 %) spinal stenosis, early and terminal improvement rates following anterior surgery were significantly higher ($P > 0.0001$) (Table 2), suggesting canal stenosis extent can be used to select an approach surgical

Table 2 Correlation between cervical curvature, canal stenosis, MRIT2 signal, JOA scoring, and neurological function improvement rate (mean ± SD)

	Surgical approach	*n* (%)	Before surgery	After surgery (1 week)	After surgery (1 year)	After surgery (5 years)	Early improvement rate (%)	Terminal improvement rate (%)
Cervical curvature change								
Lordosis	Anterior	19 (27.9)	8.62 ± 3.21	12.85 ± 2.44	13.76 ± 2.37	15.65 ± 2.42	50.48 ± 8.74	83.89 ± 7.62
	Posterior	27 (45.8)	8.25 ± 2.25	12.25 ± 3.14	13.34 ± 2.54	14.14 ± 2.37	45.71 ± 8.67	67.31 ± 7.83
Straight	Anterior	28 (41.2)	7.75 ± 2.78	12.52 ± 3.51	14.71 ± 2.35	15.35 ± 2.22	51.57 ± 8.25	82.16 ± 7.15
	Posterior	21 (36.2)	7.15 ± 2.12	11.87 ± 3.33	12.64 ± 2.82	13.55 ± 2.34	47.92 ± 8.65	64.97 ± 7.33
Kyphosis	Anterior	21 (30.9)	6.88 ± 3.13	11.84 ± 2.25	13.17 ± 2.46	13.48 ± 2.33	49.01 ± 7.38	65.22 ± 7.92
	Posterior	11 (19.0)	7.32 ± 2.85	10.05 ± 2.53	11.33 ± 2.13	11.56 ± 2.43	28.20 ± 8.64	43.80 ± 7.19
Canal stenosis extent								
<50 %	Anterior	22 (52.4)	8.32 ± 2.17	12.90 ± 2.68	14.56 ± 2.45	15.84 ± 3.24	52.76 ± 8.25	86.64 ± 7.45
	Posterior	20 (47.6)	7.75 ± 3.12	12.64 ± 2.48	14.15 ± 3.25	14.12 ± 2.82	52.86 ± 9.10	68.86 ± 8.75
50–60 %	Anterior	36 (67.9)	7.46 ± 2.83	12.87 ± 2.54	14.59 ± 2.81	15.12 ± 2.32	56.71 ± 7.84	80.29 ± 8.23
	Posterior	17 (32.0)	8.17 ± 2.54	11.05 ± 2.25	12.28 ± 2.46	13.25 ± 2.15	32.62 ± 6.85	57.53 ± 7.39
>60 %	Anterior	10 (31.2)	6.73 ± 2.03	12.33 ± 2.25	12.85 ± 2.87	13.77 ± 2.92	54.53 ± 7.64	68.55 ± 7.82
	Posterior	22 (68.8)	7.26 ± 2.54	10.05 ± 3.06	11.02 ± 2.23	11.38 ± 2.43	28.64 ± 7.45	42.30 ± 8.24
MRI signal change								
No change	Anterior	61 (90.0)	8.22 ± 3.34	11.75 ± 3.18	14.58 ± 2.95	15.64 ± 3.35	40.21 ± 7.32	84.51 ± 9.25
	Posterior	49 (83.1)	8.76 ± 3.51	10.28 ± 2.64	13.18 ± 3.28	14.22 ± 2.51	27.27 ± 9.25	69.91 ± 8.77
High signal	Anterior	7 (10.3)	6.75 ± 2.67	9.54 ± 3.25	11.85 ± 2.12	12.95 ± 2.33	27.22 ± 9.62	62.36 ± 9.47
	Posterior	10 (17.0)	6.24 ± 3.12	9.87 ± 2.45	11.13 ± 2.33	11.25 ± 2.11	33.74 ± 8.85	43.90 ± 10.13

approach with the goal of reducing cervical spinal stenosis extent.

MRIT2 signal change is affected by surgical approach

No change in spinal MRIT2-weighted signals was observed in 110 patients (86.6 %), and high MRIT2 signals were observed in 17 patients (13.4 %) after preoperative cervical MRI examination in both groups. The extent of spinal stenosis in these 17 patients was >60 % in all cases. Of these patients, seven patients (41.2 %) and ten patients (58.8 %) were treated with anterior surgery and posterior surgery, respectively. Patients exhibiting no spinal MRIT2 signal change had significantly greater terminal improvement rates during anterior surgery compared to those observed in posterior surgery (Table 3).

JOA score change and mixed model analysis

Statistical analyses using a mixed model approach revealed that surgical approach, OPLL occupying ratio, cervical curvature change, and postoperative MRIT2 signal were statistically significant in determining postoperative JOA scoring. Correlation of surgical outcome and relevant factors was analyzed (Table 3). JOA scores for patients treated with anterior surgery were better than those treated with posterior surgery when spinal stenosis extent was 50–60 % or >60 % at 1 week, 1, and 5 years after surgery ($P < 0.05$).

Surgical approach affects neurological function improvement

Different surgical approaches, spinal stenosis extent, changes in cervical curvature, and MRIT2 signal were statistically significant in determining neurological function improvement rate (Table 3). Anterior surgery produced significantly superior neurological function results in patients with mild spinal stenosis, though no improvement or decline was observed in patients with moderate and severe spinal stenosis. Similarly, anterior surgery produced significantly superior outcomes in patients with lordosis and no curvature (straight) than in kyphosis patients. Patients exhibiting no MRIT2 signal change had significantly better outcomes than those with high MRIT2 signal (Table 3).

Discussion

Appropriate selection of surgical approach for OPLL patients, either anterior or posterior, is widely debated. The

Table 3 Improvement rate change based on parameter estimation in the mixed effect model

Processing and level	Estimation	SE	DF	*t*	*P* value
Intercept	9.7429	0.1452	120	67.09	<0.0001
Surgery					
Anterior approach	4.1787	0.1202	120	34.75	<0.0001
Posterior approach	0	–	–	–	–
Canal stenosis					
Mild	1.1532	0.2692	120	4.28	<0.0001
Moderate	0.2891	0.1861	120	1.55	0.1230
Severe	0	–	–	–	–
Cervical curvature					
Lordosis	2.0542	0.2581	120	7.96	<0.0001
Straight	1.1337	0.1730	120	6.55	<0.0001
Kyphosis	0	–	–	–	–
MRI signal					
No change	0.4937	0.2418	120	2.04	0.0434
High signal	0	–	–	–	–
Cervical curvature					
BS	−5.8179	0.1081	360	−53.81	<0.0001
AS 1 week	−1.4426	0.09060	360	−15.92	<0.0001
AS 1 year	−0.8470	0.06577	360	−12.88	<0.0001
AS 5 years	0	–	–	–	–
Surgical approach × JOA scoring time					
Anterior × BS	−0.1209	0.08953	360	−1.35	0.1778
Anterior × AS 1 week	−0.3638	0.07502	360	−4.85	<0.0001
Anterior × AS 1 year	0.03992	0.05446	360	0.73	0.4640
Anterior × AS 5 years	0	–	–	–	–
Canal stenosis × JOA scoring time					
Mild × BS	0.09433	0.2005	360	0.47	0.6383
Mild × AS1 week	−0.1725	0.1680	360	−1.03	0.3050
Mild × AS 1 year	−0.1917	0.1219	360	−1.57	0.1168
Mild × AS 5 years	0	–	–	–	–
Moderate × BS	0.008118	0.1386	360	0.06	0.9533
Moderate × AS 1 week	0.05115	0.1161	360	0.44	0.6599
Moderate × AS 1 year	−0.3037	0.08431	360	−3.60	0.0004
Moderate × AS 5 years	0	–	–	–	–
Cervical curvature × JOA scoring time					
Lordosis × BS	−0.06888	0.1922	360	−0.36	0.7203
Lordosis × AS 1 week	−0.09751	0.1610	360	−0.61	0.5452
Lordosis × AS 1 year	0.4267	0.1169	360	3.65	0.0003
Lordosis × AS 5 years	0	–	–	–	–
Straight × BS	−0.05900	0.1288	360	−0.46	0.6473
Straight × AS 1 week	−0.1619	0.1079	360	−1.50	0.1346
Straight × AS 1 year	0.1167	0.07837	360	1.49	0.1373
Straight × AS 5 years	0	–	–	–	–
MRI signal × JOA scoring time					
No change × BS	−0.4378	0.1800	360	−2.43	0.0155
No change × AS 1 week	−0.04684	0.1508	360	−0.31	0.7564

Table 3 continued

Processing and level	Estimation	SE	DF	*t*	*P* value
No change × AS 1 year	0.2968	0.1095	360	2.71	0.0071
No change × AS 5 years	0	–	–	–	–

In the interactive effects view, the anterior approach after surgery 5 years, mild spinal stenosis × after 5 years, moderate occupying ratio of OPLL × after 5 years, cervical lordosis × after 5 years, straight cervical spine surgery × after 5 years, and no MRI signal change × after 5 years all represent baseline data. There was a significant difference between post-operative week 1 and 5 years in moderate occupying ratio of OPLL, cervical lordosis, and patients with no MRI signal change

BS before surgery, *AS* after surgery, *JOA* Japanese Orthopedic Association

current study indicated that spinal stenosis extent, cervical curvature, MRIT2 signal change, and surgical approach can affect neurological function following surgery, as indicated by JOA scores. These findings suggest that selection of surgical approach should be carefully considered on an individual basis in order to improve treatment outcomes in OPLL patients.

Some reports have indicated that similar outcomes occur in patients with spinal stenosis <60 % using both anterior and posterior approaches, while others recommend anterior surgery when spinal stenosis is >60 %, ossifications are large, or spinal cord compression is severe [14–16]. Ogawa et al. [17] reported that of 72 patients receiving posterior laminoplasty, 15.3 % exhibited symptom aggravation. Furthermore, symptoms improved in 63.1 % of these patients over the course of a 5-year follow-up period. Iwasaki et al. [18] suggested that anterior and posterior surgeries produced similar outcomes only when OPLL occupying ratios were <60 %, contrary to the current findings. Notably, the current study suggests that for OPLL occupying ratio <50 %, both surgeries produce comparable results at 1 week and 1 year, but anterior surgery outcomes, including neurological results, are significantly better by 5 years after surgery ($P < 0.05$). Thus, it is the recommendation of the authors that the anterior surgical approach be considered the preferred surgical approach for most OPLL patients. It is important to consider, however, that the risk of iatrogenic complications might increase in patients treated with anterior surgery, though increases in JOA score and recovery of neurological function may outweigh this potential detriment.

Surgical treatment for cervical spinal curvature in OPLL patients is similarly controversial, with some studies indicating that preoperative cervical curvature does not affect the postoperative recovery of OPLL patients, which suggests that cervical kyphosis is not a contraindication for posterior surgery [18]. While the full extent of kyphosis resulting from posterior surgery will require further study, the current findings suggest that changes in cervical lordosis prior to surgery may impact surgical outcomes. While no immediate impact on neurological function or JOA score was seen at 1 week, both the terminal improvement rate and the JOA score at 1 and 5 years were improved in patients treated with anterior surgery. In patients with cervical kyphosis, anterior surgery produced both superior short- and long-term results. This suggests that when patients present with degenerative cervical vertebra, no spinal curvature, or kyphosis, the long-term efficacy of anterior surgery is superior to that of posterior surgery.

Low recovery rates for posterior surgery patients in the current study indicated that the change in cervical spine curvature is important in determining surgical outcomes for posterior surgery, consistent with the previous findings of Iwasaki et al. [18]. Because cervical spine curvature may be altered by surgery, patients with preoperative instability of the cervical spine and patients presenting with kyphosis are not suitable for posterior surgery. For these patients, posterior fixation is generally necessary to avoid kyphosis progress following posterior surgery [19–21], increasing risks to patients.

Spinal MRIT2 signal change can signal pathological changes in the spinal gray matter [22]. Matsuda et al. [22] found that patients with preoperative spinal MRIT2 signal change exhibited an increased tendency to be affected by heavy spinal cord injury, often resulting in poor postoperative recovery. Based on the current findings, OPLL patients with higher levels of spinal stenosis are much more likely to have elevated spinal MRIT2 signals. As expected, JOA scores and neurological function were also significantly lower than in these patients. Early surgery may be able to preempt these altered MRIT2 signals, thus improving response to surgery and surgical outcomes. Notably, no difference was observed in short-term results for either anterior or posterior surgery in these patients, but anterior surgery produced significantly better long-term outcomes. Notably, special care should be taken to minimize iatrogenic spinal cord injury during surgical treatment of patients with elevated MRIT2 signals, who may be at increased risk for spinal damage and thus poor outcomes.

Several important factors should be carefully observed when applying these surgical approaches in clinical settings based on the experiences of the current study. The incidence of cerebrospinal fluid leakage in OPLL patients treated with anterior surgery has been reported to be higher than that observed in patients treated with posterior surgery [23, 24]. Only five cases of cerebrospinal fluid leakage occurred during anterior surgery in the present study, primarily associated with ossification adherence or merger to the dural sac. Even though this risk is relatively small, clinicians should pay careful attention when signs of adherence are present to avoid surgical complications. Additionally, C4–C5 segments in patients treated with anterior surgery were demonstrated to require more careful decompression on both sides. In patients receiving posterior surgery, increases in cervical curvature may also be associated with nerve palsy, though further study will be required to confirm and characterize this association. Most notably, as spinal stenosis increase, the surgical risk also increases for both surgery types. Patients with OPLL occupying ratios >60 % are at increased risk for iatrogenic nerve injury during anterior surgery. Thus, patients with significant spinal cord compression associated with elevated MRIT2 signals are candidates for posterior surgery.

It is important to consider that the current study may be limited by several factors, including determination of surgical approach. Because the application of posterior and anterior surgery was determined based on current hospital standards, these groupings may not reflect identical patient populations. Also, as a specialized spinal center, the patients admitted to the current facility may be more severe, and thus not represent the general patient population affected by OPLL. The effects of secondary treatment, including surgery, were not considered in these results. In cases where surgery is unable to relieve spinal cord compression, stop progression of OPLL symptoms, improve cervical instability, and prevent aggravated kyphosis, a combined anterior and posterior decompression surgery should be recommended to decompress up to the maximum. Further research, however, will be required to fully explore this combined technique, patient eligibility, and patient outcomes.

Conclusions

The OPLL occupying ratio, cervical curvature changes, and elevated MRIT2 signals may be indicators of optimal treatment selection, indicating that either anterior or posterior surgical approaches for treatment of OPLL patients will produce significantly superior outcomes. Therefore, multiple preoperative factors should be considered on a case-by-case basis for appropriate determination of surgical treatment approach in these patients.

Conflict of interest The authors declare no conflict of interest.

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