Article published online: 2024-10-08

Original Article

Sex Disparity in the Canal-to-Body Ratio of the Cervical Spine Indicating the Prevalence of Cervical Myelopathy: A Cross-Sectional Study

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J Health Allied Sci[NU]

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Abstract

Background A narrow spinal canal and large vertebral body have been thought to be risk factors for cervical myelopathy. It is generally known that males are more likely to develop cervical myelopathy than females. Thus, sex is also a factor that contributes to myelopathy. The anteroposterior (AP) diameter of the cervical spinal canal is well-established as a primary factor of myelopathy.

Objective To investigate the sex discrepancy in the canal-to-body ratio of the cervical spine on magnetic resonance imaging (MRI).

Materials and Methods This cross-sectional study included 59 males and 59 females, all aged between 20 and 40 years. Morphological parameters, including height, AP diameter of the vertebral body, and AP diameter of the spinal canal, were measured on sagittal T2-weighted MRI cervical spine images for each participant. The canal-to-body ratio, obtained by dividing the spinal canal's AP diameter by the vertebral body's AP diameter, served as a key metric. The average canal-to-body ratio values compared between male and female groups at each spinal level (C3–C7) elucidate potential gender-related differences.

Results The height and the AP diameter of the vertebral body were larger in males than in females throughout C3–C7. There was a statistically significant difference between males and females. The AP diameter of the spinal canal was similar for both genders, with no statistically significant difference between them. The mean canal-to-body ratio was significantly larger in females than in males, with a statistically significant difference between males and females at each spinal level.

Conclusion Females had a larger canal-to-body ratio, and men had a significantly lower one. The canal-to-body ratio method was thought to be superior to the absolute value of the AP diameter of the spinal canal for the diagnosis of canal stenosis.

Keywords
- cervical vertebrae
- gender
- magnetic resonance imaging
- myelopathy
- vertebral body

Introduction

Myelopathy is a condition that develops when the spinal cord is severely compressed. Many disorders, including congenital stenosis, degenerative alterations, rheumatoid arthritis, and trauma, can cause it.[1] Patients with cervical spondylotic myelopathy (CSM) frequently complain of neck pain, radicular pain, numbness, paresthesia, muscle weakness, and

DOI https://doi.org/10.1055/s-0044-1790530.
ISSN 2582-4287.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

upper extremity stiffness.[2] It mainly affects male patients, and its clinical symptoms like hyperreflexia, gait, and coordination issues eventually proceed with changes to the upper motor neuron.[3]

A significant risk factor for CSM has been identified as developmental spinal canal stenosis. Many investigations were conducted to evaluate the dimensions of the cervical vertebral canal using radiography and computed tomography (CT) images.[4] Numerous methods are employed to measure the cervical spinal canal's size. Plain radiographs cannot accurately assess the cervical canal's diameter since direct measurements are prone to inaccuracy due to magnification.[5,6]

The cervical vertebral body and spinal canal must be precisely measured for accurate diagnosis, prognosis, and treatment of diseases affecting the cervical spine and spinal cord, such as spinal stenosis and intraspinal tumors. The anteroposterior (AP) diameter of the spinal canal is the most accurate midline sagittal dimension, according to an analysis of radiography, CT, and magnetic resonance (MR) images.[7]

The cervical spinal canal's dimensions are measured using various procedures. The assessment of osseous structures is possible primarily with routine CT scans. CT provides advantages over traditional radiography since it allows for direct measurement of dimensions. Spinal canal diameters examined with CT vary and correlate poorly with clinical findings. A CT imaging study comparing cervical spine–injured patients and control participants found that the shape of the spinal canal, rather than the area, can increase the likelihood of spinal cord damage.[5]

The canal-to-body ratio, also known as the Torg–Pavlov ratio, is the radiologic measurement that is most commonly used on conventional radiographs.[5] Torg et al and Pavlov et al looked at how the size of the sagittal spinal canal develops in athletes who momentarily experience cervical spinal neurapraxia after sports-related injuries. To diagnose growing spinal canal stenosis, they measured the sagittal spinal canal-to-vertebral body ratio in general radiography.[8,25]

Plain radiographs can identify osseous structures but not soft-tissue abnormalities, which are a significant cause of cervical spinal canal stenosis. The AP diameter of the cervical spinal canal is well established as a primary factor of myelopathy. The most accurate way to measure the developing stenosis of the cervical spinal canal is lateral plane radiography. Magnification mistakes can occur while doing measurements on plain radiographs.[9] magnetic resonance imaging (MRI) is noninvasive and accurately measures the dimensions of the spinal canal and spinal cord in various planes that are important for functional purposes and also allow for the evaluation of both soft-tissue and bone abnormalities.[5]

It has been proven that males are more likely than females to develop cervical myelopathy. So, one of the factors contributing to myelopathy is gender. According to several research, having a prominent cervical spine vertebral body increases your risk of developing myelopathy.[10,11] Therefore, this study's goal was to assess the gender disparity, using the canal-to-body ratio by estimating the height of the vertebrae, AP diameter of the vertebral body, and spinal canal.

Materials and Methods

This prospective cross-sectional observational study was conducted from April 2022 to March 2023 in the Department of Radiodiagnosis and Imaging of Justice KS Hegde charitable hospital. Ethical clearance was taken from the Institutional Ethical Committee.

This study included all the patients who were referred to MRI cervical spine who were within the age group of 20 to 40 years. The exclusion criteria include patients with congenital anomalies and trauma patients. Importantly, age matching was employed to ensure parity between the male and female groups. This process involved selecting participants so that the age distribution was comparable between the genders within the specified 20- to 40-year age range. This study included all patients referred for MRI of the cervical spine within the 20 to 40-year age range. Patients with congenital anomalies and those with a history of trauma were excluded. To ensure comparability between the male and female groups, age matching was employed. This involved selecting participants so that the age distribution was similar across genders within the specified age range. The sample size estimated was 59 in each group and an overall 118 patients were included in this study using the following formula:

$$N = \frac{[Z \propto /2 + Z\,\beta\,]^2 \sigma^2}{d^2}$$

where ($Z \propto /2 = 1.96$ and $Z\,\beta = 0.84$), σ = population variance, and d = difference.

Patients were screened for any metallic objects, and a proper patient history was taken for any surgical intervention involving implant placement that was not MR compatible. Written informed consent was obtained from all the participants undergoing the scan, and they were then asked to change into a hospital gown.

The patient was placed in the supine position in the head first orientation with the arms extended alongside the body. A dedicated neck coil was placed and centered on the mandibular symphysis. Foam pads were placed under the knee for comfort and stabilization of the patient, and earplugs and blankets were provided. MR images were acquired with the help of a 1.5-T MRI scanner (Siemens Magnetom Avanto—a TIM + DOT system). Conventional routine sequences of the cervical spine were performed. The parameter analysis used a T2 turbo spin echo sagittal sequence with a 3-mm slice thickness.

After the scan, from the sagittal plane, the vertebral height, vertebral body's AP diameter, and spinal canal's AP diameter from the C3 vertebrae to C7 vertebrae were measured in picture archiving and communication system (PACS) using a measurement tool, and values were recorded.[7,11] The height of the vertebrae was measured from the superior edge to the inferior edge of the vertebrae in the middle. The vertebral body's AP diameter was measured from the anterior border to the posterior border at the center of the vertebrae. The spinal canal's AP diameter was measured from the spinal canal's anterior border to the spinal canal's posterior border (►Fig. 1). Then, the canal-to-body ratio was calculated by dividing the spinal canal's AP diameter by the vertebral body's AP diameter.

Statistical Analysis

Statistical analysis of the data was performed using Statistical Package for Social Sciences (SPSS) 20.0 software. The descriptive statistics have been presented using mean and standard deviation. A comparison between the groups was done using an unpaired *t*-test. The correlation was performed using Karl Pearson's coefficient of correlation. A *p*-value less than 0.05 was considered statistically significant.

Results

Descriptive statistics of vertebral height, AP diameter of the vertebral body, AP diameter of the spinal canal, and canal-to-body ratio in the third to seventh cervical vertebrae were expressed using mean and standard deviation.

►**Table 1** analyzes the vertebral height, AP diameter of the vertebral body, AP diameter of the spinal canal, and canal-to-body ratio in males and females at each vertebral level.

The vertebral height is significantly higher in males compared with females. There was statistical significance between males and females at each vertebral level with a *p*-value less than 0.001.

The width of the vertebral body was measured from the anterior border to the posterior border at the center of the vertebrae. As shown in ►**Table 1**, males have larger values for the AP diameter of each vertebral level (C3–C7) than females. With *p*-values less than 0.05, there was a statistically significant difference between males and females.

The AP diameter of the spinal canal was measured from the spinal canal's anterior border to the spinal canal's posterior border (posterior to the corresponding vertebrae). ►**Table 1** illustrates the AP diameter of the spinal canal that is similar in both males and females. There is no statistically significant difference between males and females and it demonstrates the nonsignificance of the AP diameter of the spinal canal in males and females.

After measuring the AP diameter of the vertebral body and the AP diameter of the spinal canal, the canal-to-body ratio was calculated. ►**Table 1** shows the canal-to-body ratio that is larger in females than in males with a statistically significant difference ($p < 0.05$).

Regression analysis was performed using Karl Pearson's coefficient of correlation. It showed that the height of the vertebral body was not correlated with the size of the spinal canal at any measured level in both sexes. In contrast, the AP diameter of the vertebral body was significantly correlated with a spinal canal in females at all measured segments, but in males, there was significant correlation only at the level of C5 and C6 vertebrae.

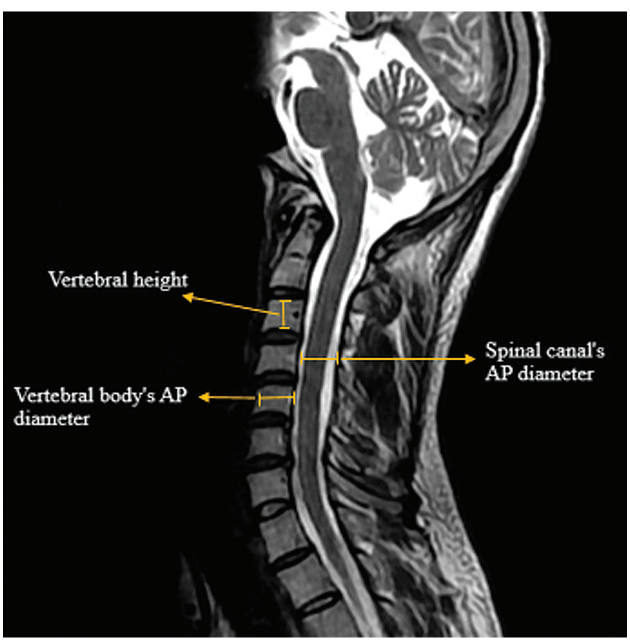

Fig. 1 Measurement of the height of the vertebral body, vertebral body's anteroposterior (AP) diameter, and spinal canal's AP diameter.

Discussion

CSM is the most common type of spinal cord injury in adults. The most frequent nontraumatic cause of myelopathy in the cervical spine is cervical spondylosis. This progressive condition causes degenerative changes in the vertebrae, intervertebral disks, facets, and connected ligaments. CSM is caused by these changes directly compressing the spinal cord and surrounding blood vessels.[11,12]

The most common causes of cervical spinal canal stenosis include disk degeneration with a narrow vertebral body-to-canal ratio, hypertrophic osteoarthropathy, and hypertrophic soft tissue.[11] AP and lateral radiographs can detect spinal alignment and the Torg–Pavlov ratio, which is lower in CSM patients.[13] Plain radiographs are unreliable for determining the diameter of the cervical canal because direct measurements are vulnerable to fluctuation owing to magnification.[6]

A CT myelogram can be performed as a near-equivalent test for patients who cannot get an MRI. CT images can be used for preoperative evaluation and planning, as well as for assessing the transverse foramen of each cervical vertebrae through which the vertebral arteries travel. Because of its noninvasive nature, excellent resolution, and capacity to view soft tissues, MRI is favored for conclusive assessment, and with the easy availability of MR scanning, the area of the spinal canal can now be precisely calculated.[13,14]

Many investigations on various populations have been conducted on the vertebral body, spinal canal, and canal-to-body ratio. These studies proposed various values of the usual range of this dimension in different groups, such as age, gender, and race. The variations caused were not just by genetic and hormonal reasons but by magnification issues with plain X-rays (from either source to image distance (SID) or the shadow of the shoulder). To address these disparities, Torg et al and Pavlov et al assessed cervical spinal canal stenosis with a different approach than the "ratio method"

Table 1 Comparison of the vertebral height, anteroposterior (AP) diameter of the vertebral body, AP diameter of the spinal canal, and canal-to-body ratio of each vertebral level among genders

Vertebral level	Vertebral height		*p* value
	Male	Female	
C3	11.36 ± 1.30	10.05 ± 1.16	0.001
C4	10.80 ± 1.25	9.48 ± 1.09	0.001
C5	10.5 ± 1.09	9.29 ± 1.10	0.001
C6	10.59 ± 0.97	9.35 ± 1.03	0.001
C7	12.56 ± 1.04	11.10 ± 1.12	0.001
Vertebral level	**AP diameter of vertebral body**		***p* value**
	Male	**Female**	
C3	14.80 ± 1.57	13.23 ± 1.20	0.001
C4	14.63 ± 1.56	13.14 ± 1.46	0.001
C5	14.24 ± 1.65	12.75 ± 1.52	0.001
C6	14.78 ± 1.74	13.21 ± 1.49	0.001
C7	15.27 ± 1.58	13.53 ± 1.52	0.001
Vertebral level	**AP diameter of spinal canal**		***p* value**
	Male	**Female**	
C3	13.09 ± 1.43	13.09 ± 1.36	0.984
C4	12.85 ± 1.28	12.74 ± 1.26	0.649
C5	13.01 ± 1.23	12.88 ± 1.22	0.568
C6	12.94 ± 1.12	13.10 ± 1.13	0.445
C7	13.07 ± 0.99	13.24 ± 1.14	0.389
Vertebral level	**Canal-to-body ratio**		***p* value**
	Male	**Female**	
C3	0.89 ± 1.60	1.00 ± 1.60	0.001
C4	0.89 ± 1.48	0.98 ± 1.83	0.002
C5	0.93 ± 1.67	1.03 ± 1.85	0.001
C6	0.89 ± 1.47	1.01 ± 1.76	0.000
C7	0.86 ± 1.22	1.00 ± 1.67	0.001

Note: A *p*-value less than 0.05 was considered statistically significant.

that compares the sagittal diameter of the spinal canal with the AP width of the vertebral body.[15] The Torg ratio (canal-to-body ratio) accurately identifies substantial cervical spinal stenosis.[16] MRI and CT scans are favored for diagnosing cervical spinal canal stenosis.[14]

In the current study, the vertebral height and the AP diameter of the vertebral body were more significant in males than in females, with a *p*-value less than 0.05. According to the study by Hukuda and Kojima[11] from spinal vertebrae C3 to C7, the height and AP diameter of the vertebral body were more significant in males than in females. In a study by Morales-Avalos et al,[17] the AP diameter of the vertebral body was greater in men than in women. They discovered that the vertebral body's AP diameter in men tends to grow larger as they age, while it increases in women from the age of 18 to 59 years and then declines around the age of 60 years. For the age group of 18 to 39 years, the mean diameter at the C3 vertebral level is 15.58 ± 1.50 mm in men and 13.71 ± 0.78 mm in women. For patients aged 40 to 59 years, the mean diameter is 15.70 ± 1.60 mm in men and 13.89 ± 0.85 mm in women, and for those aged ≥60 years, the mean diameter is 15.80 ± 1.46 and 13.86 ± 1.22 mm for males and females, respectively. Similarly, there was an observed increase in vertebral body diameter across each vertebra from C4 to C7, corresponding to the age range.[17]

In a study conducted by Kathole et al,[18] the mean AP diameter of the spinal canal was lower in females than in males. The AP diameters of the cervical spinal canal and vertebral bodies in males and females exhibited a statistically significant difference ($p \leq 0.05$), demonstrating sexual dimorphism. In a study conducted by Morales-Avalos et al,[17] in all age groups and at all cervical spinal levels, men had a larger AP diameter of the spinal canal than women, with a statistically significant difference ($p \leq 0.05$). However, the present study found no statistically significant difference in the AP diameter of the spinal canal between males and females. Similarly, the outcome of the study by Hukuda and Kojima in Japanese population. The spinal canal AP diameter was identical for males and females, with no statistically significant difference.[11]

The regression analysis revealed that the height of the vertebral body was not correlated with the size of the spinal canal at any measured segment in both sexes, whereas the AP diameter of the vertebral body strongly correlated with the size of the spinal canal in females. But in males, there was a positive correlation only at C5 and C6 level, but not in other segments such as C3, C4, and C7. According to the study of Hukuda and Kojima,[11] there was no correlation between the vertebral height and the size of the spinal canal in both sexes, but there was a significant correlation between the AP diameter of the vertebral body and the size of the spinal canal in males but not in females.

Significantly lower canal-to-body ratio values indicate developmental cervical spinal canal stenosis.[9] In the present study, we found that the canal-to-body ratio was larger in females than in males. There was a statistically significant difference between males and females at all vertebral levels, with a p-value less than 0.05. A study conducted by Morales-Avalos et al[17] categorized patients into three age groups, including the age ranges of 18 to 39, 40 to 59, and $\geq$60 years. They concluded that across all age categories and spinal levels of the vertebrae, women had larger canal-to-body ratios than men. In particular, the second and third age categories had a statistically significant difference in the mean canal-to-body ratios ($p < 0.05$). In a study by Rijal et al,[19] the mean canal-to-body ratio of the C4 to C7 spinal level was higher in females except at the C3 level, which was identical in both genders. In a study by Lee et al,[20] the mean canal-to-body ratio was significantly lower in male patients than in female patients, and older male patients were more likely to be at an increased risk of spinal stenosis. These findings are crucial evidence for predicting future spinal disorders in patients with cervical spinal canal stenosis.

Many studies on the canal-to-body ratio in different populations showed similar results as the current study.[11,12,18,21–23] However, according to Pavlov et al,[24] there were no statistical differences in the spinal canal/vertebral body ratios between genders.

The study by Toki et al[4] categorized myelopathic and nonmyelopathic groups in males and females. They calculated the mean canal-to-body ratio in males and females separately. The male myelopathy group had a lower canal-to-body ratio than the nonmyelopathy group, and the female myelopathy group had a lower canal-to-body ratio than the nonmyelopathy group. When compared between males and females, the male myelopathy group had a lower canal-to-body ratio than females. A similar result was found in the Singapore population, that is, the male myelopathy group had a lower canal-to-body ratio.[22]

The participants in this study underwent MRI rather than CT and plain radiography because it is invasive and accurately measures the spinal canal and spinal cord in various planes. This study reveals a sex discrepancy in the canal-to-body ratio of the cervical spine, which may contribute to the higher prevalence of cervical myelopathy in men.

A comparative study of normal and cervical myelopathic patients could be conducted to clearly identify sex-based differences. Additionally, future research could compare age and ethnicity to strengthen the study further.

Limitations

This study has some limitations that includes the limited sample size. The sample size was small, and we compared only young patients between the ages of 20 and 40 to determine the canal-to-body ratio between males and females. We had no control group, and we compared normal patients with no symptoms related to cervical myelopathy. There was no comparison between age and ethnicity in our study.

Ethical Approval

Ethical approval is taken from the Institutional Ethical Committee with letter number INST.EC/EC/027/2022.

Consent to Participate and Publish

Informed consent was taken from all the participants.

Conflict of Interest

None declared.

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