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Kyphotic malalignment after anterior cervical fusion is one of the factors promoting the degenerative process in adjacent intervertebral levels

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Abstract The aim of this study was to determine whether postoperative malalignment of the cervical spine after anterior interbody fusion surgery promotes degenerative changes in the neighboring intervertebral discs. Forty-two patients who underwent anterior interbody fusion surgery for cervical spondylosis and disc herniation (34 men, 8 women) were followed for an average of 9.8 years. The average age at surgery was 50.2 years. Twenty-three patients underwent a single-level fusion, 17 underwent two-level fusion, and 2 had three levels fused. The Japanese Orthopaedic Association cervical myelopathy score, with a normal score 17 points, was 11.7 before surgery and 14.9 at follow-up. Neurological status was significantly improved postoperatively, and the improvement was preserved thereafter in most cases (paired *t*-test, $P<0.001$). Degenerative changes were evident on radiological examination in the levels adjacent to the fused segment in 21 of the 42 (50%) patients. Eight of these 21 patients demonstrated neurological deterioration caused by an adjacent disc lesion. A total of 43% of the patients with adjacent-level degeneration had malalignment of the cervical spine, such as kyphosis or sigmoid curvature. In addition, degenerative change in adjacent intervertebral levels was observed in 77% of kyphoses of the fused segment. These were statistically significant (Fisher exact method, $P<0.05$, $P<0.04$, respectively). Our findings suggest that one of the factors promoting degenerative change in adjacent intervertebral levels after anterior cervical fusion for degenerative disorders is postoperative kyphotic change in the cervical spine and the fused segment.

Key words Cervical spine · Anterior fusion · Adjacent disc degeneration · Cervical alignment

Introduction

Anterior decompression and fusion for myelopathy and radiculopathy due to degenerative disorders of the cervical spine yields marked improvement if patients are properly selected [3, 4, 8, 11, 18]. However, degenerative change in intervertebral levels adjacent to the fused segment is an inevitable long-term sequela of fusion operation [9, 19, 21, 22]. The incidence of degeneration of adjacent levels, including symptomatic changes, is quite high and cannot be ignored, even though it depends on the diagnostic criteria used or the follow-up period. There are few reports describing factors which promote or prevent this degenerative change in levels adjacent to the fused segment, and these factors therefore remain unclear [10].

In this study, we retrospectively examined whether cervical malalignment, such as kyphotic deformity, following anterior fusion was responsible for the progression of degenerative changes in intervertebral levels adjacent to the fused segment.

Materials and methods

From 1978 to 1992, anterior cervical fusion for degenerative disorders was performed in 93 patients in our department, 42 (34 males and 8 females) of whom returned to participate in this study. All of these 42 patients have been followed for more than 5 years after surgery. The average age at surgery was 50.2 years, and the period of follow-up ranged from 60 months to 264 months, with an average of 9.8 years (Table 1).

The preoperative cervical disorder was cervical spondylosis in 31 patients and cervical disc herniation in 11 patients. We determined the operative levels by radiography, myelography, and CT scan, including dynamic study after neurological examination, in all cases. The surgical methods we used were Robinson-Smith in 37, Cloward in 4, and subtotal corpectomy in one. No instrumentation, such as anterior plating, was used. The number of fused motion segments was one in 23 cases, two in 17 cases, and three in 2 cases.

At follow-up, the patients' neurological findings were graded by the JOA (Japanese Orthopaedic Association) score (17-point method) for cervical myelopathy and compared with those immediately after operation [14] (Table 2). If the score worsened by more than two points, the cause of deterioration was investigated. Radiological examination of the cervical spine (including dynamic study) was performed in all patients to evaluate degenerative changes in intervertebral levels adjacent to the fused segment as well as alignment of the total cervical spine and of the fused segment.

We diagnosed adjacent-level degeneration when at least one of the following criteria was met in comparison with preoperative radiographic findings: (a) evident intervertebral disc space narrowing; (b) newly developed instability (more than 3 mm) on flexion-extension radiographs; (c) vertebral posterior spur formation.

The alignment of the entire cervical spine was classified as lordotic, straight, kyphotic or sigmoid based on overall shape and the angle formed by tangent lines to the posterior edges of C2 and C7 (Fig. 1, angle A). The alignment of the fused segment was classified as lordotic or kyphotic based on the angle formed by the upper plane and the lower plane of the fused segment (Fig. 1, angle B).

Data analysis was performed with Statview-J 4.02 and SPSS (version 6.1). All continuous variables were analyzed with the

Table 1 Baseline characteristics of study population (*n*=42) (*JOA* Japanese Orthopaedic Association, *NS* nonsignificant)

	Total cohort (*n*=42)	Degenerated adjacent level (*n*=21)	Normal adjacent level (*n*=21)	*P* value
Mean age (SD)	50.2 (9.4)	48.1 (10.6)	52.7 (7.8)	NS
Gender (M/F)	34/8	19/2	15/6	NS
Follow-up (months)	117.5 (60–264)	122.4 (64–264)	112.7 (60–169)	NS
Fused level (SD)	1.4 (0.5)	1.5 (0.6)	1.3 (0.4)	NS
Preop JOA (SD)	11.7 (3.3)	12.7 (2.0)	10.7 (4.1)	NS
Postop JOA (SD)	15.9 (1.4)	16.1 (1.1)	15.7 (1.6)	NS
Follow-up JOA (SD)	14.9 (2.3)	14.5 (2.5)	15.3 (2.0)	NS

Table 2 Japanese Orthopaedic Association score for cervical myelopathy

Function	Score	Remarks
Motor function of upper extremity	4	Normal
	3	Able to feed with chopsticks regularly, but a little awkwardly
	2	Able to feed with chopsticks, although awkwardly
	1	Able to feed with a spoon but not with chopsticks
	0	Unable to feed oneself with either chopsticks or a spoon
Motor function of lower extremity	4	Normal
	3	Able to walk on a level surface or climb stairs without a cane or support but awkwardly
	2	Able to walk on a level surface without a cane or support, but unable to climb stairs without either of them
	1	Needs a cane or support even in walking on a level surface
	0	Unable to walk
Sensory		
Upper and lower extremity, trunk	2	Normal
	1	Slight sensory loss or numbness
	0	Definite sensory loss
Bladder function	3	Normal
	2	Mild dysuria
	1	Severe dysuria
	0	Complete retention of urine

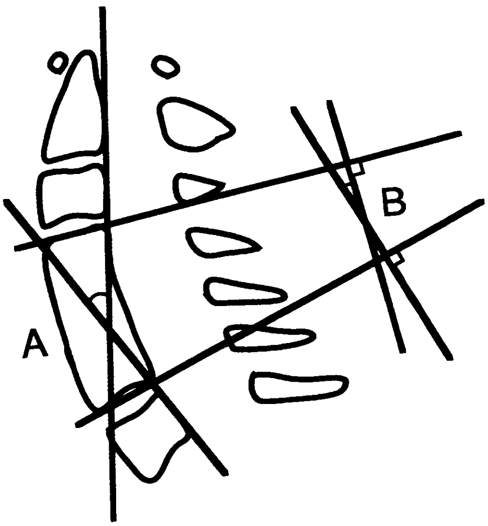

Fig. 1 Measurement of the alignment of the entire cervical spine (angle A) and of the fused segment (angle B). Angle A was the supplementary angle between the line parallel to the dorsal border of the C2 and the line parallel to that of the C7. Angle B was formed by the upper plane and the lower plane of the fused segment

Mann-Whitney U test. Proportions were tested with either Fishers' exact test or the chi-square test. All summary statistics were evaluated by two-tailed tests with findings of $P<0.05$ considered significant.

Results

With use of the adjacent-level degeneration criteria described above, the total cohort was partitioned into two groups, degeneration and normal. In 21 out of 42 patients (50%), degenerative change in adjacent intervertebral levels was observed radiographically with or without neurological deterioration. Degenerative change was observed above the fusion in 4, below the fusion in 11, and both above and below the fusion in 6 cases. The mean age, gender, length of follow-up, and number of fused levels did not differ significantly between two groups (Table 1). The following variables were also compared between these groups.

Changes in neurological symptoms

The mean JOA score changed from 11.7±3.3 preoperatively to 15.9±1.4 (paired *t* test, $P<0.001$) postoperatively, and to 14.9±2.3 (paired *t* test, $P<0.001$) on reassessment at final follow-up. Thus, patients not only exhibited significant improvement after surgery but maintained good scores during the follow-up period (Table 1).

Although the JOA score, whether preoperative, postoperative, or follow-up, did not differ significantly between the degeneration and normal groups, the neurological deterioration indicated by a lower JOA score at final follow-up of more than two points below the postoperative score was observed in 10 patients (24%). In 8 of these patients, imaging and neurological examination revealed that the deterioration was caused by lesions of adjacent levels (six at the superior level, and two at the inferior level). Three of these eight patients required additional salvage surgery.

Pattern of curvature of the cervical spine

The alignment of the whole spine at final follow-up was lordotic in 27 cases, straight in 3 cases, kyphotic in 8 cases and sigmoid in 4 cases. While physiologic cervical lordosis was preserved in 18 cases (85.7%) in the group with normal adjacent levels, it was present in only 9 cases (42.8%) in the group with adjacent level degeneration; this difference was significant ($P=0.0148$, chi-square test) (Table 3).

Alignment of the whole cervical spine (angle A) and the fused segment (angle B)

Angle A before operation and at follow-up were both significantly smaller in the degeneration group than in the

Table 3 Cervical alignment in degeneration and normal groups (*NS* nonsignificant)

	Total cohort (*n*=42)	Degenerated adjacent level (*n*=21)	Normal adjacent level (*n*=21)	*P* value
Preop angle A (SD)	14.3 (13.0)	8.8 (12.1)	19.0 (12.1)	0.0081
Postop angle A (SD)	14.1 (12.3)	7.9 (10.8)	20.3 (10.7)	0.0015
Preop angle B (SD)	2.2 (4.5)	2.0 (5.2)	2.5 (3.9)	NS
Postop angle B (SD)	1.7 (6.7)	–0.8 (7.1)	4.4 (5.1)	0.0096
Curve pattern				0.0148
Straight	3	3	0	
Lordosis	27	9	18	
Kyphosis	8	7	1	
Sigmoid	4	2	2	

Table 4 Multiple regression analysis for the indication of cervical alignment after surgery

Variable	Beta	*P* value
Angle A, preoperative	0.5952	<0.0001
Angle B, preoperative	0.0565	0.6466
Angle B, postoperative	0.2345	0.0671

normal group (P=0.0081 and 0.0015, respectively). In contrast, angle B was significantly smaller (P=0.0096) in the degeneration group only at follow-up (Table 3).

Multivariate analysis of predictors of postoperative cervical alignment

Preoperative angle A, preoperative angle B, and postoperative angle B were considered potential determinants of cervical alignment after surgery. Multiple regression analysis with postoperative angle A as the dependent variable and the above three factors as independent variables revealed that preoperative angle A was highly significant of a determinant (P<0.0001) and that postoperative angle B was a possible determinant (P=0.0671) (Table 4).

Anteroposterior diameters of the spinal canal at adjacent intervertebral levels above and below the fused segment

The AP diameters of the spinal canal both above and below the fused segment were similar in the two groups. However, in 8 patients with neurological deterioration caused by adjacent intervertebral lesions, the diameter of the affected spinal canal was 13±0.6 mm, and significantly narrower than that of the 13 asymptomatic patients, 14±0.3 mm (unpaired *t*-test, P=0.04).

Discussion

Anterior decompression and fusion has been widely performed for 40 years after its first presentation by Cloward [6] and Robinson-Smith [17] because its outcome is excellent with proper selection of patients. However, long-term follow-up after this operation has revealed the frequent appearance of degenerative changes at adjacent intervertebral levels, although the degree of correlation of these changes with clinical symptoms is unclear [2, 7]. The factors enhancing this degenerative change are still unclear. We focused our attention on postoperative malalignment (especially kyphosis) of the cervical spine. There are several reports available in the world literature suggesting that malalignment after spinal fusion promotes degenerative change at the intervertebral levels adjacent to the fused segment [12, 13, 16, 20]. However, no investigator has examined the adverse effect of postoperative cervical malalignment on the adjacent segments in clinical study.

In the present study, degenerative change in intervertebral levels adjacent to the fused segment was observed more frequently in patients with malalignment, such as kyphosis or sigmoid curvature of the cervical spine, than in those with a normal or lordotic pattern of the fused segment. When the intervertebral levels were fused in kyphosis, the stress distribution on the adjacent levels might be changed compared with that in patients fused in lordosis. We speculate that the reason for this would be that more posterior slipping force was loaded on the adjacent intervertebral levels during cervical flexion and extension in kyphosis as a result of retaining the posterior extensor elements. Additionally, Oda suggested that the kyphotic spinal fusion caused higher loads on the posterior column than did the in situ fusion [16]. Therefore it is highly desirable to restore a lordotic curve for the whole cervical spine by creating a lordotic fused segment. This is compatible with Breig's report that a kyphotic pattern of a cervical and fused segment complicated by degeneration of adjacent intervertebral levels increases forward contact pressure, putting pressure on the spinal cord [5]. Physiological lordotic fixation is thus required for extended prevention of neurological deterioration.

Local kyphosis at the fused segment was observed in only 13% of patients with single-level intervertebral fusion, but in 53% of patients with multiple-level fusion. We have already confirmed that for patients with anterior multiple-level fusion for degenerative disorders, use of an anterior plate is effective in maintaining local lordosis [15]. Therefore, use of instrumentation should be considered to maintain lordotic alignment in cases of multiple fixation, which can have a deleterious effect on adjacent intervertebral levels.

Of 21 cases of degenerative change in adjacent intervertebral levels, neurological deterioration greater than 2 points on the JOA score was observed in 8 patients during follow-up. The cause of this neurological deterioration appeared to be degenerative change in adjacent intervertebral levels, based on neurological findings and the results of imaging examinations. Neurological impairment was due to more frequent degenerative change in the upper level than the lower level as in Baba's report [1]. The anteroposterior diameter of the spinal canal in these 8 patients was significantly smaller than that in asymptomatic patients. Therefore, if the anteroposterior diameter of the spinal canal is small, laminoplasty should be considered a preferable method of operation.

Innumerable factors may be responsible for degeneration of the intervertebral disc. It was not clarified whether the fusion operation itself was the major factor, but the individual predisposition and life habits seemed to correlate with the degeneration of the intervertebral disc.

In this study, MRI images were not evaluated in detail, and degeneration of the fused segment above and below was observed only on radiography. The severity of degeneration was not quantitatively determined. Although there were therefore limitations in the data we obtained, our findings do suggest that kyphotic malalignment may be one of the many factors responsible for degeneration of intervertebral levels adjacent to a fused segment.

Conclusion

One of the factors promoting degenerative change in adjacent intervertebral levels after anterior cervical fusion for degenerative disorders is postoperative kyphotic change in the cervical spine and of the fused segment.

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