JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 26:466–473, 2017

Surgical results and complications of anterior decompression and fusion as a revision surgery after initial posterior surgery for cervical myelopathy due to ossification of the posterior longitudinal ligament

Seiichi Odate, MD, Jitsuhiko Shikata, MD, PhD, Tsunemitsu Soeda, MD, PhD, Satoru Yamamura, MD, and Shinji Kawaguchi, MD

Department of Orthopaedic Surgery, Spine Center, Gakkentoshi Hospital, Kyoto, Japan

OBJECTIVE Ossification of the posterior longitudinal ligament (OPLL) is a progressive disease. An anterior cervical decompression and fusion (ACDF) procedure for cervical OPLL is theoretically feasible, as the lesion exists anteriorly; however, such a procedure is considered technically demanding and is associated with serious complications. Cervical laminoplasty is reportedly an effective alternative procedure with few complications; it is recognized as a comparatively safe procedure, and has been widely used as an initial surgery for cervical OPLL. After posterior surgery, some patients require revision surgery because of late neurological deterioration due to kyphotic changes in cervical alignment or OPLL progression. Here, the authors retrospectively investigated the surgical results and complications of revision ACDF after initial posterior surgery for OPLL.

METHODS This was a single-center, retrospective study. Between 2006 and 2013, 19 consecutive patients with cervical OPLL who underwent revision ACDF at the authors' institution after initial posterior surgery were evaluated. The mean age at the time of revision ACDF was 66 ± 7 years (± SD; range 53–78 years). The mean interval between initial posterior surgery and revision ACDF was 63 ± 53 months (range 3–235 months).

RESULTS The mean follow-up period after revision ACDF was 41 ± 26 months (range 24–108 months). Before revision ACDF, the mean maximum thickness of the ossified posterior longitudinal ligament was 7.2 ± 1.5 mm (range 5–10 mm), and the mean C2–7 angle was 1.3° ± 14° (range –40° to 24°). The K-line was plus (OPLL did not exceed the K-line) in 8 patients and minus in 11 (OPLL exceeded the K-line). The mean Japanese Orthopaedic Association score improved from 10 ± 3 (range 3–15) before revision ACDF to 11 ± 4 (range 4–15) at the last follow-up, and the mean improvement rate was 18% ± 18% (range 0%–60%). A total of 16 surgery-related complications developed in 12 patients (63%). The main complication was an intraoperative CSF leak in 8 patients (42%). Neurological function worsened in 5 patients (26%). The deterioration was due to spinal cord herniation through a defective dura mater in 1 patient, unidentified in 1 patient, and C-5 palsy that gradually recovered in 3 patients. Reintubation, delirium, and hoarseness were observed in 1 patient each (5%). No patient required reoperation for reconstruction failure, and all patients eventually had a solid bony fusion.

CONCLUSIONS ACDF as revision surgery after initial posterior surgery for cervical myelopathy due to OPLL is associated with a high incidence of intraoperative CSF leakage and an extremely low improvement rate. The authors think that while the use of revision ACDF must be limited, it is indispensable in special cases, such as progressing myelopathy following posterior surgery due to a very large beak-type OPLL that exceeds the K-line. Postoperative OPLL progression and/or kyphotic changes can possibly cause later neurological deterioration. Fusion should be recommended at the initial surgery for many cases of cervical OPLL to prevent such a challenging revision surgery.

https://thejns.org/doi/abs/10.3171/2016.9.SPINE16430

KEY WORDS ossification of the posterior longitudinal ligament; cervical myelopathy; anterior cervical decompression and fusion; cervical laminoplasty; revision surgery; cerebrospinal fluid leak

ABBREVIATIONS ACDF = anterior cervical decompression and fusion; JOA = Japanese Orthopaedic Association; OPLL = ossification of the PLL; PCDF = posterior cervical decompression and fusion; PLL = posterior longitudinal ligament.

SUBMITTED April 19, 2016. **ACCEPTED** September 23, 2016.

INCLUDE WHEN CITING Published online January 27, 2017; DOI: 10.3171/2016.9.SPINE16430.

Ossification of the posterior longitudinal ligament (OPLL) of the cervical spine is recognized as one of the causes of cervical myelopathy. Several surgical options for cervical OPLL have been established and involve anterior surgery or posterior surgery. The anterior cervical decompression and fusion (ACDF) procedure for the treatment of cervical OPLL is theoretically feasible, as the lesion exists anteriorly;[11,12,33] however, it is considered technically demanding and is associated with serious complications, such as intraoperative neural injury, symptomatic CSF leakage, graft dislodgment, and adjacent-segment disease.[32,35] Excellent results following cervical laminoplasty have been reported in the treatment of patients with OPLL, and it has been reported to be an effective alternative procedure with few complications.[2,7,10,24] Cervical laminoplasty is therefore recognized as a comparatively safe procedure and has been widely used as an initial surgery for cervical OPLL. The long-term outcomes of cervical laminoplasty seem to be favorable, although late neurological deterioration has been noted in some patients.[11,16,17,21,24] There are 2 main explanations for late deterioration after cervical laminoplasty. First, postoperative kyphotic changes in cervical alignment are not uncommon after cervical laminoplasty, but they are after ACDF.[2,12] Second, OPLL tends to progress more often after cervical laminoplasty than after ACDF.[3,8,10,21] Therefore, after cervical laminoplasty, some patients require revision surgery due to late neurological deterioration.[29] Worsening myelopathy after posterior surgery is a challenging condition to treat because it consists of a combination of progressive kyphosis, segmental instability due to preceding posterior decompression, massive OPLL causing anterior neural compression, and an ossified posterior longitudinal ligament (PLL) that is often strongly adherent to the dura or dural ossification due to its long duration. We hypothesized that revision ACDF in such situations might be associated with a high possibility of surgery-related complications and a low improvement rate in terms of neurological function. The purpose of this study was to investigate the surgical results and complications of revision ACDF after initial posterior surgery for cervical OPLL.

Methods

Patient Population

We conducted a retrospective, single-center study of ACDF as revision surgery performed after initial posterior surgery for cervical myelopathy due to OPLL. The study was carried out with the approval of the institutional ethics committee. Between 2006 and 2013, 20 consecutive patients who had undergone earlier posterior surgery for cervical OPLL underwent revision ACDF in our hospital. The 19 patients who underwent follow-up for at least 24 months are included in this study. One patient was lost to follow-up because he died of lung cancer. The patients' demographic information is summarized in Table 1.

Radiographic Assessment

Based on preoperative radiographic findings, OPLL of the cervical spine is classified into 3 types: continuous, segmental, and mixed.[30] In addition, based on their sagittal shape, the ossified lesions are classified as plateau or hill shaped.[11] The maximum thickness of the ossified PLL was evaluated, and K-lines were measured. The K-line connects the midpoints of the spinal canal at C-2 and C-7 on neutral lateral radiographs. When anterior compression of the OPLL exceeds the line, K-line is defined as minus, and the patient is regarded as an unsuitable candidate for posterior decompression.[6]

TABLE 1. Summary of patient demographics and results of revision ACDF following initial posterior surgery for cervical OPLL

Variable	Value
Sex	
Male	13
Female	6
Mean age at op in yrs	66 ± 7 (53–78)
Previous pst op	
Laminectomy	3
Laminoplasty	15
Decompression & fusion	1
Type of ossification	
Segmental	7
Continuous	8
Mixed	4
Mean C2–7 angle in °	1.3 ± 14 (−40 to 24)
K-line	
Minus	11
Plus	8
Mean max ossified PLL thickness in mm	7.2 ± 1.5 (5–10)
Mean no. of operated disc segments	3.2 ± 0.6 (2–4)
Mean interval btwn initial pst op & revision ACDF in mos	63 ± 53 (3–235)
Mean follow-up period after ACDF in mos	41 ± 26 (24–108)
Mean op time in mins	142 ± 46 (86–262)
Mean blood loss in ml	140 ± 173 (20–600)
Halo vest immobilization	7
Mean JOA score*	
Before ACDF	10 ± 3 (3–15)
At last follow-up	11 ± 4 (4–15)
Improvement rate as %	18 ± 18 (0–60)
Surgery-related complications	
Intraop CSF leakage	8
Neuro deterioration	
C-5 palsy	3
Other	2
Reintubation	1
Delirium	1
Hoarseness	1
No. of additional ops performed	0

Neuro = neurological; pst = posterior.
Values are presented as the number of patients (%) unless indicated otherwise. Mean values are presented as the mean ± SD.
* Maximum JOA score: 17.

Neurological Assessment

All patients presented with long tract signs, including spastic gait disturbance, clumsiness of the hands, and segmental-type myelopathy. Surgical outcomes were evaluated using Japanese Orthopaedic Association (JOA) scores (maximum 17 points). The improvement rates were calculated using the following formula: (JOA scores at follow-up – JOA scores before surgery)/(17 – JOA scores before surgery) × 100 (%).[7]

Surgical Procedure

All surgeries were performed under spinal cord evoked potential monitoring. ACDF was performed through a standard left-sided Robinson-Smith anterior approach. An operating microscope was routinely used. Before revision ACDF, we planned to decompress the segment with the maximum thickness and/or discontinuity of the ossified PLL. After corpectomy was performed by removing discs and vertebral bodies, the ossified PLL was shaved with the aid of a diamond bur to make it as thin as possible. Ossified lesions were removed if they could be easily released, but this was not attempted if they were strongly adherent to the dura or if the dura itself was ossified. When CSF leaks occurred during surgery, we routinely patched the dural defect with a polyglycolicacid sheet and fibrin glue, followed by postoperative lumbar drainage. During surgery, after shaving and floating the ossified PLL mass, we determined that sufficient decompression had been accomplished when we could see the expansion and pulsation of the dura mater. The cervical spine was reconstructed using an autologous bone graft from the fibula and fixed internally using a plate and screw system. The average treated distance spanned 3.2 ± 0.6 intervertebral discs (range 2–4). For 7 patients (37%), immobilization was initially maintained using a halo vest, and all patients were fixed in a collar for 3 to 4 months postoperatively. After surgery, we performed CT and MRI to confirm sufficient decompression in accordance with the preoperative plan. Fusion was assessed by the presence of bridging bone on radiographs and by angular measurement of motion on the flexion-extension lateral radiographs. When the measurement of motion was difficult to determine on radiographs alone, we also assessed bone bridge formation on CT scans.

Results

The individual clinical and radiographic data of all 19 patients are shown in Table 2. According to physical and radiological findings just before revision ACDF, we considered the major reason for neurological deterioration to be anterior spinal cord compression due to residual OPLL at the discontinued portion of the ossified PLL and local kyphosis.

Surgical Results of Anterior Surgery

The mean operation time was 142 ± 46 minutes (range 86–262 minutes), and the mean blood loss during surgery was 140 ± 173 ml (range 20–600 ml). The mean JOA score improved from 10 ± 3 (range 3–15) before revision ACDF to 11 ± 4 (range 4–15) at the last follow-up; the mean improvement rate was 18% ± 18% (range 0%–60%).

Surgery-Related Complications After ACDF

A total of 16 complications developed in 12 patients (63%; Table 1). Intraoperative CSF leakage occurred in 8 patients (42%). None of these patients developed meningitis and none had CSF leakage from the wound. C-5 palsy, which gradually resolved, was observed in 3 patients (16%). Aside from the C-5 palsy, neurological function worsened in 4 other patients (22%), then improved gradually, but it failed to recover completely in 2 patients (11%). Both of these patients exhibited a partial Brown-Séquard syndrome. The cause of neurological worsening was spinal cord herniation through a defective dura mater in one patient and it was unidentified in the other. Reintubation, delirium, and hoarseness occurred in 1 patient each (5%). No patient required reoperation for reconstruction failure, and all patients eventually had a solid bony fusion.

Illustrative Cases

Case 6

A 70-year-old man with cervical OPLL had undergone C5–7 ACDF 20 years prior and C1–7 laminectomy 10 years prior to admission to our clinic. Over the last several years, he experienced deterioration with bilateral hand numbness and gait disturbance. Before performing the revision ACDF, we considered that the maximum thickness of the ossified PLL at C3–4, in which OPLL exceeded the K-line (Fig. 1A), and the residual discontinuity of the ossified PLL at C4–5 (Fig. 1B) were the segments responsible for the progression of myelopathy. The patient underwent revision ACDF (corpectomies at C-3 and C-4), with autologous bone graft from the fibula supplemented with anterior plating (Fig. 1C and D). Intraoperative CSF leakage during shaving of the ossified lesion was seen. The patient's persistent numbness in his hands and gait disturbance persisted even after surgery. His JOA score before revision ACDF was 7, and at the 5-year follow-up it was 8; the improvement rate was 10%. In retrospect, if the patient had undergone ACDF instead of laminoplasty 10 years before, revision surgery for OPLL progression and kyphosis progression might have prevented the patient's persistent neurological deterioration.

Case 12

A 53-year-old man with cervical OPLL underwent C2–T1 posterior decompression and instrumented fusion 2 years prior to admission to our clinic. Neuropathic arm pain and deterioration of upper-extremity function developed after surgery. Before the patient's initial posterior surgery, the ossified PLL already greatly exceeded the K-line at C3–4 (Fig. 2A), and there was ossified PLL discontinuity at the same segment (Fig. 2C). After this initial posterior surgery, the spinal cord could not shift backward sufficiently away from the ossified PLL (Fig. 2B). Residual cord compression by the ossified PLL led to gradual neurological deterioration. The patient visited our clinic because of gradual worsening of clumsiness of his hands and gait disturbance. Revision ACDF (corpectomies at C-3 and C-4) was performed (Fig. 2D). The patient's JOA score before revision ACDF was 7, and at the 24-month follow-up it was 8; the improvement rate was

TABLE 2. Clinical and radiological characteristics in 19 patients undergoing revision ACDF following initial posterior surgery for cervical OPLL

Case No.	Age (yrs), Sex	Initial Pst Op	Interval Btwn Initial Pst Op & Revision ACDF (mos)	Type of Ossification	C2–7 Angle (°)	K-Line Before ACDF	Max Ossified PLL Thickness (mm)	JOA Score: Before ACDF	JOA Score: At Last FU	JOA Score: Improvement Rate (%)	ACDF Levels	Op-Related Complication
1	74, F	C1–T6 laminectomy	36	Continuous, plateau	−1	Minus	10	3	5	14	C2–6	CSF leakage
2	60, M	C3–7 laminoplasty	60	Continuous, plateau	10	Minus	7	14	13	0	C2–5	CSF leakage, neuro deterioration
3	68, F	C3–T2 laminectomy	43	Segmental, plateau	−1	Plus	7	9	9	0	C3–6	
4	75, M	C3–6 laminoplasty	58	Mixed, plateau	0	Plus	6	7	8	10	C5–7	
5	67, M	C3–6 laminoplasty	36	Segmental, hill	−1	Plus	5	10	13	43	C4–7	C-5 palsy
6	70, M	C1–7 laminectomy	125	Continuous, hill	0	Minus	10	7	8	10	C2–6	CSF leakage
7	63, M	C3–6 laminoplasty	10	Segmental, hill	20	Minus	7	12	14	40	C2–4	Hoarseness
8	67, M	C3–6 laminoplasty	24	Mixed, plateau	7	Minus	6	8	9	11	C2–5	
9	59, M	C3–5 laminoplasty	108	Mixed, hill	−10	Minus	8	14	15	33	C2–5	CSF leakage
10	78, F	C3–6 laminoplasty	84	Segmental, hill	24	Minus	7	5	4	0	C3–6	CSF leakage, neuro deterioration
11	65, M	C5–7 laminoplasty	235	Continuous, hill	10	Plus	6	12	15	60	C3–7	
12	53, M	C2–T1 laminectomy & fusion	6	Continuous, hill	−22	Minus	10	7	8	10	C2–5	
13	63, M	C1–T1 laminoplasty	3	Continuous, hill	5	Minus	8	10	10	0	C3–7	CSF leakage
14	72, M	C3–6 laminoplasty	48	Segmental, plateau	1	Minus	6	12	13	20	C3–6	Delirium
15	64, F	C2–6 laminoplasty	50	Mixed, hill	10	Plus	7	15	15	0	C2–5	CSF leakage, reintubation
16	66, M	C2–7 laminoplasty	47	Mixed, plateau	5	Plus	7	14	15	33	C2–5	
17	57, F	C1–6 laminoplasty	72	Continuous, plateau	−40	Minus	6	9	9	0	C4–7	C-5 palsy
18	68, F	C3–6 laminoplasty	48	Segmental, hill	6	Plus	6	12	14	40	C4–7	
19	67, M	C3–T2 laminoplasty	96	Continuous, hill	0	Plus	8	10	11	14	C4–7	CSF leakage, C-5 palsy

FU = follow-up.

10%. In retrospect, anterior decompression at the initial surgery would probably have eliminated or lessened the need for revision surgery.

Case 19

A 67-year-old man with severe myelopathy due to cervical OPLL had undergone C3–T2 laminoplasty 8 years prior to admission to our clinic. During the follow-up period, gait disturbance and clumsiness of the hands gradually worsened. Although the ossified PLL did not exceed the K-line, the maximal thickness and the discontinuity of the ossified PLL both occurred at C-5 (Fig. 3B), in which there was myelomalacia (Fig. 3A). Insufficient posterior shift of the spinal cord and residual motion in this segment after the initial posterior surgery (laminoplasty) led to the subsequent neurological deterioration. The patient underwent revision ACDF (corpectomies at C-3, C-4, and C-5) (Fig. 3C). CSF leakage was seen intraoperatively,

FIG. 1. Case 6. **A and B:** MR (A) and CT (B) images obtained before revision ACDF, showing that a C5–7 ACDF (*arrowheads*) and a C1–7 laminectomy (*arrows*) had been previously performed, but a continuous type OPLL (*asterisks*) remains in front of the spinal cord at C2–5. The maximum thickness of the ossified PLL was 10 mm. The K-line (*white line*) was minus. **C and D:** MR (C) and CT (D) images obtained after revision ACDF, showing adequate anterior decompression (*asterisk*).

and right-sided C-5 palsy occurred postoperatively. The patient's JOA score before revision ACDF was 10 and it was 11 at the 24-month follow-up; the improvement rate was 14%. In retrospect, fusion during the initial surgery should have been recommended for this case.

Discussion

ACDF and cervical laminoplasty are both common treatment options for cervical myelopathy due to OPLL. ACDF is indicated in cases in which the canal is more significantly compromised, and it can be performed effectively in patients with reduced cervical lordosis. ACDF yields better results than cervical laminoplasty on long-term follow-up.[11,21] ACDF, however, was found to be associated with less satisfactory outcomes, with incidences of nonunion and reconstruction failure. The procedure is technically demanding because of ossification of the dura or massive bleeding from the epidural space. On the other hand, cervical laminoplasty has been shown to safely achieve decompression of the spinal cord in patients with cervical lordosis and a small ossified PLL[11,16,21,22] and is therefore recognized as a comparatively safe procedure that has been widely used as an initial surgery for cervical OPLL. However, several authors have reported limiting factors for the indication of cervical laminoplasty for OPLL, because it is effective only when the spinal cord can shift posteriorly after decompression. The reported risk factors for suboptimal decompression are lordosis of less than 10° or kyphosis in the preoperative sagittal alignment and a preoperative OPLL thickness of more than 7–7.2 mm,[22,34] and an ossified PLL diameter of more than 50%–60% of the spinal canal.[10,11,28]

Late Neurological Deterioration After Posterior Surgery

Tani et al. reported that 33% of the patients who underwent laminoplasty demonstrated neurological deterioration after surgery.[28] Postoperative progression of OPLL has been reported to occur frequently after cervical laminoplasty[3,8,10] and has caused late neurological deterioration requiring revision surgery.[29] Sakai et al.[21] reported that postoperative progression of the OPLL at the 5-year follow-up period was observed in 5% of patients after ACDF but in 50% of patients after cervical laminoplasty. The overall improvement rates in the JOA scores were the

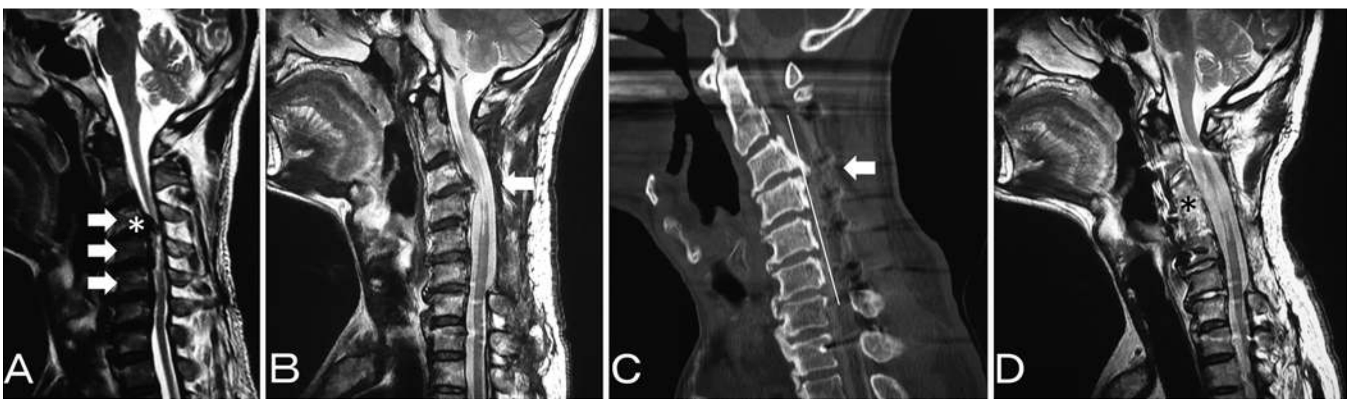

FIG. 2. Case 12. **A:** MR image obtained before initial posterior surgery, showing massive ossification and local kyphosis from C-3 to C-6 (*arrows*). A hill-shaped ossification at C3–4 (*asterisk*) occupies 90% of the spinal canal. **B:** MR image obtained after posterior surgery, showing insufficient posterior shift of the cord (*arrow*). **C:** CT myelogram showing persistent anterior impingement of the cord at the C3–4 level (*arrow*). The maximum thickness of the ossified PLL was 10 mm. The K-line (*white line*) was minus. In retrospect, posterior decompression was not suitable for this case. **D:** MR image obtained after revision ACDF, showing adequate anterior decompression (*asterisk*).

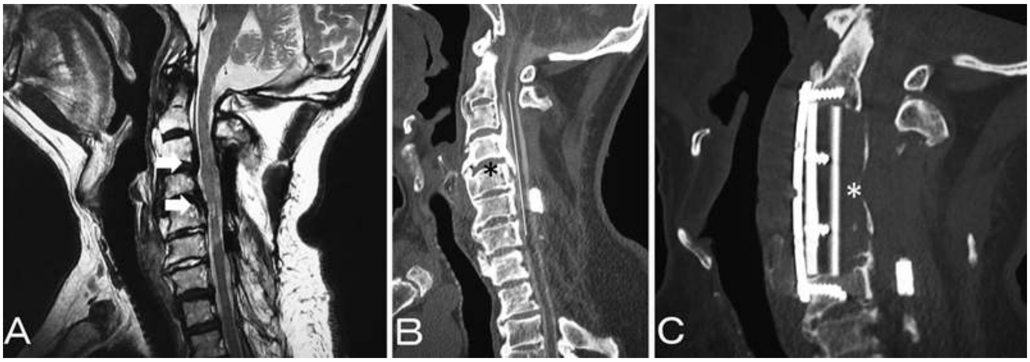

FIG. 3. Case 19. **A:** MR image obtained before revision ACDF, showing anterior cord compression from C-3 to C-5 (*arrows*). **B:** CT myelogram obtained before revision ACDF, showing discontinuity of the ossification at C-5 (*asterisk*), meaning that residual motion exists at this portion. The maximum thickness of the ossified PLL was 8 mm. The K-line (*white line*) was plus. **C:** CT scan obtained after revision ACDF, showing adequate anterior decompression (*asterisk*).

same in both groups at the 3-year follow-up; however, at the 5-year follow-up, late neurological deterioration was evident in the cervical laminoplasty group but not in the ACDF group.[21]

Fujiyoshi et al. evaluated the kyphotic alignment of the cervical spine and canal compromise from OPLL using a new index, the K-line, which they defined as the line that connects the midpoints of the spinal canal at C-2 and C-7.[6] They found that neither sufficient posterior shift of the spinal cord nor neurological improvement was achieved after posterior decompression surgery in patients with an ossified PLL that exceeded the K-line (the K-line minus group).

During preoperative planning, we must keep in mind the risk that cervical laminoplasty is associated not only with a high probability of OPLL progression but also with the development of postoperative kyphosis.[2,8,12,18,21] Therefore, even for the K-line plus cases before cervical laminoplasty, postoperative OPLL progression and/or kyphotic changes can possibly lead to later neurological deterioration. In addition, the dynamic aspects of the cervical spine (i.e., segmental instability due to posterior decompression surgery) might be important for the development of late neurological deterioration after cervical laminoplasty.

Fusion Surgery for Cervical OPLL

An alternative to cervical laminoplasty, fusion at the initial surgery should be recommended for many cases of cervical OPLL to prevent future revision surgery, given that fusion eliminates kyphosis progression and is associated with a lower incidence of OPLL progression compared with decompression alone.[14,15,18] Chen et al. retrospectively investigated 75 patients with multilevel OPLL.[1] Twenty-two of these patients underwent ACDF, 28 underwent posterior cervical decompression and fusion (PCDF), and 25 underwent laminoplasty. The JOA score improvement rates after ACDF were significantly higher than those after laminoplasty, with improvement rates after PCDF in between (ACDF, 63%; PCDF, 44%; and laminoplasty, 25%). Thus, the authors concluded that ACDF was significantly more effective for OPLL than PCDF. Although both ACDF and PCDF can prevent progression of kyphosis and OPLL, we think that ACDF should be the first choice for the initial OPLL surgery in most cases, because myelopathy causes anterior compression and OPLL is a progressive disease. However, when the ossified PLL occupies too much of the canal or involves multiple vertebrae, ACDF becomes a technical challenge. Although there is some risk involved, it is important to consider how much benefit might actually be achieved by direct anterior decompression. In the face of these technical difficulties, PCDF may be valid for most cases of cervical OPLL, and it may be a solution to the problems unique to ACDF.[6,9,16,21] However, the incidence of postoperative C-5 palsy is higher after PCDF.[1] In addition, patients who have undergone posterior surgery often complain of axial pain[1] due to disruption of posterior neck tissue, leading to decreased satisfaction. A disadvantage of posterior decompression is that the ossified PLL remains ventral to the spinal cord. Lee et al. reported a 30% progression rate of OPLL after PCDF.[15] Moreover, cervical lordosis decreased over time even after PCDF.[15,27] Based on the results of these studies, PCDF is inadequate for some cases with very large beak-type ossified PLLs that greatly exceed the K-line (such as our Case 12), because there is a possibility of gradual neurological deterioration due to loss of cervical lordosis or OPLL progression even after PCDF.

When considering revision surgery for patients who underwent prior posterior decompression surgery, it is impossible to once again perform decompression from the posterior aspect. Moreover, even with posterior instrumentation, the amount of kyphosis correction for cervical OPLL patients with kyphotic alignment is insufficient and often falls short of surgeons' expectations.

To date, due to the limited number of studies that focus on PCDF for the treatment of cervical OPLL, we were unable to directly compare the clinical results of ACDF versus PCDF. Further randomized controlled trials comparing the 2 procedures for the treatment of OPLL are needed to draw more convincing conclusions.

Surgical Results After Revision ACDF

Improvement rates of the JOA score as a way of determining outcomes after ACDF for cervical OPLL have been reported to be 43%–63%.[11,16,20,21,23] In our experience, the mean improvement rate of 68 consecutive patients with cervical OPLL who underwent ACDF as the initial surgery at our institution was 63%.[20] Notably, in the current series of 19 patients who underwent revision ACDF after initial posterior surgery, the mean improvement rate was extremely low (18%). The interval between initial posterior surgery and revision ACDF was 24–108 months. Irreversible changes as a result of the long duration of a massive ossified PLL causing cord compression may have contributed to the poor improvement. Although we do not have evidence from this study, we believe that early surgery for those patients might have helped reduce further spinal cord injury.

Surgery-Related Complications After Revision ACDF

In the current series, surgery-related complications occurred in 63% of the patients, the main complication being intraoperative CSF leakage (42%). CSF leakage after ACDF can be troublesome and can lead to a pseudomeningocele, respiratory obstruction, a cutaneous CSF fistula, and meningitis.[4] The reported incidence of CSF leakage after ACDF for OPLL ranges from 4% to 32%.[4,13,26] The high incidence of CSF leakage in the current series is likely specific to the advanced stages of the OPLL, as we have rarely encountered intraoperative CSF leakage in patients who undergo ACDF as initial surgery (7%).[20]

In general, ACDF becomes technically more demanding with the increasing thickness of the ossified PLL, because such an advanced stage of OPLL usually incorporates the dura.[26] The longstanding OPLL can often be associated with dural ossification, and, therefore, removal of the ossified lesion can lead to a dural defect. In the current series, the mean maximal ossified PLL thickness was 7.2 ± 1.5 mm, perhaps contributing to the increased number of intraoperative CSF leaks during shaving of the ossified lesions.

In this study, 4 of 8 patients with intraoperative CSF leakage experienced neurological problems immediately after the surgery. Although their symptoms improved gradually, 2 patients did not reach their preoperative levels of function. As Seichi et al. mentioned, the greater the area occupied by the ossified PLL, the higher the risk of postoperative neurological sequelae.[23] Spinal cord herniation through the defective dura mater might also have caused neurological sequelae.[19]

The safety of anterior decompression depends on less traumatic manipulation of the spinal cord and on protection of the epidural vascular plexus. During surgery, if the surgeon encounters massive bleeding or CSF leakage due to dural ossification, halting the decompression to avoid neurological complications is crucial.

In the current series, 90% of the patients underwent operations on more than 3 disc segments, and the preceding posterior decompression surgery might have weakened the stability of the cervical spine. Although long anterior reconstruction has been reported to be associated with a high incidence of pseudarthrosis and instrumentation failure,[5,25,31,36] there were no incidences in the present series. This may be attributed to the structural stability in patients with OPLL, as range of motion of cervical spine is usually decreased in these patients.

Conclusions

The results of the present study demonstrated that revision ACDF is a challenging surgery associated with a high probability of intraoperative CSF leakage and an extremely low improvement rate. We think that while the use of revision ACDF must be limited, it is indispensable for special cases, such as progressive myelopathy following posterior surgery due to very large beak-type OPLL that exceeds the K-line. The surgical results of our revision ACDF offers extremely important information to surgeons who plan to perform initial posterior surgery or revision ACDF for cervical OPLL. A surgical plan for the initial surgery that prevents such a challenging revision surgery is ideal. Postoperative OPLL progression and/or kyphotic changes can possibly cause later neurological deterioration. While a surgical strategy should be made based on the individual patient, fusion at the initial surgery should be recommended for many cases of cervical OPLL to prevent future revision surgery.

References

1. Chen Y, Guo Y, Lu X, Chen D, Song D, Shi J, et al: Surgical strategy for multilevel severe ossification of posterior longitudinal ligament in the cervical spine. **J Spinal Disord Tech 24:**24–30, 2011
2. Chiba K, Ogawa Y, Ishii K, Takaishi H, Nakamura M, Maruiwa H, et al: Long-term results of expansive open-door laminoplasty for cervical myelopathy—average 14-year follow-up study. **Spine (Phila Pa 1976) 31:**2998–3005, 2006
3. Chiba K, Yamamoto I, Hirabayashi H, Iwasaki M, Goto H, Yonenobu K, et al: Multicenter study investigating the postoperative progression of ossification of the posterior longitudinal ligament in the cervical spine: a new computer-assisted measurement. **J Neurosurg Spine 3:**17–23, 2005
4. Choi S, Lee SH, Lee JY, Choi WG, Choi WC, Choi G, et al: Factors affecting prognosis of patients who underwent corpectomy and fusion for treatment of cervical ossification of the posterior longitudinal ligament: analysis of 47 patients. **J Spinal Disord Tech 18:**309–314, 2005
5. Epstein N: The surgical management of ossification of the posterior longitudinal ligament in 51 patients. **J Spinal Disord 6:**432–455, 1993
6. Fujiyoshi T, Yamazaki M, Kawabe J, Endo T, Furuya T, Koda M, et al: A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. **Spine (Phila Pa 1976) 33:**E990–E993, 2008
7. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K: Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. **Spine (Phila Pa 1976) 6:**354–364, 1981
8. Hori T, Kawaguchi Y, Kimura T: How does the ossification area of the posterior longitudinal ligament thicken following cervical laminoplasty? **Spine (Phila Pa 1976) 32:**E551–E556, 2007
9. Houten JK, Cooper PR: Laminectomy and posterior cervical plating for multilevel cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament: effects on cervical alignment, spinal cord compression, and neurological outcome. **Neurosurgery 52:**1081–1088, 2003
10. Iwasaki M, Kawaguchi Y, Kimura T, Yonenobu K: Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up. **J Neurosurg 96 (2 Suppl):**180–189, 2002
11. Iwasaki M, Okuda S, Miyauchi A, Sakaura H, Mukai Y, Yonenobu K, et al: Surgical strategy for cervical myelopathy

due to ossification of the posterior longitudinal ligament: Part 1: Clinical results and limitations of laminoplasty. **Spine (Phila Pa 1976) 32:**647–653, 2007
12. Iwasaki M, Okuda S, Miyauchi A, Sakaura H, Mukai Y, Yonenobu K, et al: Surgical strategy for cervical myelopathy due to ossification of the posterior longitudinal ligament: Part 2: Advantages of anterior decompression and fusion over laminoplasty. **Spine (Phila Pa 1976) 32:**654–660, 2007
13. Joseph V, Kumar GS, Rajshekhar V: Cerebrospinal fluid leak during cervical corpectomy for ossified posterior longitudinal ligament: incidence, management, and outcome. **Spine (Phila Pa 1976) 34:**491–494, 2009
14. Katsumi K, Izumi T, Ito T, Hirano T, Watanabe K, Ohashi M: Posterior instrumented fusion suppresses the progression of ossification of the posterior longitudinal ligament: a comparison of laminoplasty with and without instrumented fusion by three-dimensional analysis. **Eur Spine J 25:**1634–1640, 2016
15. Lee CH, Jahng TA, Hyun SJ, Kim KJ, Kim HJ: Expansive laminoplasty versus laminectomy alone versus laminectomy and fusion for cervical ossification of the posterior longitudinal ligament: is there a difference in the clinical outcome and sagittal alignment? **Clin Spine Surg 29:**E9–E15, 2016
16. Matsumoto M, Chiba K, Toyama Y: Surgical treatment of ossification of the posterior longitudinal ligament and its outcomes: posterior surgery by laminoplasty. **Spine (Phila Pa 1976) 37:**E303–E308, 2012
17. Matsunaga S, Kukita M, Hayashi K, Shinkura R, Koriyama C, Sakou T, et al: Pathogenesis of myelopathy in patients with ossification of the posterior longitudinal ligament. **J Neurosurg 96 (2 Suppl):**168–172, 2002
18. Mehdi SK, Alentado VJ, Lee BS, Mroz TE, Benzel EC, Steinmetz MP: Comparison of clinical outcomes in decompression and fusion versus decompression only in patients with ossification of the posterior longitudinal ligament: a meta-analysis. **Neurosurg Focus 40(6):**E9, 2016
19. Min JH, Jung BJ, Jang JS, Kim SK, Jung DJ, Lee SH: Spinal cord herniation after multilevel anterior cervical corpectomy and fusion for ossification of the posterior longitudinal ligament of the cervical spine. **J Neurosurg Spine 10:**240–243, 2009
20. Odate S, Shikata J, Kimura H, Yamamura S: Anterior corpectomy with fusion in combination with an anterior cervical plate in the management of ossification of the posterior longitudinal ligament. **J Spinal Disord Tech 25:**133–137, 2012
21. Sakai K, Okawa A, Takahashi M, Arai Y, Kawabata S, Enomoto M, et al: Five-year follow-up evaluation of surgical treatment for cervical myelopathy caused by ossification of the posterior longitudinal ligament: a prospective comparative study of anterior decompression and fusion with floating method versus laminoplasty. **Spine (Phila Pa 1976) 37:**367–376, 2012
22. Seichi A, Chikuda H, Kimura A, Takeshita K, Sugita S, Hoshino Y, et al: Intraoperative ultrasonographic evaluation of posterior decompression via laminoplasty in patients with cervical ossification of the posterior longitudinal ligament: correlation with 2-year follow-up results. **J Neurosurg Spine 13:**47–51, 2010
23. Seichi A, Hoshino Y, Kimura A, Nakahara S, Watanabe M, Kato T, et al: Neurological complications of cervical laminoplasty for patients with ossification of the posterior longitudinal ligament-a multi-institutional retrospective study. **Spine (Phila Pa 1976) 36:**E998–E1003, 2011
24. Seichi A, Takeshita K, Ohishi I, Kawaguchi H, Akune T, Anamizu Y, et al: Long-term results of double-door laminoplasty for cervical stenotic myelopathy. **Spine (Phila Pa 1976) 26:**479–487, 2001
25. Shinomiya K, Okamoto A, Kamikozuru M, Furuya K, Yamaura I: An analysis of failures in primary cervical anterior spinal cord decompression and fusion. **J Spinal Disord 6:**277–288, 1993
26. Smith MD, Bolesta MJ, Leventhal M, Bohlman HH: Postoperative cerebrospinal-fluid fistula associated with erosion of the dura. Findings after anterior resection of ossification of the posterior longitudinal ligament in the cervical spine. **J Bone Joint Surg Am 74:**270–277, 1992
27. Tang JA, Scheer JK, Smith JS, Deviren V, Bess S, Hart RA, et al: The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. **Neurosurgery 71:**662–669, 2012
28. Tani T, Ushida T, Ishida K, Iai H, Noguchi T, Yamamoto H: Relative safety of anterior microsurgical decompression versus laminoplasty for cervical myelopathy with a massive ossified posterior longitudinal ligament. **Spine (Phila Pa 1976) 27:**2491–2498, 2002
29. Tokuhashi Y, Ajiro Y, Umezawa N: A patient with two resurgeries for delayed myelopathy due to progression of ossification of the posterior longitudinal ligaments after cervical laminoplasty. **Spine (Phila Pa 1976) 34:**E101–E105, 2009
30. Tsuyama N: Ossification of the posterior longitudinal ligament of the spine. **Clin Orthop Relat Res (184):**71–84, 1984
31. Vaccaro AR, Falatyn SP, Scuderi GJ, Eismont FJ, McGuire RA, Singh K, et al: Early failure of long segment anterior cervical plate fixation. **J Spinal Disord 11:**410–415, 1998
32. Wada E, Suzuki S, Kanazawa A, Matsuoka T, Miyamoto S, Yonenobu K: Subtotal corpectomy versus laminoplasty for multilevel cervical spondylotic myelopathy: a long-term follow-up study over 10 years. **Spine (Phila Pa 1976) 26:**1443–1448, 2001
33. Yamaura I, Kurosa Y, Matuoka T, Shindo S: Anterior floating method for cervical myelopathy caused by ossification of the posterior longitudinal ligament. **Clin Orthop Relat Res (359):**27–34, 1999
34. Yamazaki A, Homma T, Uchiyama S, Katsumi Y, Okumura H: Morphologic limitations of posterior decompression by midsagittal splitting method for myelopathy caused by ossification of the posterior longitudinal ligament in the cervical spine. **Spine (Phila Pa 1976) 24:**32–34, 1999
35. Yonenobu K, Hosono N, Iwasaki M, Asano M, Ono K: Neurologic complications of surgery for cervical compression myelopathy. **Spine (Phila Pa 1976) 16:**1277–1282, 1991
36. Zdeblick TA, Bohlman HH: Cervical kyphosis and myelopathy. Treatment by anterior corpectomy and strut-grafting. **J Bone Joint Surg Am 71:**170–182, 1989

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Odate, Shikata. Acquisition of data: Odate, Yamamura, Soeda, Kawaguchi. Analysis and interpretation of data: Odate, Yamamura, Soeda, Kawaguchi. Drafting the article: Odate. Critically revising the article: Odate, Shikata, Yamamura. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Odate. Administrative/technical/material support: Shikata, Soeda. Study supervision: Shikata.

Correspondence

Seiichi Odate, Department of Orthopaedic Surgery, Spine Center, Gakkentoshi Hospital, 7-4-1 Seikacho, Seikadai, Sorakugun, Kyoto 619-0238, Japan. email: odasei1101@gmail.com.