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ORIGINAL ARTICLE

Indication for anterior spinal cord decompression via a posterolateral approach for the treatment of ossification of the posterior longitudinal ligament in the thoracic spine: a prospective cohort study

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Abstract

Purpose For ossification of the posterior longitudinal ligament (OPLL) in the thoracic spine, anterior decompression is the most effective method for relieving spinal cord compression. The purpose of this study was to prospectively analyze the surgical outcomes based on our strategy in the treatment of thoracic OPLL.

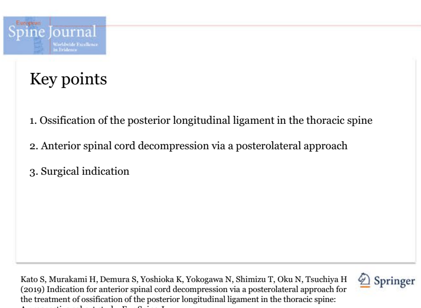
Methods This study included 23 patients who underwent surgery for thoracic OPLL based on the following strategy between 2011 and 2017. For patients with a beak-type OPLL in the kyphotic curve with a ≥ 50% canal occupying ratio, circumferential decompression via a posterolateral approach and fusion (CDF) was indicated. For other types of OPLL, posterior decompression and fusion (PDF) was commonly indicated. Posterior fusion without decompression (PF) was applied when the spinal cord was separated from the posterior spinal elements. Clinical and radiological outcomes were compared among the CDF, PDF, and PF groups with a minimum of 20-month follow-up.

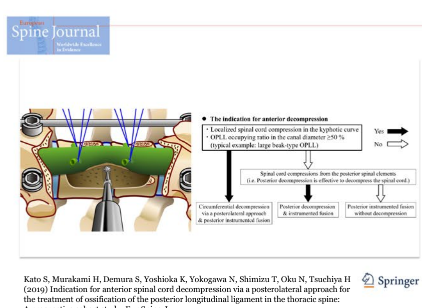
Results Ten, eleven, and two patients underwent CDF, PDF, and PF, respectively. The preoperative Japanese Orthopedic Association (JOA) score in the CDF group was significantly lower than that in the PDF group. The average recovery rate, according to JOA score, was 63%, 56%, and 25% in the CDF, PDF, and PF groups, respectively. The result in the CDF group was better than that in the PF group.

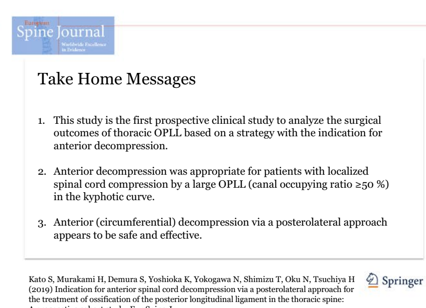
Conclusions Anterior decompression was appropriate for patients with localized spinal cord compression by a large OPLL in the kyphotic curve, and CDF via a posterolateral approach appears to be safe and effective.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







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Keywords Anterior decompression · Ossification of the posterior longitudinal ligament · Thoracic spine · Posterolateral approach · Surgical indication

Introduction

Ossification of the posterior longitudinal ligament (OPLL) in the thoracic spine is a rare but clinically significant spinal disorder that causes progressive thoracic myelopathy and responds poorly to conservative therapy. Surgery is the only effective treatment option. However, spine surgeons have faced significant challenges in determining the most effective surgical procedure and preventing surgical complications [1–3]. In patients with thoracic myelopathy resulting from OPLL in the thoracic spine with a kyphotic curve, anterior spinal cord decompression via OPLL removal or floating is logical and the most effective method for relieving pressure on the spinal cord [4–7]. However, anterior decompression is technically demanding and associated with significant surgical complications, including postoperative neurologic degradation [4–7]. Although anterior decompression is recommended owing to the anatomical features of thoracic OPLL, posterior decompression and instrumented fusion are widely applied for the treatment of this disease [1, 8–10]. Most spine surgeons perform posterior decompression surgery as the primary treatment, regardless of the type of OPLL and spinal alignment at the affected level [3, 8–10]. Moreover, concrete surgical indications for anterior decompression according to the morphology of OPLL and the spinal alignment, which can affect the severity of myelopathy and treatment strategy, have not been evaluated from the surgical perspective [4–7].

Since 2011, we have employed a surgical technique to remove or float the OPLL in the thoracic spine via a

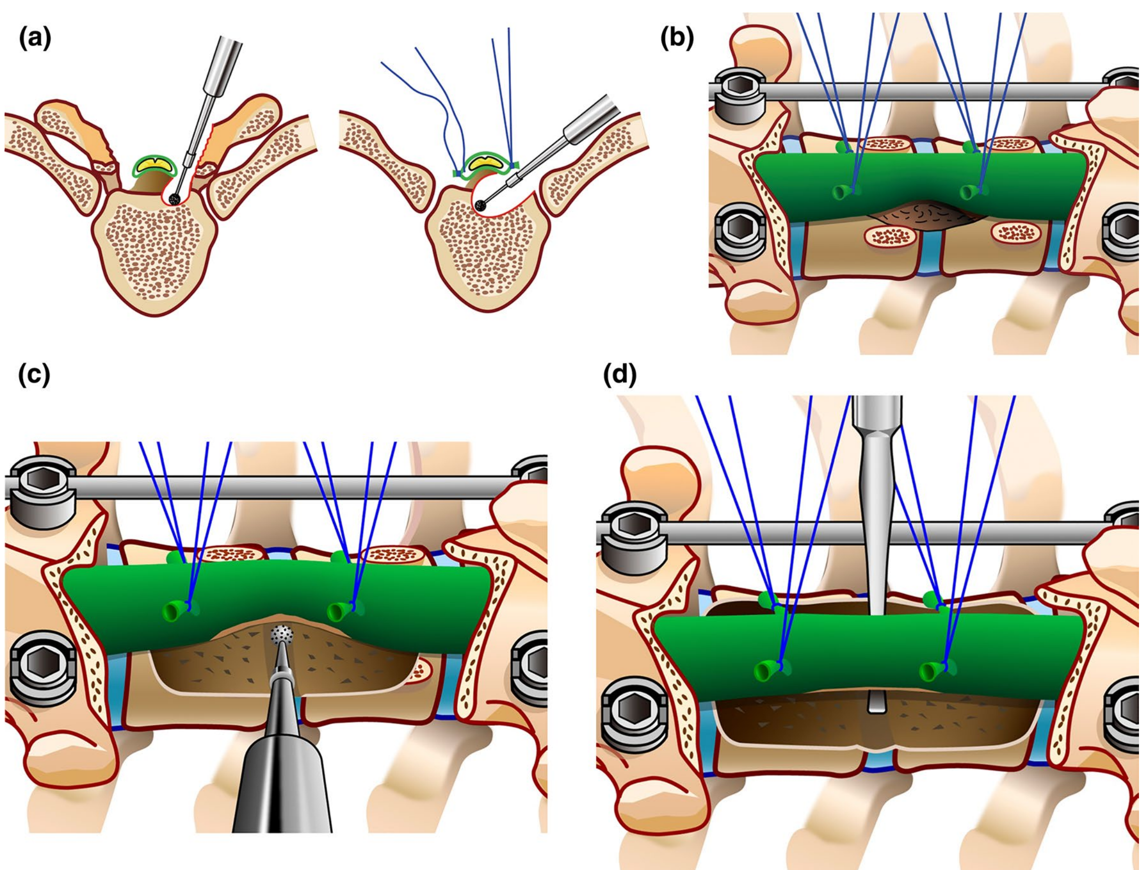

Fig. 1 Anterior (circumferential) decompression via a posterolateral approach. **a** Axial image of a conventional posterior approach (left) and our posterolateral approach (right). **b** Total resection of the posterior elements plus lifting of the ligated thoracic nerves allows surgeons to directly visualize the targeted ossification of the posterior longitudinal ligament (OPLL) and the anterolateral aspect of the dural sac. **c** In this procedure, surgeons can perform anterior decompression with adequate recognition of the positions of the OPLL and the whole dural sac. **d** After anterior decompression (floating of OPLL), a surgical spatula can be easily inserted into the ventral side of the dural sac, and the tip of the spatula can be observed from the opposite side

posterolateral approach [11] (Fig. 1) that allows the surgeon to perform anterior decompression for thoracic OPLL more safely and effectively than the conventional procedures and is especially useful for cases of beak-type OPLL, the most complicated type to treat surgically [8, 10, 12]. The literature concerning cervical OPLL reported that patients with OPLL occupying > 50% [13, 14] or 60% [15] of the canal diameter should be indicated for anterior decompression. Based on these reports and development of our surgical technique, we established our surgical strategy for thoracic OPLL, including an indication for anterior decompression (Fig. 2). We have treated patients with the disease based on this strategy since 2011. This study aimed a prospective analysis of the clinical outcomes of surgical treatments based on our strategy with a minimum of 20-month follow-up.

Methods

Subjects

This prospective cohort study included 23 patients (10 men and 13 women) with thoracic OPLL, with a mean age of 56.0 years. This study was approved by the ethics committee of our University Hospital, and written informed consent was obtained from each participant. Each patient underwent surgery for thoracic OPLL at the author's institute between April 2011 and July 2017 with at least 20-month follow-up. Figure 2 shows the algorithm of the surgical strategy, consisting of three categories. For patients with localized spinal cord compression by the ossification focus typified by a beak-type OPLL in the kyphotic curve occupying ≥ 50% spinal canal diameter, a circumferential spinal cord decompression via a posterolateral approach and posterior instrumented fusion (CDF) is indicated (Fig. 3). For other types of OPLL, posterior spinal cord decompression and instrumented fusion (PDF) is most commonly indicated. When the OPLL compresses the spinal cord from the ventral side, but not from the posterior spinal elements (i.e., there is a space between the spinal cord and the posterior spinal elements at the level of the OPLL, as shown in Fig. 4), posterior decompression by laminectomy is not effective. In those cases, posterior instrumented fusion without decompression (PF) is applied for neurologic improvement by spinal fusion [1–3, 16]. In this case series, all patients were treated according to the surgical strategy. Therefore, revision surgeries due to insufficient neurological improvement were not performed in the follow-up period.

Circumferential spinal cord decompression via a posterolateral approach

The features of this surgical technique were derived from the surgical maneuver in total *en bloc* spondylectomy for spinal tumors [17–19]. With the patient in the prone position, we performed total resection of the posterior elements at the anterior decompression levels. This maneuver includes laminectomies and removal of the transverse processes and pedicles, which allows space creation bilateral to the dural sac and the targeted OPLL for subsequent anterior decompression (Fig. 1a). The thoracic nerves at the levels of anterior decompression were ligated bilaterally and lifted to improve the view of the OPLL and the anterolateral aspect of the dural sac (Fig. 1b). Lifting the nerve roots facilitates control of bleeding from the varix in the canal and vessels in the intervertebral foramen. It does not create the risk of spinal cord rotation because the anterior aspect of the dural sac adheres to the OPLL. After these maneuvers afforded adequate working space and good visualization of the operative field with controlled bleeding, anterior decompression was performed posterolaterally (Fig. 1c). This is similar in terms of approach and visualization to methods used when treating the epidural tumor from the vertebral body, the dural sac, and the nerve

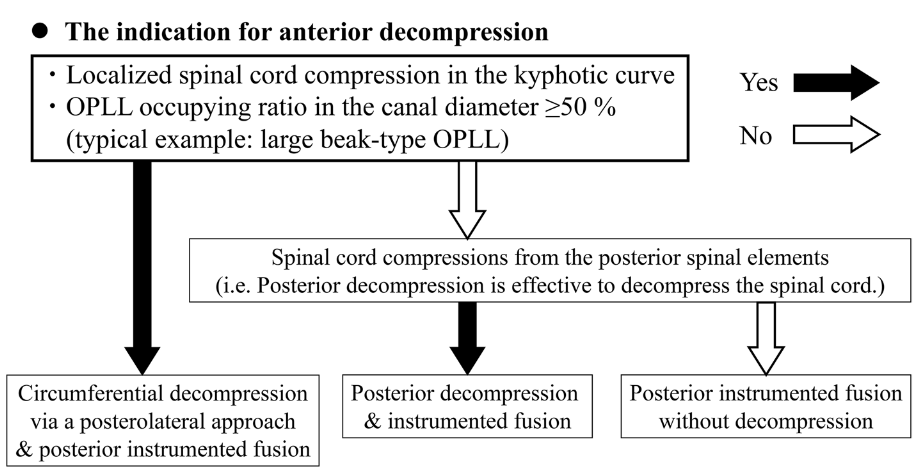

Fig. 2 Our surgical strategy in the treatment of ossification of the posterior longitudinal ligament in the thoracic spine

Fig. 3 A representative case undergoing circumferential decompression and instrumented fusion via a posterolateral approach (the CDF group). **a** Axial (left) and sagittal (right) images of preoperative computed tomography (CT). **b** Axial (left) and sagittal (right) images of postoperative CT myelogram. Sufficient spinal cord decompression was achieved by OPLL floating

roots to remove the tumor including negative margins in total *en bloc* spondylectomy for spinal tumors [17, 18]. In every step of anterior decompression using this approach, surgeons can have visual contact with both the ossified PLL and dural sac. This is a major advantage of the procedure that cannot be obtained with the conventional anterior or posterior approaches. Moreover, in this procedure, the surgeons were allowed to leave the OPLL floating, and OPLL removal was not required (Fig. 1d). Gradual migration of the floated plaques provided additional spinal cord decompression during the postoperative course [20]. After anterior decompression, we performed posterior instrumentation at the spinal level, including that at least two levels above and two levels below the anterior decompression, and posterolateral fusion using local bone chips of the resected laminae and transverse processes [11]. We used intraoperative spinal cord monitoring during the surgery in all patients.

Outcome measures

The morphology of the ossification foci was assessed using multiplanar reconstruction computed tomography (CT) and categorized into beaked, liner, continuous waveform, or continuous cylindrical types according to the classification established by The Research Group for Ossification of the Spinal Ligament sponsored by the Japanese Ministry of Health, and Welfare [1]. All patients, except those undergoing emergency surgery due to severe myelopathy, underwent CT myelogram with multiplanar images, and the maximum compression level was determined. For emergency surgery patients (three patients), the level was determined using CT

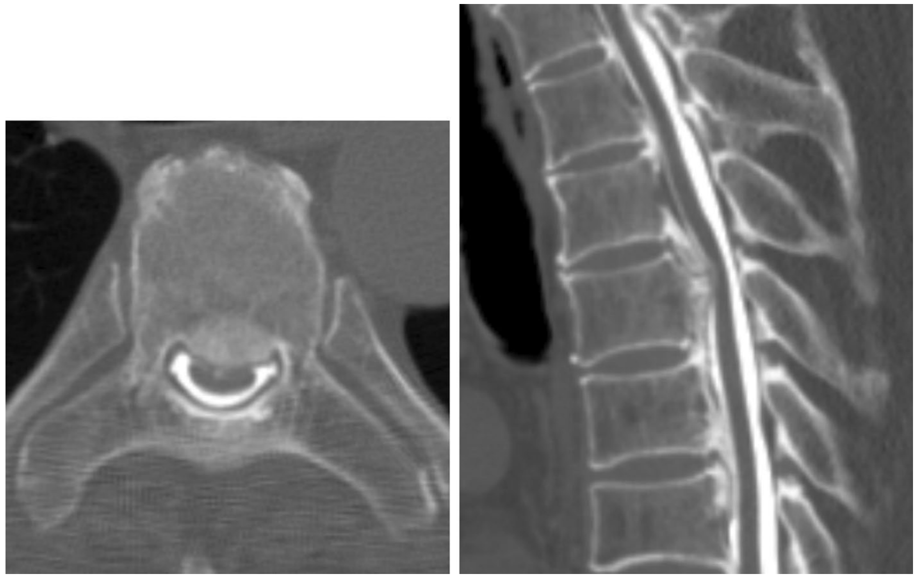

Fig. 4 A representative case undergoing posterior instrumented fusion without decompression (the PF group). Axial (left) and sagittal (right) images of preoperative CT myelogram. Posterior decompression was not effective because the cord was not compressed by the posterior spinal elements

scan and magnetic resonance imaging. The OPLL occupying ratio in the canal diameter was measured using multiplanar reconstruction CT. Age, sex, body mass index, diabetes mellitus, and pre- and postoperative ambulatory status were recorded. Operative parameters, including length of the operation, blood loss, number of anterior and posterior decompression levels, number of fusion levels, and perioperative complications, were evaluated. Neurological recovery was assessed using the Japanese Orthopedic Association (JOA) score for thoracic myelopathy (total of 11 points) derived from the JOA scoring system for cervical myelopathy after eliminating the motor and sensory scores for the upper extremities [1], and the Hirabayashi recovery rate [21]. JOA scores were recorded before surgery and at final follow-up after surgery. The Hirabayashi recovery rate (%) was calculated using the following formula: (postoperative JOA score − preoperative JOA score)/(11 − preoperative JOA score) × 100.

Statistical analyses

All data are presented as means and standard deviations. Tukey–Kramer honestly significant difference test and Fisher's exact test were used for statistical analysis. All significance levels were set at .05. SPSS software version 19.0 for Windows (SPSS Inc., Chicago, Illinois, USA) was used for all statistical analyses.

Results

According to our surgical strategy, ten, eleven, and two patients underwent CDF via a posterolateral approach (CDF group), PDF (PDF group), and PF (PF group), respectively (Table 1). The average preoperative JOA score was 3.0, 5.9, and 1.8 points in the CDF, PDF, and PF groups. The average preoperative JOA score in the CDF group was significantly lower than that in the PDF group. Seven of the ten patients (70%) in the CDF group and three of the 11 patients (27%) in the PDF group were non-ambulatory preoperatively. Both patients in the PF group were non-ambulatory preoperatively. The average OPLL canal occupying ratio in the CDF group was significantly higher than that in the PF group. One patient with beak-type OPLL in the PDF group underwent PDF because her OPLL was in the upper thoracic region with straight alignment. Two patients in the PF group underwent PF because the canal occupying ratio of their OPLL was < 50% and spinal cord compression from the posterior spinal elements was not observed (Fig. 4).

The average recovery rate, according to the JOA score, was 63%, 56%, and 25% in the CDF, PDF, and PF groups, respectively (Table 2). The result in the CDF group was better than that in the PF group. The average postoperative JOA score in the PDF group was significantly higher than that in the PF group. In all ten patients in the CDF group, adequate OPLL removal (three patients) or floating (seven patients) was achieved. Of the seven patients in the CDF group and three in the PDF group who had been non-ambulatory preoperatively due to severe myelopathy, all recovered ambulatory status postoperatively. Of the two patients in the PF group who had been non-ambulatory preoperatively, one remained non-ambulatory postoperatively. In the CDF procedure, anterior decompression via a posterolateral approach was additionally performed after the PDF procedure. Differences in operative time and intraoperative blood loss between the CDF and PDF groups were 37 min and 229 ml, respectively. These differences were not significant. Concerning perioperative

Table 1 Demographics

	CDF group ($n=10$)	PDF group ($n=11$)	PF group ($n=2$)
Age (years)	56.8 (34–76)	53.4 (31–91)	66.0 (52–80)
Gender (male/female)	5/5	4/7	1/1
Body mass index (kg/m^2)	28.6 (22.7–36.9)	29.8 (21.6–48.0)	23.7 (22.6–24.8)
Diabetes mellitus	4 (44%)	3 (33%)	2 (100%)
Preoperative JOA score	3.0 (0.5–8.0)	5.9* (2.5–9.0)	1.8 (1.0–2.5)
Preoperative non-ambulatory status (%)	7 (70%)	3 (27%)	2 (100%)
History of spine surgeries (%)	4 (40%)	2 (18%)	1 (50%)
OPLL canal occupying ratio (%)	72.9 (51–93)	61.8 (38–85)	46.0* (44–48)
OPLL type in the affected level			
Beaked	9	1	0
Liner	0	0	0
Continuous waveform	1	4	1
Continuous cylindrical	0	6	1

CDF circumferential decompression via a posterolateral approach and posterior instrumented fusion, *PDF* posterior decompression and instrumented fusion, *PF* posterior instrumented fusion without decompression, *JOA score* the Japanese Orthopaedic Association score for thoracic myelopathy (total of 11 points)

*$P<0.05$ versus CDF group

Table 2 Surgical outcomes

	CDF group ($n=10$)	PDF group ($n=11$)	PF group ($n=2$)
Operative time (min)	395 (228–621)	358 (264–590)	153* (147–159)
Intraoperative blood loss (ml)	678 (200–1680)	449 (200–1360)	210 (40–380)
Number of anterior decompression levels	2.2 (2–3)	0	0
Number of posterior decompression levels	2.6 (2–5)	4.2 (3–9)	0
Number of instrumented fusion levels	6.3 (4–9)	5.8 (3–11)	6 (6)
Concomitant cervical laminoplasty	0	1 (9%)	0
Postoperative JOA score	7.6 (5–11)	8.7 (5–11)	4** (3–5)
Postoperative non-ambulatory status	0	0	1 (50%)
Recovery rate (%)#	63.1 (50 to 100)	55.8 (−25 to 100)	25.4* (21 to 29)
Perioperative complications			
Transient neurological deterioration	1	1	0
Dural tear	1	1	0

CDF circumferential decompression via a posterolateral approach and posterior instrumented fusion, *PDF* posterior decompression and instrumented fusion, *PF* posterior instrumented fusion without decompression, *JOA score* the Japanese Orthopaedic Association score for thoracic myelopathy (total of 11 points)

#In one case, the total JOA score was calculated as eight points by eliminating the score of three points for bladder function due to chronic renal failure. In four cases, the total JOA score was calculated as eight points by eliminating the score of three points for lower-extremity motor function due to cerebral palsy, brain infarction, and super-aging (91 years old)

*$P<0.05$ versus CDF group; **$P<0.05$ versus PDF group

complications, transient neurological deterioration with at least one grade aggravation in manual muscle test score of the lower extremities and dural tear was observed in one patient each in the CDF and PDF groups (Table 2). Other perioperative complications, including surgical site infection and instrumentation failure, were not observed in the 23 patients. These results indicated that CDF via a posterolateral approach was not invasive or high risk compared with PDF and was not associated with excessive operative time, bleeding, or complication rate.

Discussion

We established our surgical strategy for thoracic OPLL, including an indication for anterior decompression. This study sought to prospectively analyze the surgical outcomes according to our strategy with a minimum of 20-month follow-up. In patients who underwent CDF with a large and localized OPLL in the kyphotic curve, the preoperative JOA scores and rate of ambulatory status were lower than those of the patients who underwent PDF. However, their neurological recovery after surgery was favorable without any significant perioperative complications, whereas, in patients who underwent PF with a relatively small OPLL in the kyphotic curve without spinal cord compression from the posterior spinal elements (i.e., posterior decompression was not effective to decompress the spinal cord), neurological recovery after surgery was limited.

The surgical outcomes of thoracic OPLL unfavorably compare with those of cervical OPLL [1]. The thoracic spine is naturally kyphotic, and therefore, posterior decompression is less effective because the backward movement of the spinal cord is restricted. Anterior spinal cord decompression is ideal for thoracic OPLL if it can be achieved safely and effectively. In all patients who underwent anterior decompression via a posterolateral approach in this series, this procedure was used to remove or sufficiently float beak-type OPLL without any difficulties or significant complications. A main advantage of this procedure is that it provides more space on the bilateral sides of the dural sac for maneuvering during anterior decompression relative to the conventional posterior approach. Additionally, this space, combined with lifting of the ligated thoracic nerves, allows surgeons to directly visualize the targeted OPLL and the anterolateral aspect of the dural sac. In this procedure, surgeons can perform anterior decompression with adequate recognition of the positions of the OPLL and the whole dural sac at every point in time, and this facilitates the anterior decompression procedure. This advantage is not afforded during anterior decompression via an anterior approach. We therefore consider that our surgical technique based on a posterolateral approach is relatively safe and feasible for anterior decompression of thoracic OPLL. Our surgical technique was introduced in the recent review article concerning thoracic OPLL [22]. Imagama et al. [23] reported a similar surgical procedure and its favorable outcome.

In the literature on OPLL in the cervical spine, for patients with a more severely compromised spinal canal, especially canal occupying ratio > 50% [13, 14] or 60% [15], data suggest that the results of anterior decompression and fusion (ADF) were better than those of laminoplasty (LMP) or PDF. Koda et al. [24] examined the clinical outcomes of patients with K-line (−) OPLL who underwent surgical treatments consisting of LMP, PDF, and ADF. They demonstrated that JOA score recovery rate was significantly higher in the ADF group than those in the LMP and PDF groups. The results of these studies demonstrate that even for a certain portion of patients with OPLL in the lordotic cervical spine, anterior decompression is indicated owing to severely compromised spinal cord compression by a large OPLL from the ventral side and/or local kyphotic alignment. These studies on cervical OPLL and the development of a safe, effective, and feasible anterior decompression for thoracic OPLL via the posterolateral approach helped us establish the surgical strategy with an indication for anterior decompression presented in this study. Previously, anterior decompression surgeries and resection of thoracic OPLL using the anterior, posterior, and posterior–anterior combined approaches were reported [4–7, 25, 26]. However, only a limited number of surgeons have employed these surgeries, and a concrete indication for anterior decompression in the treatment of thoracic OPLL, and results according to the strategy have not been presented.

The results of our study show that neurological symptoms among patients in the CDF group with localized spinal cord compression by a large OPLL in the kyphotic curve occupying 50% or more of the spinal canal diameter (canal occupying ratio ≥ 50%) were more severely compromised than those with the PDF group patients. CDF via a posterolateral approach afforded the most favorable result (recovery rate) among the three surgeries, although most patients in the CDF group were non-ambulatory preoperatively. Thus, at a minimum, patients with a localized spinal cord compression by a large OPLL with a ≥ 50% canal occupying ratio in the kyphotic thoracic spine (e.g., large beak-type OPLL) are indicated for anterior decompression. Imagama et al. reported their case series with beak-type thoracic OPLL treated with PDF and risk factors for ineffectiveness of the surgery and concluded that OPLL canal occupying ratio, OPLL length in the sagittal plane on CT, and spinal cord kyphotic angle difference from upper instrumented vertebra to lowest instrumented vertebra were risk factors associated with ineffectiveness of PDF and revision surgery of anterior decompression [10]. In cases with these types of thoracic OPLL, CDF via a posterolateral approach has the best indication and should be considered for the primary surgery. In the procedure, a risk of ischemic spinal cord injury was presented because thoracic nerve roots were ligated at the anterior decompression levels. There were no significant changes detected on monitoring in the patients after ligation of the thoracic nerve roots in a maximum of two consecutive levels bilaterally. Based on the results of the clinical and animal studies of total spondylectomy for spine tumors [27, 28], ligation of the thoracic nerve roots should be limited to three pairs or less to prevent ischemic spinal cord injury. Considering risk prevention, a localized spinal cord compression by a large OPLL is a good indication for the surgical procedure. However, the procedure should not be applied for thoracic OPLL with multi-level spinal compressions. The advantages and pitfalls of this surgical technique have been described in detail in the previous studies [11, 20].

Although there were only two patients who underwent PF according to our surgical strategy, their postoperative neurological improvements were limited to 25%. In both patients, the ossification focus was relatively small (< 50% canal occupying ratio), and spinal cord compression from the posterior spinal elements was not observed (i.e., there was a space between the spinal cord and the posterior spinal elements at the level of the OPLL, as shown in Fig. 4). Although neurologic improvement afforded by spinal fusion was reported [1, 2, 13], CDF might be more effective than PF in the patients.

The limitations of this study include its relatively small sample size of patients with the rare pathology and the study design of non-randomized comparison. The sample size in this study was equivalent to that in similar studies conducted in a single institution [5, 7, 8, 12, 26]. A selection bias surely existed according to our surgical strategy, which resulted in CDF group patients being more severely compromised preoperatively than PDF group patients. The number of PF group patients was limited and insufficient to analyze the clinical outcome. Future studies with larger cohorts are warranted to evaluate the indication of anterior decompression and the utility and feasibility of circumferential decompression via a posterolateral approach. These studies can further improve the surgical strategy and clinical outcome of thoracic OPLL.

Conclusions

This study is the first prospective clinical study to analyze the surgical outcomes of thoracic OPLL based on a strategy with the indication for anterior decompression. Our results in terms of postoperative clinical outcomes were favorable without significant complications. The results indicate that anterior decompression was appropriate for patients with localized spinal cord compression by a large OPLL in the kyphotic curve, which generally causes severe neurological symptoms. In these cases, anterior (circumferential) decompression via a posterolateral approach appears to be safe and effective. This technique could be feasible and generalizable among spine surgeons.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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