ORIGINAL ARTICLE https://doi.org/10.3126/njr.v12i1.46795

Measurement of Space Available for Cord of Cervical Spine in MRI

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Received: April 6, 2022 **Accepted:** May 6, 2022 **Published:** June 30, 2022

Cite this paper:
Gwachha S, Joshi BR. Measurement of Space Available for Cord of Cervical Spine in MRI. *Nepalese Journal of Radiology*.2022;12(1):2-7. https://doi.org/10.3126/njr.v12i1.46795

ABSTRACT

Introduction:
Cervical spinal stenosis has been established as a predisposing factor of cervical myelopathy and is associated with cord injury. Space available for the cord (SAC) can be used as an indicator of spinal stenosis.

Methods:
This study was performed on patients referred for MRI examinations of the cervical spine for various clinical indications to a tertiary centre in Nepal. Data were collected for a period of four months from January to April after IRB approval. Convenience sampling was employed and a total of 72 examinations were included. Data were obtained from the 1.5T Magnetom Amira Siemens MRI scanner. Sagittal diameters of the spinal canal and spinal cord were traced and measured from C3 to the C7 vertebra. The space available for the spinal cord (SAC) was calculated by subtracting the sagittal cord diameter from the corresponding sagittal canal diameter.

Results:
The average space available for cord was 4.48mm±1.04mm at C3, 4.44mm±1.03mm at C4, 4.63mm±1.01mm at C5, 5.11mm±1.07mm at C6, 5.87mm±1.14mm at C7 vertebral level. The SAC value was not significant according to gender and age ($p>0.05$).

Conclusions:
The smallest SAC value was detected at the C4 vertebral level with a mean value of 4.44mm and the greatest value was at C7 vertebral level with a mean value of 5.87mm. There was no significant gender difference in SAC values.

Keywords: *Magnetic Resonance Imaging; Spinal Canal; Spinal Stenosis*

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INTRODUCTION

Cervical spinal stenosis has been established as a predisposing factor of cervical myelopathy and is associated with cord injury.[1] The progressive compression of the spinal cord may lead to spinal cord ischemia.[2] Evaluation of critical spinal canal stenosis using Torg's ratio and space available for cord enables discrimination between a patient at risk for cervical spinal cord injury and those not at risk.[3] Space available for the cord (SAC) can be used as an indicator of spinal stenosis. SAC is determined by subtracting the sagittal diameter of the spinal cord from the sagittal diameter of the spinal canal. Since stenosis is due to spinal canal encroachment on the spinal cord and spinal cord varies among individuals, SAC may be more effective for identifying stenosis. The objective of this study was to measure the space available for a cord of the cervical spine and to compare males and females from different age groups.

METHODS

This descriptive, cross-sectional study was performed on patients referred for magnetic resonance imaging (MRI) examinations of the cervical spine and screening of the cervical spine for various clinical_indications to the Department of Radiology and Imaging of a tertiary hospital in Nepal. Data were collected for a period of four months from January to April 2021 after IRB approval. Non-probability convenience sampling was employed and a total of 72 examinations were included. Patients with a history of cervical trauma or cervical surgery were excluded from the study. Data were obtained from the 1.5T Magnetom Amira Siemens MRI scanner. Informed consent forms were taken from the patients meeting the inclusion criteria. The Routine department protocol was followed for the cervical spine examinations. The patients were thoroughly screened as per department guidelines for any ferromagnetic material. The routinely performed department protocol were as follows:

- T2 TSE SAGITTAL:FOV-250 cm, slice thickness- 3mm, slice gap-10%,TR3500ms,TE-86,Matrix- 256 x256,NEX-2.
- T1 TSE SAGITTAL:FOV-250 cm, slice thickness- 3mm, slice gap-10%,TR660ms,TE-9.9ms,Matrix- 256x256,NEX-2.
- T2 STIR SAGITTAL:FOV-280 cm, slice thickness- 3mm, slice gap-10%,TR3870ms, TE-86ms,TI-130ms, Flip angle-130,Matrix-256x256,NEX-2. • T2 TSE AXIAL-FOV-200 cm, slice thickness- 3.5mm, slice gap-40%,TR4000ms,TE-86ms, Flip angle-130,Matrix- 256x256,NEX-2.
- T1 TSE AXIAL:FOV-180 cm, slice thickness-3.5mm, slice gap-40%,TR550ms,TE-12ms, Flip angle-130,Matrix- 256x256,NEX-2.

Measurements were taken from the midsagittal T2W image. Sagittal diameters of the spinal canal and spinal cord were traced and measured from the C3-C7 vertebra. The sagittal 16 spinal canal diameter was measured as the shortest distance from the midpoint between the vertebral body's superior and inferior endplates of the vertebral body to the spinolaminar line. The sagittal spinal cord diameter was measured at the transversal midline of the vertebral body at the same level. Three subsequent measurements were taken at the same level of each vertebra to reduce the intraobserver variability. The average of three such measurements was recorded. The space available for the spinal cord (SAC) was calculated by subtracting the sagittal cord diameter from the corresponding sagittal canal diameter. [Figure. 1]

Figure 1: Midsagittal T2 weighted image of the cervical spine with the measurements

Mean, standard deviation, minimum value, maximum value, and range were calculated for the patient parameter (age and gender). One way ANOVA test was used to compare the mean value of SAC in different age groups. A p-value of 0.05 was considered for statistical significance. All the statistics and the data were calculated using SPSS version 25 and MS Excel 2007.

RESULTS

A total of 72 patients were included in the study. Among them, 45.8%[33] were male and 54.1% [39]were female. The mean age was 41.46±14.53 with a minimum age of 20 years and maximum age was 77 years. The highest sagittal spinal canal diameter was at C6 vertebral level at 12.55±1.14mm whereas the lowest sagittal spinal canal diameter was at C4 vertebral level at 12.19mm±1.11mm. The greatest sagittal spinal cord diameter was 7.75mm±0.70mm at C4 and the least spinal cord diameter was 6.15 mm ±.65mm at C7. [Table 1]

The average space available for the cord was4.44mm ± 1.03mm at C4 and 5.87mm ± 1.14mm at C7. The SAC value was more in males than in females at C4, C5, C6 and C7 vertebral levels. However, it was more in females than in males at the C3 level. [Table 2]

One way ANOVA test was used to compare means of SAC in different age groups. There was no significant difference between age and SAC.

DISCUSSION

Spinal stenosis may result in compression of the spinal cord and nerve roots and cause symptoms associated with cervical radiculopathy or cervical myelopathy. Paynee et al. stated the narrowing of spinal canal diameter as a good indicator of spinal canal stenosis by measuring spinal canal diameter in plain radiograph in his study carried out in 1957.[4] In our study we found the average sagittal canal diameter from C3 to C7 level as 12.24mm,12 .19mm,12.20mm,12.55mm,12.36mm respectively. A study carried out by Morishita et al. reported the average sagittal diameter from C3 to C7 level to be 13.73mm±1.37mm.[6] Using 469 cadaver specimens, Lee et al. reported that the mean sagittal cervical canal diameter from C3 to C7 level was 14.1mm±1.6mm.[8] The spinal canal diameter results of our study and that of Morishita et al. have comparatively lesser value than the study of Lee et al.[6,8] This may be because our measurements and the measurements carried out by Morishita et al. were obtained using MRI and hence soft-tissue structures might have influenced these studies.[6]

Table1: Descriptive statistics of the spinal canal and cord diameter at different cervical vertebral regions

Spinal Canal Level	Minimum (mm)		Maximum (mm)		Mean (mm)		Standard deviation (mm)	
	Spinal Canal Diameter	Spinal Cord Diameter	Spinal Canal Diameter	Spinal Cord Diameter	Spinal Canal Diameter	Spinal Cord Diameter	Spinal Canal Diameter	Spinal Cord Diameter
C3	9.93	5.96	15.56	9.20	12.24	7.72	±1.17	±0.75
C4	10.00	6.20	14.90	9.96	12.19	7.75	±1.11	±0.70
C5	9.86	6.46	14.56	9.30	12.20	7.56	±1.06	±0.59
C6	9.86	5.86	15.00	9.13	12.55	7.12	±1.14	±0.65
C7	10.10	5.13	15.13	8.46	12.36	6.15	±1.07	±0.65

Table 2: Values of SAC in males and females

SAC and SEX	Mean (mm)	Standard deviation (mm)	p-value
C3			
Male	4.44	±1.13	0.75
Female	4.52	±.97	
C4			
Male	4.52	±1.20	0.57
Female	4.38	±.88	
C5			
Male	4.67	±1.04	0.75
Female	4.60	±1.00	
C6			
Male	5.16	±1.21	0.69
Female	5.06	±.96	
C7			
Male	6.08	±1.37	0.16
Female	5.70	±.88	

Table 3: Mean SAC value at different cervical vertebral in different age group

Age group	C3 (mm)	C4 (mm)	C5 (mm)	C6 (mm)	C7 (mm)
20-30	4.63±0.64	4.45±0.73	4.80±0.91	5.15±0.91	5.70±0.88
30-40	4.23±1.14	4.25±1.22	4.33±1.19	4.90±1.18	5.50±1.20
40-50	4.65±1.38	4.61±1.09	4.87±0.98	5.32±1.13	6.16±1.37
50-60	4.32±1.07	4.17±1.15	4.44±0.95	4.68±1.17	5.82±1.07
60-70	4.47±0.59	4.98±1.04	4.44±0.86	5.67±0.39	6.50±0.80
70-80	4.82±0.92	5.04±0.40	5.20±0.98	5.87±0.66	6.67±1.02

In a study performed on the North Bengal population by Kar et al. using MRI, they reported the average sagittal canal diameter was 11.99mm±1.34mm in males and 12.15mm±1.24 mm in the females which is similar to our study.[13] In a study carried out in the eastern Nepalese population by Singh et al. using plain radiograph, they measured the average sagittal canal diameter as 17.18mm±1.67mm which is slightly higher than in our study.[10] This may be because of variations in magnification and the distance from the X-ray source to the film as well as from the subject to the film as these can confound the measurements.

Torg et al. devised the Torg's ratio (also known as the Pavlov ratio) which compares the sagittal diameter of the spinal canal with the anteroposterior width of the vertebral body both of which are equally affected by radiological magnification factors.[5] Torg's ratio is independent of magnification factors caused by differences in target distance, object-to-film distance, or body type. Since Torg's ratio depends on the vertebral body also, the ratio was lesser in males and athletes who have a comparatively larger vertebral body. Herzog et al. clarified the reason behind the false-positive results of Torg's ratio in his study.[11] Tierney et al. compared Torg's ratio and SAC and stated that SAC is a better indicator of stenosis.[7]

SAC was calculated as the difference between sagittal spinal canal diameter and sagittal spinal

cord diameter. In our study, we measured the greatest spinal cord diameter at C4 vertebral level. This enlargement might have occurred because of the increased neural tissue required for the brachial plexus. The average sagittal spinal cord diameter was 7.72mm ± 0.75 mm at C3, 7.75mm ± 0.70 mm at C4, 7.56mm ± 0.59mm at C5, 7.12mm ± 0.65mm at C6 and 6.15mm ± 0.65mm at C7 vertebral level. This is similar to a study carried out by Sherman et al. and Kar et al. [12,13]

The maximum SAC value was noted at the C7 vertebral level [5.78mm] and the minimum SAC was noted at C4 vertebral level. Tierney et al. found that SAC ranged from 2.5 to 10.4 mm and was maximum at C7 and minimum at C3 and C5 in 71% of the subjects.[7] Kar et al. found the SAC value in males to be 4.84+1.47 mm and in females 5.2+1.380 mm.[13] A similar result was observed in a study on the Nigerian population in which they recorded the mean SAC as 4.9mm±1.4 mm(C3/4), 4.5mm±1.2 mm (C4/5), 4.6mm±1.4 mm (C5/6), 4.9mm±1.2 mm (C6/7). The findings from this study revealed that the C4/5 and C5/6 levels were the narrowest segments in the subaxial cervical spine. In the Macedonian population, Matveevea et al. noted that at C7 the average SAC was maximum, 9.25 mm ± 1.76 in males, and 8.9 mm ± 1.38 in females.[15] However, the SAC value was slightly lower in our study than that of the Macedonian population. This may be due to racial differences. [15]

There was no significant difference in SAC values between the sexes as observed in our study. This finding was similar to the finding of a study carried out on the North Indian population. Similarly, there was no significant difference in the Nigerian population either. This was further supported by the observations of the Macedonian population.

When we compared the mean SAC value in different age groups, there was no significant difference. However, in a study performed on the Caucasian population by Nell et al., they provided a range value of 3-10mm in males as and 2-9 mm in females as the normal value.[14] Age had a significant effect on SAC according to that study. This was further supported by the study of the Nigerian population performed by Ndubuisi et al.[9] Age contributed as high as 11.8% effect to the variations in the values of SAC in their study. The findings of low SAC may also indicate an increased predisposition of the study population to the possible risk of posttraumatic and degenerative myelopathy, especially around the C4 level. Individuals with small SAC or sagittal canal dimensions are at an increased risk of myelopathy as well as recurrence of neurapraxia.[15] A low SAC value increases the risk of neurological injury and its recurrence.[16] Many research reports showed that fewer SAC values are associated with an increased risk of cervical-cord neuropraxia episodes. Herzog et al. recommended that SAC was of great importance if the symptomatic individuals had a Torg's ratio less than 0.80 or a sagittal spinal-canal diameter value less than 12.5 mm.[11]

This study has helped to establish baseline values for SAC as a more direct cervical canal stenosis indicator for this study population. These values will form a useful baseline for further studies. It will also provide a base for clinical screening, early identification of individuals with a pre-existing threat to the cervical spinal cord and follow-up of patients for early surgical decision making. Early identification and advice would help to reduce the risk of exposure from participation in certain high risk occupational, social and contact sports activities for individuals with increased predisposition to cervical spinal cord injury from pre-existing congenital or acquired canal stenosis, especially at a relatively young age. [12]

One limitation of our study included a small number of normal subjects. The average of three measurements was recorded at each vertebral level for spinal canal diameter and spinal cord diameter to reduce the intraobserver variability. However, measurement biases may have occurred. Another limitation of this study is its clinical relevance because radiographs may be more routinely included as a screening method.

CONCLUSION

The smallest SAC value was found at the C4 level with a mean value of 4.44mm and the greatest value was at the C7 level with a mean value of 5.87mm. There was no significant gender difference in SAC values. The age factor did not affect the SAC value.

CONFLICT OF INTEREST

None

SOURCES OF FUNDING

None

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