J Orthop Sci (2007) 12:207–213
DOI 10.1007/s00776-007-1122-5

JOURNAL OF
ORTHOPAEDIC SCIENCE

Original article

Anterolisthesis and retrolisthesis of the cervical spine in cervical spondylotic myelopathy in the elderly

Motohiro Kawasaki, Toshikazu Tani, Takahiro Ushida, and Kenji Ishida

Department of Orthopaedic Surgery, Kochi Medical School, Kohasu Oko-cho, Nankoku, Kochi 783-8505, Japan

Abstract

Background. Degenerative spondylolisthesis of the cervical spine has received insufficient attention in contrast to that of the lumbar spine. The authors analyzed the functional significance of anterior and posterior degenerative spondylolisthesis (anterolisthesis and retrolisthesis) of the cervical spine to elucidate its role in the development of cervical spondylotic myelopathy (CSM) in the elderly.

Methods. A total of 79 patients aged 65 or older who eventually had surgical treatment for CSM were evaluated radiographically.

Results. Altogether, 24 patients (30%) had displacement of 3.5 mm or more (severe spondylolisthesis group), 31 had displacement of 2.0–3.4 mm (moderate spondylolisthesis group), and 24 had less than 2.0 mm displacement (mild spondylolisthesis group). The severe spondylolisthesis group consisted of 14 patients with anterolisthesis (anterolisthesis group) and 10 patients with retrolisthesis (retrolisthesis group). Patients with severe spondylolisthesis had a high incidence (93%) of degenerative spondylolisthesis at C3/4 or C4/5 and significantly greater cervical mobility than those with mild spondylolisthesis. The anterolisthesis group, but not the retrolisthesis group, had a significantly wider spinal canal than the mild spondylolisthesis group, although the degree of horizontal displacement and cervical mobility did not differ significantly between the anterolisthesis and retrolisthesis groups. Severe cord compression seen on T1-weighted magnetic resonance imaging (MRI) scans and high-intensity spinal cord signals seen on T2-weighted MRI scans corresponded significantly to the levels of the spondylolisthesis.

Conclusions. Degenerative spondylolisthesis is not a rare radiographic finding in elderly patients with CSM, which tends to cause intense cord compression that is seen on MRI scans. Greater mobility of the upper cervical segments may be a compensatory reaction for advanced disc degeneration of the lower cervical segments, leading to the development of degenerative spondylolisthesis. With a similar degree of displacement, anterolisthesis tends to have a greater impact on the development of CSM than retrolisthesis.

Offprint requests to: M. Kawasaki
Received: June 23, 2006 / Accepted: January 29, 2007

Introduction

According to previous reports,[1–6] degenerative spondylolisthesis of the cervical spine is not as commonly observed as that of the lumbar spine. In our experience, however, the condition is much more prevalent than previously suggested. In particular, unstable degenerative spondylolisthesis of the cervical spine may characterize cervical spondylotic myelopathy (CSM) in the elderly. Therefore, radiological findings were analyzed to elucidate the functional significance of this condition based on data from CSM patients who were 65 years or older and who eventually underwent surgery.

Patients and Methods

A total of 79 CSM patients (33 men, 46 women) 65 years and older (mean 75 years; range 65–88 years) had surgery for moderate to severe spastic limb paresis between 1991 and 2000. All patients underwent conventional radiographic examinations of the cervical spine preoperatively, including lateral views in flexion and extension with a tube-to-film distance of 120 cm. On lateral radiographs, horizontal displacement of one vertebra in relation to that immediately below it was measured (Fig. 1).

The 79 patients were categorized into three groups according to the measured values of the maximum horizontal displacement on radiographs obtained in either flexion or extension: severe spondylolisthesis (24 patients), moderate spondylolisthesis (31 patients), and mild spondylolisthesis (24 patients). Patients with severe spondylolisthesis had unequivocal horizontal displacement of 3.5 mm or more, a criterion established by White et al.[7] as suggestive of instability in the cervical spine, whereas those with moderate spondylolisthesis had horizontal displacement of 2.0–3.4 mm, and those with mild spondylolisthesis had a horizontal displace-

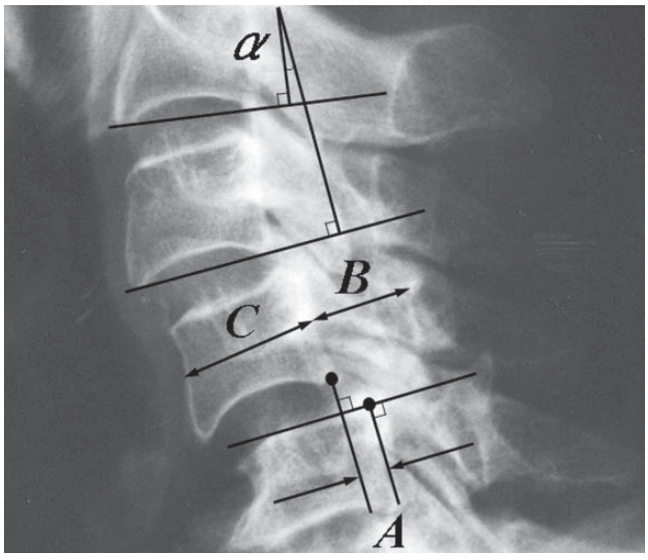

Fig. 1. Lateral radiograph of the cervical spine showing the method used to measure horizontal displacement (*A*), the sagittal diameter of the spinal canal (*B*), the sagittal diameter of the vertebral body (*C*), and the intervertebral angle (α). *A* is the linear distance between the two lines perpendicular to the line drawn along the upper vertebral end-plate of the vertebra below the displaced vertebra. One of the perpendicular lines runs through the posteroinferior edge of the displaced vertebral body, and the other runs through the posterosuperior edge of the vertebral body below. *B* is the distance from the center of the posterior surface of the vertebral body to the nearest point on the spinolaminar line; *C* is measured at the midpoint of the anterior and the posterior surface of the vertebral body; α is the angle formed between the lines running through the inferior aspects of the two adjacent vertebrae

ment of less than 2.0 mm. To elucidate the characteristic features of degenerative spondylolisthesis of the cervical spine, the radiographs of patients with severe spondylolisthesis were compared with those of patients with mild spondylolisthesis.

Other measurements on the lateral radiographs included (1) the intervertebral angle (formed between the lines running through the inferior aspects of two adjacent vertebrae on a lateral radiograph with the neck in neutral position); (2) range of angular movement (ROM), given by the difference in the intervertebral angles between flexion and extension[8]; and (3) the sagittal diameter ratio of the spinal canal to the corresponding vertebral body on a neutral lateral radiograph, which is independent of object-to-film distance and therefore more reliable than measuring the sagittal canal diameter in millimeters for determining cervical canal stenosis, as demonstrated by Pavlov et al.[9] (Fig. 1). Disc degeneration at each intervertebral level was graded 0–4 on lateral radiographs according to Lawrence's method[10]: grade 0, normal; grade 1, slight anterior wear of the vertebral lip; grade 2, anterior osteophytes; grade 3, anterior osteophytes and narrowing of the disc; grade 4, anterior osteophytes, disc narrowing, and sclerosis of vertebral plates.

Patients with severe spondylolisthesis underwent surface coil magnetic resonance imaging (MRI) of the cervical spinal cord preoperatively with one of three superconducting systems (0.5 T MRT-50 and 1.5 T MRT-200, Toshiba, Tokyo, Japan, or 1.5 T Signa, GE Corp., Milwaukee, WI, USA). The MRI protocol included sagittal and axial T1-weighted images, and sagittal T2-weighted images, with a slice thickness of 5 mm. Spinal cord measurements at each intervertebral level from C2/3 to C6/7 included the anteroposterior (AP) diameter, assessed by vernier calipers on midsagittal T1-weighted images, and the cross-sectional area, evaluated using a digitizer (Mitablet-II KD 4030 A; Graphtec, Yokohama, Japan) on axial T1-weighted images. The values were converted to the actual diameter and area using appropriate magnification factors. Attention was also directed to increased signal intensity on sagittal T2-weighted images resulting from spinal cord compression.[11] To test a significant association of the degenerative spondylolisthesis with spinal cord compression shown by MRI, the intervertebral level of degenerative spondylolisthesis was designated as 0, with the other levels numbered in order of increasing distance from this level, assigning a minus sign caudally. When severe spondylolisthesis involved two levels in a patient, the level with a greater horizontal displacement was designated 0.

The same investigator (M.K.) performed measurements using the same vernier calipers to the nearest 0.1 mm for length and the same protractor to the nearest 0.5° for angle. Each measurement was repeated three times, and the average value was taken as the final measurement value to minimize intraobserver error.

We used one-way analysis of variance (ANOVA) followed by Dunnett's post hoc test for statistical difference in the set of intervertebral and vertebral data and the Mann-Whitney U-test for evaluating intergroup differences. Values are expressed as the mean ± SD and were considered significant when $P < 0.05$. All statistical analyses were performed with a commercially available software program (SAS Institute, Cary, NC, USA).

Results

The severe spondylolisthesis group consisted of 9 men and 15 women, and the mild spondylolisthesis group consisted of 11 men and 13 women. No significant difference in age was noted between the two groups (75 ± 6 vs. 73 ± 6 years; $P > 0.2$).

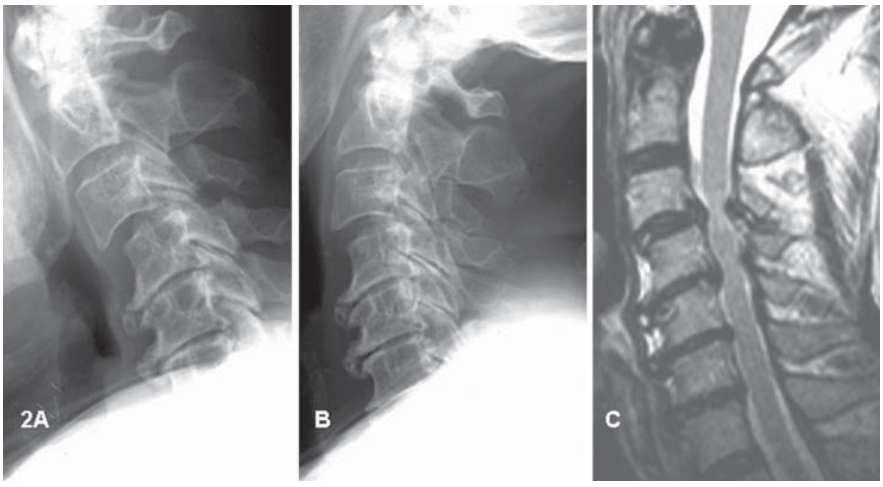

Fig. 2. A,B Lateral radiographs of the cervical spine with the neck in flexion (**A**) and in neutral position (**B**). **C** Sagittal T2-weighted magnetic resonance imaging (MRI) scan shows anterior degenerative spondylolisthesis in a 68-year-old patient with cervical spondylotic myelopathy

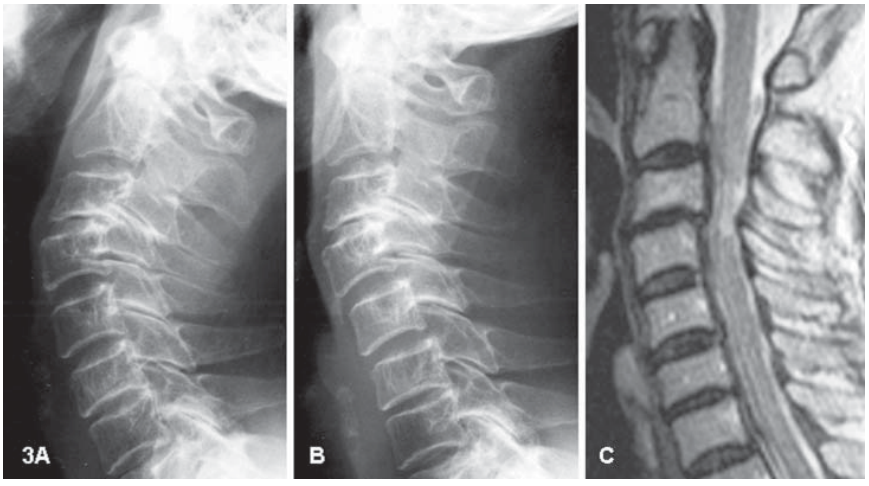

Fig. 3. A,B Lateral radiographs of the cervical spine with the neck in extension (**A**) and in neutral position (**B**). **C** Sagittal T2-weighted MRI scan shows posterior degenerative spondylolisthesis, referred to as retrolisthesis, in a 76-year-old patient with cervical spondylotic myelopathy

Horizontal displacement

Patients with severe spondylolisthesis had an average horizontal displacement of 4.2 ± 0.7 mm (range 3.5–6.0 mm), whereas those with mild spondylolisthesis showed an average horizontal displacement of 1.1 ± 0.8 mm (range 0–1.9 mm). The 24 patients with severe spondylolisthesis had 27 displacements of 3.5 mm or more; 14 patients had either one or two anterior displacements (anterolisthesis group); and 10 patients had one posterior displacement (retrolisthesis group) (Fig. 2). Of the 27 displacements, 15 were at C3 on C4 (8 anteriorly, 7 posteriorly) (Fig. 3), 10 were at C4 on C5 (8 anteriorly, 2 posteriorly), one was at C5 on C6 posteriorly, and one was at C7 on T1 anteriorly (Fig. 4). None of those displacements changed from anterolisthesis in flexion to retrolisthesis in extension. The degree of horizontal displacement did not differ significantly between the anterolisthesis and retrolisthesis groups (4.4 ± 0.7 vs. 4.0 ± 0.6 mm; $P > 0.1$) or between C3 on C4 and C4 on C5 (4.3 ± 0.8 vs. 4.2 ± 0.6 mm; $P > 0.7$).

Intervertebral angle

Patients with severe spondylolisthesis (anterolisthesis and retrolisthesis combined) had a significantly greater intervertebral angle at C3/4 (9.1° ± 5.1° vs. 4.6° ± 4.7°; $P < 0.005$) but not at the other levels, compared with patients with mild spondylolisthesis (Table 1). In patients with severe spondylolisthesis, the C3/4 level had a significantly ($P < 0.05$) greater intervertebral angle than the remaining levels (Table 1, Fig. 2B). The intervertebral angles were similar ($P > 0.1$) between the anterolisthesis and retrolisthesis groups at C3/4 through C6/7, although at C2/3 they were significantly greater ($P < 0.05$) in the anterolisthesis group than in the retrolisthesis group (5.6° ± 3.1° vs. 1.1° ± 4.4°).

Range of angular movement

Patients with severe spondylolisthesis (anterolisthesis and retrolisthesis combined) had a significantly greater ROM at C2/3 ($P < 0.05$), C3/4 ($P < 0.04$), C4/5 ($P < 0.04$),

and C5/6 ($P < 0.05$), but not at C6/7, compared with patients with mild spondylolisthesis (Table 2). The anterolisthesis and retrolisthesis groups showed a similar ROM at all levels ($P > 0.08$). The upper cervical segments (C3/4 or C4/5) had significantly ($P < 0.05$) greater ROM than the lower segments (C5/6 or C6/7) in the severe and mild spondylolisthesis groups combined.

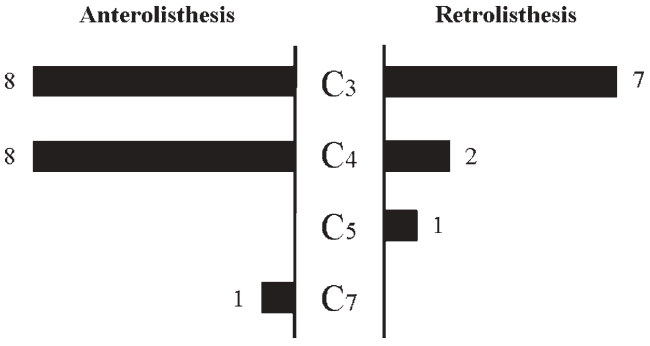

Fig. 4. Vertebral levels of 27 displacements of the cervical spine with a displacement of 3.5 mm or more. There are high incidences of degenerative spondylolisthesis at the upper cervical segments

Sagittal diameter ratio of spinal canal to vertebral body

Of the patients with severe spondylolisthesis, the anterolisthesis group had a significantly ($P < 0.005$) greater sagittal diameter ratio of the spinal canal to the vertebral body than the mild spondylolisthesis group at every vertebral level from C2 to C7. However, there was no significant difference in the ratio between the retrolisthesis group and the mild spondylolisthesis group at any level (Table 3).

Evaluation of cervical disc degeneration

Cervical disc degeneration became progressively more severe at more caudal levels, showing a significant change from C2/3 to C3/4 ($P < 0.01$), C3/4 to C4/5 ($P < 0.01$), and C4/5 to C5/6 ($P < 0.01$) in both the severe spondylolisthesis group and the mild spondylolisthesis groups. However, no significant difference in grade was evident between the severe and mild spondylolisthesis groups ($P > 0.1$) or between the anterolisthesis and retrolisthesis groups ($P > 0.09$) at every vertebral level from C2/3 to C6/7 (Table 4).

Table 1. Intervertebral angle in the neutral position

Intervertebral level	Severe spondylolisthesis group (°)		Mild spondylolisthesis group (°) ($n = 24$)	$P^{\dagger}$	$P^{\dagger\dagger}$	$P^{\dagger\dagger\dagger}$
	Anterolisthesis group ($n = 14$)	Retrolisthesis group ($n = 10$)				
C2/3	5.6 ± 3.1	1.1 ± 4.4	3.5 ± 5.6	<0.05	NS	NS
C3/4	8.5 ± 5.3*	9.9 ± 5.0*	4.6 ± 4.7	<0.04	<0.01	<0.005
C4/5	–0.1 ± 5.6	2.6 ± 6.8	3.5 ± 6.5	NS	NS	NS
C5/6	1.9 ± 4.3	1.9 ± 4.5	3.0 ± 5.6	NS	NS	NS
C6/7	3.6 ± 5.2 ($n = 12$)[a]	6.2 ± 4.6 ($n = 7$)[a]	4.5 ± 3.8 ($n = 18$)[a]	NS	NS	NS
C2–C7	19.0 ± 9.5 ($n = 12$)[a]	21.7 ± 8.8 ($n = 7$)[a]	16.2 ± 13.0 ($n = 18$)[a]	NS	NS	NS

*Significantly greater intervertebral angle than the remaining more caudal and rostal levels (Dunnett's post hoc test; $P < 0.05$)
[†,††,†††] Calculated according to Mann-Whitney U-test comparing the mean value of the anterolisthesis group ([†]), retrolisthesis group ([††]), or severe spondylolisthesis group ([†††]) with that of the mild spondylolisthesis group at each level
[a] Superimposition of shoulders precluded the assessment of intervertebral angle at C6/7 in five patients with severe spondylolisthesis and six patients with mild spondylolisthesis

Table 2. Range of angular movement in flexion and extension

Intervertebral level	Severe spondylolisthesis group (°)		Mild spondylolisthesis group (°) ($n = 24$)	$P^{\dagger}$	$P^{\dagger\dagger}$	$P^{\dagger\dagger\dagger}$
	Anterolisthesis group ($n = 14$)	Retrolisthesis group ($n = 10$)				
C2/3	4.9 ± 3.1	4.9 ± 2.2	3.6 ± 3.5	NS	NS	<0.05
C3/4	12.1 ± 4.5	10.8 ± 6.7	8.7 ± 4.4	<0.02	NS	<0.04
C4/5	11.2 ± 5.1	11.1 ± 2.5	9.1 ± 4.4	NS	<0.05	<0.04
C5/6	8.3 ± 4.7	10.7 ± 3.4	6.7 ± 4.5	NS	<0.04	<0.05
C6/7	6.7 ± 3.8 ($n = 13$)[a]	5.9 ± 2.4	4.5 ± 4.7 ($n = 20$)[a]	NS	NS	NS
C2–C7	43.9 ± 14.5 ($n = 13$)[a]	43.3 ± 8.8	34.0 ± 14.2 ($n = 20$)[a]	<0.03	<0.03	<0.02

[†,††,†††] Calculated according to Mann-Whitney U-test comparing the mean value of the anterolisthesis group ([†]), retrolisthesis group ([††]), or severe spondylolisthesis group ([†††]) with that of the mild spondylolisthesis group at each level
[a] Superimposition of shoulders precluded assessment of range of angular movement at C6/7 in one patient with severe spondylolisthesis and four patients with mild spondylolisthesis

Table 3. Spinal canal/vertebral body diameter ratio

Vertebral level	Severe spondylolisthesis group		Mild spondylolisthesis group ($n = 24$)	$P^{\dagger}$	$P^{\dagger\dagger}$
	Anterolisthesis group ($n = 14$)	Retrolisthesis group ($n = 10$)			
C2	0.90 ± 0.13	0.77 ± 0.08	0.77 ± 0.09	<0.002	NS
C3	0.82 ± 0.10	0.72 ± 0.06	0.69 ± 0.09	<0.002	NS
C4	0.78 ± 0.07	0.68 ± 0.05	0.66 ± 0.09	<0.0007	NS
C5	0.76 ± 0.08	0.69 ± 0.05	0.67 ± 0.08	<0.003	NS
C6	0.78 ± 0.09	0.68 ± 0.07	0.67 ± 0.09	<0.004	NS
C7	0.81 ± 0.11 ($n = 13$)[a]	0.69 ± 0.09	0.70 ± 0.08 ($n = 20$)[a]	<0.005	NS

†,†† Calculated according to Mann-Whitney U-test comparing the mean value of the anterolisthesis group (†) or retrolisthesis group (††) with that of the mild spondylolisthesis group at each level
[a] Superimposition of shoulders precluded assessment of canal to body ratio at C7 in one patient with severe spondylolisthesis and four patients with mild spondylolisthesis

Table 4. Intervertebral disc degeneration of the cervical spine

Intervertebral level	Severe spondylolisthesis group		Mild spondylolisthesis group ($n = 24$)	$P^{\dagger}$
	Anterolisthesis group ($n = 14$)	Retrolisthesis group ($n = 10$)		
C2/3	0.2 ± 0.4*	0.4 ± 0.5*	0.3 ± 0.6*	NS
C3/4	1.3 ± 1.1*	1.7 ± 1.1*	1.3 ± 0.9*	NS
C4/5	2.6 ± 0.8*	2.3 ± 0.9*	2.1 ± 1.0*	NS
C5/6	3.4 ± 0.7	2.8 ± 0.8	2.8 ± 0.9	NS
C6/7	3.3 ± 0.8 ($n = 13$)[a]	2.9 ± 1.0	2.9 ± 1.0 ($n = 20$)[a]	NS

* The degree of intervertebral disc degeneration is progressively higher with more caudal level (Dunnett's post hoc test; $P < 0.01$)
† Calculated according to Mann-Whitney U-test comparing the mean value of the severe spondylolisthesis group with that of the mild spondylolisthesis group at each level
[a] Superimposition of shoulders precluded assessment of intervertebral disc degeneration at C6/7 in one patient with severe spondylolisthesis and four patients with mild spondylolisthesis

Table 5. Cervical spinal cord measurement in patients with severe spondylolisthesis

Intervertebral level	No. of patients	Anteroposterior diameter		Cross-sectional area	
		Mean ± SD (mm)	Range (mm)	Mean ± SD (mm^2)	Range (mm^2)
+2	7	7.3 ± 1.1	6.2–8.8	78.9 ± 7.8	69.0–92.1
+1	23	6.6 ± 1.4	3.2–9.3	69.9 ± 15.8	43.4–93.3
0	24	4.5 ± 1.1*	2.2–6.2	54.4 ± 11.3*	29.1–79.8
–1	24	5.8 ± 1.0	3.7–8.0	62.6 ± 9.9	40.8–83.7
–2	23	5.7 ± 1.0	3.6–7.2	62.6 ± 10.8	42.9–82.8
–3	13	5.9 ± 0.9	4.1–7.7	65.3 ± 12.0	43.8–83.4

* Significantly smaller anteroposterior diameter and cross-sectional area than those at the remaining more caudal and rostral levels (Dunnett's post hoc test; $P < 0.05$)

MRI evaluation

Table 5 shows the quantitative assessment of spinal cord compression in relation to the level of severe spondylolisthesis (0 level). The 0 level had a significantly smaller anteroposterior diameter ($P < 0.05$) and cross-sectional area ($P < 0.05$) than the remaining more caudal or rostral levels (Figs. 2C, 3C). Sagittal T2-weighted images showed high-intensity spinal cord signals at 18 intervertebral levels in 24 patients with severe spondylolisthesis: 8 at C3/4, 6 at C4/5, 3 at C5/6, and 1 at C6/7. All but three matched the site of the spondylolisthesis.

Discussion

The current data, although from a highly selective group of patients in the absence of a control series, indicate that degenerative spondylolisthesis of the cervical spine is not uncommon in elderly CSM patients.[12] This finding contrasts with the low prevalence in younger populations.[1,3] Severe spondylolistheses of 3.5 mm or more occurred in 30% of elderly CSM patients. If moderate spondylolisthesis of 2.0–3.5 mm is included, as in some reports,[1,12–16] the prevalence was as high as 70% in the

current series of surgically treated CSM patients. Degenerative spondylolisthesis seems to have a predilection for the upper cervical levels with advancing age: 93% of the displacements involved the C3/4 or C4/5 level in the current series (Fig. 4).

In agreement with previous studies,[17,18] the current study showed that age-related degenerative changes of the cervical spine develop with progressive severity at more caudal segments (Table 4). Furthermore, the lower cervical segments showed less mobility than the upper cervical segments (Table 2), reflecting an advanced grade of disc degeneration in elderly CSM patients.[12,17] Paradoxically, this tendency may protect the lower segments.[19,20] In contrast, an excessive compensatory movement imposed on the higher segments may contribute to instability, leading to degenerative spondylolisthesis.[21,22] In fact, patients with severe spondylolisthesis had greater preservation of cervical mobility at C2/3 through C5/6 than did patients with mild spondylolisthesis (Table 2). An increase of the intervertebral angle at C3/4,[22] as seen in patients with severe spondylolisthesis (Table 1), is likely to be a compensatory reaction because the lower cervical segments tend to become kyphotic with advancing disc degeneration (Fig. 2B).

Regardless of the underlying mechanism, degenerative spondylolisthesis of the cervical spine plays an important role as a cause of CSM in the elderly[12,23-26]; this was supported by our finding that intense cord compression seen on T1-weighted MRI scans and high-intensity spinal cord signals seen on T2-weighted MRI scans significantly corresponded to the sites of spondylolisthesis (Table 5; Figs. 2, 3). In addition, the anterolisthesis group, but not the retrolisthesis group, had a significantly wider canal than the mild spondylolisthesis group (Table 3). This implies that anterolisthesis has a greater impact on the development of CSM than retrolisthesis because the degree of horizontal displacement did not differ significantly between the anterolisthesis and retrolisthesis groups. Had it not been for the spondylolisthesis, CSM might not have developed in patients in the anterolisthesis group, who had a relatively wide canal. In contrast, a congenitally narrowed cervical spinal canal coupled with age-related hypertrophic changes is more likely to be responsible in the mild spondylolisthesis group.

Conclusion

Degenerative cervical spondylolisthesis of 3.5 mm or more occurred in as many as 30% of elderly CSM patients. In this age group, greater mobility and a larger intervertebral angle of the upper, rather than the lower, cervical segments may lead to a high incidence (93%) of spondylolisthesis at C3/4 or C4/5. A significant association between spondylolisthesis and intense cord compression, despite a relatively wide canal for anterolisthesis, indicates the functional significance of severe spondylolisthesis in CSM in the elderly. Awareness of this possibility improves patient care and management, particularly when determining the possible need for stabilizing the segment in addition to decompression.

The authors did not receive and will not receive any benefits or funding from any commercial party related directly or indirectly to the subject of this article.

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