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Mid-sagittal Canal Diameter and Vertebral Body/Canal Ratio of the Cervical Spine in Koreans

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In order to ascertain the normal values of the mid-sagittal canal diameter and the canal/body ratio of the cervical spine in Korean adults, ninety sets of cervical vertebral columns were examined. The average mid-sagittal canal diameters from C3 through C7 in the normal Korean are 13.2±1.3 millimeters in male and 13.1±2.6 millimeters in female. The normal average canal/body ratio of the cervical spine is 0.93±0.10 in male and 1.02±0.09 in female. The mid-sagittal canal diameter is largest in the White population and smallest in Asian, but there is no racial differences in the canal/body ratio, and the lower limit of normal canal/body ratio is 0.8 in Korean. The authors conclude that measurement of the canal/body ratio is more reliable than direct measuring of the mid-sagittal diameter of the cervical spinal canal in the diagnosis of cervical spinal stenosis or predicting the prognosis of cervical spinal cord injury.

Key Words: Measurement, mid-sagittal canal diameter, canal/body ratio, cervical spine

In the diagnosis of lumbar spinal canal stenosis, computerized tomography has been used as a useful diagnostic tool, but plain lateral radiography is more reliable than computerized tomography in the diagnosis of cervical spinal stenosis due to cervical lordosis (Di-Chiro and Fisher, 1964). The measurement of the sagittal diameter of the cervical spinal canal in plain lateral radiography performed to assist in the diagnosis of cervical spinal stenosis has been an handy method (Boijsen, 1954; Wolf *et al.* 1956; Wells *et al.* 1959; Hinck *et al.* 1962; Wilkinson *et al.* 1969; Moiel *et al.* 1970). However, actual measurements in millimeters on the lateral radiograph to document cervical spinal stenosis can be incorrect due to the differences in the distance between the focus to the film, and the distance between the object to the film (Boijsen, 1954). Torg *et al.* (1986) reported the ratio method to determine cervical spinal stenosis. In this method the sagittal diameter of the spinal canal, measured from the mid-point of the posterior aspect of the vertebral body to the near point on the corresponding spinolaminar line is compared, with the anteroposterior width of the vertebral body (Fig. 1). Reports have been written about the relationship between this ratio and neurological symptoms resulting from trauma or cervical spinal stenosis (Edward and LaRocca, 1983; Pavlov *et al.* 1987; Moon *et al.* 1989; Chung and Kim, 1991), but the fact that these researchers measured the

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dimensions on the radiographic films could be a weak point. Regarding the canal dimension, Murone (1974) reported that the diameter of the midsagittal canal in the cervical spine was smaller in the Japanese compared with the European. The purposes of this study are to determine the normal dimension of the cervical spinal canal from anatomical specimens, to set the normal range of the vertebral canal/body ratio of the cervical canal in the Korean adult population, and to know whether there are any racial differences in the cervical spinal canal size and the canal/body ratio of the cervical spine.

MATERIALS AND METHODS

Spinal canal measurements were obtained from 90 dried human spinal columns (63 male, 27 female) that were stored in the Department of Anatomy Yonsei University College of Medicine. The age at death was between 19~70, the average age being 40.4 years. The 40~49 age group was the largest (Table 1). No apparent evidence of cervical spinal disease was found. Any vertebrae showing osteophytes or abnormalities were excluded.

Table 1. Age and sex distribution of vertebral columns(%)

Age	Male	Female	Total
19~20	9(14.3)	8(29.6)	17(18.9)
30~39	7(11.2)	4(14.8)	11(12.2)
40~49	17(27.0)	5(18.5)	22(24.4)
50~59	18(28.5)	3(11.1)	21(23.4)
60~69	12(19.0)	7(26.0)	19(21.1)
Total	63(100)	27(100)	90(100)

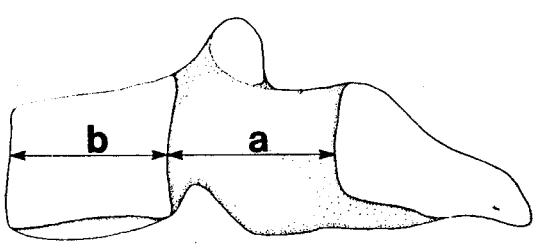

Fig. 1. *The measurement of the cervical spinal canal diameter (a) and anteroposterior diameter of the vertebral body (b) described by Torg et al. (1986).*

Measuring the morphometry of the canal and vertebral body were done by vernier calipers (Peacock Co., Tokyo, Japan) and dial calipers (Kori Co., Tokyo, Japan). The accuracy was 0.1mm. In this study, the mid-sagittal diameter of the canal and the anteroposterior diameter of the body were measured. The mid-sagittal diameter of the cervical spinal canal is more useful than transverse diameter in the diagnosis of cervical spinal stenosis.

The vertebral levels examined were from C3 to C7. The atlas and the axis are excluded because they have different shapes compared with other cervical vertebrae, and most cases of the cervical stenosis or trauma of the cervical vertebrae occur at the levels between C4 and C6. The anteroposterior diameters of the vertebral bodies were measured at the mid waist level of the body and the midsagittal diameters of the canal were measured where the canal was narrowest (Fig. 1). For consistency, all measurements were taken by one researcher. All data were analyzed using the Student's t-test and Anova test.

RESULTS

Mid-sagittal diameter

The midsagittal diameter of the cervical spinal canal was widest at the C7 level in male. The midsagittal diameter was narrowest at C4 level in male.

Table 2 shows the mean and standard deviations of the mid-sagittal diameter of the cervical spinal canal from C3 to C7. The mean diameters were narrowest at the C4 level in both sexes (Fig. 2). Although mid-sagittal diameters demonstrated an hour-glass constriction pattern with the narrowest level at C4, there was no statistical significance between the levels or between males and females.

Comparison of the mid-sagittal canal diameters among races

Comparison of the results in this study with those reported by previous authors (Okamoto, 1930; Francis, 1955; Hashimoto and Tak, 1977) indicates considerable differences between the Asian, the White, and the Black (Table 3). In the Asian, mid-sagittal canal diameters were narrowest at the C4 level in both male and female. In Whites and Blacks alike, female population demonstrated significantly narrower mid-sagittal canal diameters in the lower cervical levels than in the upper levels. However, in male population, the mid-sagittal canal diameter had a similar pattern with the Asian with the C4 level measuring the narrowest (Fig. 3 and Fig. 4). Although there were significant statistical differences at all cervical spine levels between the White and the Korean, as well as between the Black and the Korean ($P < 0.01$), there were no statistically significant differences in the range of mid-sagittal canal diameter of the cervical spine between the Korean and the Japanese. Like the Asian female, the White and Black female showed a smaller mid-sagittal diameter of the cervical spinal canal compared to that of the male, while relative sizes were not significantly different.

Table 2. Mid-sagittal diameter of cervical spinal canal in Koreans(millimeters)

Level	Male	Female	Total
C3	13.3±1.3	13.3±2.5	13.3±2.1
C4	12.8±1.4	12.9±2.7	12.9±2.0
C5	13.0±1.4	13.0±2.7	13.0±1.9
C6	13.2±1.3	12.9±2.6	13.1±2.1
C7	13.4±1.3	13.3±2.3	13.4±1.8
Average	13.2±1.3	13.1±2.6	13.1±1.9

Mean±Standard deviation

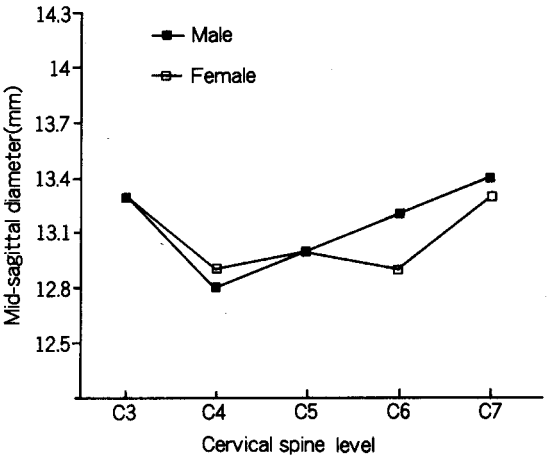

Fig. 2. *Mid-sagittal diameter of cervical spinal canal in Koreans.*

Table 3. Racial comparison of the mid-sagittal diameter of the cervical spinal canal(millimeters)

Level	Korean (Lee et al)		Japanese (Okamoto)		Japanese (Hashimoto and Tak)		White (Francis)		Black (Francis)	
	M	F	M	F	M	F	M	F	M	F
C3	13.3	13.4	13.3	12.8	13.8	13.6	16.5	15.5	15.2	15.1
C4	12.8	12.9	12.6	12.4	13.3	12.9	15.4	14.8	14.8	14.5
C5	13.0	13.0	12.9	12.4	13.5	13.2	15.4	14.4	15.1	14.6
C6	13.2	12.9	13.3	12.4	13.9	13.5	15.4	14.1	15.2	14.4
C7	13.4	13.3	13.3	12.7	13.7	13.6	15.5	14.4	15.5	14.3

M: Male
F: Female

Changes of the mid-sagittal canal diameter 1with age

The data regarding the changes in the mid-sagittal canal diameters according to age in Korean are displayed in Table 4. Although the narrowest diameter appeared at the C4 level in all age groups except in the twenties,

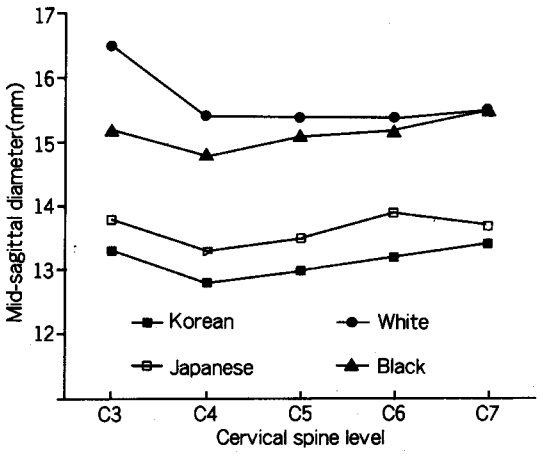

Fig. 3. Mid-sagittal diameter of cervical spinal canal in males

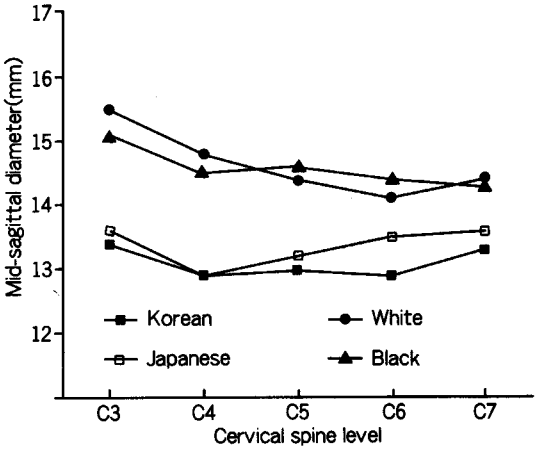

Fig. 4. Mid-sagittal diameter of cervical spinal canal in females.

Table 4. Relationship between the mid-sagittal diameter and the age groups(millimeters)

Level \ Age	19~29	30~39	40~49	50~59	Over 60
C3	13.3	13.2	13.5	13.4	13.1
C4	13.2	12.8	12.9	12.7	12.9
C5	13.2	12.9	13.3	13.3	13.2
C6	13.1	12.9	1.35	13.5	13.2
C7	13.3	13.3	1.34		1.36
Average	13.2	13.0	13.3	13.2	13.2

Table 5. Cervical spinal canal values in the Korean population

Level	Mid-sagittal diameter(mm)		Canal/body ratio	
	Male	Female	Male	Female
C3	13.3±1.3	13.4±2.5	0.92±0.12	0.97±0.11
C4	12.8±1.4	12.9±2.7	0.90±0.11	1.02±0.08
C5	13.0±1.4	13.0±2.7	0.94±0.10	1.02±0.07
C6	13.2±1.3	12.9±2.6	0.95±0.09	1.04±0.08
C7	13.4±1.3	13.3±2.3	0.96±0.10	1.05±0.10
Average	13.2±1.3	13.1±2.6	0.93±0.10	1.02±0.09

Mean±Standard deviation

there were no significant differnces in the mid-sagittal canal diameters among different age groups.

Cervical vertebral canal/body ratio of the Korean

Measurements of the sagittal diameter of the cervical spinal canal and canal/body ratio from C3 to C7 in the Korean are detailed in Table 5. In the male, the mean sagittal canal diameter from C3 through C7 was 13.2 mm, and the mean sagittal canal/body ratio was 0.93. In the female, the mean sagittal canal diameter was 13.1 mm, and the mean sagittal canal/body ratio was 1.02. Although the mean sagittal canal diameter was somewhat larger in the male group than in the female, the female group showed a larger mean canal/body ratio than the male. However there were no significant statistical differences in the diameter and the canal/body ratio between male and female.

DISCUSSION

Since Payne and Spillane (1957) described the relationship between developmental myelopathy and spinal canal size, the diagnostic importance of the sagittal diameter of the cervical spinal canal has been reported by many authors (Burrows, 1963; Hinck and Sachdev, 1966; Wilkinson *et al.* 1969; Murone, 1974; Hashimoto and Tak, 1977), and a myelogram was proven to be a useful method in the measurement of the cervical spinal canal in athletes who showed neurologic impairments after a hyperextension injury (Ladd and Scranton 1986). However, because of some variable enlargement factors in both sexes, these measurements have some drawbacks in the diagnosis of cervical spondylosis and do not reflect the actual size of the cervical spinal canal in men. To solve these problems, some authors suggested canal/body ratio in the diagnosis of myelopathy caused by cervical spondylosis (Torg *et al.* 1986; Pavlov *et al.* 1987), and stressed the significance of this ratio.

By the actual measurements in bony specimens, there were no sexual differences in the mid-sagittal canal diameters at all levels, but there have been radiographic reports stating that average mid-sagittal diameters of the cervical spinal canal were larger in males than in females (Boijsen, 1954; Payne and Spillane, 1957; Burrows, 1963). Therefore, it can be concluded that there are no essential differences in the mid-sagittal canal diameters of both sexes and the differences in gender of the mid-sagittal diameters of the cervical spinal canal reported by those authors could be the result of the effect of sexual differences in magnifications caused by the differences in shoulder breadth between men and women (approximately a 5 cm difference in the object-to-film distance and a four percent difference of magnification of images). Comparing the Japanese data (Okamoto, 1930; Hashimoto and Tak, 1977), the Korean measurements showed no significant differences in the mid-sagittal diameter of the cervical spinal canal in either sexes, but there was a 2.4 mm difference between Korean males and White males an d a 1.5 mm difference between the female groups. These differences were statistically significant ($p<0.01$), and it can be considered that these differences were caused by the differences in the heights and physiques. The mid-sagittal canal diameters of the Korean were smaller than those of the Black in both sexes ($p<0.01$). The mid-sagittal diameter of the cervical spinal canal was largest in the White, followed by the Black, with the Asian showing the smallest mid-sagittal diameter of the cervical spinal canal. There were no statistical differences in the mid-sagittal canal diameters between the White and the Black. It is known, through radiologic measurements, that the mid-sagittal diameter of the Japanese cervical spinal canal is narrower by 2.25 mm than those of European adults (Murone, 1974) and it could be concluded that the Asian would sustain spondylotic myelopathy more easily than the White.

In all races, the cervical spinal canal showed an "hour-glass" constriction pattern with the narrowest measurement at the C4 level, but this phenomenon was not as promi-

nent as the one in the lumbar spinal canal. The "hour-glass" constriction in the lumbar spinal canal has been reported by many authors (Amono-Kuofi, 1985; Piera *et al.* 1988), and they considered this phenomenon as a reflection of the lumbar enlargement of the spinal cord at the L1 level and due to the functional transitional area between the thoracic spine and the lumbar spine. With these considerations, it might be concluded that the cervical enlargement of the spinal cord is not as large as the lumbar enlargement and the motion in the cervicothoracic junction is not so complex compared to the motion in the thoracolumbar junction. There were no differences in the mid-sagittal diameters of the canal according to the age groups, and this may indicate that there is no change of the bony architecture of the spine or spinal cord once they become mature.

The average diameter of the cervical spinal canal measured radiographically was 17.7 mm in the Korean male and 17.0 mm in the Korean female (Moon *et al.* 1989). There were marked differences between the radiographic data and our data measured anatomically. The magnification rate from our study is higher than that which has been reported, but the canal/body ratio indicates a relatively close correlation between the two studies. This finding indicates that the radiographic images can be affected by many factors and the images are dependent on the focus-to-film distance and the object-to-film distance. Therefore, the diagnosis of cervical spinal stenosis or neurapraxia of the spinal cord after cervical spine injury could be difficult if only direct radiographic measurement of the spinal canal were to be performed. However, the canal/body ratio of the cervical spine is not influenced by the magnification rate. Compared with normal control groups studied previously (Pavlov *et al.* 1987; Moon *et al.* 1989), no racial differences of the canal/body ratio were found. In all studies, the female group showed a larger canal/body ratio than the male, and considering the relatively smaller or equal mid-sagittal canal diameters in the female group, it can be attributed to the smaller anteroposterior diameters of the cervical vertebral bodies in the female.

Finally, the mid-sagittal diameter of the cervical spinal canal was narrower in the Asian than in the White or Black population and the measurement of the canal/body ratio was a more reliable method than measuring the mid-sagittal diameter of the cervical canal in detecting cervical spinal stenosis or predicting the prognosis of the cervical cord injury.

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