Long-term Outcome for Surgically Treated Cervical Spondylotic Radiculopathy and Myelopathy

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Abstract

Long-term follow-up results were examined to verify the efficacy of anterior osteophyctomy for cervical spondylotic myelopathy and radiculopathy, in particular the outcome for patients with developmentally narrow cervical canals and patients with associated ossification of the posterior longitudinal ligament (OPLL). One hundred thirty-nine patients who had undergone anterior osteophyctomy with interbody fusion between 1976 and 1990 were followed up for 1 to 22.5 years (mean 11.4 years). Overall results evaluated by the neurosurgical cervical spine scale scoring and grading showed significant improvement in both improvement score (2.7 ± 2.3) and improvement rate ($52.3 \pm 45.7\%$). Lower extremity motor function improved in 66.1% of patients, upper extremity motor function in 82.0%, and sensory/pain function in 70.5%. Improvement ranged from one to three grades. Severely affected patients showed good recovery. Outcome for patients with narrow cervical canals (41 patients, 29.5%) did not differ significantly from that for patients with normal canals (98, 70.5%). Patients with associated OPLL (32 patients, 23.0%) had approximately the same outcomes as those with only spondylosis (107, 77.0%). Fifteen patients (10.8%) underwent reoperation because of myelopathy due to disc degeneration adjacent to the fused level (11 patients) or OPLL (4 patients). Anterior osteophyctomy with interbody fusion can achieve good outcomes in patients with cervical spondylotic myelopathy and radiculopathy, regardless of the size of the spinal canal and association with OPLL.

Key words: spinal osteophytosis, ossification of posterior longitudinal ligament, narrow cervical canal, spinal cord compression, osteophyctomy, anterior cervical fusion

Introduction

Degenerative changes in the cervical spine, such as disc degeneration and chondro-osseous spur (osteophyte) formations, are part of the aging process and are more common in people aged over 60 years but without neurological symptoms.^{30,34} However, such neurological deterioration may compromise physical daily activities, and surgery is then required. The outcome of surgery for cervical spondylotic radiculopathy is usually satisfactory, but the benefits of surgery for cervical spondylotic myelopathy are controversial. Furthermore, spondylosis is an age-related, degenerative disease, so the patients may later show deterioration at long-term follow-up examinations, although their neurological symptoms were relieved shortly after surgery.^{12,13,35}

Neurological symptoms caused by cervical spondylosis are mediated by various factors: static compression of the cervical cord and radicle due to

degenerated disc, osteophytes, and hypertrophic yellow ligaments, and dynamic compression derived from unstable vertebrae.³³ We used the anterior approach to excise the compressing components, such as osteophytes and degenerated discs, and to fuse the intervertebral disc space using an autologous iliac bone graft to eliminate vertebral instability. This procedure was applied to patients who had cervical spondylotic myelopathy in developmentally narrow canals, for whom the anterior approach generally is considered to be contraindicated,^{17,19,37} and we previously reported good early surgical outcomes.²⁴

Ossification of the posterior longitudinal ligament (OPLL) in the cervical spine is present in about 2.0% of adult Japanese,³⁴ so patients with cervical spondylosis frequently have OPLL. However, associated OPLL is not always the main cause of cervical cord dysfunction in some patients. We treated these patients but made no attempt to remove the OPLL, except for ossified foci localized in the degenerated disc space. Whether this approach is adequate requires evaluation based on long-term follow-up

examinations.

The present retrospective study was designed to assess the long-term outcomes and determine the various factors that influence the surgical outcomes for cervical spondylotic myelopathy and radiculopathy, in particular the prognosis for cervical spondylotic myelopathy occurring in the developmentally narrow spinal canal and the association with OPLL. Patients in whom OPLL was the main lesion that caused cervical myelopathy and radiculopathy were not included in this study.

Materials and Methods

I. Patient population and characteristics

One hundred fifty-seven patients with cervical spondylotic myelopathy and radiculopathy underwent surgery between 1976 and 1990. The patients were followed up at regular intervals in our outpatient clinic and by means of questionnaires. One hundred thirty-nine patients, who had been followed up for more than one year postoperatively, were studied retrospectively. Eighteen patients were excluded because of less than one-year follow up; 13 were lost to follow up, and five had died of unrelated causes (1 patient each of sarcoma of the right extremity, cardiac disease, bronchial asthma, ileus, and acute alcohol intoxication). We previously reported early surgical outcomes for 43 patients with cervical spondylotic myelopathy²³⁾ and 19 patients with developmentally narrow canals.²⁴⁾ These were subsequently followed up consecutively and are included in this study. Baseline characteristics of the 139 patients are shown in Table 1. All had undergone anterior discectomy and osteophyctectomy with interbody fusion done by the first author (S.K.). The final follow-up examination for this study was performed by the co-authors (I.H., T.N.) at the outpatient clinic for 74 patients (53.2%) and by questionnaire for 65 (46.8%). The follow-up period ranged from 1 to 22.5 years (median 12.0, mean 11.4 years).

The 139 patients were divided into two groups based on association with OPLL of the cervical spine. One group included all patients with only cervical spondylosis (CSA group, 107 patients), in whom osteophytes (92 patients) or degenerated disc herniation (15 patients) were the main offending structures. The other group included all patients with cervical spondylosis associated with OPLL (CSO group, 32 patients), in whom spondylotic changes were the main lesions causing neurological deficits and the associated OPLLs were less important. OPLLs of the segmental, continuous, and mixed types were left untouched during the surgical

Table 1 Characteristics of 139 patients treated surgically for cervical spondylosis

Sex (male/female)	93/46
Age (yrs) at operation	
mean	52.8
range	29–78
Follow-up period (yrs)	
mean	11.4
range	1.0–22.5
Age (yrs) at last follow up	
mean	64.1
range	35–85
Length (mos) from onset to initial operation	
mean	25.1
range	132–1
Spondylosis only*	107 (77.0)
Spondylosis with OPLL*	32 (23.0)
segmental type OPLL	22 (68.8)
mixed type OPLL	9 (28.1)
continuous type OPLL	1 (3.1)
Cervical canal size***	
normal	98 (70.5)
narrow	41 (29.5)
No. of discs treated*	
one	73 (52.5)
two	50 (36.0)
three	15 (10.8)
subtotal corpectomy (2 vertebrae)	1 (0.7)
No. of operations*	
1	124 (89.2)
2	13 (9.4)
3	2 (1.4)

*Number of patients (%). **Size (sagittal diameter) of the cervical spinal canal determined at the C-4 or C-5 vertebra by Burrows' method.⁴⁾ Less than a 12.0 mm sagittal diameter was classified as narrow canal. OPLL: ossification of the posterior longitudinal ligament.

procedure. The localized type of OPLL was located in the degenerated disc space. Patients with the localized type of OPLL were included in the CSA group because these ossified foci were resected completely together with the degenerated disc and osteophytes.

II. Surgical procedure and cervical spinal canal size

Details of the surgical technique are reported elsewhere.²¹⁾ In brief, we approached the cervical vertebra anteriorly and completely removed the pathological intervertebral discs and osteophytes, as well as any ossified mass located in the disc space, under the operating microscope. The posterior longitudinal ligament was not resected unless a fragmented disc extruded into the space between the superficial and deep layers of the ligament. The vertebra was stabilized with a horseshoe-shaped autologous iliac

bone graft.

All patients with cervical spondylotic myelopathy and radiculopathy were treated using the anterior approach described above regardless of whether the cervical canal was normal or developmentally narrow. No patients were candidates for primary posterior decompression. The sagittal diameter of the cervical spinal canal, the shortest distance from the center of the posterior surface of the vertebral body to the cortex of the internal surface of the spinous process, was measured on a lateral radiograph of the cervical spine exposed at a film-focus distance of 1.5 m.⁴⁾ A diameter of less than 12.0 mm at the C-4 or C-5 vertebra was classified as a developmentally narrow canal. The magnification coefficient was calculated by placing a ruler on the spinous process,¹⁵⁾ but no correction was made. Forty-one of the 139 patients (29.5%) had such narrow canals.

III. Pre- and postoperative evaluations

The pre- and postoperative severities of neurological symptoms were assessed on the neurological cervical spine scale (NCSS) designed by the Japanese Society of Spinal Surgery.²²⁾ The scale consists of two parts: A, a neurological status evaluation based on grading and scoring systems; and B, a performance status evaluation. The motor functions of the lower and upper extremities, as well as sensory function and pain, radicular or non-radicular, are measured independently. Postoperative results were evaluated in terms of the improvement score and improvement rate. The improvement score is the value obtained at the last follow-up score minus the value at the initial preoperative examination. The improvement rate is expressed by the formula: $A (\%) = (Tf - Ti) / (14 - Ti) \times 100$, where A is the improvement rate (%), Ti the total score in the initial examination, and Tf the total score in the follow-up examination. The grade of recovery for each neurological function (improved, unchanged, or worsened postoperatively) was also used to show postoperative results.

IV. Signs and symptoms

Table 2 lists the preoperative signs and symptoms of the 139 patients. Myelopathy, the predominant feature in 122 patients (87.8%), was grouped into seven types according to Crandall and Batzdorf's classification.⁶⁾ Radicular pain, a sign of radiculopathy, was present in 53 patients (38.1%). The most common complaints were paresthesia and clumsiness of the fingers (in approximately 90% of the patients), followed by difficulty in walking (77%). Twenty-three patients (16.5%) complained of urina-

Table 2 Summary of signs and symptoms

Characteristic	No. of patients	Percentage of total patients
Radiculopathy (radicular pain)	56	40.3
Myelopathy	122	87.8
transverse syndrome	17	13.9
motor syndrome	18	14.8
motor and posterior column dysfunction	6	4.9
anterior cord syndrome	42	34.4
central cord syndrome	20	16.4
Brown-Séquard syndrome	9	7.4
brachialgia and cord syndrome	10	8.2
Signs and symptoms		
weakness of lower limbs and gait disturbance	107	77.0
paresthesia of fingers	125	89.9
finger clumsiness and arm weakness	126	90.6
shoulder, neck, and radicular pain	89	64.0
radicular pain	53	
non-radicular pain	36	
sensory disturbance of trunk and lower limbs	69	49.6
girdle sensation of trunk	26	18.7
Lhermitte's sign	23	16.5
urinary disturbance	23	16.5

ry disturbance, indicative of severe myelopathy.

V. Statistical analysis

StatView J-4.5 software (Abacus Concepts, Inc., Berkley, Calif., U.S.A.) was used for all statistical analysis.

Results

I. Neurological and performance status outcomes

Clinical outcomes evaluated by the NCSS are shown in Table 3. The mean postoperative score for all patients at the last follow-up examination (11.5 ± 2.3) differed significantly from the mean preoperative score (8.7 ± 1.8) ($p < 0.001$). Analysis of the CSA and CSO groups showed similar pre- and postoperative scores, and significant differences between these scores in both groups ($p < 0.001$). There were no significant differences between the two groups.

Neurological status improved in 66.1% to 82.0% of all patients with cervical spondylosis by one to three steps. The other patients were worse or unchanged, although there was variation in each neurological function. Similar improvements were seen in the CSA and CSO groups with no significant differences.

Recovery for each neurological function varied.

Table 3 Clinical outcomes for neurological cervical spine scale (NCSS) in patients surgically treated for cervical spondylosis related to cervical spinal canal size

Outcome (score and grade)	Spondylosis (total)				Spondylosis only				Spondylosis with OPLL			
	Total	Normal canal	Narrow canal	p Value	Total	Normal canal	Narrow canal	p Value	Total	Normal canal	Narrow canal	p Value
Total NCSS score*												
no. of patients	139	98	41		107	78	29		32	20	12	
preoperative score	8.7 ± 1.8	8.9 ± 1.8	8.3 ± 1.8		8.7 ± 1.9	8.9 ± 1.9	8.2 ± 1.9		8.9 ± 1.5	9.1 ± 1.4	8.5 ± 1.7	
postoperative score	11.5 ± 2.3	11.7 ± 2.2	11.0 ± 2.6		11.5 ± 2.4	11.6 ± 2.2	11.1 ± 2.8		11.6 ± 2.3	11.9 ± 2.3	11.0 ± 2.1	
improvement score	2.7 ± 2.3	2.7 ± 2.1	2.8 ± 2.8	0.396#	2.8 ± 2.3	2.7 ± 2.0	2.9 ± 2.8	0.196#	2.7 ± 2.3	2.8 ± 2.1	2.5 ± 2.7	NS#
improvement rate (%)	52.3 ± 45.7	55.2 ± 39.4	45.6 ± 58.1	0.603#	52.3 ± 47.2	54.1 ± 39.3	47.6 ± 64.4	0.769#	52.4 ± 41.0	59.3 ± 40.4	40.9 ± 41.0	NS#
Grade recovery**												
lower extremity motor function												
no. of patients (%)	118	79	39		89	61	28		29	18	11	
improved	78 (66.1)	50 (63.3)	28 (71.8)	0.359##	60 (67.4)	39 (63.9)	21 (75.0)	0.301##	18 (62.1)	11 (61.1)	7 (63.6)	0.892##
worse and no change	40 (33.9)	29 (36.7)	11 (28.2)		29 (32.6)	22 (36.1)	7 (25.0)		11 (37.9)	7 (38.9)	4 (36.4)	
upper extremity motor function												
no. of patients (%)	129	88	41		98	69	29		31	19	12	
improved	105 (82.0)	72 (81.8)	33 (80.5)	0.857##	82 (83.7)	56 (81.2)	26 (89.7)	0.230##	23 (74.2)	16 (84.2)	7 (58.3)	0.109##
worse and no change	24 (18.0)	16 (18.2)	8 (19.5)		16 (16.3)	13 (18.8)	3 (10.3)		8 (25.8)	3 (15.8)	5 (41.7)	
sensory function and/or pain												
no. of patients (%)	132	91	41		101	72	29		31	19	12	
improved	93 (70.5)	66 (72.5)	27 (65.9)	0.437##	72 (71.3)	52 (72.2)	20 (69.0)	0.743##	21 (67.7)	14 (73.7)	7 (58.3)	0.378##
worse and no change	39 (29.5)	25 (27.5)	14 (34.1)		29 (28.7)	20 (27.8)	9 (31.0)		10 (32.3)	5 (26.3)	5 (41.7)	
Performance status***												
no. of patients (%)	139	98	41		107	78	29		32	20	12	
normal ADL to work	108 (77.7)	77 (78.5)	31 (75.6)	0.702##	84 (78.2)	61 (78.2)	23 (79.3)	0.902##	24 (75.0)	16 (80.0)	8 (66.7)	0.399##
limited ADL or disabled	31 (22.3)	21 (21.5)	10 (24.4)		23 (21.8)	17 (21.8)	6 (20.7)		8 (25.0)	4 (20.0)	4 (33.3)	

*Total NCSS score values are presented as means ± standard deviation. **Grade recovery values represent the number of patients (%). ***Performance status: patients classified as normal activity of daily living (ADL) to work were grades C, D, and E; and those of limited ADL or disabled were grades A and B. p Value: statistical difference between patients of the normal and narrow canal groups. #Mann-Whitney U test, ##chi-square for independence test or Fisher's exact probability test. NS: not statistically significant, OPLL: ossification of the posterior longitudinal ligament.

Fig. 1 Graphs showing postoperative Neurosurgical Cervical Spine Scale improvement scores for the three neurological functions: Lower extremity motor function (LE), upper extremity motor function (UE), and sensory/pain function (S/P). Improvement scores for upper motor function were significantly better for all patients with cervical spondylosis (left, $n = 139$) and patients with cervical spondylosis only (center, $n = 108$), but not in patients with cervical spondylosis with ossification of the posterior longitudinal ligament (right, $n = 32$). * $p = 0.0004$, ** $p = 0.003$, *** $p = 0.173$, # $p = 0.0002$, ## $p = 0.029$, ### $p = 0.118$; Wilcoxon signed-rank test.

For all patients with cervical spondylosis, the upper extremity motor function improved in 82.0%, significantly better than for the lower extremity motor function (66.1%) and sensory/pain function (70.5%) ($p < 0.05$). Both the CSA and CSO groups had similar improved grades of recovery for upper extremity motor function. The improvement was significant in the CSA group ($p < 0.05$) but not in the CSO group. For all patients with cervical spondylosis, the mean improvement score for upper extremity motor function was 1.1 ± 0.9 , significantly better than for sensory/pain function (0.9 ± 1.0) and lower extremity motor function (0.7 ± 1.2) (Fig. 1). The CSA and CSO groups also showed a better improvement score for upper extremity motor function. There was a statistically significant difference in the CSA group but not in the CSO group.

Fifty-three of the 139 (38.1%) patients complained of radicular pain which was resolved completely in 48 (90.6%).

The NCSS also evaluates postoperative performance status (Table 3). Of all patients with cervical spondylosis, 108 (77.7%) were able to return to their previous work or had recovered enough to take up normal daily activities, and 31 (22.3%) had limited physical activity or were disabled. These values were 78.2% and 21.8% in the CSA group, and 75.0% and 25.0% in the CSO group. No statistically significant difference was found between these groups.

II. Cervical spondylosis related to cervical spinal canal size

Patients with cervical spondylosis were divided into normal and narrow canal groups based on the sagittal diameter of the cervical spinal canal (Table 4). The sagittal diameter of normal adult Japanese (measured by the first author using the same method as in this study) is given for comparison.³⁴ The mean sagittal diameters of normal and narrow canal patients with cervical spondylosis and of normal Japanese adults differed significantly at each vertebra.

We evaluated the outcomes for normal and narrow canal patients with cervical spondylosis (Table 3). The improvement score and the improvement rate showed no significant differences between the narrow canal group and the normal canal group. Recovery of neurological function and performance status also showed no significant differences between the normal and narrow canal groups. The CSA and CSO groups had similar outcomes regardless of the size of the cervical spinal canal, with no significant differences.

Table 5 shows the number of discs and cervical spinal canal size. No patients were operated on at more than four levels. More multiple disc operations were done on patients in the narrow canal group than in the normal group (23 patients, 56.1% vs. 43, 43.9%), but there was no significant difference.

Table 4 Sagittal diameter of the cervical spinal canal

Factor	No. of patients	Sagittal diameter *							Mag.CO*
		C-1	C-2	C-3	C-4	C-5	C-6	C-7	
Patients with cervical spondylosis									
total	139	19.5 ± 2.1	16.2 ± 1.6	13.9 ± 1.6	13.0 ± 1.3	13.3 ± 1.4	13.5 ± 1.4	14.0 ± 1.5	1.17 ± 0.02
normal canal**	98	20.1 ± 2.0	16.9 ± 1.6	14.8 ± 1.4	13.8 ± 1.2	14.0 ± 1.1	14.3 ± 1.1	15.0 ± 1.1	1.17 ± 0.02
narrow canal**	41	18.6 ± 1.9	15.2 ± 1.0	12.8 ± 0.9	11.9 ± 0.4	11.8 ± 0.5	12.2 ± 0.6	12.6 ± 0.7	1.16 ± 0.01
Japanese normal adult***	997	21.0 ± 2.2	18.0 ± 1.7	15.8 ± 1.5	15.2 ± 1.5	15.3 ± 1.5	15.7 ± 1.5	15.9 ± 1.4	1.17 ± 0.02

*Sagittal diameter and Mag.CO values are shown as means ± standard deviation (mm). **Significant difference between normal and narrow canal patients at each cervical vertebra ($p < 0.001$, Student's t-test). ***Values for Japanese normal adult were determined by the senior author (S.K.),³⁴⁾ and are significantly different from the values for the all patients with cervical spondylosis at each vertebra ($p < 0.001$, Student's t-test). Mag.CO: magnification coefficient calculated on a lateral radiograph of the cervical spine exposed at a film-focus distance of 1.5 m.

Table 5 No. of discs treated and cervical spinal canal size

Cervical spinal canal size	No. of patients	No. of discs (%)		
		One	Two	Three
Normal canal	98	55 (56.1)	34 (34.7)	9 (9.2)*
Narrow canal	41	18 (43.9)	16 (39.0)	7 (17.1)

No significant difference between the normal and narrow canal groups ($p = 0.215$, chi-square for independence test). *One patient with subtotal corpectomy is included.

Table 6 Late deterioration in preoperative neurologically normal patients

Factor	Lower extremity motor function	Sensory/pain function
No. of preoperative normal patients	32	12
No. of patients showing late deterioration (%)	11 (34.4)	5 (41.7)
spondylosis alone	9	5
spondylosis with OPLL	2	0
normal/narrow canal	10/1	2/3
male/female	6/5	3/2
age (yrs)	54.5 (47-66)	44.6 (34-60)
follow-up period (yrs)	14.1 (5.7-20.5)	14.0 (1.2-20.5)
Causes (no. of patients)		
degenerative knee joint disorders	4	1
lumbar spondylosis	3	0
cervical spondylotic myelopathy	2	4
cerebral infarction	1	0
lung emphysema	1	0

No deterioration was found in upper extremity motor function. OPLL: ossification of the posterior longitudinal ligament.

III. Patients showing postoperative worsening

Two groups of patients showed neurological function deterioration during the follow-up period: patients who preoperatively were neurologically normal but later showed deterioration, and patients whose preoperative neurological deficits worsened postoperatively.

Table 6 shows the characteristics of the former group. Normal lower extremity motor function was found in 32 of the 139 patients (23.0%) preoperatively, but had worsened in 11 of the 32 (34.4%) 5.7 to 20.5 years later. Cervical spondylotic myelopathy caused deterioration in two patients. Degenerative knee joint disorders, lumbar spondylosis, cerebral infarction, and lung emphysema were responsible

Table 7 Reoperations

Factor	Total no. of patients	No. of patients with reoperation (%)		
		Total	Once	Twice
Spondylosis (total)	139	15 (10.8)	13 (9.4)	2 (1.4)
Spondylosis only (CSA group)*	107	9 (8.4)	7 (6.5)	2 (1.9)
normal canal	78	6 (7.7)	5 (6.4)	1 (1.3)
narrow canal	29	3 (10.3)	2 (6.9)	1 (3.4)
Spondylosis with OPLL (CSO group)*	32	6 (18.8)	6 (18.8)	0
normal canal	20	3 (15.0)	3 (15.0)	0
narrow canal	12	3 (25.0)	3 (25.0)	0

*No significant difference between the CSA and CSO groups ($p = 0.095$, Fisher's exact probability test). No significant difference between the normal and narrow canal patients in the CSA and CSO groups ($p = 0.460$ and 0.399 , respectively, Fisher's exact probability test). OPLL: ossification of the posterior longitudinal ligament.

Table 8 Causes of reoperation*

Causes of reoperation	Spondylosis (total)			Spondylosis only			Spondylosis with OPLL		
	Total	Normal canal	Narrow canal	Total	Normal canal	Narrow canal	Total	Normal canal	Narrow canal
Adjacent disc degeneration	11	7	4	9	6	3	2	1	1
OPLL	4	2	2	0	0	0	4	2	2

*Values represent the numbers of patients. OPLL: ossification of the posterior longitudinal ligament.

for postoperative deterioration in the other nine patients. Sensory/pain function was normal in 12 of the 139 patients (8.6%) preoperatively, but had deteriorated in five of the 12 (41.7%) 1.2 to 20.5 years later. Deterioration was caused by cervical spondylotic myelopathy in four patients and degenerative knee joint disorder in one patient. Upper extremity motor function was normal in 10 of the 139 patients (7.2%) preoperatively, and none showed deterioration throughout the follow-up periods.

In the latter group, postoperative worsening of lower extremity motor function occurred in eight of 118 patients (6.8%). Cervical spondylotic myelopathy caused postoperative worsening in three patients and OPLL in one patient. Lumbar spondylosis, lung emphysema, diabetes mellitus, and degenerative knee joint disorder each caused deterioration in one patient each. Upper extremity motor function deteriorated in four of 129 patients (3.1%) postoperatively. Cervical spondylotic myelopathy and OPLL were responsible in two patients each. Sensory/pain function deteriorated in three of 132 patients (2.3%) because of cervical spondylotic myelopathy.

IV. Reoperations

Table 7 shows the numbers of reoperations.

Fifteen of the 139 patients (10.8%) with cervical spondylosis underwent reoperation because myelopathy had worsened, more in the CSO than the CSA group (18.8% vs. 8.4%), but there was no significant difference. Nine of 98 patients with normal canal (9.2%) and six of 41 patients with narrow canal (14.6%) needed reoperation, but the difference was not significant. There was no significant difference between the normal and narrow canal patients in the CSA and CSO groups.

Reoperation was performed for disc degeneration at levels adjacent to the initially fused cervical segment (11 patients) or OPLL (4 patients) (Table 8). Adjacent disc degeneration occurred in seven of 98 patients with normal canal (7.1%) and four of 41 patients with narrow canal (9.8%), but the difference was not significant. OPLL occurred in two of 98 patients with normal canal (2.0%) and two of 41 patients with narrow canal (4.9%), but there was no statistically significant difference.

Nine patients in the CSA and two in the CSO group had reoperations because of adjacent disc degeneration. Discectomy with interbody fusion at a single level was performed in nine patients and at two levels in one patient, and corpectomy in one patient. Reoperations were done at the next level above the disc initially operated on in eight patients

Fig. 2 Period from the initial surgery to reoperation. Fifteen patients needed reoperation because of adjacent disc degeneration (open column, $n = 11$) and ossification of the posterior longitudinal ligament (shaded column, $n = 4$).

(72.7%) and at the next lower in three patients (27.3%), including the patient who underwent corpectomy. Laminectomy was performed in three and corpectomy in one of the four OPLL patients (CSO group).

Figure 2 shows the period from the first to second operation, which ranged from 0.1 to 18.4 years (mean 7.0 years) in the 11 patients with adjacent disc degeneration. Six patients (54.5%) were reoperated on within 4 years, and five (45.5%) between 9.4 and 18.4 years. No relationship was found between reoperation and the follow-up period. However, the period ranged from 1.1 to 2.7 years (mean 2.0 years) in the four patients with OPLL. Reoperation was required significantly more in the relatively early follow-up period ($p = 0.008$, chi-square for independence test).

Two patients in the CSA group required a third operation because of adjacent disc degeneration. Single level discectomy with interbody fusion was done on one patient with normal cervical canal 15.4 years after the time of reoperation, and laminoplasty on another patient with narrow canal 4 months after.

V. Radiographic fusion

Dense and mature bone tissue in the disc space on the follow-up radiographs was judged as fused. Fusion outcomes are shown in Table 9. One hundred twenty-seven of the 139 patients (91.4%) with cervical spondylosis underwent follow-up radiography. Solid fusion was obtained in 110 of these 127 patients (86.6%), in 86 of 98 patients

Table 9 Radiographic fusion

Factor	No. of patients*	Fusion status	
		Fusion (%)	Non-fusion (%)
Spondylosis (total)**	127	110 (86.6)	17 (13.4)
spondylosis only (CSA group)	98	86 (87.8)	12 (12.2)
spondylosis with OPLL (CSO group)	29	24 (82.8)	5 (17.2)
No. of discectomies***			
one	67	62 (92.5)	5 (7.5)
two	45	36 (80.0)	9 (20.0)
three	15	12 (80.0)	3 (20.0)

*Follow-up radiographs were taken for 127 of the 139 patients (91.4%). **No significant difference between the fusion status of the CSA and CSO groups ($p = 0.487$, Fisher's exact probability test). ***No significant difference between fusion status and the no. of discectomies ($p = 0.117$, chi-square for independence test). OPLL: ossification of the posterior longitudinal ligament.

(87.8%) in the CSA group and in 24 of 29 (82.8%) in the CSO group. No significant difference was found between the CSA and CSO groups. Solid fusion was completed in 62 of 67 patients (92.5%) after discectomy at a single level, in 36 of 45 (80.0%) at two levels, and in 12 of 15 (80.0%) at three levels. The fusion rate was somewhat lower in patients with multiple level discectomies, but the difference was not significant. The mean age of the patients with fusion was 53.3 ± 10.0 years and those with non-fusion was 53.1 ± 9.4 years, but there was no statistically significant difference.

VI. Pre- and postoperative variables related to surgical outcome

Pre- and postoperative variables related to the NCSS improvement score and improvement rate are given in Table 10. Symptom duration was the only factor that significantly influenced both the improvement score and rate. Patients operated on more than 49 months after onset had poorer outcomes than those operated on at 48 months or less. The preoperative NCSS score, which represents disease severity, was associated with statistically significant differences in the improvement score. Severely affected patients with preoperative NCSS scores below 8–9 had significantly better outcomes than mildly affected patients with scores above 10–11, but there was no significant difference in the improvement rate. Patients more than 70 years old had significantly poorer improvement rates than those less than 69 years old. The improvement score

Table 10 Relationships of the pre- and postoperative variables to the neurological cervical spine scale (NCSS) improvement score and rate

Variable	No. of patients	Improvement score*	p Value	Improvement rate* (%)	p Value
Follow-up period (yrs)					
1-4	29	2.1 ± 1.8	0.197##	40.9 ± 34.3	0.146##
5-9	22	3.1 ± 2.3		62.9 ± 43.6	
10-14	43	3.2 ± 1.9		60.7 ± 34.9	
15-19	36	2.6 ± 2.6		49.2 ± 52.3	
≥ 20	9	2.4 ± 3.4		35.9 ± 83.9	
Age at surgery (yrs)					
29-39	12	3.4 ± 1.6	0.273##	71.0 ± 30.6	0.014##
40-49	41	3.1 ± 2.5		61.1 ± 51.0	
50-59	48	2.7 ± 2.0		52.8 ± 36.9	
60-69	32	2.3 ± 2.7		37.2 ± 54.3	
70-78	6	0.7 ± 3.9		11.1 ± 57.4	
Duration of symptoms (mos)					
0-6	50	3.3 ± 2.0	0.010#	65.3 ± 37.0	0.001##
7-12	29	2.9 ± 2.1		57.6 ± 40.9	
13-24	19	3.0 ± 1.8		57.2 ± 33.3	
25-48	16	2.5 ± 2.1		54.0 ± 39.8	
≥ 49	25	1.2 ± 2.7		15.7 ± 60.3	
Preoperative NCSS					
4-5	8	4.5 ± 2.0	0.0003#	49.2 ± 21.6	0.628##
6-7	22	3.6 ± 2.0		48.5 ± 27.7	
8-9	61	3.0 ± 2.2		56.7 ± 40.8	
10-11	39	1.8 ± 2.3		47.6 ± 61.7	
12-13	9	1.1 ± 1.1		55.6 ± 52.7	
No. of operations					
1	124	2.8 ± 2.1	0.263###	55.7 ± 41.6	0.045###
2-3	15	1.9 ± 3.1		24.3 ± 66.4	
No. of discs operated on					
1	73	2.9 ± 2.3	0.576#	58.3 ± 44.2	0.277#
2	50	2.5 ± 2.3		45.7 ± 47.6	
3**	16	2.6 ± 2.3		46.0 ± 45.5	
Radiographic fusion					
fused	110	2.8 ± 2.4	0.429###	52.0 ± 47.8	0.509###
not fused	17	2.4 ± 1.9		48.8 ± 38.9	
not examined	12				
Hyperintense lesion on postoperative T ₂ -weighted magnetic resonance image					
positive	16	2.4 ± 2.0	0.241###	42.8 ± 37.7	0.069###
negative	54	3.1 ± 2.3		59.2 ± 37.7	
Performance grade***					
A and B	31	0.3 ± 2.1	8.352E-15#	-1.3 ± 51.0	1.014E-20#
C	18	2.1 ± 1.4		35.9 ± 20.3	
D	20	3.1 ± 1.7		54.3 ± 22.4	
E	70	3.9 ± 1.7		79.8 ± 26.2	

*Improvement score and rate values are presented as means ± standard deviation. **One patient with subtotal corpectomy was included. ***Grades A (4 patients) and B (27 patients) are combined. p Value: #one-way analysis of variance, ##Kruskal-Wallis test, ###Mann-Whitney U test.

also was poor in those over 70 years, but there was no significant difference. Patients operated on more than twice had poorer improvement rates than those without reoperation. The improvement score also

was poor for patients with reoperation, but there was no statistically significant difference.

No magnetic resonance images were available for the early patients of this series, but those obtained

during the follow-up examinations were evaluated. Patients with a hyperintense lesion on the T₂-weighted images had poorer improvement scores and rates than those without, but there was no significant difference.

Performance status evaluated at the follow-up examination was significantly related to both the improvement score and rate. Patients who had a higher improvement score or rate were apparently able to return to their previous preoperative work or engage in normal daily activities.

Discussion

This retrospective, long-term follow-up study of cervical spondylotic myelopathy and radiculopathy showed that anterior osteophylectomy with interbody fusion resulted in good recovery of cervical cord function, in particular for myelopathy, for which the benefit of surgical intervention is controversial.^{8,14,20,26,28,32,38} The presence of a developmentally narrow cervical canal and an association with OPLL did not significantly influence the overall outcome.

I. Outcomes for cervical spondylotic myelopathy and radiculopathy

Outcomes for patients with surgically treated cervical spondylotic myelopathy and radiculopathy showed significant recovery in both improvement score and rate as assessed by the NCSS scoring system. NCSS grading, which separately evaluates lower extremity motor function, upper motor function, and sensory/pain function showed differences in the recoveries of these neurological functions. The NCSS grade for lower extremity motor function, which is equivalent to Nurick grading²⁷ and reflects myelopathy, improved 1 to 3 grades postoperatively in 78 of 118 patients (66.1%), but 40 patients (33.9%) remained unchanged or worsened postoperatively. These results correlate well with other reported results for anterior osteophylectomy with interbody fusion and cervical spondylotic myelopathy evaluated by Nurick grading. Twenty-four of 33 patients (72.7%) showed improved early outcome and 18 of 33 (54.5%) had improved late outcome.⁸ Moreover, 48 of 65 patients (74%) showed improvement.³²

The NCSS grade of recovery for upper extremity motor function, which reflects the segmental cord sign, was significantly better than for lower extremity motor function and sensory/pain function. The grade of recovery for sensory/pain function, which reflects myelopathy, the segmental cord sign, and radiculopathy, was also better than that for lower

extremity motor function, but the difference was not statistically significant. Radicular pain, which represents only radiculopathy, disappeared in 90.6% of the patients with cervical spondylotic radiculopathy. The improvement score on the NCSS scale similarly showed significantly better recovery of upper extremity motor function than of lower extremity motor function and sensory/pain function.

Better recovery for upper than lower extremity motor function suggests that muscle weakness caused by cervical spondylotic myelopathy was resolved after anterior cervical decompression with fusion but that lower extremity spasticity persisted.⁵ In our series, degenerative diseases of the knee joints and lumbar spondylosis contributed to a poor outcome for lower extremity motor function in about half of the patients. Aging of musculo-skeletal organs progresses during follow-up periods that last years, so approximately one-third of the patients who had no walking difficulties preoperatively complained of gait disturbance postoperatively. If these patients are excluded, lower extremity motor function improved in 78 of 109 patients (71.9%). On the other hand, cervical spondylotic myelopathy or OPLL was the cause of almost all postoperative deterioration of upper extremity motor and sensory/pain functions.

In our previous report of relatively short-term follow ups (mean 34 months), lower extremity motor function improved in 39 of 43 patients (91%) based on Nurick grading.²³ The present series includes these 43 patients who had been followed up for longer. The final outcome of cervical spondylotic myelopathy decreased to 71.9%, which agrees with other suggestions that patients with surgically treated cervical spondylotic myelopathy showed initial improvement. The causes of chronic postoperative worsening are diverse.^{7,8,12}

Our series includes four patients with cervical spondylotic radiculo-myelopathy and athetoid-dystonic cerebral palsy described earlier.¹⁸ All patients were preoperatively bedridden, but regained the ability to walk with or without a cane at follow ups from 1 to 4.5 years. Thereafter, two patients were lost, but we followed the other two patients for 6.0 and 22.5 years. One patient needed another operation 2.8 years later because of disc degeneration adjacent to the initially fused level. The improvement scores and rates were 2, 22.2 and 1, 14.3, respectively. These values were relatively low considering the present mean outcome.

II. Necessity of osteophyte removal

The necessity for osteophyte removal is controversial because surgeons fear that osteophylectomy

may cause irreversible cord damage.³⁾ Osteophytes in the cervical spondylotic spine were believed to be reabsorbed after anterior interbody fusion,³³⁾ but the osteophytes are not reabsorbed after simple discectomy.³⁶⁾ Subtotal corpectomy, which makes osteophyte removal safe, results in a good outcome for 57.5% to 98% of patients with cervical spondylotic myelopathy.^{2,9,10,25,29,35)} One argument is that adequate osteophyte removal cannot be achieved by conventional discectomy because the procedure is limited and so the same results as corpectomy may not be expected.¹⁰⁾ Since 1976 we have accomplished complete removal of osteophytes by the conventional anterior discectomy procedure under the operating microscope.^{23,24)} We believe that the present study shows that a satisfactory outcome for cervical spondylotic myelopathy can be obtained by simple discectomy and osteophytectomy. No deterioration has resulted from these osteophytectomy procedures.

III. Association with OPLL

OPLL is a common disease in the Japanese, with an overall incidence of about 2.0% but higher in people aged 50 years or over.³⁴⁾ In this study, 32 of the 139 cervical spondylotic patients (23%) had associated OPLL, but these cases were considered as least offending on the imaging studies (myelogram, computed tomography myelogram, and magnetic resonance imaging), and were left untouched during osteophytectomy. Patients showing apparent cervical cord compression due to OPLL on the imaging studies were not included in this study. The overall surgical outcomes evaluated by both NCSS scoring and grading did not differ significantly from those of patients who did not have associated OPLL. However, the NCSS grades of recovery for these patients for all three neurological function categories were inferior to those for patients with only cervical spondylosis. Furthermore, four patients needed another operation within 3 years. We conclude that for cervical spondylotic patients with associated OPLL, subtotal corpectomy removing all ossified foci might produce a better outcome than by our present surgical procedure in which OPLLs are not removed.

IV. Developmentally narrow spinal canal and anterior osteophytectomy

Posterior decompressive procedures are the generally accepted standard surgical approach for patients with cervical spondylosis and associated developmentally narrow canals, particularly over several segments.^{8,17)} However, the spinal cord readapts to a narrow canal when multiple anterior

discectomies and fusion are performed.¹⁾ Treatment of cervical spondylotic myelopathy by anterior cervical decompression showed that neither the sagittal diameter of the cervical canal nor the Pavlov ratio³¹⁾ of the cervical vertebra were associated with the postoperative severity of the myelopathy.⁹⁾ We previously reported that patients with cervical spondylotic myelopathy associated with narrow cervical canals could be successfully treated by anterior osteophytectomy with interbody fusion.²⁴⁾ However, the follow-up periods were relatively short (1 to 8 years, mean 38 months), and the patient could easily deteriorate due to mild disc degeneration or spondylosis of minor degree at adjacent levels of the fused segment.²⁹⁾ The follow ups of up to 22.5 years (mean 11.4 years) in this study showed no significant difference in outcome for patients with normal and narrow canals.

Reoperation was more frequent for patients with narrow canals than for those with normal canals (14.6% vs. 9.2%). Disc degeneration adjacent to the initially fused site was the cause of reoperation for 9.8% of patients with narrow canals and for 7.1% of those with normal canals. OPLLs were the cause of reoperation for 4.9% of patients with narrow canals and 2.0% of patients with normal canals. None of these differences were significant. The number of discs treated was similar for patients with normal and narrow canals. No patient required discectomy of more than four levels. We can affirm the conclusion that patients with cervical spondylosis and developmentally narrow canals can be treated satisfactorily by anterior discectomy and osteophytectomy with interbody fusion.

Evaluation of laminectomy, anterior discectomy with fusion, and subtotal corpectomy for cervical spondylotic myelopathy concluded that cervical spondylosis of up to three levels should be treated by subtotal corpectomy and fusion regardless of the canal diameter.³⁹⁾ We think that anterior discectomy and osteophytectomy are sufficient to treat patients with cervical spondylosis and developmentally narrow canals and that subtotal corpectomy should be reserved for treating patients with cervical spondylotic myelopathy with associated OPLL.

V. Preoperative variables predictive of outcome

Analysis of preoperative variables predictive of outcome agree that the duration of symptoms significantly influences surgical outcome. Surgery using anterior or posterior approaches done more than one year after symptom onset usually has a poor outcome because of probable irreversible cord damage due to prolonged cervical cord compression.^{7,8,14,16)} We found that the duration of symptoms

Table 11 Performance status and patient age

Performance grade	No. of patients	Patient age (yrs)	
		Mean	SD
A and B	31	57.9	9.8
C	18	56.3	9.5
D	20	53.3	10.0
E	70	49.6	8.9

Significant difference between performance grade and patient age ($p=0.0003$, analysis of variance). SD: standard deviation.

was the only factor that produced a significant difference in both NCSS improvement score and rate, as these values were significantly lower in patients with onset of symptoms more than 49 months before surgery. The patient's age at surgery is reported not to influence the outcome,^{8,14,20,26} but for patients younger than 50 or 40 years old the outcomes were better.^{11,16} We found that both the improvement score and rate decreased with greater age, significantly in the improvement rate. Disease severity influenced the improvement score but not the improvement rate. The improvement score was significantly higher in patients with a low preoperative score, indicating that severely affected patients improved more than mildly affected patients. However, the improvement rate was similar regardless of the preoperative score. This contradicts other reports that patients with severe myelopathy showed less improvement than those with milder disease.^{1,5,28} Previously, we found that patients recovered more than one grade from the bedridden state.^{23,24} Analysis of 121 cervical spondylotic myelopathy patients also found that no obvious relationship between the grade of paralysis and the final results.⁴⁰

VI. Postoperative performance status

Evaluation of the surgical outcomes of patients with cervical spondylosis should determine how many patients have returned to their previous work or resumed normal daily activities. The NCSS evaluates postoperative performance status. In our present series, 108 of 139 patients (77.7%) resumed normal activity of daily life. Of these, 70 (50.4%) returned to their previous jobs, 20 (14.4%) changed jobs but were able to work full time, and 18 (12.9%) were able to work part time. There are similar reports that 72.6% of 106 patients were able to resume normal activity⁴⁰ and that 70% of 207 patients returned to full or part time work.³⁸

However, only 11 of 30 patients (42%) returned to work in one series,²⁶ and 58% in another series.³² Performance was significantly proportional to age in the present series (Table 11). Younger patients achieved better postoperative performance. This agrees with the findings that the NCSS improvement rate and score decreased with greater age. Outcomes for younger patients are better than those for aged patients.^{11,16}

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Commentary on this paper appears on the next page.

Commentary

Patients who present with myelopathy and radiculopathy due to spondylitic bony changes, often with associated ossification of the posterior longitudinal ligament, continue to be a challenge. When we can do the operation anteriorly in a reasonable fashion, we prefer the procedure. If there are extensive changes, we too, most commonly will use a more extensive posterior approach. More recently, we are doing more and more combined operations. We elect to do the anterior procedures first, and reduce the osteophytes and get a marked decompression and restoration of the cervical lordotic canal. Then we turn the patient over and do a posterior decompression and a posterolateral fusion with metallic fixation.

This series reports patients who were treated from 1976 to 1990. At that time, like the authors, we were doing most of these procedures anteriorly. The authors have done a better job in the follow-up than we did. Our follow-ups often go up to one to two years. We rarely get a follow-up in any significant numbers after ten to twenty years.

Our data is similar to the authors. The greatest improvement comes in the upper extremities. The patients regain the loss of the numbness and clumsiness that they had in their arms and hands. Clearly, more than 80% of our patients can expect that. The second good result was a significant reduction in pain. That came as a surprise to us; however, the authors of this article show that 70% of the patients had decreased pain and better sensation. Getting a real improvement in gait or the lower extremities is more difficult. We found that only half of our patients truly

improved. For that reason, we have gone to the anterior and posterior reconstructions for the more severely affected patients. We often found the patients with only the anterior reconstruction with severe disease would tell us that they were much, much better but they were using their upper extremities with canes and crutches to get around better while the gait itself still remained significantly abnormal. The reflexes hardly ever change. So the data reported in this article, in my opinion, is very accurate and very good. I think it is information we all can use.

Table No. 5 needs to be reviewed. As you can see, the authors preferred to do one level cases and possibly two. Rarely did they do a three level case, and more extensive levels clearly has its limitations. So this report deals with a select number of patients with isolated disease in whom we can really do a good job anteriorly in reconstructing the spine at the time we are doing a good decompression.

We also agree with the authors that 10% of these patients will require a re-operation. Rarely do we have to do the space which was previously treated. It is certainly not uncommon for an adjacent level to undergo changes. There is a large debate whether this is just the natural progression of the disease versus extra stresses on that segment. The real answer is probably both of these apply.

The authors are to be congratulated for doing all of the extensive work to follow up this large group of patients.

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