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Original Article

Reconstruction to decrease postoperative deformity after cervical benign extramedullary tumor resection

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Abstract: Laminectomy will result in spinal instability or even deformity when is performed for patients with benign cervical extramedullary tumors, therefore, spinal reconstruction is necessary though the surgical indications are not clear, especially for adult patients. We conducted a prospective study investigating prognostic factors and clinical outcomes in a consecutive series of patients with resection of cervical benign extramedullary tumors. 50 consecutive patients with cervical benign extramedullary tumors were prospectively enrolled in this study. For each patient, a laminectomy/hemi-laminectomy with or without fusion were performed. The patients were followed up for a mean duration of 36.2 months (range; 5-66 months). The Japanese Orthopedic Association (JOA) score system was used to investigate preoperative and postoperative neurological status. Fisher's exact method was used to analyze the postoperative deformity rate between the groups with or without fusion. Apart from spinal reconstruction, other relevant risk factors such as age, decompression extent, and the removal of C2 lamina were analyzed. According to the JOA scores, surgical intervention improved neurological status significantly. The overall postoperative deformity occurrence rate was 4% in our cohort without cases of sustained complications among those with reconstruction. Post-laminectomy deformity occurred in relatively young patients who had lamina in more than 3 levels, especially in C2, removed without reconstruction. Spinal reconstruction can significantly decrease postoperative spinal deformity after cervical benign extramedullary tumor resection. Fusion may be necessary based on risk factors, such as young age and removal of laminas from, more than 3 levels and/or from C2.

Keywords: Benign cervical tumor, extramedullary, spinal reconstruction, postoperative deformity

Introduction

Spinal cord tumors are relatively rare, with national incidence of 10 per 100,000 people [1]. In China, the average ratio of brain tumors to spinal cord tumors is 8:1. The most common spinal cord tumors are nerve sheath tumors and the ratio of neurinomas to meningiomas in China is 3.8:1, which is much higher than ratios in western countries (almost 1:1), but close to the ratio reported in the Japanese literature (3.9:1) [1, 2]. Of the spinal cord tumors identified, 69% are non-malignant, and two-thirds are extramedullary, either intra- or extradural in nature [2, 3]. The majority of benign cervical intradural extramedullary) spinal tumors involve meningiomas, nerve sheath tumors (e.g., schwannomas and neurofibromas with rare cases such as solitary fibrous tumors), and ependymomas of the filum terminale, among others [4-6]. Laminectomy has been the primary approach for safe resection of spinal tumors because it is mandatory to keep the lesion well exposed [5]. However, although spinal cord tumors themselves, especially intramedullary spinal cord lesions, can also result in spinal instability even without surgery [1, 5, 6] post-laminectomy kyphotic deformity, ranging from focal kyphosis to more complicated swan-neck deformities, which was first reported by Eiselsberg [6], affects 14% of patients with a lordotic cervical spine, 30% of those with a straight spine and 24-100% of children who have not reached bone maturity [7]. Such deformities, which were presumed to become stabilized in adults and increase gradually in children [8], contribute to progressive neurological deficits, negating clinical improvements [9]. The mechanism was experimental simulated. By observing after removing the posterior ligaments and spinous processes, the tension was transferred to the facet, resulting in imbalance and increased

Table 1. Clinical information of 50 cases

Case no. and Sex	Age	Levels of the tumor	Location of tumors		Level of bilateral or unilateral fusion after laminectomy or hemilaminectomy	Lamina removal numbers	Additional anterior operations	Redicality of resection	Complications	Neurological status			Status	Postoperative recurrence	Follow-up period (months)
										JOA Score (Pre OP)	JOA Score (Final)	Improvement ratio (%)			
1. F	43	C5	Intradural/extramedullary (dumbbell)	Ventral	C4-7/total laminectomy+ bilateral fusion	4	No	Complete		15	14	50	Improved	None	45
2. M	43	C5-6	Intradural/extramedullary	Ventrolateral	C4-7/total laminectomy+ bilateral fusion	4	No	Complete		14	16	66.6	Improved	None	66
3. F	51	C4-6	Intradural/extramedullary	Ventral	C4-6/total laminectomy+ bilateral fusion	3	No	Complete		13	15	50	Improved	None	64
4. M	46	C3-4	Intradural/extramedullary	Dorsal	C3-5/total laminectomy+ bilateral fusion	3	No	Complete		16	16	0	Unchanged	None	63
5. F	52	C7-T1	Intradural/extramedullary	Unilateral	C6-T1/ hemilaminectomy+ unilateral fusion	3	No	Complete		15	17	100	Improved	None	63
6. M	47	C4-6	Intradural/extramedullary	Dorsal	C4-7/total laminectomy+ bilateral fusion	4	No	Complete		14	15	33.3	Improved	None	60
7. M	44	C5-7	Intradural/extramedullary	Unilateral	C4-7/total laminectomy+ bilateral fusion	4	No	Complete		15	17	100	Improved	None	60
8. M	35	C4-5	Intradural/extramedullary	Ventrolateral	C4-6/total laminectomy+ bilateral fusion	3	No	Complete		14	15	33.3	Improved	None	60
9. F	48	C4-5	Intradural/extramedullary	Unilateral	C4-5 total laminectomy and excision without fusion	2	No	Complete		13	16	75	Improved	None	56
10. F	22	C2	Intradural/extramedullary (dumbbell)	Dorsolateral	C1-3 total laminectomy and excision without fusion	3	No	Complete		15	16	50	Unchanged	None	55
11. F	65	C4-5	Intradural/extramedullary	Dorsolateral	C3-5/total laminectomy+ bilateral fusion	3	No	Complete		13	17	100	Improved	None	51

12. M	48	C7	Intradural/extramedullary	Ventrolateral	C6-T1/total laminectomy+ bilateral fusion	3	No	Complete		15	16	50	Improved	None	46
13. F	74	C6-7	Intradural/extramedullary	Dorsolateral	C5-T1/total laminectomy+ bilateral fusion	4	No	Complete		14	16	66.6	Improved	None	44
14. M	16	C2-5	Intradural/extramedullary	Dorsolateral	C2-5 total laminectomy and excision without fusion	4	No	Complete	Swan-neck deformity	11	10	-16.7	Worsened	Recurrence of neurofibroma at C2-5	12
15. F	72	C4-6	Intradural/extramedullary (dumbbell)	Dorsal	C4-7/total laminectomy+ bilateral fusion	4	No	Complete		12	16	80	Improved	None	40
16. F	57	C1	Intradural/extramedullary	Ventral	C1-2 total laminectomy and excision without fusion	2	No	Complete		15	16	50	Improved	None	37
17. F	27	C7	intradural/extramedullary (dumbbell)	Ventrolateral	C5-T1/total laminectomy+ bilateral fusion	4	No	Complete		14	15	33.3	Improved	None	35
18. F	55	C5-6	Intradural/extramedullary	Ventrolateral	C4-6/ hemilaminectomy+ bilateral fusion	3	No	Complete		15	16	50	Improved	None	31
19. M	59	C3-4	Intradural/extramedullary	Ventrolateral	C2-4/total laminectomy+ bilateral fusion	3	No	Complete		14	15	33.3	Unchanged	None	30
20. M	34	C3-4	Intradural/extramedullary	Ventral	C3-5/total laminectomy+ bilateral fusion	3	No	Complete		15	17	100	Improved	None	66
21. M	74	C4-5	Intradural/extramedullary	Dorsolateral	C3-6/total laminectomy+ bilateral fusion	4	No	Complete		16	16	0	Improved	None	55
22. F	19	C6-7	intradural/extramedullary (dumbbell)	Dorsal	C6-T1/ hemilaminectomy+ unilateral fusion	3	No	Complete		16	17	100	Improved	None	34
23. M	56	C1-2	Intradural/extramedullary	Unilateral	C1-3/total laminectomy+ bilateral fusion	3	No	Complete		14	15	33.3	Improved	None	28
24. F	40	C1-2	Intradural/extramedullary	Unilateral	C1-3/total laminectomy+ bilateral fusion	3	No	Complete		15	15	0	Improved	None	28
25. M	36	C1-2	intradural/extramedullary (dumbbell)	Ventral	C1-4/total laminectomy+ bilateral fusion	4	No	Complete		14	17	100	Improved	None	30
26. F	41	C2-3	Intradural/extramedullary	Dorsolateral	C1-4/total laminectomy+ bilateral fusion	4	No	Complete		15	16	50	Improved	None	28

27. F	39	C2-3	Intradural/extramedullary (dumbbell)	Ventrolateral	C2-4/total laminectomy+ bilateral fusion	3	No	Complete	14	14	0	Improved	None	22
28. F	36	C2-3	Intradural/extramedullary	Ventral	C2-4/total laminectomy+ bilateral fusion	3	No	Complete	14	15	33.3	Improved	None	21
29. F	29	C4-6	Intradural/extramedullary	Dorsolateral	C3-6/ hemilaminectomy+ unilateral fusion	4	No	Complete	16	17	100	Improved	None	20
30. F	55	C7	Intradural/extramedullary	Ventral	C7-T1/total laminectomy+ bilateral fusion	2	No	Complete	14	14	0	Unchanged	None	30
31. F	72	C4-5	Intradural/extramedullary	Ventrolateral	C3-6/total laminectomy+ bilateral fusion	4	No	Complete	13	16	75	Improved	None	40
32. M	40	C4-6	Intradural/extramedullary	Dorsal	C3-6/total laminectomy+ bilateral fusion	4	No	Complete	15	16	50	Improved	None	25
33. M	33	C5-6	Intradural/extramedullary	Dorsolateral	C5-6/total laminectomy+ bilateral fusion	2	No	Complete	15	15	0	Improved	None	52
34. M	76	C2-3	Intradural/extramedullary	Ventral	C1-4/total laminectomy+ bilateral fusion	4	No	Complete	15	17	100	Improved	None	27
35. M	59	C3-4	Intradural/extramedullary	Ventrolateral	C2-4/total laminectomy+ bilateral fusion	3	No	Complete	15	16	50	Improved	None	30
36. M	58	C2-3	Intradural/extramedullary (dumbbell)	Dorsal	C1-3/total laminectomy+ bilateral fusion	3	No	Complete	14	16	66.7	Improved	None	10
37. F	38	C1-2	Intradural/extramedullary	Dorsolateral	C1-3/total laminectomy+ bilateral fusion	3	No	Complete	15	17	100	Improved	None	5
38. F	50	C1-2	Intradural/extramedullary	Dorsal	C1-5/total laminectomy+ bilateral fusion	5	No	Complete	13	14	25	Unchanged	None	19
39. M	26	C6-7	Intradural/extramedullary (dumbbell)	Unilateral	C6-T1/total laminectomy+ bilateral fusion	3	No	Complete		15	0	Improved	None	18
40. F	53	C2	Intradural/extramedullary	Ventral	C1-3 /total laminectomy+ bilateral fusion	3	No	Complete	15	17	100	Improved	None	11
41. F	47	C4-6	Intradural/extramedullary (dumbbell)	Ventral	C4-7/total laminectomy+ bilateral fusion+ anterior fusion	4	Yes C5-7	Complete	15	16	50	Improved	None	27

42. F	40	C1-2	Intradural/extramedullary	Unilateral	C1-2 total laminectomy and excision without fusion	2	No	Complete		14	16	66.7	Improved	None	18
43. F	27	C7	Intradural/extramedullary	Ventral	C5-T1/total laminectomy+ bilateral fusion	4	No	Complete		12	14	40	Unchanged	None	36
44. M	58	C6-7	Intradural/extramedullary	Ventrolateral	C6-7 total laminectomy and excision without fusion	2	No	Complete		14	15	33.3	Unchanged	None	50
45. M	33	C5-7	Intradural/extramedullary	Ventral	C5-T1/total laminectomy+ bilateral fusion	4	No	Complete		13	15	50	Unchanged	None	55
46. F	24	C7	Intradural/extramedullary (dumbbell)	Ventral	C6-T1/total laminectomy+ bilateral fusion	3	No	Complete		14	16	66.7	Improved	None	32
47. F	74	C6-7	Intradural/extramedullary	Dorsal	C6-T1/total laminectomy+ bilateral fusion	3	No	Complete		14	16	66.7	Improved	None	45
48. M	55	C7	Intradural/extramedullary (dumbbell)	Ventral	C5-T1/total laminectomy+ bilateral fusion	4	No	Complete		13	15	50	Improved	None	5
49. F	56	C1-2	Intradural/extramedullary (dumbbell)	Ventral	C1-4/total laminectomy+ bilateral fusion	4	No	Complete		15	16	50	Improved	None	12
50. F	20	C2-4	Intradural/extramedullary (dumbbell)	Ventral	C2-5 total laminectomy and excision without fusion	4	No	Incomplete	Swan-neck deformity	14	14	0	Unchanged	Recurrence of neurofibroma at C2-5	12
Average	46.03					3.34				14.26	15.58	51.73333333			36.18
S.D	15.7					0.717421687				1.071031673	1.230397314	34.23767256			17.8

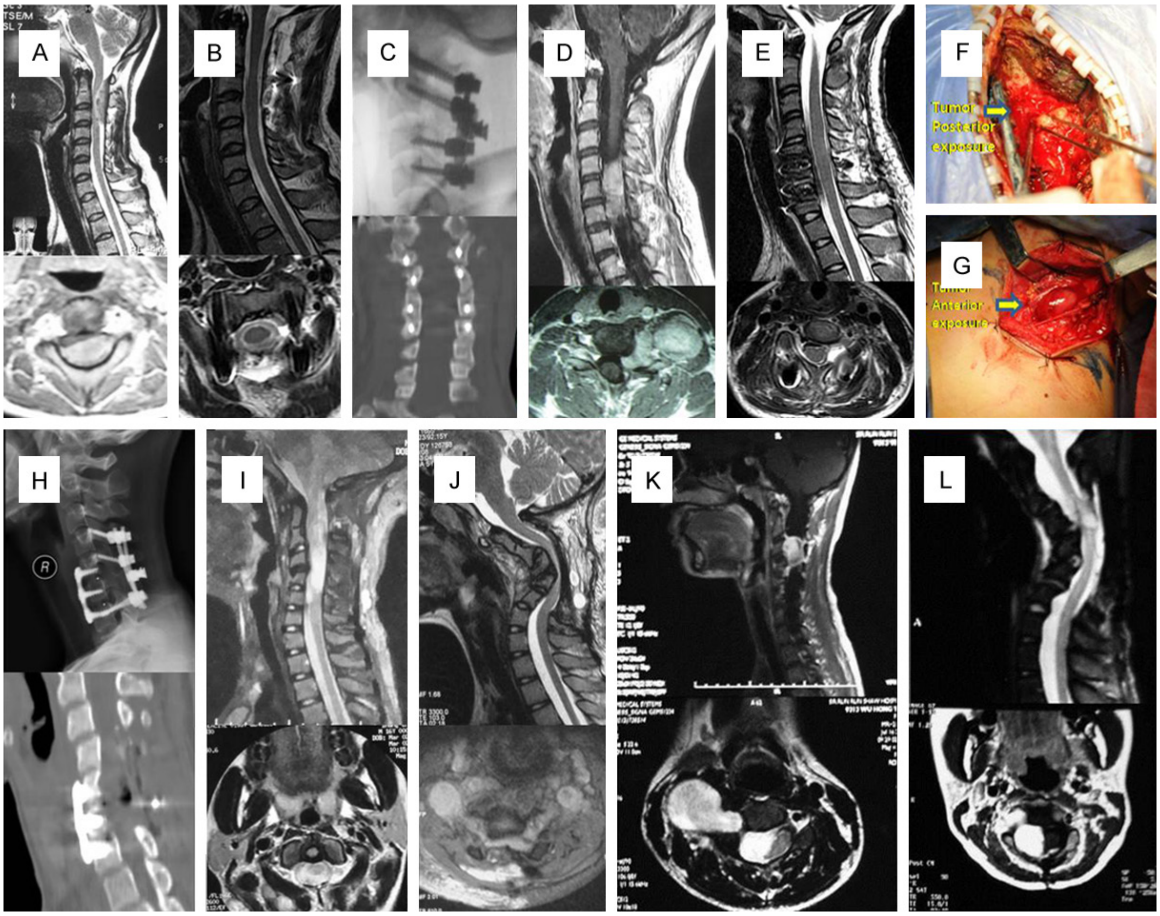

Figure 1. A. Preoperative MRI from case 26 showing an intradural/extramedullary schwannoma of the cervical spine; B. Postoperative MRI showing tumor resection via total laminectomy; C. X-ray cervical spine lateral views showing normal cervical alignment with a lateral mass plate and screws at 28-month follow-up; D. Preoperative MRI from case 41 showing an intra- and extradural/extramedullary (dumbbell-shaped) neurinoma of the cervical spine; E. Postoperative MRI revealing tumor excision via the laminectomy; F. Tumor resection via the posterior procedure; G. Additional anterior approach for resection; H. X-ray and CT images of the cervical spine showing normal cervical alignment with the lateral mass plate, anterior plate and screws at 27-month follow-up; I. Preoperative MRI for case 14; J. The tumor was completely removed, although severe kyphosis occurred 12 months after the operation; K. Preoperative MRI for case 50; L. Incomplete resection and swan-like deformity occurred 12 months after the operation.

stress on the vertebral body. As such the anterior -posterior direction of the gravitational center of the head, result in lordotic deformity, while its location in the anterior direction led to kyphotic deformity [8].

The actual causes of post-laminectomy deformities remain unclear [8] although the list of risk factors previously shown to be associated with post-laminectomy cervical deformities includes patient characteristics such as age, extent of decompressive surgery [7] (especially involving the removal of C2), preoperative sagittal alignment [10], intramedullary disease [11], and preoperative spinal radiation therapy [12]. Furthermore, the clinical result and indications of subsequent spinal reconstruction after cervical extramedullary tumor resection is unclear. Therefore, we examined post-laminectomy deformity in 50 patients who were consistently followed after their diagnosis and who underwent a total extirpation of the extramedullary tumor with or without spinal reconstruction and made a systematic analyze about the potential factors such as age, decompression extent and so on.

Subjects and methods

Patients

Fifty patients (28 female and 22 male) with cervical spinal cord tumors treated surgically by total laminectomy and hemi-laminectomy (50 operations) at our institute between 2006 and 2011 were followed-up and reviewed in a prospective study (**Table 1**). This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Huashan Hospital. Written informed consent was obtained from all participants.

The age (mean ± SD) at the time of surgery was 46 ± 15.7 years (range: 16-76 years), and the mean ± SD follow-up period was 36.2 ± 17.8 months (range: 5-66 months). One patient underwent hemi-laminectomy for the removal of tumors followed by bilateral fusion, and 3 patients underwent hemilaminectomy with unilateral fusion. In addition, 7 cases received only a posterior total laminectomy without fusion. All of the patients sustained local or radiating pain or motor disturbance of the extremities. Enhanced and plain magnetic resonance imaging (MRI) was used to diagnose spinal cord compression caused by tumors. Both total laminectomy and hemilaminectomy were selected for tumors with clear borders or extradural dorsal and unilateral lesions. Ventral tumors of the spinal cord were removed by posterior laminectomy or hemilaminectomy, both of which provided a better view and safer removal of the tumors.

Levels and locations of tumors

The locations of the tumors were intradural/extramedullary and, dumbbell in shape in 28% of the cases (n = 14). Those located ventral (ventrolateral) aspects of the spinal cord represented 52% (n = 26) of the cases, whereas dorsal (dorsolateral) represented 34% (n = 17), those located on unilateral areas of the spinal cord accounted for 14% (n = 7) of the cases (**Table 1**).

Timing of the surgery

Surgery was performed after the tumors were definitively diagnosed via imaging and after the patients sustained sensory or motor disorders, which caused serious adverse effects in their daily lives. Compared with other literature reports, there were no obvious differences in the timing of the surgery.

Surgical procedures

Three surgeons at our institution performed all of the operations. With the patient in the prone position, a midline incision was made on the posterior neck. According to the border of the tumor, bone and ligaments resection were restricted, and the vertebral arch was removed piecemeal via punches. With total laminectomy, the spinous process, the laminae, part of the facet complex, interspinous ligament, supraspinous ligaments, and the ligamentum flavum were all removed. With hemi-laminectomy, the spinous process and its base as well as the contralateral lamina, including the flavum and muscle, were all preserved. The flavum was removed until that the contralateral root or dural curve was in direct view. For meningiomas, after their gross removal, the place of origin from the dura was coagulated or resected. Fusion was performed only when necessary (**Figure 1A-C**). When a complete resection could not be realized from the posterior approach, an additional anterior procedure was performed, as in Case 41 (**Figure 1D-H**).

Pathological diagnoses of the tumors

Pathological diagnoses were made using specimens from the resected tumors (**Table 1**).

Radicality of resection

The radicality of resection was assessed by the surgeons as either complete resection or incomplete resection.

Complications

Postoperative complications were analyzed.

Changes in neurological status

Neurological status was evaluated using the Japanese Orthopedic Association (JOA) scores for cervical myelopathy (JOA-C). The JOA-C was recorded within one month before surgery and at the final follow-up. Increases in these scores (i.e., the difference between the final and preoperative scores), were also evaluated. A full JOA-C score [13, 14] was defined as 17 points: 8 for the upper and lower motor functions, 6 for sensory functions, and 3 for bladder-rectal function. The improvement ratio of these scores, indicating the degree of postoperative improvement, was calculated as follows [15]: Improvement in the JOA-C ratio: (postoperative score-preoperative score) × 100/[17 (full score)-preoperative score] (%).

Table 2. Postoperative kyphosis in the groups receiving reconstruction and laminectomy

Group	Kyphosis	Relative normal cervical curve	Total
Reconstruction	0	43	43
Tumor resection without reconstruction	2	5	7
Total	2	48	50

Fiser's exact = 0.017, α = 0.05.

Changes in neurological status were classified into three grades: improved, unchanged, and worsened.

Postoperative recurrence of tumors

Combined with clinical symptoms, MRI was used to assess the presence or absence of recurrences of tumor sat the time of final follow-up.

Statistical analysis

The neurological improvement ratio was compared among patients with preoperative and postoperative conditions using Fisher's exact method.

Results

Pathological diagnosis of tumors

Pathological examinations revealed schwannoma in 39 cases (78%), meningioma in 6 cases (12%), neurofibroma in 2 cases (4%), hemangioblastoma in 2 cases (4%) and benign tumor-like lesions in 1 case (2%) (**Table 1**).

Radicality of resection

A total of 49 cases (98%) received complete resections. Only one case (Case 50) received incomplete excision (2%) (**Table 1**).

Laminae removal

The average number of laminae removed was 3.34 (3.34 ± 0.7). Tumor resections that required C2 removal comprised 38% of cases (n = 19).

Complications

Case 14 involved a 16-year-old male (neurofibroma, C2-5 levels) with, severe kyphosis that occurred after his operation, followed by tumor recurrence and severe motor and sensory disturbance over the subsequent 12 months (**Figure 1I**, **1J**). In Case 50, a 20-year-old woman (neurofibroma, C2-4 levels) experienced swan-neck deformity that occurred at 1 year follow-up as well as neurofibroma recurrence at C2-5 (**Figure 1K**, **1L**; **Table 1**).

Changes in the neurological status

A total of 40 patients (80%) experienced postoperative improvements, while 9 cases (18%) failed to show any changes; 1 case (2%) displayed worse outcome. No significant improvements in neurological status were observed in Cases 14 and 50. The mean improvement ratio in neurological status scores was 51.7% (**Table 1**). T-text was used to compare the preoperative and postoperative JOA scores, indicating that surgical interventions could definitively improve the neurological status ($P < 0.05$).

Fisher's exact method was used to compare the occurrence of deformity in the reconstruction group with that in the laminectomy only group. Reconstruction was found to effectively decrease the incidence of kyphosis ($P < 0.05$) (**Table 2**).

Postoperative recurrence of the tumor

Case 14 and case 50 sustained neurofibromarecurrence at the level of C2-5, although without severe motor dysfunction or sensory disturbance/deterioration.

Discussion

In cases in which compression of the spinal cord is severe and the risk of neurological deterioration increases, surgery is needed to relieve compression, and aggressive surgical approaches are recommended by orthopedic surgeons for the treatment of intradural extramedullary tumors [16], the overwhelming majority of which are consists of meningiomas and nerve sheath tumors (schwannomas and neurofibromas) [17]. Only a few authors have performed laminectomy for such tumors (**Table 3**) and the clinical result, risk factors and reconstruction introductions is insufficient so far. Laminectomy without fusion will result in deformity ranged from 20%~100% except Kyung-

Table 3. Literatures focusing on postoperative deformities after cervical benign extramedullary resection without fusion

Authors	Year	Total cases	Cases of cervical benign extramedullary tumors without fusion	Number of laminae removal	Surgical strategy	Cases with post-laminectomy deformity (ratio)	Follow-up years before the occurrence of deformity	Management for deformity
DANIEL M et al.	2008	45	13	2~6	Total laminectomy	3 (23.1%)	19 (range 1-35 months)	Anterior and posterior fusion
Kyung-Won Song et al.	2009	12	1	2	Total laminectomy	0	/	/
Yoshihiro M et al.	1987	64	8	/	Total laminectomy	2 under 20 years old (25%)	mean 3.6 months	Anterior fusion
Yutaka K et al.	1989	34	30	1~3	Total laminectomy	9 (30%)	7.6 ± 2.9 weeks	Anterior fusion
Akira I et al.	1996	36	24	2~9	Laminectomy + laminoplasty + hemi-partial laminectomy	11 (45.8%)	0.5~8.4 years	Anterior and posterior fusion
Sunil V et al.	2010	22	22	2~5	Hemilaminectomy + laminotomy	3 (13.6%)	4~6 months	Posterior fusion
Shozo Yasuoka, Hamlet A., Peterson	1982	248	23	3~10	Total laminectomy	23 (100%)	2~74 months	Anterior fusion
MATTI T SEPPÄLÄ et al.	1995	187	49	/	Total laminectomy	4 (8.2%)	Median follow-up period was 12.9 years	/
Matthew J et al.	2010	238	111	3~5	Laminectomy + Laminoplasty	9 (19.1%)	3~24 months	Anterior and posterior fusion

Table 4. Postoperative kyphosis in the groups receiving reconstruction and laminectomy

	Cases with C2 removal along with fusion	Cases with C2 removal without fusion	Cases without C2 removal with fusion	Cases without C2 removal or fusion	Total
Normal	14	3	29	2	48
Deformity	0	2	0	0	2
Total	14	5	29	2	50

won and Sunil (**Table 3**). Kyung-won operated only on a single cervical case, whereas, Sunil applied both hemi-laminectomy and laminotomy, which are believed to result in a decreased incidence of post-laminectomy deformity [2, 3, 16, 18, 19].

In the present study, clinical outcomes after 50 cases involving removal of spinal tumors by total laminectomy or hemi-laminectomy, with or without fusion, were reviewed with an average follow-up of 36.18 months. Post-laminectomy deformity was the major postoperative complication of focus. According to our research, there were no occurrences of deformity in the reconstruction group but two cases sustained severe kyphosis in the group without fusion. Spinal reconstruction reveals a good result after laminectomy as there is significantly fewer cases sustained post-laminectomy deformity with well improved JOA score, just as general believed--with respect to neurological status, stabilization, pain reduction, and radiographic evidence of post-laminectomy kyphosis, posterior instrumented fusion following cervical laminectomy provided good results [7]. However, a review of the literatures revealed no gold standard for spinal reconstruction after the resection of cervical benign extramedullary tumors (except in young patients) and the actual causes of post-laminectomy deformities remain unclear [8].

It is well believed that age seems to be a well related factor. Tachdjian and Matson found scoliosis or kyphosis in approximately 30% of 115 pediatric patients undergoing laminectomy for spinal cord tumors and Lonsterin reported a 50% rate in patients less than 19 years of age [6]. In our study, case 14 sustained swan-like deformities occurred at one year follow-up who was just 16 years old. Similarly, case 50, who is only 20-year, spinal deformity occurred after laminectomy without fusion. The reason is that the ligamentous structures of the pediatric spine are more lax and the orientation of the facet complex of the cervical spine is more horizontal, the young spine becomes unstable much more easily [8, 16, 18], furthermore, deformity tends to progress in the presence of a growing spine because of abnormal growth associated with changes in spinal biomechanics [5]. In the other side, preventive fusion of the cervical spine is considered necessary and effective in combination with multilevel laminectomy in young patients [9].

Extent of decompressive surgery [7] plays an important role in post-laminectomy spinal deformity, which is guided by the anatomy of the lesion, intraoperative monitoring, surgeon' experience and preliminary histological diagnosis on frozen sections of the lesion [20]. Actually, It includes the medial-to-lateral extent of decompression (e.g., laminectomy with or without facetectomy), cranial-to-caudal extent of decompression (e.g., number of laminae removed), and location of laminectomy (i.e., upper, middle, or lower cervical spine) [7].

Facetectomy, which is necessary in certain cases, such as those involving dumbbell-shaped and ventral lesions like case 14 and 50, to gain sufficient access and exposure, will cause postoperative spinal instability [21]. Instability has been noted after resection of as low as 25% of facets, although most authors warn against resection of more than 50% of the medial facet complex [22].

Each increase in the number of laminectomies performed was associated with a 3.1-fold increase in the likelihood of subsequent vertebral instability [7], similarly, Katsumi et al. [6] Reported a 46% incidence of post-laminectomy cervical kyphosis in patients with removal of four or more laminas, which was four times higher than the risk in patients with fewer than four removals. However, this allegedly direct correlation between the incidence of kyphosis and the number of laminae removed is not confirmed [5, 7, 23]. But in our study, the cases with spinal deformity both had 4 lamina removed via total laminectomy and those with ≤

3 levels of laminectomy without fusion did not sustain postoperative kyphosis or deformity by the final follow-up. As a result, more than 3 levels of laminectomy should have spinal reconstruction followed.

Other than lamina numbers removed, laminectomy at high-stress areas like the craniocervical and cervicothoracic junctions will probably have a higher risk of postoperative spinal deformities [5]. As such, careful attention should be paid to cases with upper cervical cord tumors, especially dumbbell-shaped tumors [24]. In our study, 19 cases had laminae removed from C2 (**Table 4**). Both cases involving postoperative deformity had laminae removed from C2. Though it may of little statistical significance, we still believe that C2 plays a significant role in the remaining cervical stability, as laminectomy in this location would result in a reduction in the area of insertion of the extensor muscles (semispinal muscle) with a consequent lack of supportive structure.

Kaptain et al. stated that pre-existing deformities including preoperative loss of lordosis doubled the possibility of progressive deformity after laminectomy for tumor resection [10]. This is one of the major limitations of our study, because we did not pay attention to statistical analysis about preoperative sagittal alignment. But as there was no radiographic evidence of overt postoperative instability with good decompression for myelopathy in adults with relative normal preoperative spine [25], the relationship between abnormal preoperative spine and postoperative deformity was not confirmed in patients of benign cervical extramedullary tumors without severe disc degeneration. For instance, Mikawa et al. [26] said deformities occurred mostly among 20-to 40-year-old, but in older patients with severe spondylotic changes, deformities were relatively few. And in cases with ossification of the posterior longitudinal ligament (OPLL), when the ossification foci is assumed to create a condition similar to anterior spinal fusion, the incidence of post-laminectomy kyphosis was not rare. So there are too many factors to consider about preoperative sagittal alignment and it need further research to explore. But in patients with preoperative kyphosis, performing a stabilization procedure at the time of the initial laminectomy for tumor resection seems necessary [5].

Another risk factor reported is radiotherapy. Cyber Knife radiosurgical ablation of almost any small-volume tumors is technically feasible and associated with low morbidity [27]. If total removal of the tumor cannot be achieved due to solid adhesion to the dura and critical structure involvement [28] or in cases with early recurrence followed by total resection, radiotherapy should be performed as adjuvant therapy [29]. Though radiotherapy has many advantages, it can also result in possible spinal instability. This is especially true in cases involving an immature spine with growth plates, where deformity can be induced by creating asymmetrical growth patterns even with relatively low doses [5].

Many techniques can prevent post-laminectomy deformities. It is strongly recommended that plain X-ray films of the cervical spine (anteroposterior and lateral) are obtained preoperatively to serve as a baseline for future comparisons. Furthermore, the risk of post-laminectomy kyphosis should always be considered before approaching tumors in the spinal canal for resection, especially for higher-risk patients such as children and young adults. During surgery, efforts should be made to limit facet resection and the number of laminae removed as long as sufficient surgical exposure is achieved for tumor resection [5]. Furthermore, laminotomy, hemi-laminectomy, and minimally invasive procedures may be effective alternatives [3, 30].

Once a deformity occurs, prompt fusion is recommended, as shown by Katsumi et al. [6] the general indications for surgical intervention for postoperative deformity include progressive deformity, axial pain in the area, and neurological symptoms attributable to the deformity. Surgical options include anterior, posterior, and combined anterior-posterior procedures, the last of which may be used in severe cases of kyphosis. Swan-neck deformities are much more complex in terms of surgical stabilization, reduction of alignment and stabilization may be achieved by an anterior procedure alone, with either multilevel discectomy and fusion or corpectomy with strut grafts [5]. Patients who are at high-risk should be followed for 5 years (6 years for children) with radiological evaluation on a twice-yearly basis to check for changes in cervical alignment [19].

There were several limitations in the design of this study. First, the mean follow-up period was 36 months, ranging from 5 to 66 months. Evaluations at consistent time periods are required in future studies to obtain more clinically relevant data. Second, the patients in this study were relatively middle-aged (median age: 46 years) and thus may not have been representative of a generalized patient population. The inclusion of elderly and/or younger patients may have altered our results. Third, our mix of tumor types was skewed, as schwannoma comprised 78% of all cases (although it does seem to be the most common spinal cord tumor). Forth, there is no statistical analysis about preoperative sagittal alignment. Finally, our study would be more convincing with a larger patient cohort.

There are no clear indications for fusion after resection of cervical benign extramedullary tumors in adults. In relatively young patients, resection combined with fusion seems to be more beneficial, which we strongly recommend, especially in cases with removal of more than 3 laminae and/or C2 laminae. Other factors that may contribute to post-laminectomy deformities should be taken into consideration before surgery, and the strategies for preventing and treating postoperative deformities should be selected prudently based on individual patient characteristics.

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Disclosure of conflict of interest

None.

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