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Cervical Laminoplasty to Enlarge the Spinal Canal in Multilevel Ossification of the Posterior Longitudinal Ligament with Myelopathy

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Summary. We studied 23 patients with severe myeloradiculopathy involving multiple (more than three) levels of ossification of the posterior longitudinal ligament (OPLL) of the cervical spine, who were treated with laminoplasty to enlarge the spinal canal. The resected spinous processes were used as bone grafts to support the opened laminae. These patients were analyzed pre- and postoperatively with a neurological evaluation according to the Japanese Orthopedic Association (JOA) score system for cervical myelopathy. Follow-up was from 2.0 to 5.3 years with an average of 31.5 months. The results were compared with those in 31 patients with the same degree (multilevel) of OPLL who had been operated upon previously by laminectomy (14 cases) or anterior resection (17 cases). Postoperative neurological recovery by improvement ratio of the JOA score was observed in 81.2% of those who had undergone expansive laminoplasty, in 72.4% of those with laminectomy, and in 63.6% of those with anterior decompression. We concluded that expansive laminoplasty is a safer procedure with fewer complications. Stability is achieved by fixing the expanded laminae permanently with a bone graft. The neurological recovery following our technique of laminoplasty and fusion appears to be superior to that with laminectomy or anterior decompression.

Zusammenfassung. Wir haben 23 Patienten mit schwerem Myeloradikulopathie, begleitet von verschiedenen Stufen der Ossifikation des Ligamentum longitudinalis posterior der Hals-Wirbelsäule untersucht. Diese Patienten wurden mit Wirbelbogenplastik behandelt, um den Wirbelkanal auszuweiten. Der entfernte Wirbeldornfortsatz wurde als Knochentransplantat verwendet, um den geöffneten Wirbelbogen zu stabilisieren. Die Patienten unterzogen sich der Analyse der neurologischen Auswertung aufgrund des Punktzahlsystems der Japanischen Orthopädischen Gesellschaft (JOG) für Zervikalrückenmarksleiden vor und nach Operation. Die weitere Verfolgung der Operationsergebnisse fand 2,0 bis 5,3 Jahre lang statt. Diese Ergebnisse wurden mit denselben von 31 Fällen mit den gleichen Stufen der OPLL verglichen, die früher entweder mit Laminektomie (14 Fälle) oder ventraler Dekompression (17 Fälle) operiert worden waren. Die neurologische Wiederherstellung nach Operation mit expansiver Wirbelbogenplastik, die als Verbesserungsverhältnis der JOG Punktzahl dargestellt werden kann, wurde beobachtet und betrug 81,2%, während sie 72,4% durch Laminektomie und 63,6% durch ventrale Dekompression betrug. Wir haben die Schlussfolgerung gezogen, daß die expansive Wirbelbogenplastik eine sichere Operationstechnik sei und wenig Komplikationen habe. Die Stabilität wurde dauerhaft durch Fixierung des expansiven Wirbelbogens mit Knochentransplantation gewonnen. Die neurologische Wiederherstellung aufgrund unserer Operationstechnik der Wirbelbogenplastik und Spondylodese scheint günstiger als Laminektomie bzw. ventrale Dekompression zu sein.

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Ossification of the posterior longitudinal ligament (OPLL) is a major cause of severe cervical myeloradiculopathy in the Japanese [3, 12]. Several surgical procedures for decompressing the spinal cord anteriorly or posteriorly have been reported by other authors. Resecting the ossified tissue anteriorly to decompress the cord is ideal if the OPLL is limited to three vertebral bodies [8].

However, in advanced cases of myelopathy with multiple levels of OPLL, resection of ossified tissue of all levels may be difficult because the unevenly grown ossified tissue adheres to the dura and compresses the spinal cord severely; it is therefore difficult to remove without causing damage to the spinal cord. Furthermore, reconstruction with a long-bone graft following resection of several vertebral bodies is technically difficult and may require halo immobilization [9]. Some patients have hypertrophied ligamentum flavum posteriorly in the adjacent vertebral level of OPLL, causing myelopathy, and this should be resected.

For these reasons, posterior decompression with extensive laminectomy [7, 9] or laminoplasty [4, 5, 11] was introduced for the multilevel type of OPLL; it had originally been used to decompress a developmentally narrow canal or in multiple levels of cervical spondylosis. In long-term follow-up studies [2, 5] it became apparent that some of these patients developed kyphosis or swan-neck deformity due to the laminectomy, and myeloradiculopathy recurred due to constriction by the scar or the so-called laminectomy membrane. It might be dangerous to expose the spinal cord to the trauma without laminar protection after extensive laminectomy. After laminoplasty without a bone graft, the lamina may gradually return to its normal position and compress the cord.

We now utilize expansive laminoplasty: the laminae are lifted up and supported by bone grafts in the enlarged position, consisting of resected spinous processes. Our operative procedure is compared with the results of other conventional procedures such as anterior decompression and extensive laminectomy.

Materials and Methods

For patients with OPLL and myelopathy in our hospital, the operation for cord decompression is indicated when the neurological deficits score less than 12 points based on the criteria of the Japanese Orthopedic Association for cervical myelopathy [6] (Table 1). Twenty of our patients were male and only three were female; ages ranged from 37 to 74, with an average of 60.3 years. There were 15 cases of the continuous type of OPLL and eight cases of the mixed type (either partially continuous or partially segmental). Expansive laminoplasty was applied to those patients whose OPLL extended over more than three vertebral bodies. The number of levels to be decompressed was decided on the basis of roentgenograms, myelograms, and CT scans. The range of decompression was four laminae in two cases, five laminae in 15, six laminae in three, seven laminae in two, and eight laminae in one case.

At present, anterior decompression is applied only in cases of limited OPLL involving less than three vertebral bodies. In those patients who are either more than 75 years old or at high risk, extensive laminectomy without reconstruction is performed to shorten the operating time.

Table 1. Evaluation system for cervical myelopathy (compiled by the Japanese Orthopedic Association [6])

Section	Score
I. *Upper extremity function*	
Impossible to eat with either chopsticks or spoon	0 point
Possible to eat with spoon, but not with chopsticks	1
Possible to eat with chopsticks, but inadequate	2
Possible to eat with chopsticks, but awkward	3
Normal	4
II. *Lower extremity function*	
Impossible to walk	0
Need cane or aid on flat ground	1
Need cane or aid on stairs	2
Possible to walk without cane or aids, but slow	3
Normal	4
III. *Sensory*	
A. Upper extremity	
Apparent sensory loss	0
Minimal sensory loss	1
Normal	2
B. Lower extremity	
Apparent sensory loss	0
Minimal sensory loss	1
Normal	2
C. Trunk	
Apparent sensory loss	0
Minimal sensory loss	1
Normal	2
IV. *Bladder function*	
Urinary retention or incontinence	0
Severe dysuria (sense of retention, straining)	1
Slight dysuria (pollakiuria, retardation)	2
Normal	3

Normal condition = total of best score (I + II + III + IV) = 17 points

To carefully evaluate the spinal disorder, somatosensory evoked potentials (SSEP) [2] are recorded pre- and postoperatively. Spinal cord monitoring is utilized throughout surgery to confirm the safety of each step of the operative procedure.

The follow-up period was from 2 to 5.3 years, with an average of 31.5 months.

Operative Technique

The patient is placed in a prone position with the cervical spine slightly flexed and the operating table sloped 30° upward cranially. This position prevents congestion of venous blood in the head and neck.

By a posterior midline incision, the spinous processes, vertebral laminae, and joints are exposed. The spinous processes are excised at the basal part and are stored for use as bone grafts. Two longitudinal grooves are then made with a burr

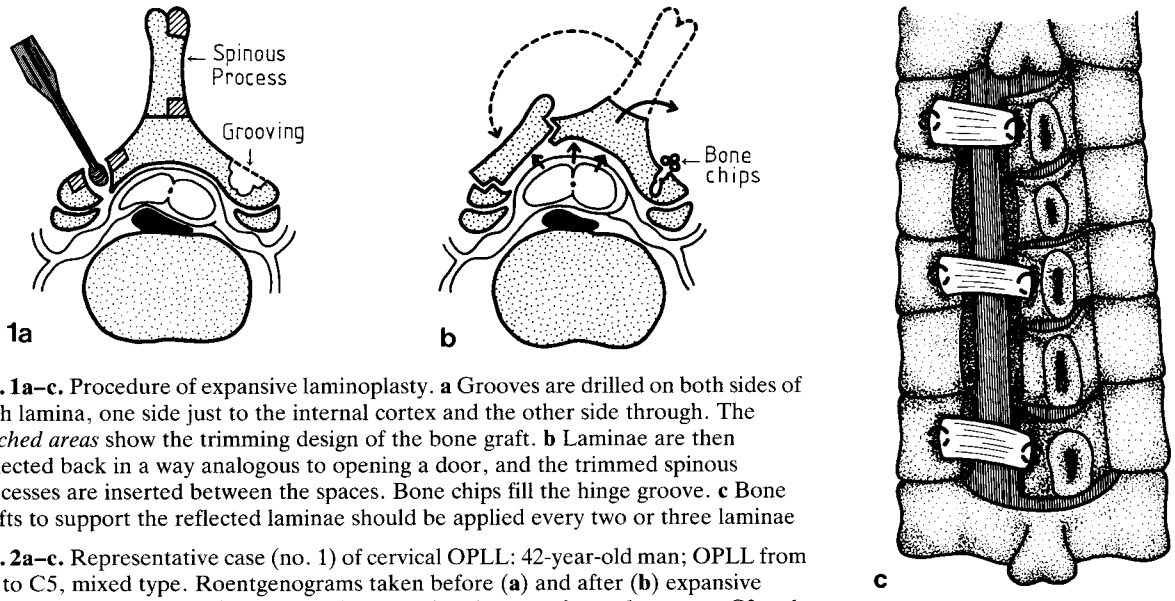
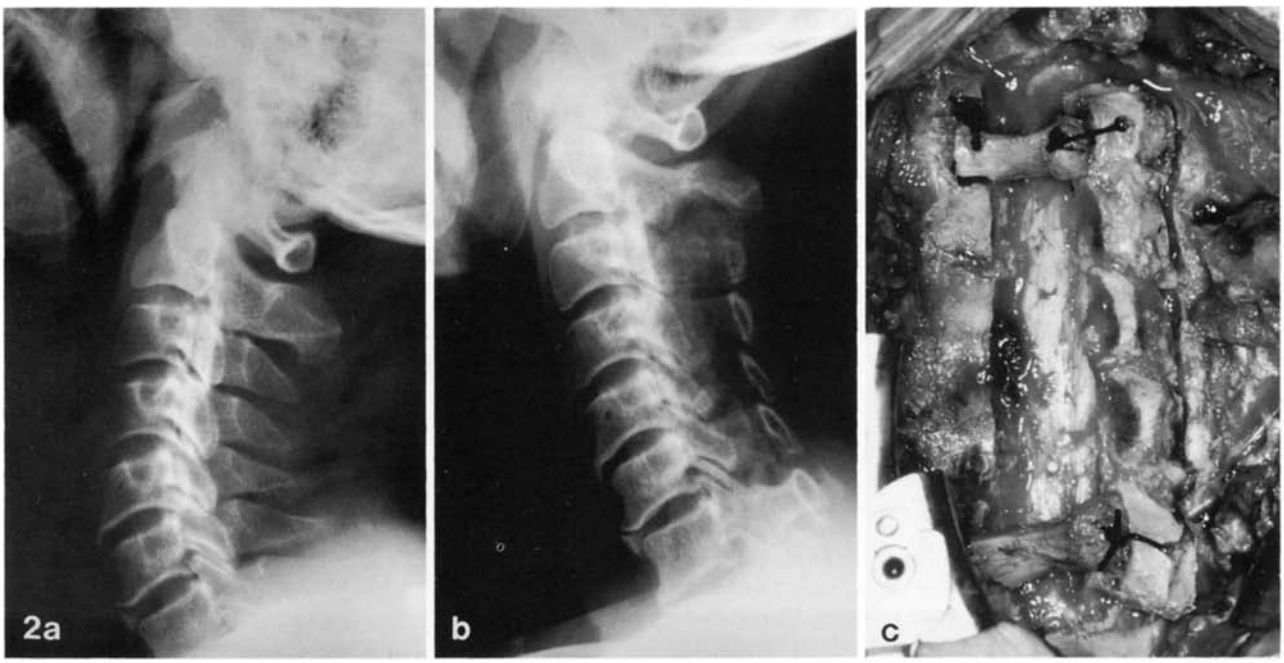


Fig. 1a–c. Procedure of expansive laminoplasty. **a** Grooves are drilled on both sides of each lamina, one side just to the internal cortex and the other side through. The *hatched areas* show the trimming design of the bone graft. **b** Laminae are then reflected back in a way analogous to opening a door, and the trimmed spinous processes are inserted between the spaces. Bone chips fill the hinge groove. **c** Bone grafts to support the reflected laminae should be applied every two or three laminae

Fig. 2a–c. Representative case (no. 1) of cervical OPLL: 42-year-old man; OPLL from C2 to C5, mixed type. Roentgenograms taken before (**a**) and after (**b**) expansive laminoplasty (lateral view). **c** During the operation: bone grafts can be seen at C3 and C7; a final bone graft will be inserted at C5



bilaterally at the base of the laminae, medial to the facet joints, until the thin inner cortex of the laminae remains. The laminoplasty extends from one level above to one below the stenotic site (C3–C7 in most cases) as determined from the myelogram. With attention being paid to the posterior internal vertebral venous plexus, the lamina on the side where radiculopathy is dominant are drilled through with a diamond burr (Fig. 1a).

Then all of the laminae that have been released are lifted together toward the other side, as if one were opening a door, with the contralateral side acting as a hinge. Mild fibrous adhesions between the dura and laminae are carefully dissected using a microelevator. The spinal cord is thus decompressed and shifted posteriorly. Simultaneous decompression of all levels is a very delicate part of the procedure, since partial herniation of the spinal cord substance is a serious hazard if only step-by-step laminar decompression is performed. Usually, pulsation of the dura returns and improvement of the spinal evoked potentials (SEP) by spinal cord monitoring can be observed, both of which indicate sufficient decompression. The second cervical lamina should be reserved for attachment of the semispinal muscles, but if further decompression seems necessary, undercutting of the C-2 lamina is recommended. Occasionally, a midline incision of the dura or unroofing of the roots may be required for further decompression, if pulsation does not return and these structures still look tight. The

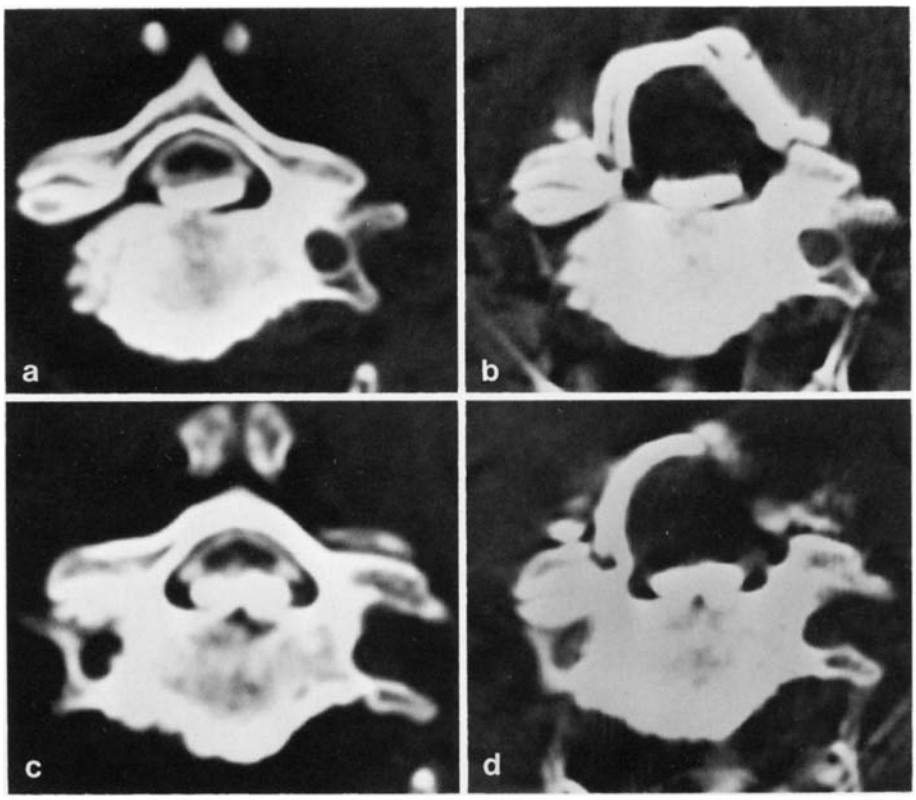


Fig. 3a–d. CT scans of the same case (case 1). The myelo-CT scans made before surgery (**a** C3; **c** C4) show critical compression of the spinal cord by the OPLL. The CT scans made at the same levels **b** C3, **d** C4 after expansive laminoplasty show sufficient space allowed by the lamina reflected (**d**) and fixed with bone graft (**b**)

arachnoidea should be left in place, and release of the denticulate ligament is not necessary for further decompression.

The opened laminae should be fixed in their open position to maintain permanent decompression of the spinal cord. Bone blocks are obtained utilizing the resected spinous processes, trimmed as shown in Fig. 1b. The ends of these bone grafts are sutured tightly to the edges of the opened laminae and the articular processes. These supports are made on every two or three laminae (Fig. 1c). On the hinged side, bone chips from the remaining resected spinous processes are placed in the grooves. Suction drainage is used before muscle closure.

The head is kept in a neutral position for a week; the patient is then allowed to ambulate with a cervical orthosis for 1 month and can return to standard daily activity 2 months postoperatively.

Case Report

A 42-year-old man (case 1) with C2–5 OPLL (mixed type) had suffered from spastic paralysis and sensory impairment below the C-6 dermatome for 2 years (Figs. 2 and 3). The canal narrowed (anteroposteriorly) by a maximum of 36% at the C-4 level and the preoperative JOA score was 12 (I:4, II:2, III-A:2, III-B:1, III-C:1, IV:3).

Since the patient's left side showed more marked symptoms the left side of the vertebral column was opened. The left side was reflected about the right side, which acted as a hinge, and laminoplasty was carried out from C3 to C7, with additional undercutting of the C-2 lamina. The operating time was 2.5 h and bleeding was 560 g.

Immediately after the operation sensory disturbance was alleviated, and motor dysfunction disappeared steadily. The patient returned to his job 3 months postoperatively. Ten months after the operation, his neurological deficits had mostly improved and his JOA score was 17 points. He was quite well at the 2-year follow-up examination.

Results

Expansive cervical laminoplasty was used in 23 patients with myelopathy (Table 2). The mean preoperative score was 8.50 ± 2.52 (3–12), and the mean postoperative score was 15.25 ± 2.07 (9–17). The improvement ratio was 81.2% on the average. Twenty patients who had suffered from myeloradiculopathy for periods ranging from more than half a year to 11 years (2.8 years on the average) showed improvement immediately after surgery or within several months postoperatively. The three patients cases (21, 22, 23) who had accidentally injured their spinal cords before surgery achieved the lowest scores.

Expansive laminoplasty appears to achieve better results than the other operations (anterior decompression and extensive laminectomy) which were previously used for cervical myelopathy secondary to multilevel OPLL (Table 3). Our laminoplasty requires slightly more operating time (30 min); it can be accomplished within 2.0–3.0 h. CT scans revealed that the expansion ratio, based on anteroposterior diameters of the spinal canal, was increased by an average of 124% ($n = 18$), and at the most constricted site by as much as 165%; thus, effective decompression to the deteriorated spinal cord was obtained.

Table 2. Cases of multilevel OPLL receiving expansive laminoplasty (EL)

Case	Age/sex	OPLL[a]		Type	EL	JOA Evaluation[b]			Follow-up (months)
		Level	(Max-%)			pre-op : post-op		IR (%)	
						(A)	(B)		
1. MT	42/♂	C2–5	(C4–36)	mixed	C2–7	12	17	(100)	25
2. SG	72/♂	C3–6	(C4–33)	mixed	C3–7	7	14	(70)	30
3. KN	43/♂	C2–7	(C6–60)	mixed	C2–T1	11	15	(67)	30
4. GK	68/♂	C2–6	(C3–56)	contin.	C2–6	9	16	(88)	31
5. TD	64/♂	C4–7	(C6–53)	contin.	C3–7	6	17	(91)	31
6. TI	57/♂	C2–5	(C4–64)	mixed	C3–6	11	17	(100)	30
7. NH	74/♂	C3–6	(C5–23)	contin.	C3–7	6	15	(82)	24
8. TA	45/♂	C3–5	(C4–32)	mixed	C3–7	8	17	(100)	24
9. YM	68/♂	C3–7	(C5–58)	contin.	C3–7	8	14	(67)	26
10. KK	53/♂	C3–5	(C4–46)	contin.	C3–7	12	15	(60)	30
11. AY	52/♂	C2–6	(C4–35)	contin.	C3–6	9	17	(100)	29
12. SF	58/♂	C1–6	(C4–68)	mixed	C3–7	3	17	(100)	32
13. Sm	62/♂	C2–5	(C3–50)	contin.	C2–7	10	14	(57)	38
14. SN	72/♂	C2–T2	(C6–33)	mixed	C2–T2	5	10	(67)	32
15. MO	72/♀	C4–7	(C6–44)	contin.	C3–7	8	11	(38)	27
16. SU	55/♀	C4–6	(C5–50)	contin.	C3–7	6	13	(64)	27
17. HI	59/♀	C3–6	(C4–38)	mixed	C3–7	11	16	(83)	28
18. FU	64/♂	C2–7	(C4–22)	contin.	C2–T1	10	17	(100)	51
19. TO	37/♂	C2–5	(C4–24)	contin.	C2–6	11	17	(100)	52
20. FU	56/♂	C4–7	(C6–36)	contin.	C3–T1	7	16	(90)	38
21. TI	73/♂	C1–7	(C5–69)	contin.	C2–7	9[c]	9	(0)	died
22. EN	73/♂	C4–7	(C5–64)	contin.	C3–7	9[c]	11	(25)	35
23. IN	64/♂	C4–7	(C5–84)	contin.	C3–7	9[c]	9	(0)	25

[a] Max-% = level at which maximal ossification occurred and percentage by which the canal narrowed. Advanced multilevel OPLL includes two types: continuous and mixed (partially continuous and segmented OPLL)
[b] IR = Improvement ratio = (B-A)/(17-A) × 100 (%). Average IR excluding the three cases resulting from accidents, was 78.8%. Average follow-up period was 31.5 months
[c] Patient was injured in an accident

Table 3. Comparison of JOA scores achieved by patients with multilevel OPLL before and after various surgical procedures

JOA score[a]	Operation		
	Expansive laminoplasty ($n = 23$)	Extensive laminectomy ($n = 14$)	Anterior decompression ($n = 17$)
Pre-op	8.50 ± 2.52 (3–12)	8.78 ± 3.63 (7–13)	7.82 ± 3.05 (4–10)
Post-op	15.25 ± 2.07 (9–17)	15.23 ± 1.00 (9–17)	13.25 ± 2.70 (10–17)
Improvement ratio [%][b]	81.20 ± 18.67	72.44 ± 22.85	63.58 ± 34.33

[a] JOA score, average ± SD. Numbers in parenthesis are ranges
[b] Improvement ratio (explained in Table 2)

Postoperative CT scans showed neither contact nor compression of the lamina or bone graft with the spinal cord in any patient. Clinical recovery was not correlated with the number of lamina expanded. The length of osseous support by the resected spinous process was sufficient at about 10 mm. In the follow-up examinations there has been no case of postoperative instability, malalignment, subluxation, or swan-neck deformity. There has been no recurrence of myeloradiculopathy.

Discussion

Since the ossifying lesions seen in cases of OPLL are located in the anterior spinal canal, it seems theoreti-

cally ideal to directly excise these. Of course, in cases of OPLL involving not more than two vertebrae, where myeloradiculopathy is usually not so advanced, anterior decompression followed by spondylodesis gives sufficient results [10]. However, in our experience with anterior decompression for multilevel OPLL the results were rather discouraging [8]; the ossified lesions frequently adhered to the dura and/or grew up unevenly like mushrooms. In this condition it is extremely dangerous if mechanical stimuli are given through the lesions to the adjacent compressed spinal cord, which is already more vulnerable. In particular, spinal edema, which may be readily induced, may lead to secondary pressure on the spinal cord. Hence, it is quite difficult to excise these ossified lesions without damaging the adjacent spinal cord. Furthermore, after resecting an OPLL involving more than three vertebral bodies, anterior spondylodesis using long-bone grafts is needed, at least between the five vertebral bodies. Strict fixation of the neck for quite a long period is required. For these reasons, anterior decompression is applied in our hospital only to patients whose OPLL is in an early stage and limited to three vertebral bodies.

Posterior decompression is safer and easier for patients with multilevel OPLL and, hopefully, will be generally accepted. Reliable results are expected because the spinal cord can be widely and totally decompressed from the back without disturbing the spinal cord itself. Postoperative management is also easy. The above points are demonstrated by our data, showing that the improvement ratio with posterior decompression (laminectomy or laminoplasty) is superior to that with anterior decompression.

Extensive laminectomy [7, 9] is the simplest and easiest method of posterior decompression. In the high-risk or elderly patient this operation is preferable. However, of 14 patients who underwent this procedure, two developed malalignment, one had swan-neck deformity, and two suffered from Lhermitte-like cord pain within 2 years after the operation. Thus, for a short period after laminectomy, results as favorable as those with laminoplasty can be obtained. However, instability of the spinal column is increased after laminectomy because of a weakened posterior supporting mechanism [1, 5].

Laminoplasty was introduced [4, 5, 11] because of the above-mentioned shortcomings of extensive laminectomy. In our expansive laminoplasty, the reconstructed laminae re-cover the bone canal and protect the spinal cord. They also allow for the reattachment of the posterior muscle group, and thus, the supporting mechanism is regained. In addition, the laminae cannot return to their former positions because they are supported by bone grafts utilizing resected spinous processes, so scar tissue around the dura will be minimized. Thus, secondary constricture or compression of the cord is prevented, resulting in the highest improvement ratio in the follow-up examinations.

In conclusion, the advantages of our expansive laminoplasty for multilevel OPLL are ease, safety, and the assurance of better postoperative stability. All of these result in better neurological recovery and fewer postoperative complications, such as malalignment of the cervical spine, posterior spur formation seen after anterior decompression, osteoarthritic changes, or aggravation by posterior trauma all of which can occur with the laminectomized spine.

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