Etiologic Factors of Myelopathy

A Radiographic Evaluation of the Aging Changes in the Cervical Spine

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The radiographic characteristics of the cervical spine among older individuals were investigated in 100 normal subjects and compared with those of younger subjects. The cervical spine of the older subjects displayed narrowing of intervertebral discs and osteophytoses (posterior osteophytes as well as anterior osteophytes) at the levels of C5–6 and C6–7, where the range of motion was decreased. Such degenerative changes resulted in vertebrolisthesis, especially retrolisthesis, predominatly at the levels of C3–4 and C4–5, where intervertebral disc space was well maintained and mobility was well preserved. Both static and dynamic anteroposterior canal diameter decreased with age. Throughout the aging process the dynamic canal became much narrower than the static canal, except at C2–3. Posterior osteophytes at C5–6 or C6–7 and retrolisthesis at C3–4 or C4–5 were major levels of stenosis associated with changes in the dynamic canal. Following the same evaluation system, 20 elderly patients with cervical spondylotic myelopathy were assessed. Based on the above-noted characteristics of the aging process, patients with myelopathy had smaller static and dynamic canal measurements than normal subjects. The development of cervical myelopathy, however, was not always based on critical static or dynamic canal stenosis (10% in this series) and might involve other factors.

Degenerative changes involving vertebral bodies, intervertebral discs, facet joints, and other osseous or ligamentous tissues develop in the cervical spine with age. It is widely recognized that cervical myelopathy may be a result of these degenerative changes due to spinal cord compression or vascular disturbance.[3,11] Although degenerative changes are common and extensive with age, they do not always advance to myelopathy. Anteroposterior (AP) canal diameter, however, is of special interest, because a narrow canal is essential to the development of myelopathy.[5,8,10,17] Despite a number of reports[7,14,15] on AP canal diameter in relation to the aging process, the pathomechanism of cervical spondylotic myelopathy (CSM) has not yet been clarified. The purpose of the present study is to clarify radiologically the age-related changes in the cervical spine, to examine how these changes influence canal diameter, and to discuss the factors contributing to cervical myelopathy.

MATERIALS AND METHODS

One hundred subjects older than 60 years of age (Group A) were selected at random from the outpatients at the authors' institution from 1983 to 1984. The subjects had no congenital abnormalities or neurologic deficits. Two other control groups (Groups B and C) were composed of younger subjects (Table 1). In addition, 20 elderly patients with CSM were compared with the normal subjects (Table 1). These patients, who displayed long tract signs, were diagnosed by myelography and computed tomography–myelography.

Lateral roentgenograms of the cervical spine were taken during neutral and maximal flexion and extension positions with the patient sitting at a distance of 150 cm from the tube with the shoulder in contact with the roentgenographic plate. The degree of narrowing of intervertebral discs, osteophy-

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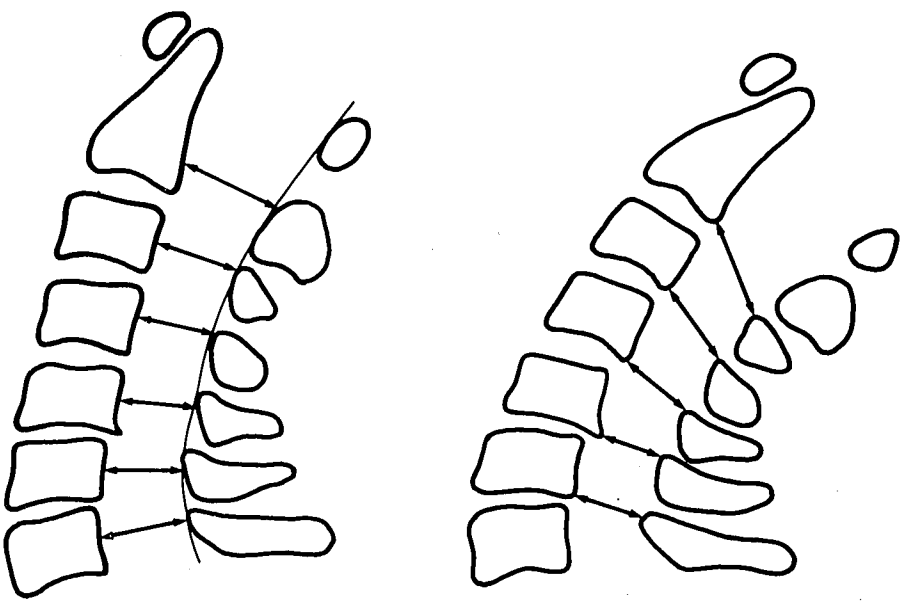
TABLE 1. Age and Sex Distribution of Subjects

Group	*No. of Subjects*	*Men/Women*	*Age (Average)*
Normal subjects			
Group A	100	46/54	60–82 (69.7)
Group B	30	16/14	40–59 (49.2)
Group C	30	16/14	20–39 (31.0)
Patients with myelopathy	20	10/10	60–77 (67.6)

tosis, and vertebrolisthesis was evaluated at each segment from the level of C2 to C7. A disc was considered narrow when maximal intervertebral disc space was less than 4 mm. Both osteophytosis and vertebrolisthesis were determined to be positive when they exceeded 2 mm. The range of intervertebral motion was measured by the method of superimposing two films (flexion and extension) as described by Penning.[13] Static AP canal diameters were measured in the neutral position and dynamic diameters in the extension position at each segment (Fig. 1). The data were compared statistically with *t*-tests and paired *t*-tests.

RESULTS

The frequencies of the narrowing of intervertebral discs and osteophytosis are shown in Figures 2 and 3. The narrowing of intervertebral discs was rarely observed in Group C, although an increased number of narrowed discs was found at the levels of C5–6 (33.3%) and C6–7 (16.7%) in Group B and was seen commonly at all levels but C2–3 in Group A. Narrowed discs were most common at the



a. Static **b. Dynamic**

FIGS. 1A AND 1B. Measurement of the cervical (A) static and (B) dynamic anteroposterior (AP) canal diameter. Static AP canal diameter is the shortest distance from the middle of the posterior surface of the vertebral body to the spinolaminar line which is drawn through the anterior surface of the lamina on neutral film. Dynamic AP canal diameter is the distance from the posteroinferior margin of the vertebral body to the anterosuperior margin of the inferior lamina on extension film.

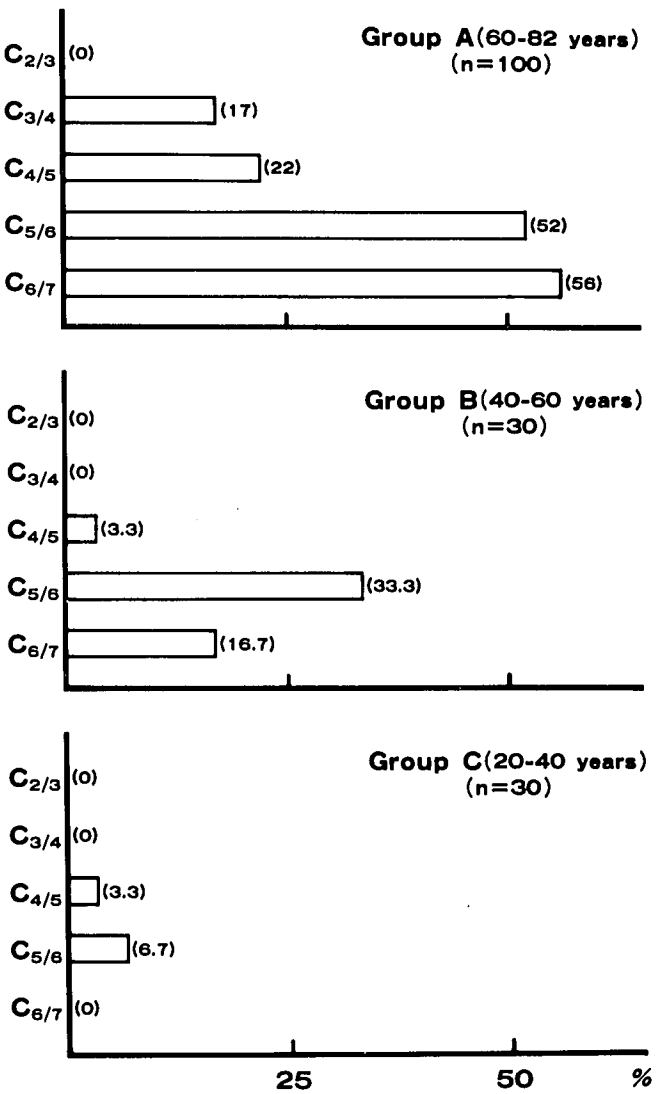


FIG. 2. Narrowing of intervertebral discs in three groups. The number in parentheses indicates the percentage of narrowed discs at each level.

levels of C5–6 and C6–7 (both more than 50%) in Group A. Osteophytosis developed in proportion to the increase of narrowed discs. Anterior osteophytes were found at many levels in Group A (Fig. 3). Posterior osteophytes, although less frequent than anterior osteophytes, were observed mostly at the lower levels of C5–6 and C6–7 in Group A. They also were observed frequently at C5–6 in Group B.

The range of intervertebral motion showed wide variations and greater mobility in women than in men. The degree of total intervertebral motion from C2–3 to C6–7 had a tendency to decrease with age (51.1° ± 11.2° in Group A; 63.7° ± 9.4° in Group B; and 67.7° ± 15.4° in Group C). Figure 4 shows the range of motion at each level in all three groups. Although the range of intervertebral motion was maximal at C5–6 in Group B (16.9° ± 5.1°) and in Group C (18.0° ± 4.3°), the place of maximal motion shifted to the higher levels in Group A, which showed comparatively greater

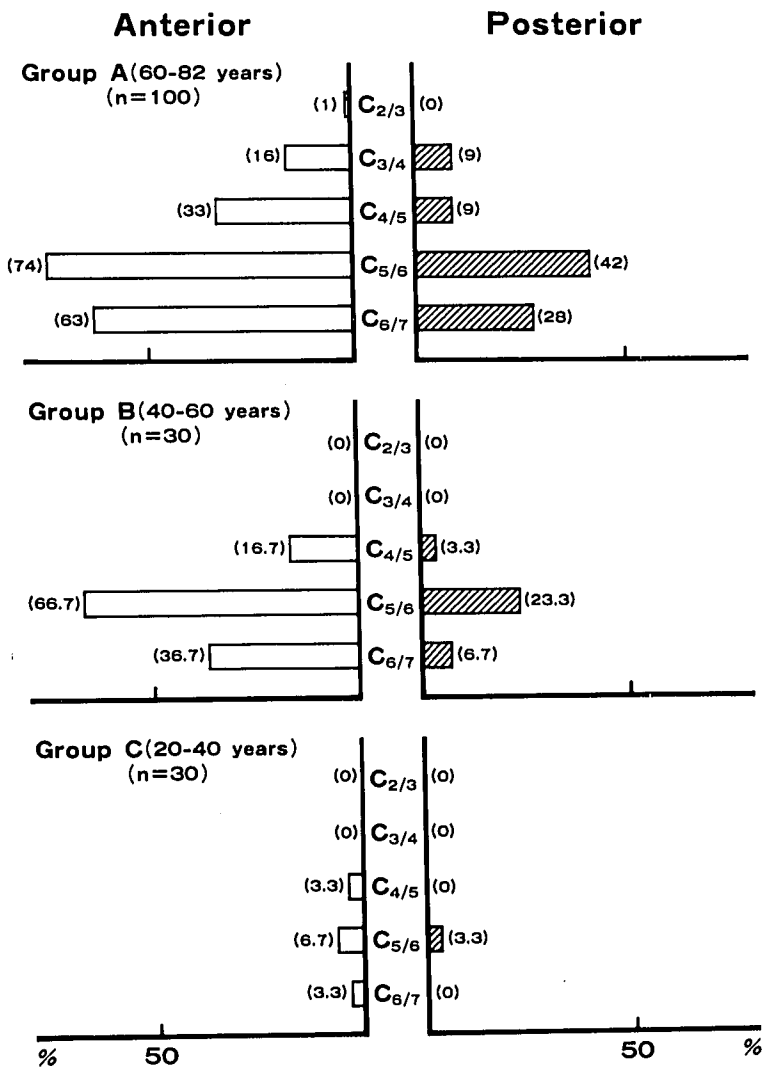


FIG. 3. The frequency of anterior (left) and posterior (right) osteophytes at each level in three groups.

mobility at the levels of C3–4 (12.0° ± 3.6°) and C4–5 (13.9° ± 3.9°). C2–3 showed minimal mobility in all three groups.

Vertebrolisthesis increased with age. Retrolisthesis was more common than anterolisthesis. Retrolisthesis, influencing the dynamic AP canal diameter, was observed frequently at the levels of C3–4 (30%) and C4–5 (38%) in Group A (Fig. 5). C2–3, C5–6, and C6–7 were rarely involved.

Figure 6 shows static and dynamic AP canal diameters of the cervical spine at the levels of C2 to C7 in each of the three groups. The static AP canal diameter had wide variations, ranging from 12 to 22 mm in Group A, 13 to 22 mm in Group B, and 13 to 22 mm in Group C. The narrowest in all three groups was C4. The static canal diameter had a tendency to decrease with age, but no significant differences among the three groups were detected. The dynamic canal diameter also varied and decreased with age. The dynamic canal, how-

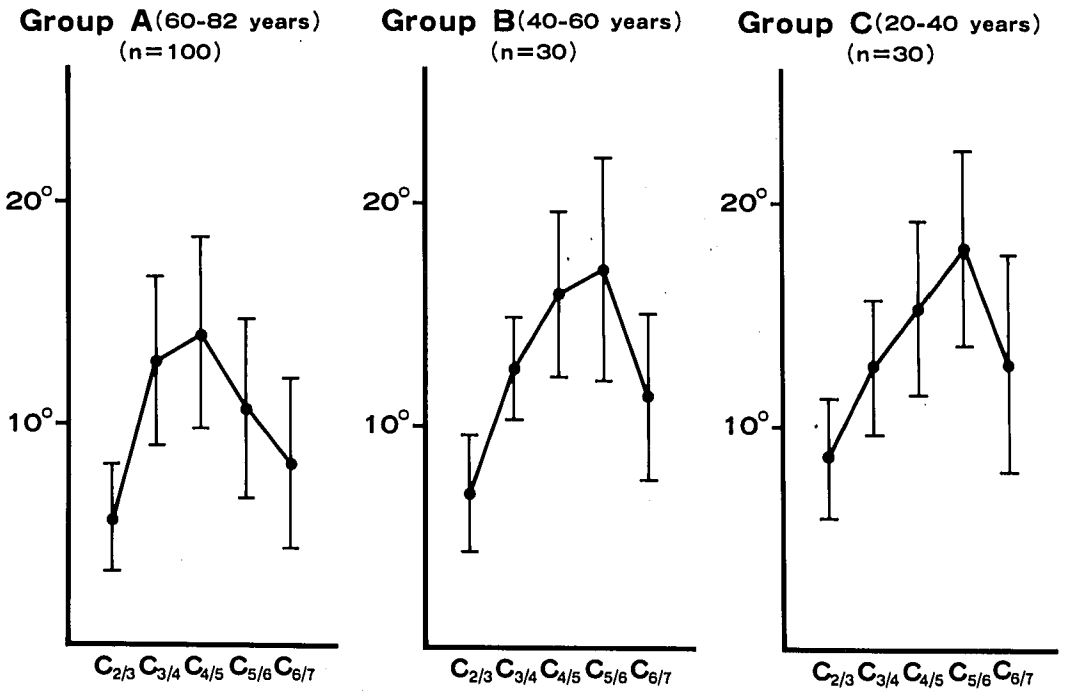


FIG. 4. The average and standard deviation of the range of intervertebral motion at each level in three groups.

ever, compared with the static canal, showed many differences in each of the three groups. Although there were no significant differences between static and dynamic canal diameters in Group C, the dynamic canal diameter significantly decreased at C5–6 in Group B ($p < 0.001$) and at all segments but C2–3 in Group A (C3–4, $p < 0.001$; C4–5, $p < 0.001$; C5–6, $p < 0.001$; C6–7, $p = 0.001$).

To define the factors resulting in dynamic canal stenosis at each level, 101 of the 500 intervertebrae (in 100 subjects) whose dynamic canal diameter was less than 13 mm were examined. The main factors contributing to diminished dynamic canal diameter were evaluated at each segment. There were 25 intervertebrae whose diminished diameter was the result of posterior osteophytes, 30 from retrolisthesis, ten from the combination of posterior osteophytes and retrolisthesis, and 36 from other factors, such as dynamic canal stenosis, based on severely narrowed static canals or anterior protrusion of lamina into the spinal canal. Table 2 indicates that posterior osteophytes were a major cause of dynamic canal stenosis at the levels of C5–6 and C6–7 and retrolisthesis was the major cause at the levels of C3–4 and C4–5.

Table 3 shows the radiographic findings of the cervical spine in patients with myelopathy. The narrowing of intervertebral discs and osteophytosis commonly were seen at the lower cervical levels, slightly more frequently than in normal subjects. Posterior osteophytes were found at a higher rate at the levels of C4–5 (30%), C5–6 (40%), and C6–7 (50%). There was no significant difference in the range of intervertebral motion between the patients with myelopathy and normal subjects. C3–4 and C4–5 showed comparatively greater mobility than C2–3, C5–6, and C6–7. Retrolisthesis was observed more frequently at the

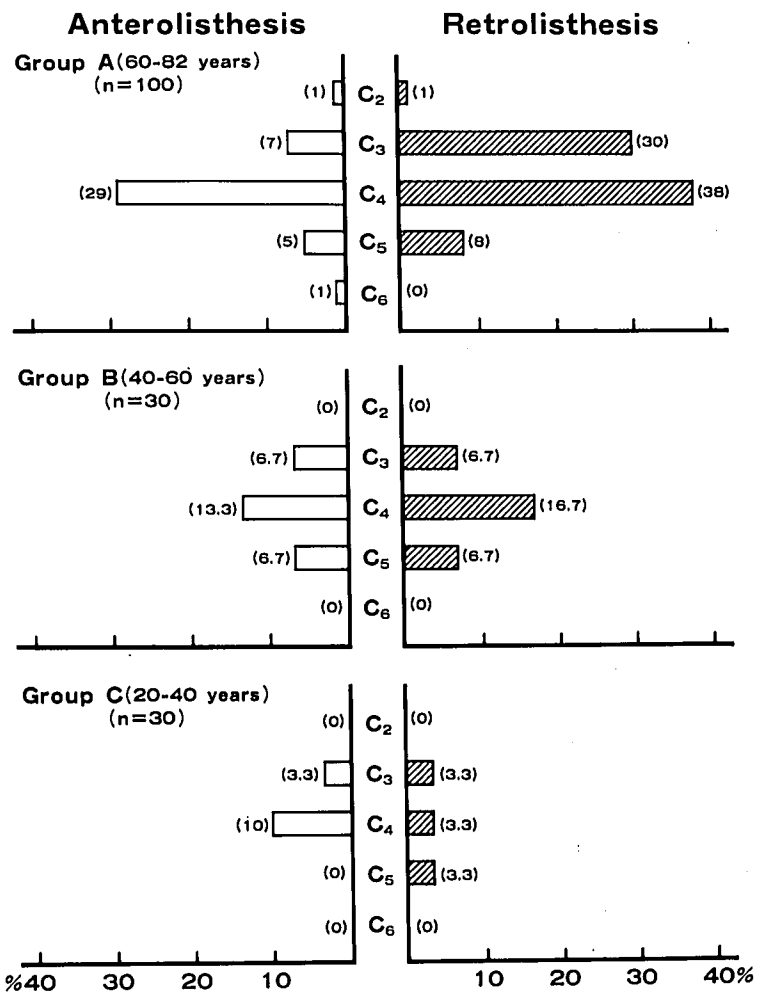


FIG. 5. The frequency of anterolisthesis (left) and retrolisthesis (right) at each level in three groups.

levels of C3–4 (55%) and C4–5 (70%) in the patients with myelopathy than in normal subjects. C2–3 (0%), C5–6 (10%), and C6–7 (0%) were rarely involved in either the patients with myelopathy or the normal subjects.

AP canal diameters of the patients with myelopathy were compared with those of normal subjects (Fig. 7). The static canal diameter ranged from 11 to 20 mm and the dynamic canal from 8 to 19 mm. Both static and dynamic canal diameters were significantly smaller in patients with myelopathy than in normal subjects at all segments ($p < 0.001$). Based on the static canal stenosis, the dynamic canal tended to be diminished further, mainly by posterior osteophytes at C5–6 and C6–7 or by retrolisthesis at C3–4 and C4–5, in patients with myelopathy. Eighteen of 20 patients with myelopathy showed static or dynamic canal stenosis less than 13 mm.

DISCUSSION

The aging process causes degenerative changes in the spinal column. The narrowing of intervertebral discs and osteophytosis are common features in the cervical spine of older people. Friedenberg and Miller[7] reported that

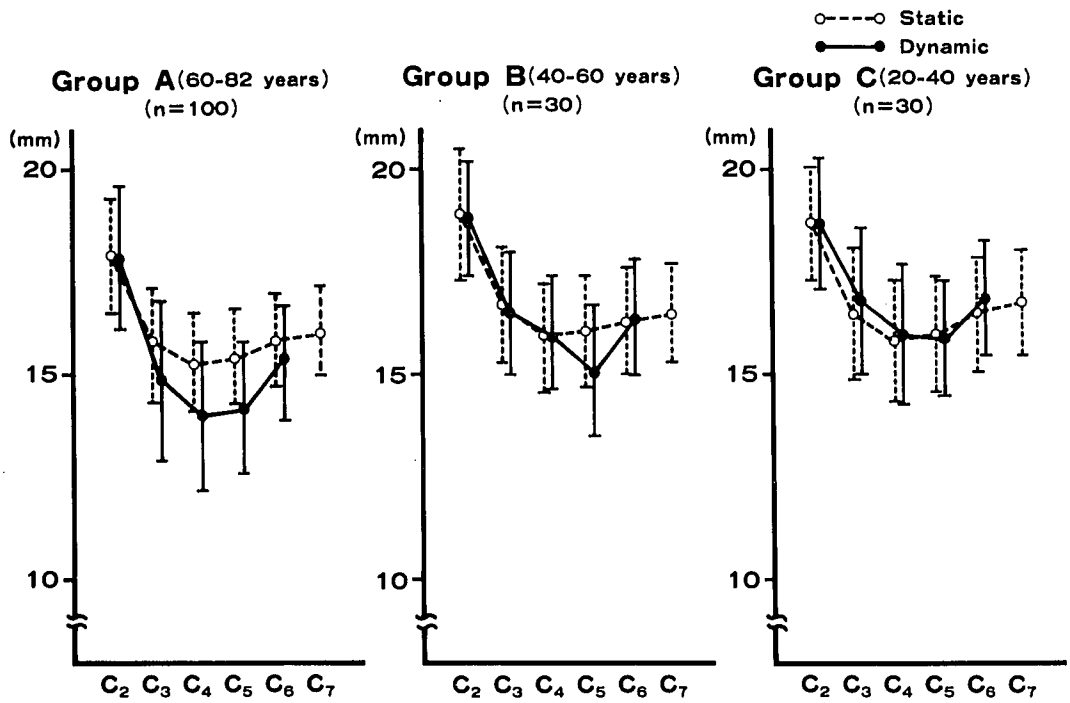


FIG. 6. The average and standard deviation of static and dynamic AP canal diameters at each level in three groups.

75% of subjects in their seventh decade showed such degenerative changes in the cervical spine. In the present series, both the narrowing of intervertebral discs and osteophytosis were commonly found at the levels of C5–6 and C6–7, although they were not always identical with each other. Spinal intervertebral mobility was well correlated with such degenerative changes. The largest range of motion was observed at C5–6 in the younger groups, whereas significant decrease of intervertebral mobility at the levels of C5–6 ($p < 0.001$) and C6–7 ($p < 0.001$) was observed in the older group. As a result, C3–4 and C4–5, where intervertebral disc space was well maintained, showed a comparatively greater mobility. Sa-

TABLE 2. Stenotic Factors for Dynamic AP Canal Diameter (101 Intervertebrae less than 13 mm)

Level	*Posterior Osteophytes*	*Retrolisthesis*	*Posterior Osteophytes and Retrolisthesis*	*Other*	*Total (%)*
C2–3	0	0	0	0	0 (0)
C3–4	0	9	6	6	21 (20.8)
C4–5	1	17	2	13	33 (32.7)
C5–6	18	4	2	8	32 (31.7)
C6–7	6	0	0	9	15 (14.9)
Total (%)	25 (24.8)	30 (29.7)	10 (9.9)	36 (35.6)	101 (100)

TABLE 3. Radiographic Findings in 20 Patients with Myelopathy

Level	Narrowing of Intervertebral Disc	Osteophytes		Range of Intervertebral Motion (degree)	Vertebrolisthesis	
		Anterior	Posterior		Anterior	Posterior
C2–3	0	0	0	5.3 ± 2.8	1	0
C3–4	4	3	2	12.5 ± 4.1	1	11
C4–5	6	6	6	14.8 ± 4.6	5	14
C5–6	10	16	8	10.1 ± 4.2	1	2
C6–7	15	16	10	7.4 ± 3.9	0	0

saki[14] pointed out that the mobility of C4–5 increased to compensate for decreased mobility of C5–6 in older patients, and this observation agrees with the present results. On the other hand, vertebrolisthesis, especially retrolisthesis in extension, had a high incidence at the levels of C3–4 and C4–5 in the older group. This may also occur as degenerative sequelae, but how or why this develops at the levels of C3–4 and C4–5 is unknown. The cervical spine shows different patterns of movement between the middle and lower cervical levels, as Penning[13] indicated: C3–4 and C4–5 show some sliding of the superior over the inferior vertebra, whereas little sliding was observed at the levels of C5–6 and C6–7 (Fig. 8). This is explained by the location of the axes of spinal movements, which are anterior to the spinal canal and below the vertebral disc. At the lower level of the cerical spine, axes of movement shift more anteriorly and superiorly. Although sliding may be caused in part by the differences of the facet angle, this type of movement tends to occur predominantly

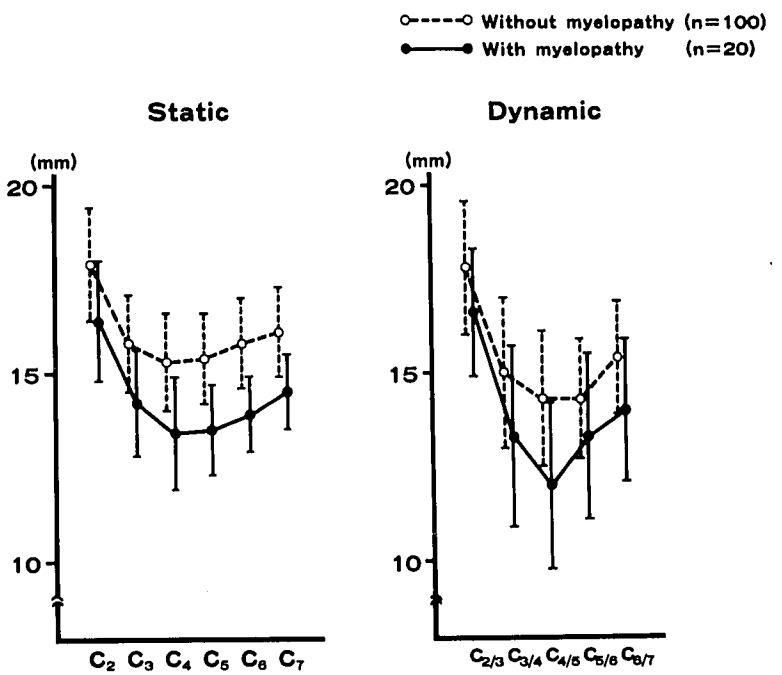


FIG. 7. The average and standard deviation of static (left) and dynamic (right) AP canal diameters in subjects with and without myelopathy. Note the significant decrease of both static and dynamic canal diameters in the patients with myelopathy.

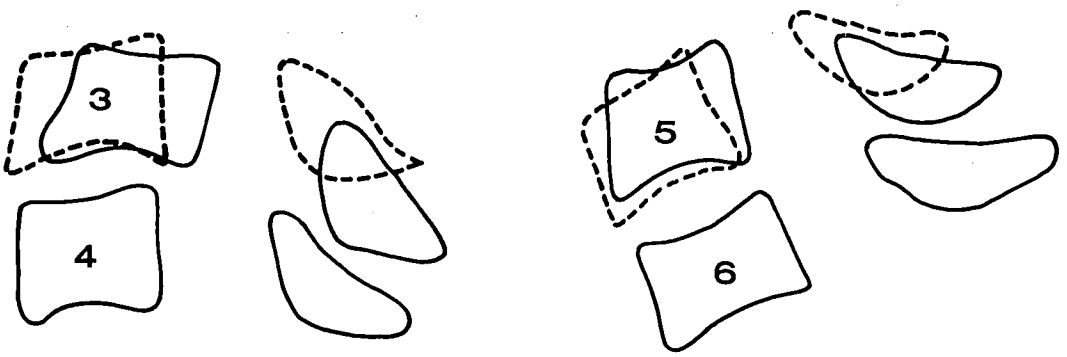


FIG. 8. Intervertebral movement at C3–4 (left) and C5–6 (right). Note the sliding of the upper vertebra on the lower one with retrolisthesis in extension at C3–4; less sliding is identified at C5–6.

at the higher levels of the cervical spine as a result of the longer distance to the axis of movement during flexion and extension. Vertebrolisthesis produced at C3–4 and C4–5 may occur to compensate for decreased mobility of C5–6 and C6–7, in addition to the relaxation of the surrounding ligaments and the degenerative changes in the articular cartilages. The above-mentioned characteristics of the cervical spine in older people are generally severe and extensive with advanced age and may infuence AP canal diameters.

There are several methods[1,2,4,12] to assess the spinal canal diameter on plain roentgenograms. Wolf *et al.*[17] measured the static AP canal diameter on 200 normal subjects, which ranged from 12 to 22 mm at the level of C3 to C7. The static canal diameter had a tendency to decrease with age in this study. This tendency might be attributed to the flattening of the vertebral body as a result of the aging process, as described by Mochida *et al.*[9] However, the evaluation of the dynamic canal in extension is important because the dynamic canal diameter can be reduced easily through a degenerative process in subjects with a normal static canal diameter. The dynamic canal became much narrower than the static canal, except at C2–3, with increasing age. This relationship indicates that the stenotic factors influencing the dynamic canal diameter may develop during the aging process. In this study,

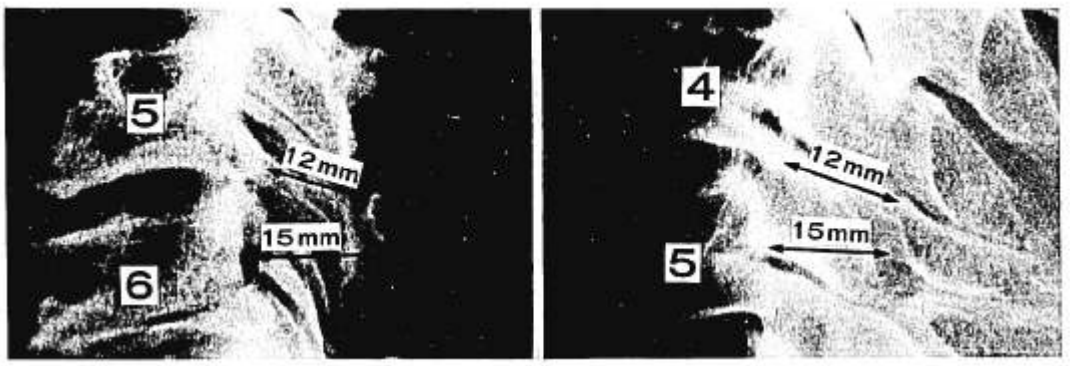


FIG. 9. Lateral roentgenograms, showing dynamic AP canal diameter reduced to 12 mm by posterior osteophytes at C5–6 (left), and by retrolisthesis at C4–5 (right) in subjects with normal static AP canal diameters (15 mm).

posterior osteophytes and retrolisthesis were closely related to dynamic canal stenosis: posterior osteophytes were the most important factor at the levels of C5–6 and C6–7, while retrolisthesis predominated at the levels of C3–4 and C4–5 in the older group (Fig. 9).

Cervical myelopathy can be caused by various factors[6,12,16] related to degenerative changes of the cervical spine in older patients. It is not evident, however, which factors play an important role in myelopathy. Radiographic demonstration of degenerative changes in the cervical spine is in itself no argument in favor of the presence of this condition, because cervical spondylosis is commonly found in elderly people.[7,14] It has been widely accepted that a decreased diameter of the spinal canal is essential to the development of CSM, as described in previous reports.[8,10,17] In this study, patients with myelopathy had significantly smaller static and dynamic canals than normal subjects. In patients with myelopathy, age-related changes causing spinal canal stenosis were amplified (Fig. 7). Edwards and LaRocca[5] reported the possibility of cervical myelopathy for patients whose static canal diameters were less than 13 mm. Penning[12] pointed out that myelopathy is strongly suspected when the dynamic canal is less than 11 mm. It is true that cervical myelopathy is based on spinal canal stenosis, but the development of myelopathy is not always correlated with AP canal diameter. Ten of 100 subjects in Group A, two of 30 in Group B, and two of 30 in Group C showed critical static canal stenosis measuring less than 13 mm, and ten of 100 subjects in Group A showed critical dynamic canal stenosis measuring less than 11 mm. None of these subjects had neurologic deficits. Further, two of 20 patients with myelopathy showed neither critical static nor dynamic canal stenosis. These results indicate that the development of cervical myelopathy may be unpredictable and dependent on other factors in addition to the narrowed spinal canal. These factors may include vascular changes in the cord, repeated traumas or soft tissue entrapments from disc protrusion, and the infolding of the ligamenta flava.

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