Original Article

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A Study to Find Normal Dimensions of Spinal Cord on MRI in Indian Population

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Abstract

Background: Knowledge of normal measurements of the spinal cord is essential in diagnosing and interpreting various spinal disorders. There is sparse data on normal morphometry of spinal cord in Indian population. Aims and objectives: To obtain dimensions of the human spinal cord, at various vertebral levels in normal population on MRI. **Subjects and Methods:** A cross sectional observational study was done on 60 healthy subjects aged between 20 to 40 years who underwent MRI in a tertiary care centre from December 2017 to Dec 2018. Dimensions of the multiple segments of human spinal cord were measured in Antero-posterior and transverse diameters at each level by high resolution T2-weighted images by 1.5 T Philips MR System Achieva. **Results:** Mean age of subjects was 28 years. In the cervical segment, the AP diameter of the spinal cord was greatest at C1 (7.74 mm in males, 6.63 mm in females) and lowest at C7. The Transverse diameter decreased from C1 to C2 level, and then increased from C2 to C5, with C5 (12.84 mm in males and 11.55 mm in females) being the maximum enlarged segment and then decreased towards C7. In the upper thoracic cord, the AP diameter and transverse diameter was maximum at D1 and decreased gradually from D1 to D6. In the lower thoracic cord, the AP diameter and transverse diameter was maximum at D12. **Conclusion:** Spinal cord dimensions vary at different segments and also between males and females. Hence, there is a need to establish normal reference values of spinal cord diameters at various levels.

Keywords: Spinal Cord, Morphometry, MRI Spine, Antero-Posterior Diameter, Transverse Diameter

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Introduction

MRI of the spine is a frequently performed investigation in everyday practice. Perplexing subtle Spinal cord signal abnormalities are often encountered on imaging which together with an arbitrary sense of altered Cord dimensions can add to the dilemma of the reporting Radiologists.[1] Establishing the normal dimensions of spinal cord at various levels in various subsets of population will provide more objective method of assessing spinal cord signal abnormalities and arrive at a plausible diagnosis along with clinical data.[2-6]

There have been only few studies worldwide and in India establishing normal reference metric data of spinal cord. This study was done to obtain normal measurements of the spinal cord on MRI at various levels.

Subjects and Methods

This study was conducted in a tertiary care hospital after taking Institutional review board clearance. Individuals of age group between 20 to 40 years were included in the study. Sample size calculation was done using Medical Calculation software version 12, at 99% confidence level and 80% power of study. Sample size calculated was 60.

The study was a cross sectional observational study. All the eligible subjects were recruited into the study consecutively till the effective sample size was reached. The data collection for the study was done between Dec 2017 to Dec 2018. Any subject, who on MRI may be found to have Compressive Myelopathy, perception of cord atrophy/enlargement, Spinal cord/ spinal canal tumors, any other pathology affecting the spinal cord directly or indirectly were intended to be excluded from the study.

After obtaining the informed consent the study subjects underwent MRI by 1.5 Tesla Philips Achieva MR system. Imaging was done in supine position with a spine coil. After acquiring survey images in all the three planes, whole spine T2 sagittal images were acquired and axial T2 acquisition was planned on Sagittal images, at each midvertebral level from C1 to D12 perpendicular to the spinal cord axis.

AP (anterio-posterior) and transverse diameters of spinal cord were measured at each midvertebral level from C1(first Cervical) to D12 (12th Dorsal) vertebrae on the high resolution T2-weighted Axial images using digital calipers available on the Philips workstation. [Figure 1]

The data was tabulated in Microsoft Excel 2016 datasheet.

Mean and standard deviation of quantitative variables and frequency and proportion of categorical variables were calculated. Non-normally distributed quantitative variables were summarized by median and interquartile range (IQR). Shapiro- wilk test was also conducted to assess normal distribution. Shapiro wilk test p value of >0.05 was considered as normal distribution. For normally distributed Quantitative parameters (Spinal cord dimensions) the mean values were compared between males and females using Independent sample t-test (2 groups) and P value < 0.05 was considered statistically significant. IBM SPSS version 22 was used for statistical analysis.

Results

A total 60 people were included in the final analysis. The mean of age of the subjects was 28.03 years ± 5.75 years. Minimum age was 20 years and maximum was 40 years in the study population. Among the study population 41(68.33%) people were aged between 20 and 30 years and 19(31.67%) were aged between 31 to 40years. Among the study population 30(50%) were males and remaining 30(50%) were females.

The mean cervical cord anterior posterior diameter at all the levels in males was 6.85 ± 0.53 mm and it was 6.41 ± 0.38 mm for females. There was statistically significant difference between males and females in their Cord AP diameters at C1, C2, C3 and also average cervical cord anterior posterior diameter (P value <0.05 for all). However, there was no statistically significant difference in AP dimensions from C4 to C7 levels between males and females. [Table 1]

The mean of average cervical cord transverse diameter in males was 11.98 ± 0.72 mm and it was 11.02 ± 0.76 mm for females. There was statistically significant difference in transverse diameter of cord from C1 to C6 levels and also average cervical cord transverse diameter between males and females. [Table 2]

The mean of average Upper dorsal cord anterior posterior diameter (Dorsal 1 to Dorsal 6 midvertebral levels) in males was 5.87 ± 0.48 mm and it was 5.73 ± 0.30 mm for females. There was no statistically significant difference in AP dimension of the Upper dorsal cord among males and females. [Table 3]

The mean of average upper dorsal cord transverse diameter in males was 8.9 ± 0.83 mm and it was 8.88 ± 0.76 mm for females. There was no statistically significant difference in Upper dorsal cord transverse diameters among males and females. [Table 4]

The mean of average Lower dorsal cord (dorsal 7 to Dorsal 12 midvertebral levels) anterior posterior diameter in males was 6.3 ± 0.52 mm and it was 5.75 ± 0.32 mm for females. There was statistically significant difference in Lower dorsal cord AP diameters at all levels between males and females except at D8 level and average AP diameter. [Table 5]

The mean of average Lower dorsal cord transverse diameter in males was 7.96 + 0.58 mm and it was 7.98 + 0.80 mm for females. There was no statistically significant difference in lower dorsal cord transverse diameters between males and females. [Table 6]

Table 1: Comparison of Cervical cord anterior posterior diameter between males and females (N= 60)

Cervical cord anterior	Male			Female			P value
posterior diameter in mm	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
C1	7.74 ± 0.75	6.80	10.70	6.63 ± 0.73	5.60	8.30	<0.001
C2	7.49 ± 0.67	6.30	9.00	6.59 ± 0.65	5.50	8.50	<0.001
C3	7.1 ± 0.72	5.10	9.00	6.6 ± 0.65	5.80	7.90	.007
C4	6.78 ± 0.92	5.10	8.20	6.4 ± 0.51	5.40	7.40	.053
C5	6.64 ± 0.86	4.60	8.10	6.49 ± 0.59	5.50	8.10	.444
C6	6.32 ± 0.7	5.20	7.90	6.24 ± 0.43	5.30	6.90	.564
C7	5.91 ± 0.63	4.40	7.20	5.94 ± 0.38	5.10	6.50	.804
Average	6.85 ± 0.53	5.99	7.77	6.41 ± 0.38	5.56	7.43	<0.001

Table 2: Comparison of Cervical cord transverse diameter between males and females (N= 60)

Cervical cord	Male			Female			P value
transverse diameter in mm	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
C1	11.63 ± 0.82	9.90	13.20	10.82 ± 0.85	9.60	12.40	<0.001
C2	11.5 ± 0.82	9.40	12.90	10.61 ± 0.76	9.40	12.20	<0.001
C3	11.94 ± 0.95	9.80	13.60	11.1 ± 0.88	9.20	13.30	.001
C4	12.76 ± 1.04	10.70	14.80	11.31 ± 0.98	9.60	13.20	<0.001
C5	12.84 ± 0.93	11.40	15.60	11.55 ± 1.05	9.80	13.40	<0.001
C6	12.45 ± 1.26	9.90	15.00	11.21 ± 0.87	9.50	13.20	<0.001
C7	10.78 ± 1.26	7.60	14.80	10.56 ± 1.09	7.90	13.30	.486
Average	11.98 ± 0.72	10.33	13.66	11.02 ± 0.76	9.81	12.81	<0.001

Table 3: Comparison of upper dorsal cord anterior posterior diameter between males and females (N= 60)

Upper dorsal cord	Male			Female			P value
anterior posterior diameter in mm	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
D1	6.11 ± 0.67	5.00	7.00	5.89 ± 0.53	4.80	7.00	0.155
D2	5.98 ± 0.7	4.50	7.10	5.8 ± 0.51	4.60	6.90	0.269
D3	5.86 ± 0.77	4.50	7.20	5.73 ± 0.34	5.10	6.30	0.388
D4	5.88 ± 0.64	4.70	7.20	5.7 ± 0.41	5.00	6.60	0.199

D5	5.74 ± 0.71	4.50	7.50	5.65 ± 0.39	5.00	6.50	0.530
D6	5.69 ± 0.6	4.60	6.70	5.61 ± 0.42	4.90	6.60	0.588
Average	5.87 ± 0.48	5.05	6.77	5.73 ± 0.30	4.97	6.18	0.167

Table 4: Comparison of upper dorsal cord transverse diameter between males and females (N= 60)

Upper dorsal cord	Male			Female			P value
transverse diameter in mm	Mean ± SD	Min	Max	Mean ± SD	M in	Max	
D1	9.7 ± 1.04	8.00	12.40	9.54 ± 1.12	8.10	12.60	.569
D2	9.34 ± 1.01	8.00	11.80	9.23 ± 0.88	8.10	11.50	.665
D3	8.9 ± 0.99	6.70	11.00	8.86 ± 0.88		10.60	
D4	8.72 ± 0.91	7.30	10.40	8.89 ± 0.81		10.10	
D5	8.47 ± 0.94	6.90	10.50	8.53 ± 0.91			.782
D6	8.26 ± 0.89	6.70	10.30	8.24 ± 0.75		9.40	.913
Average	8.9 ± 0.83	7.72	10.92	8.88 ± 0.76	7.68	10.33	.932

Table 5: Comparison of Lower dorsal cord anterior posterior diameter between males and females (N= 60)

Lower dorsal cord anterior	Male			Female			P value
posterior diameter in mm	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
D7	5.72 ± 0.63	4.10	7.40	5.45 ± 0.39	5.00		0.048
D8	5.9 ± 0.82	4.60	7.80	5.59 ± 0.38	5.00	6.40	0.065
D9	6.25 ± 0.72	4.70	8.00	5.77 ± 0.63	5.00	8.10	0.008
D10	5.98 ± 0.71	5.00	7.80	5.77 ± 0.55	5.00	7.10	0.026
D11	6.56 ± 1	5.20	8.40	6.04 ± 0.74	5.10	8.20	0.011
D12	7 ± 1.16	4.30	9.20	5.88 ± 0.81	5.00	7.50	0.001
Average	6.3 ± 0.52	5.65	7.60	5.75 ± 0.32	5.12	6.55	<0.001

Table 6: Comparison of Lower dorsal cord transverse diameter between males and females.

Lower dorsal cord	Male			Female			P value
transverse diameter in mm	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
D7	7.74 ± 0.83	6.70	10.60	8.11 ± 1.03	6.20	9.90	.132
D8	7.54 ± 0.74	6.30	9.60	7.98 ± 1.08	6.00	10.60	.068
D9	7.72 ± 0.7	6.20	9.00	7.69 ± 1.03	5.70	9.80	.895
D10	8.19 ± 0.87	6.50	10.40	7.67 ± 0.96	6.10	9.20	.088
D11	8.24 ± 0.92	5.40	10.00	8.06 ± 0.84	6.70	9.60	.465
D12	8.51 ± 1.76	5.20	12.20	8.45 ± 1.19	6.50	10.70	.971
Average	7.96 ± 0.58	6.95	9.23	7.98 ± 0.80	6.43	9.67	.088

Discussion

Determination of pattern of spinal abnormalities on MRI studies and common findings in India with particular emphasis on the commonly requested MRI examinations is the need of the hour because of the paucity in literature. The objectives of our study were similar to that of done by Frostell A et al,[7] and Sherman JL et al.[8] They investigated the meaurements for whole spinal cord and cervical part of the spinal cord respectively. In our study, we evaluated the cervical and thoracic portions of the spinal cord. The mean age of subjects in our study was 28 years and majority(68%) of subjects were aged between 20 to 30 years. Sherman JL et al,[8] did their study on 66 randomly selected healthy subjects. In our study, we also compared the parameters between equal proportion of males and females

In our study, the AP diameter of spinal cord (neuronal segment) was greatest at C1. It gradually decreased from 7.74 mm at C1 in males and 6.63 mm in females till C7 vertebrae. It was lowest at the C7 vertebrae. Frostell A et al,[7] in their study also observed that the AP diameter was greatest at C1 and gradually decreased till C7. In their study, the AP diameter of spinal cord at C1 was 8.3 mm while it was 6.9 mm at C7. It was also lowest at the C7 vertebrae with regards to cervical segment.

Sherman JL et al,[8] in their study observed that the cord varies in average anteroposterior and transverse diameters from 8.8 mm x 12.4 mm at C2 to 8.7 mm x 14 mmat C4 to 7.4 mm x 11.4 mm at C7. They measured the anteroposterior and transverse diameters of the cord at each vertebral level and computed the simple product of these diameters to provide a single useful numerical value, termed the approximate cord area (ACA). Similarly In our study, there was statistically significant difference in the dimensions of the cervical spinal cord between males and females at several cervical and dorsal levels which is similar to the findings by Fang JH et al,[9] who found that the diameters of cervical spinal cord were larger in males than in females, decreased with age, and increased with the length of C-spine.

In the present study, transverse diameter of the spinal cord was found to decrease from C1 to C2 level and then increase from C2 to C5, with C5 being the maximum enlarged segment transversely and then decreased towards C7. In our study, transverse diameter of the spinal cord was largest at C5. The Transverse diameter at C5 level in males was 12.84 mm while it was 11.55 mm for females. Frostell A et al[7] in their study also observed that the spinal cord had the largest transverse diameter at spinal cord neuronal segment C5 (13.3 mm ± 2.2). Sherman JL et al[8] in their study observed that the cervical enlargement was found from C4 to C6 and was most evident by comparing the

ACA values. Ko HY et al,[10] in their study on post mortem subjects also observed that the transverse diameter was largest at segment C5, and decreased progressively to segment T8.

In our study, AP and transverse diameter of upper thoracic cord was maximum at D1 (6.11 mm and 9.7mm) while it decreased gradually from D1 to D6. Frostell A et al,[7] in their study also observed that the maximum transverse (6.9 mm) and AP diameter was observed at D1(10.7 mm).

In the current study the AP and transverse diameters of lower thoracic cord was maximum at D12. But Frostell A et al,[7] in their study observed that the maximum transverse (8.6mm) and AP diameter was observed at D9 and D10 (6.5 mm).They also observed there was not a specific increasing or decreasing pattern with respect to these diameters in lower thoracic cord which is similar to the findings in this study.

Continuous population estimates of the transverse and anteroposterior diameters of the spinal cord could be useful in diagnosing and monitoring patients with neurodegenerative and neuroinflammatory diseases.[11-15] Without population estimates, it can be difficult to determine whether a specific patient should be considered to have a pathologically small or large spinal cord.

Multiple experimental studies for treatment of acute and chronic human spinal cord injuries are in different phases of development, some of which intend to employ devices, or involve instrumentation.[11-15] Such spinal cord dimension reference values will guide the use of appropriate innovations and management strategies for spinal pathologies.

Conclusion

Spinal cord dimensions vary at different segments and also between males and females. Hence, establishing normal reference values of spinal cord diameters at various levels will provide valuable and objective criteria for diagnosing, understanding and mangement of various pathophysiologic conditions of the spinal cord.

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