Original Research Article

Measurement of normal reference values of spinal canal diameter and space available for cord (SAC) at mid sagittal level in cervical spine (C3 to C7) in adult East Indian population by MRI

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Abstract

Background: Assessment of cervical spinal stenosis, which is not very uncommon presentation among adult age group, is necessary for planning of the management protocol, especially regarding surgical intervention, if necessary. Specific measurements used for assessing spinal canal stenosis, the spinal canal diameter and space available for cord (SAC) at mid sagittal level are considered to be very important ones. **Materials & Methods:** To determine the normal range of the absolute values of these two parameters in the local population and their importance in predicting cervical canal stenosis, we selected 100 asymptomatic adult subjects of each of both sexes and 50 symptomatic subjects of each of both sexes. The parameters used in this study for assessment of cervical spinal canal stenosis were mid sagittal spinal canal diameter and the space available for the cord (SAC), which was measured using T2 weighted axial and sagittal MRI cuts at the respective vertebral level.**Results:** In our study, we analyzed 100 asymptomatic subjects by MRI study (T2 weighted sagittal and axial images) for determination of normal reference values of canal diameter and space available for cord in C3 to C7 vertebral body level. The values of canal diameter (mean +/- 2SD) in different levels were 12.0±3.3mm (C3); 12.0±2.32mm (C4); 12.0±2.32mm (C5); 12.0±2.3mm (C6); 12.6±2.62mm (C7) and the corresponding space available for cord values were 5.0±2.76mm (C3); 5.1±1.92mm (C4); 5.3±2.14mm (C5); 5.6±2.08mm (C6); 6.3±2.54mm (C7) levels.**Conclusion:** It is well recognized that mid sagittal spinal canal diameter and space available for the cord (SAC) in cervical vertebrae (C3 to C7) varies considerably in normal adult population of both the sexes and decrease in them will result in cervical stenosis symptoms. Knowledge of normal reference values of these two parameters in Indian population will be helpful for concerned researchers and the normal acceptable range of values will be very helpful for the clinicians to predict spinal canal stenosis and to decide for the necessity of surgical intervention.

Keywords: Spinal canal diameter, spinal canal space, cervical spine, mid sagittal level, cervical stenosis, magnetic resonance imaging (MRI)

Introduction

Cervical part of the vertebral column biomechanically is a complicated articular system of the body having many joints including involvement of six inter-vertebral discs. In comparison to other regions of the vertebral column this region has a high degree of different movements which may aggravate and complicate presentation of the different pathological conditions involving cervical spine and cord [1, 2]. Dimensions of the vertebral canal of the cervical region have a high degree of variability

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among the population of the different ethnic groups and also within the population belong to the same region and this variability may influence the outcome of the presentation of different diseases [3]. For example, subjects diagnosed with different radiological features of cervical spondylosis may be symptom free. On the other hand, manifestations of cervical myelopathy, which may be due to cervical stenosis, can occur in the presence of modest radiological changes. This discrepancy between presenting symptoms and radiological findings seems to be attributable mainly to differences in the initial size of the cervical spinal canal [4].

The vertebral canal is triangular & more roomy in comparison to other areas of spine for the accommodation of cervical enlargement of spinal cord. Spinal stenosis is an abnormal narrowing (stenosis) of the spinal canal or vertebral canal that may involve any of the regions of the spine. Among the several types of spinal stenosis, lumbar stenosis and cervical stenosis are the most frequent presentation. While lumbar spinal stenosis is more common, cervical spinal stenosis is more dangerous because it involves compression of the spinal cord whereas the lumbar spinal stenosis involves compression of the cauda equina. Cervical spinal stenosis is understood to be a narrowing of the cervical spinal canal and is associated with compression of the spinal cord [2]. A mid sagittal spinal canal diameter of less than 12mm is believed to be indicative of cervical spinal stenosis according to most of the literatures till date [5-10], and is observed frequently in patients experiencing neurological symptoms related to those of cervical spinal stenosis. Prolonged and significant cervical cord compression results in cervical myelopathic features. Patients often complain of numbness and paresthesias in the distal limbs, weakness more often in the lower than upper limbs and intrinsic hand muscle wasting, tightness or spasticity of the movements and even incontinence. Pain is present when the nerves and membrane outside the spinal cord are injured as with disc disease of the spine, arthritis etc. Undiagnosed cervical spinal stenosis may have severe complications as was cited by Fujioka et al. [11], where an extended neck position during coronary artery bypass grafting caused tetraplegia, presumably because the position may have aggravated an occult pre-existing cervical spinal canal stenosis which then produced cervical injury. Compression of the spinal cord might be expected when the sagittal diameter of the spinal canal is below the lower limit of normal (taken to be as 12mm) [5-10]. The space available for the cord (SAC) measurement has been performed previously using MRI. The SAC [12-14] is determined by subtracting the sagittal diameter of the spinal cord from the sagittal diameter of the spinal canal. This variable is also an indicator of spinal canal stenosis, because stenosis is the spinal canal's encroachment on the spinal cord and spinal-cord size varies among individuals.The knowledge of relative importance of these two parameters to correlate cervical spinal canal stenosis will help us to diagnose the entity more precisely with lesser degree margin of error, specifically in the situations where decisions of interventional procedures are to be taken.

Various studies have already been done to establish the normal reference value of the spinal canal diameter and the lower most value to detect cervical spinal canal stenosis but no reference value is yet established in the Indian population. For measurement of SAC very few studies have been done till date and normal reference value and the range of values to detect stenosis are yet to be established. Study was done to determine normal reference values of mid-sagittal canal diameter and space available for the cord (SAC) in cervical vertebrae at the levels of C3 to C7 in local Indian adult population of both the sexes. It also done to determine the lower normal value of the said parameters in the same population to correlate cervical spinal canal stenosis.

Materials & methods

During the period of study, patient attending the MRI Center, IPGME&R referred for MRI of brain due to some unrelated ailment or from the patients of adult age group needing spinal MRI screening without any manifestation related to diseases involving the cervical part of spine & cord were selected for asymptomatic population. The patients referred for MRI of cervical spine due to canal stenotic manifestations such as neck or shoulder pain and stiffness, paresthesia of hands & feet, slowly progressive spastic paraparesis, other upper motor neuron signs of lower limb, dermatomal sensory loss, weakness of small muscles of hands etc were selected for symptomatic population. The study was carried out from March, 2013 to February, 2014. Around 100 asymptomatic adult subjects of each of both sexes and 50 symptomatic adult subjects of each of both sexes will be studied. This was an observational/ correlational study.

Inclusion Criteria:

For asymptomatic subjects – The patients referred to MRI Center, IPGME&R for MRI of brain due to some unrelated ailment or from the patients of adult age group needing spinal MRI screening without any manifestation related to diseases involving the cervical part of spine & cord.

For symptomatic subjects – The patients referred to the MRI center of IPGME&R for cervical spinal MRI study to evaluate for cervical spinal canal stenosis with various symptoms such as neck or shoulder pain and stiffness, paresthesia of hands & feet, slowly progressive spastic paraparesis, other upper motor neuron signs of lower limb, dermatomal sensory loss, weakness of small muscles of hands etc.

Exclusion Criteria

The subjects with following criteria was excluded from this study-

- Any congenital cervical vertebral canal or cord abnormality
- Patient with history or MRI finding suggestive of cervical spine trauma
- Degenerative or any disease process involving the cervical part of the spinal canal in case of study of asymptomatic subject group
- Any type of intramedullary, intradural extramedullary or extradural SOL of relevant sections of cervical spinal cord

The parameters used in this study for assessment of cervical spinal canal stenosis were mid sagittal spinal canal diameter and the space available for the cord (SAC), which was measured using T2 weighted axial and sagittal MRI cuts at the respective vertebral level. The mid sagittal spinal canal diameter is measured as the distance from the midpoint of the posterior margin of the vertebral body to the spino-laminar junctional point at mid sagittal level. The space available for cord (SAC) is measured by subtracting the antero-posterior diameter of spinal cord of corresponding mid-sagittal level from the spinal canal diameter at the same level [Fig 5-8].

Results

Study of selected cervical spine dimensions in normal and symptomatic adults [Software used-Statistica version 6 [Tulsa, Oklahoma: StatSoft Inc., 2001]. All numerical variables are normally distributed by Kolmogorov-Smirnoff goodness-of-fit test.

Table 1: Descriptive statistics of numerical variables – Normal [n = 100]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
	100	39.4	36.8	42.1	40.0	15.0	73.0	27.0	50.0	13.38
C3-CAD	100	12.0	11.6	12.3	12.1	1.6	16.0	11.2	12.9	1.65
C3-COD	100	6.9	6.8	7.1	7.0	5.0	8.8	6.3	7.4	0.82
C3-SAC	100	5.0	4.8	5.3	5.1	2.8	7.6	4.5	5.8	1.38
C4-CAD	100	12.0	11.7	12.2	12.0	9.0	15.6	11.3	12.7	1.16
C4-COD	100	6.9	6.7	7.0	6.9	4.9	8.9	6.3	7.4	0.83
C4-SAC	100	5.1	4.9	5.3	5.1	2.6	7.9	4.5	5.7	0.96
C5-CAD	100	12.0	11.8	12.2	12.0	9.4	15.0	11.3	12.7	1.16
C5-COD	100	6.7	6.6	6.9	6.7	4.6	9.2	6.2	7.2	0.83
C5-SAC	100	5.3	5.1	5.5	5.3	2.0	7.9	4.7	5.9	1.07
C6-CAD	100	12.0	11.8	12.3	12.0	8.2	15.1	11.1	13.0	1.15
C6-COD	100	6.5	6.3	6.6	6.4	5.0	9.2	6.0	6.9	0.75
C6-SAC	100	5.6	5.4	5.8	5.6	2.3	8.2	4.8	6.2	1.04
C7-CAD	100	12.6	12.3	12.8	12.5	9.0	16.1	11.7	13.4	1.31
C7-COD	100	6.3	6.1	6.4	6.2	4.8	7.8	5.7	6.7	0.68
C7-SAC	100	6.3	6.0	6.5	6.3	2.3	9.9	5.5	7.1	1.27

Table 2: Descriptive statistics of numerical variables – Symptomatic [n = 50]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std. Dev.
	50	42.1	38.6	45.7	41.5	20.0	60.0	32.0	55.0	12.55
C3-CAD	50	10.9	10.7	11.2	11.0	9.6	13.6	10.4	11.3	0.92
C3-COD	50	6.6	6.5	6.8	6.7	5.5	8.4	6.4	6.9	0.64
C3-SAC	50	4.3	4.0	4.5	4.2	2.8	6.8	3.9	4.8	0.89
C4-CAD	50	10.8	10.5	11.1	10.5	9.2	13.4	10.2	11.4	0.94
C4-COD	50	6.7	6.5	6.9	6.8	5.0	8.3	6.1	7.3	0.78
C4-SAC	50	4.1	3.8	4.4	4.0	2.5	6.2	3.5	4.8	0.97
C5-CAD	50	10.5	10.2	10.8	10.4	8.1	13.0	9.7	11.6	1.07
C5-COD	50	6.6	6.4	6.8	6.8	5.2	7.9	6.1	7.0	0.71
C5-SAC	50	3.8	3.6	4.1	3.6	2.6	5.3	3.2	4.6	0.79
C6-CAD	50	10.6	10.3	11.0	10.6	8.5	13.1	9.7	11.7	1.26
C6-COD	50	6.4	6.3	6.6	6.5	4.9	7.6	6.1	6.9	0.66
C6-SAC	50	4.2	3.9	4.4	4.2	3.0	6.3	3.6	4.6	0.88
C7-CAD	50	11.1	10.8	11.4	11.1	9.1	13.5	10.4	11.9	1.13
C7-COD	50	6.3	6.1	6.5	6.3	4.5	7.3	6.0	6.8	0.62
C7-SAC	50	4.8	4.5	5.2	4.8	2.3	6.8	4.3	5.5	1.15

Table 3: Descriptive statistics of numerical variables – Normal Male [n = 69]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
	69	38.4	35.4	41.4	38.0	18.0	64.0	27.0	50.0	12.46
C3-CAD	69	11.9	11.5	12.4	12.1	1.6	16.0	11.1	13.0	1.87
C3-COD	69	7.0	6.8	7.2	7.0	5.0	8.8	6.5	7.5	0.85
C3-SAC	69	4.9	4.5	5.3	5.2	-5.1	7.6	4.2	5.8	1.58
C4-CAD	69	12.0	11.7	12.3	12.0	9.5	15.6	11.3	12.5	1.19
C4-COD	69	6.9	6.7	7.1	6.9	4.9	8.9	6.3	7.4	0.87
C4-SAC	69	5.0	4.8	5.3	5.0	2.6	6.9	4.5	5.6	1.03
C5-CAD	69	12.0	11.8	12.3	12.0	9.4	15.0	11.3	12.7	1.17
C5-COD	69	6.8	6.6	7.0	6.7	5.0	9.2	6.3	7.1	0.81
C5-SAC	69	5.2	4.9	5.5	5.1	2.0	7.9	4.4	5.9	1.22
C6-CAD	69	12.1	11.8	12.4	12.1	8.2	15.1	11.4	12.9	1.19
C6-COD	69	6.6	6.4	6.8	6.4	5.1	9.2	6.0	7.0	0.77
C6-SAC	69	5.5	5.2	5.8	5.8	2.3	8.2	4.8	6.1	1.06
C7-CAD	69	12.6	12.3	13.0	12.5	9.0	16.1	11.6	13.4	1.42
C7-COD	69	6.3	6.2	6.5	6.3	5.1	7.8	5.9	6.7	0.64
C7-SAC	69	6.3	6.0	6.6	6.3	2.3	9.9	5.4	7.1	1.37

Table 4: Descriptive statistics of numerical variables – Normal Female [n = 31]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
	31	41.6	36.0	47.2	42.0	15.0	73.0	27.0	51.0	15.21
C3-CAD	31	12.1	11.7	12.4	12.1	10.0	14.1	11.3	12.7	1.02
C3-COD	31	6.8	6.5	7.1	6.9	5.0	8.3	6.2	7.3	0.74
C3-SAC	31	5.3	5.0	5.5	5.1	4.2	7.2	4.8	5.6	0.74
C4-CAD	31	12.0	11.6	12.4	12.1	9.0	14.4	11.5	12.7	1.11
C4-COD	31	6.7	6.5	7.0	6.8	5.2	8.6	6.3	7.2	0.76
C4-SAC	31	5.3	5.0	5.6	5.1	3.8	7.9	4.8	5.7	0.80
C5-CAD	31	12.0	11.5	12.4	11.9	9.5	13.7	11.3	13.1	1.15
C5-COD	31	6.6	6.3	6.9	6.6	4.6	8.2	6.0	7.3	0.88
C5-SAC	31	5.4	5.2	5.6	5.3	4.1	6.5	4.9	5.9	0.64
C6-CAD	31	12.0	11.6	12.4	11.8	10.0	13.9	11.0	13.1	1.07
C6-COD	31	6.3	6.0	6.5	6.3	5.0	7.6	5.8	6.9	0.67
C6-SAC	31	5.7	5.3	6.1	5.4	4.2	7.9	5.0	6.3	0.98
C7-CAD	31	12.4	12.0	12.8	12.3	10.6	14.3	11.7	13.4	1.02
C7-COD	31	6.1	5.9	6.4	6.0	4.8	7.7	5.6	6.7	0.77
C7-SAC	31	6.3	5.9	6.7	6.3	4.5	8.6	5.6	7.0	1.07

Table 5: Descriptive statistics of numerical variables – Symptomatic Male [n = 35]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
	35	41.3	36.9	45.6	39.0	20.0	60.0	32.0	55.0	12.63
C3-CAD	35	10.9	10.6	11.2	10.9	9.6	13.6	9.9	11.3	0.95
C3-COD	35	6.7	6.5	6.9	6.8	5.5	8.4	6.4	7.0	0.71
C3-SAC	35	4.2	3.9	4.5	4.1	2.8	6.8	3.4	4.8	0.91
C4-CAD	35	10.8	10.4	11.1	10.5	9.2	13.4	10.0	11.1	0.99
C4-COD	35	6.8	6.5	7.0	6.8	5.0	8.3	6.1	7.4	0.75
C4-SAC	35	4.0	3.7	4.3	3.9	2.5	6.2	3.4	4.7	0.95
C5-CAD	35	10.4	10.0	10.8	10.0	8.1	13.0	9.7	11.6	1.11
C5-COD	35	6.7	6.4	6.9	6.8	5.2	7.9	6.1	7.0	0.67
C5-SAC	35	3.7	3.5	4.0	3.6	2.6	5.3	3.2	4.3	0.71
C6-CAD	35	10.6	10.2	11.1	10.7	8.5	13.1	9.7	11.7	1.23
C6-COD	35	6.5	6.3	6.7	6.5	5.0	7.6	6.1	6.9	0.63
C6-SAC	35	4.1	3.9	4.4	4.2	3.0	6.3	3.5	4.6	0.84
C7-CAD	35	11.1	10.7	11.5	11.1	9.1	13.5	10.4	11.9	1.16
C7-COD	35	6.4	6.2	6.6	6.4	5.0	7.3	6.0	6.8	0.58
C7-SAC	35	4.7	4.3	5.1	4.8	2.3	6.8	4.2	5.3	1.20

Table 6: Descriptive statistics of numerical variables – Symptomatic Female [n = 15]

	Valid N	Mean	95%CI LL	95%CI UL	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
	15	44.2	37.2	51.2	46.0	26.0	59.0	29.0	56.0	12.56
C3-CAD	15	11.0	10.5	11.5	11.1	9.6	13.2	10.6	11.3	0.88
C3-COD	15	6.5	6.3	6.8	6.7	5.8	7.2	6.3	6.9	0.44
C3-SAC	15	4.5	4.0	4.9	4.3	3.1	6.4	3.9	4.8	0.86
C4-CAD	15	10.9	10.4	11.3	10.8	9.8	12.7	10.2	11.6	0.83
C4-COD	15	6.5	6.0	6.9	6.5	5.0	7.9	6.0	7.0	0.82
C4-SAC	15	4.4	3.8	5.0	4.2	2.5	6.2	3.8	5.2	1.01
C5-CAD	15	10.6	10.1	11.2	10.4	9.2	12.1	9.9	11.6	0.98
C5-COD	15	6.6	6.1	7.0	6.8	5.2	7.8	6.1	7.0	0.81
C5-SAC	15	4.1	3.6	4.6	4.2	2.9	5.2	3.0	5.2	0.93
C6-CAD	15	10.6	9.9	11.4	10.4	8.8	13.0	9.7	11.8	1.37
C6-COD	15	6.3	5.9	6.7	6.5	4.9	7.6	6.0	6.7	0.72
C6-SAC	15	4.3	3.8	4.9	3.9	3.1	6.3	3.6	4.6	0.99
C7-CAD	15	11.2	10.6	11.8	11.2	9.1	12.9	10.4	12.0	1.10
C7-COD	15	6.1	5.8	6.5	6.3	4.5	6.9	5.8	6.7	0.71
C7-SAC	15	5.1	4.5	5.7	5.1	2.6	6.4	4.6	6.0	**1.05**

So in a nutshell:
Lower margin of normal values (mean – 2SD) of CAD and SAC at the levels C3 to C7 cervical vertebrae :

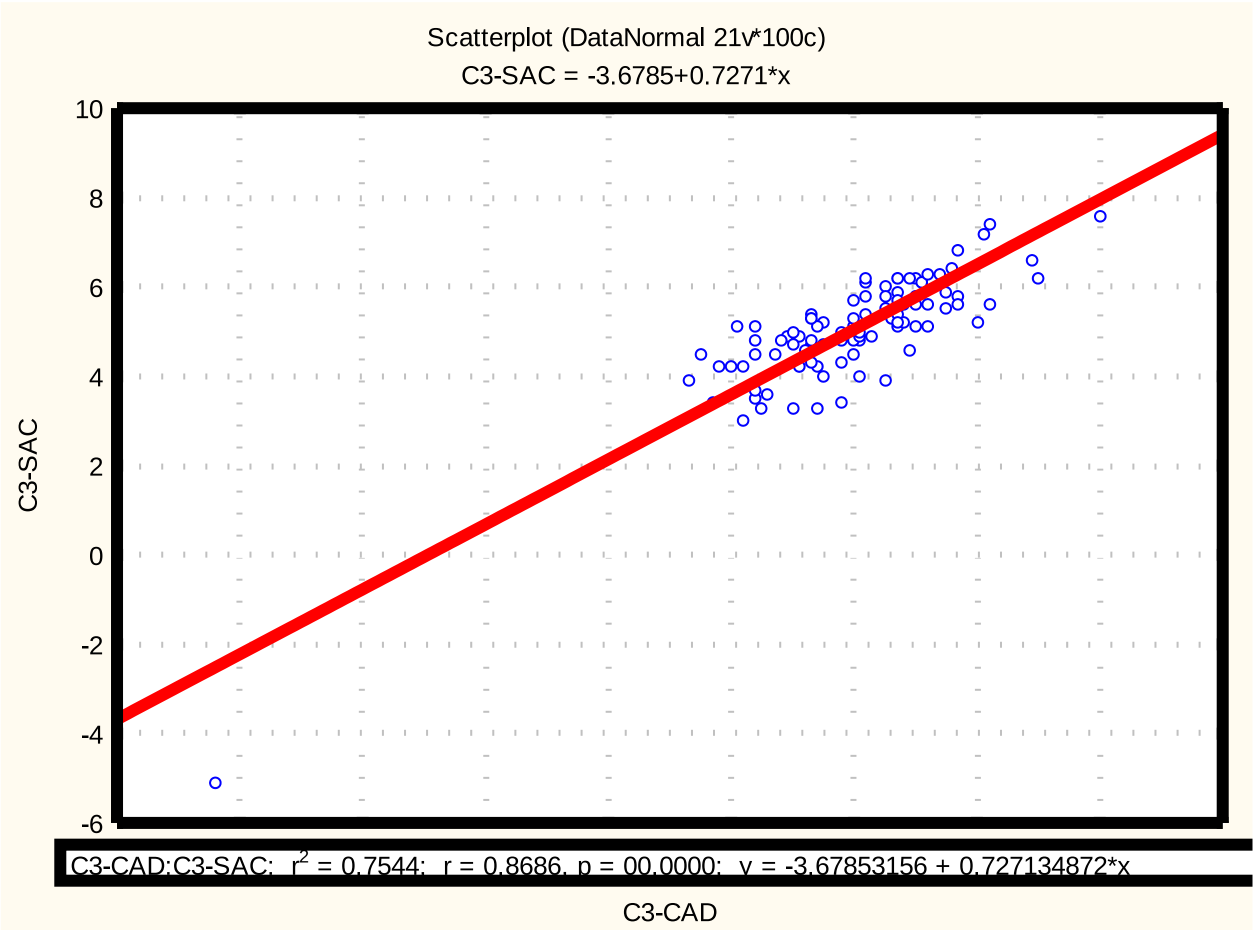
At C3 level : CAD 8.7mm SAC 2.2mm

At C4 level : CAD 9.7mm SAC 3.2mm

At C5 level : CAD 9.7mm SAC 3.2mm

At C6 level : CAD 9.7mm SAC 3.5mm

At C7 Level : CAD 10mm SAC 3.8mm



We know that r (linear correlation co-efficient) varies from -1 to+1, -1: strong –ve correlation, +1: strong +ve correlation,0: no correlation. r should be nearer to 1, if it is>0.8 then strong +ve correlation & if it is <0.5 then weak +ve correlation.

r^2 (coefficient of determination) denotes that how many of the variable are closed to the reference line. In this table we find that r >0.8 & r^2 nearer to 1 so at C3 level there is +ve correlation b/w CAD & SAC [Figure 1].

Fig 1: Correlation of CAD with SAC at C3 level in normal subjects

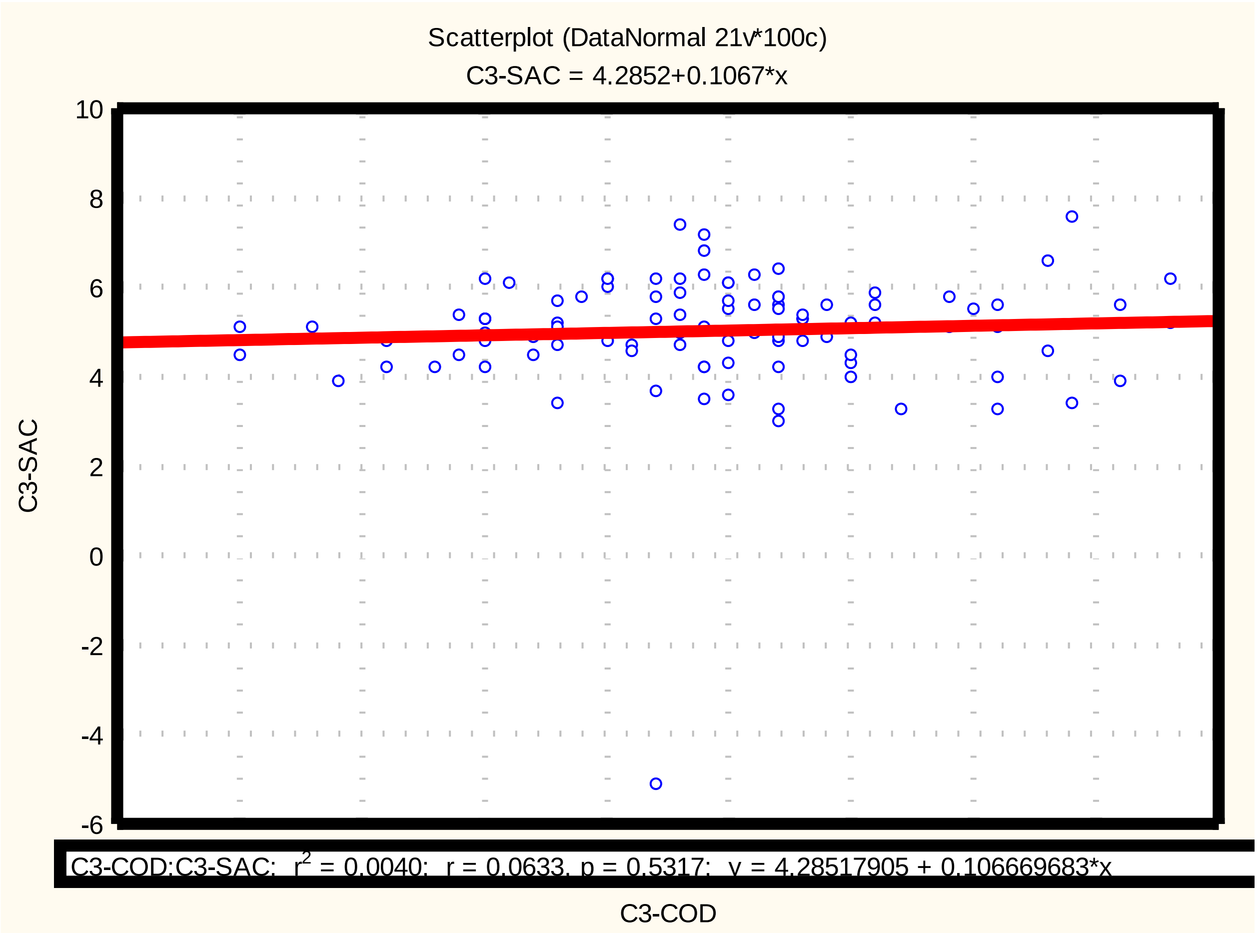
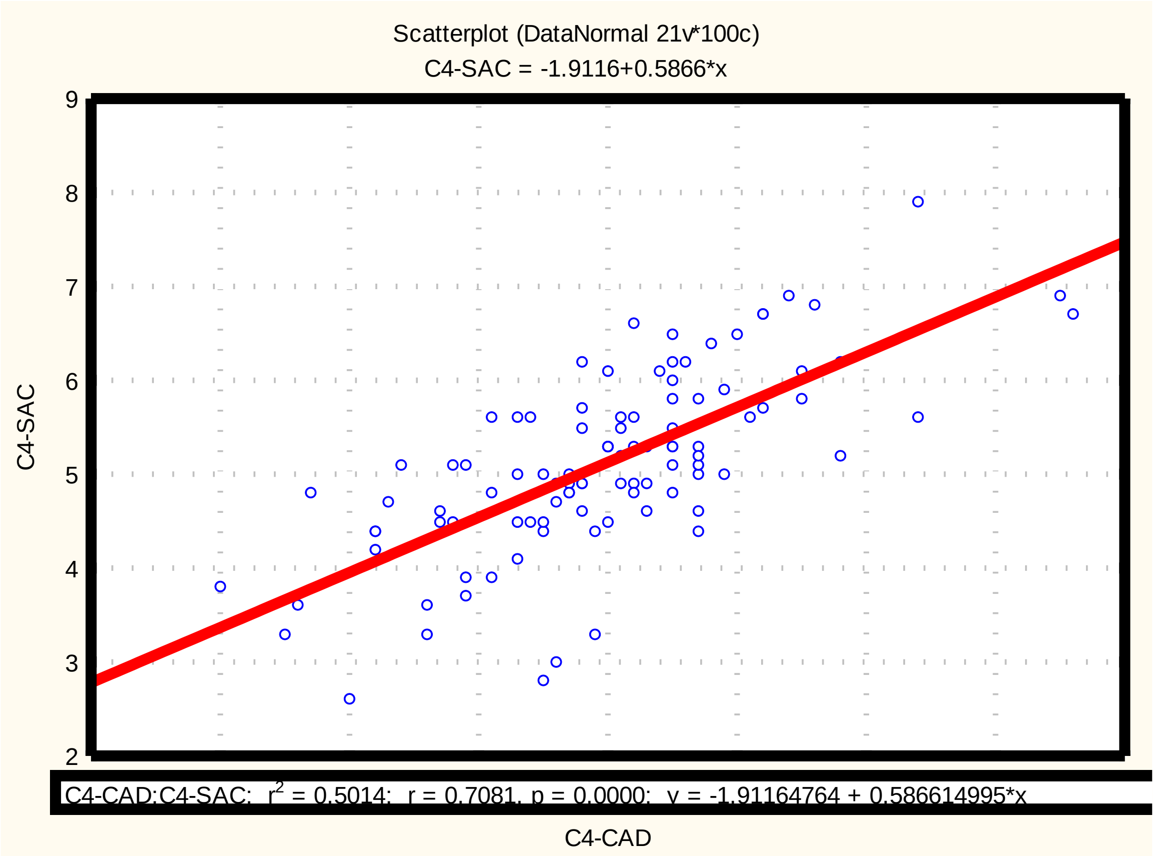


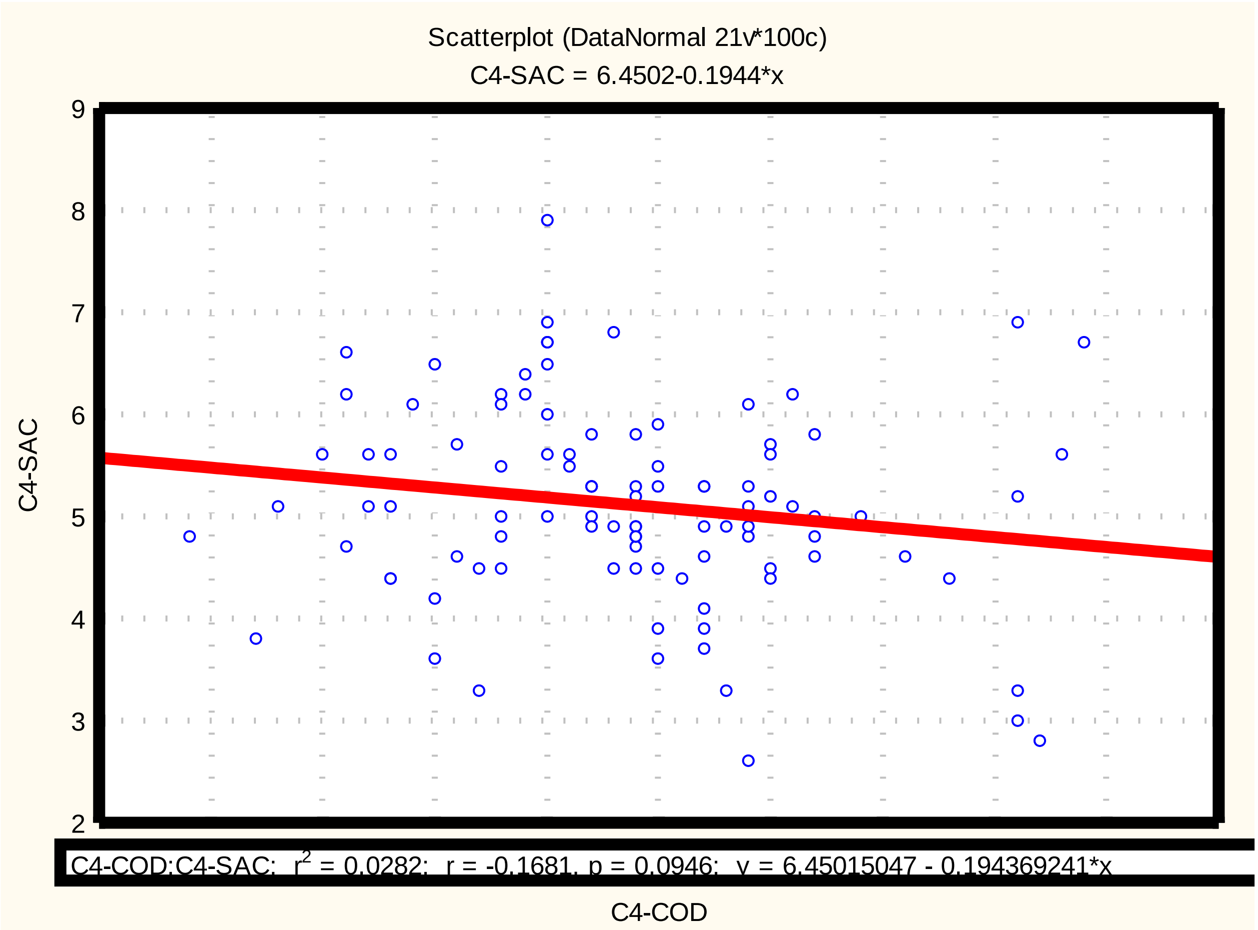
Fig 2: Correlation of COD with SAC at C3 level in normal subjects

In this table we find that r <0.1 & r^2 nearer to 0 so at C3 level there is very weak +ve correlation b/w COD & SAC [Figure 2].



Here also we find that r is nearer to 1, so there is +ve correlation between CAD & SAC at C4 cervical level [Figure 3].

Fig 3: Correlation of CAD with SAC at C4 level in normal subjects



In this table we find that r <0.2 & r^2 nearer to 0, so at C4 level there is very weak -ve correlation b/w COD & SAC [Figure 4].

Fig 4: Correlation of COD with SAC at C4 level in normal subjects

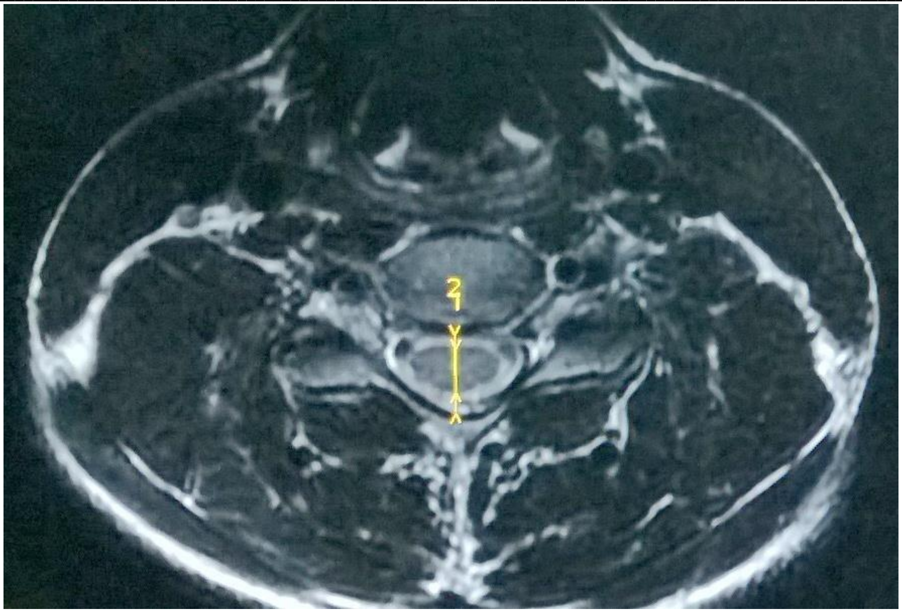


Fig 5: Measurement of mid-sagittal canal and cord diameter in a normal subject

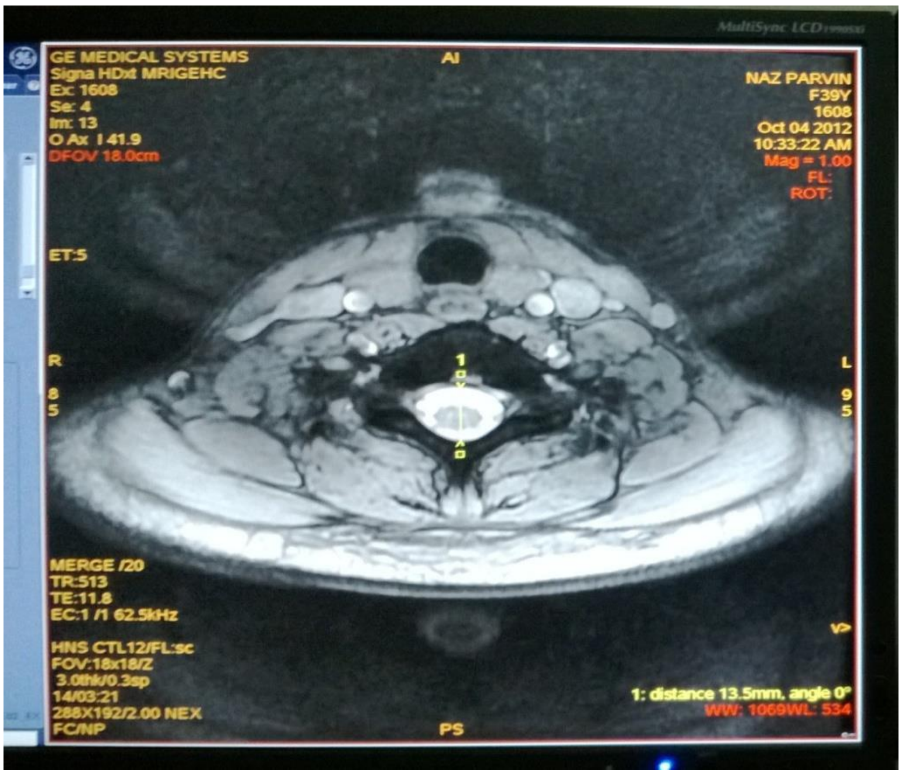


Fig 6: Measurement of canal diameter

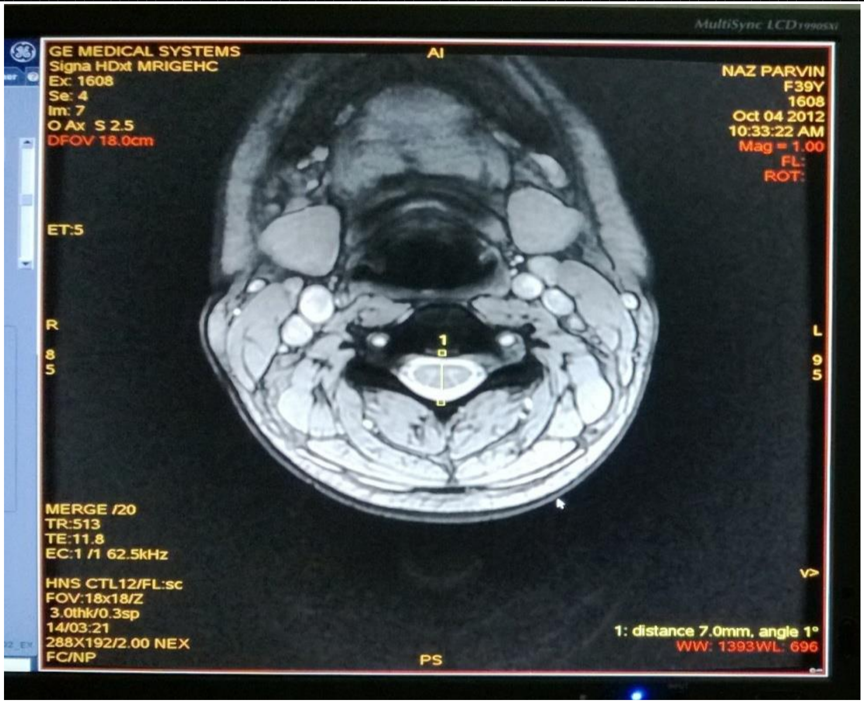


Fig 7: Measurement of cord diameter

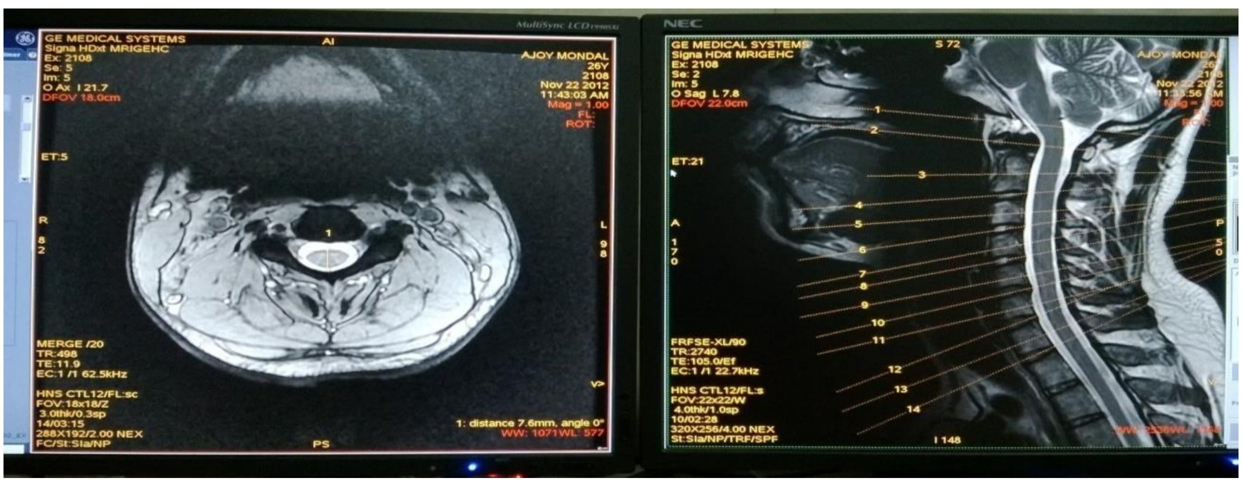


Fig 8: Measurement of cord diameter at C3 level in a normal subject

Discussion

Before analyzing the findings, the anatomical consideration of cervical vertebrae are projected here in short for a better understanding of this study. The cervical vertebrae are seven in number, among them first and second are having different type of canal anatomy in comparison to others. So, in our study; we had measured canal diameter & space available for cord at the level of cervical vertebrae, i.e., C3 to C7 level [Fig 5-8].

Each vertebra has two main parts — a body in front & vertebral arch behind. Both of them enclose a vertebral canal for the lodgement & protection of the spinal cord & its membrane covering. The canal is triangular & more roomy in comparison to other areas of spine for the accommodation of cervical enlargement of spinal cord [2]. Vertebral arch consists of a pair of pedicles & a pair of laminae & supports seven processes - a pair of transverse processes, a pair of superior & inferior articular processes and a spinous process. Pedicle – springs from the postero-lateral part of the body, somewhat midway between upper & lower surfaces, projects backwards with lateral inclination &

presents superior & inferior vertebral notches which form inter-vertebral foramina [2].

Lamina - It arises from the dorsal ends of the pedicles, passes medially & backwards, fuses with the fellow of the opposite side. Transverse processes – project laterally on each side from the junction of the pedicle and lamina. Each presents a foramen transversarium. Superior & inferior articular processes - project respectively above & below from the junction of pedicles and laminae, and they join with the articular processes of the adjacent vertebrae forming plain synovial joint. Spinous process - projects generally backward from the fused laminae & it is short, horizontal and presents bifid tip [2].

From the anatomy of cervical vertebrae, it is evident that for assessment of space available within the cervical spinal canal, the importance of measurement of the antero-posterior diameter of cervical spinal canal cannot be over emphasized. As the interpedicular distance (transverse diameter) of cervical spinal canal is nearly twice the antero-posterior diameter of the spinal canal, there is more room for the spinal cord to expand sideways while less space to expand in the antero-posterior direction. For this reason, the antero-posterior diameter of cervical spinal canal is considered the most useful measurement. The parameters used in my study for assessment of cervical spinal canal stenosis are - mid sagittal spinal canal diameter and the space available for the cord (SAC), which was measured using T2 weighted axial and sagittal MRI cuts at the respective vertebral levels, excluding first two cervical vertebrae for their atypical anatomical structures [15].

The mid sagittal spinal canal diameter is measured as the distance from the midpoint of the posterior margin of the vertebral body to the spino-laminar junctional point at mid sagittal level at all the levels (C3-C7). The space available for cord (SAC) is measured by subtracting the antero-posterior diameter of spinal cord of corresponding mid-sagittal level from the spinal canal diameter at the same level. It was also measured in all the level (C3-C7). Previously, different workers have already done many studies in this regard. Suzuki M and Shimamura T [16] in Department of Orthopedic Surgery, School of Medicine, Iwate Medical University, Japan in the year 1994 investigated the morphological changes in the cervical spinal cord in patients with cervical myelopathy. They examined the axial anatomy of the cervical spinal cord and the spinal canal using MRI and CT scans. In normal subjects, the transverse area, the sagittal diameter, and the coronal diameter of the spinal cord showed a significant positive correlation with body height, and a significant negative correlation with age. No significant difference was identified between males and females. In my study also, no significant variation was identified between males and females in regard of canal diameter and SAC. They established that the transverse area of the spinal canal in the patients with myelopathy was significantly smaller than that of normal subjects. In conclusion, a poor or no correlation between the size of the spinal cord and the spinal canal is a frequent finding in patients with myelopathy. Furthermore, the study suggested that patients with myelopathy present with a narrow spinal canal more frequently than do normal subjects [16]. Previously, some workers emphasized the value of vertebral canal/body ratio (Pavlov’s ratio), measured from plain radiograph for assessment of cervical canal stenosis. Lee HM et al [17] in their study in 1994 for establishing the normal values of the mid-sagittal canal diameter and the canal/body ratio of the cervical spine in Korean adults concluded that measurement of the canal/body ratio is more reliable than direct measurement 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 [17]. Kyung-Jin Song, et al study also highlighted importance of canal/body ratio and they argued that there is a correlation between the underlying spinal stenosis and the development of neurological impairment after a traumatic cervical spine injury and Pavlov's ratio can be used to help determine and predict the neurological outcome in cases of traumatic injury to the cervical spinal cord [18]. However most other workers contradicted the view and emphasized the importance of mid sagittal measurements like canal diameter, space available for cord etc evaluated by MR imaging. Here in our study we also have given emphasis on the measurement of Canal Diameter and SAC for correlation with stenotic symptoms instead of measuring canal/body ratio. Tierney RT et al [12] compared 2 methods of determining cervical spinal stenosis - Torg ratio and Space available for the cord [SAC] to determine which of the components of the Torg ratio and the SAC account for more of the variability in the measures; and present standardized SAC values for normal subjects using magnetic resonance imaging (MRI). The conclusion was that the SAC measure relied more on the spinal canal compared with the Torg ratio and, therefore, might be a more effective indicator of spinal stenosis. This is relevant clinically because neurologic injury related to stenosis is an outcome of the measurements of spinal canal and the spinal cord (not the vertebral body) [12].Prasad SS et al also concluded that their study showed a poor correlation between Pavlov's ratio and the space available for the cord and therefore this ratio cannot be solely relied upon to predict the area changes in that plane of the cervical spinal canal [19].Okada Y et study proved that the areas of the spinal canal, the dural tube and the spinal cord in MRI correlated better with the sagittal diameter than with the Pavlov's ratio in simple lateral radiographs. Their study further signified the importance of MRI imaging in determination of cervical spinal stenosis and its superiority over the conventional radiographic assessments [20].In this background, in our study we had used high resolution MR images (acquired with 3 Tesla MRI machine) for anatomical evaluation of cervical spinal canal. My purpose was to establish a normal reference value for spinal canal diameter and SAC values in C3 to C7 level in local eastern Indian population and to determine the lower normal limit of these parameters below which chance of canal stenosis increases.Previously some workers have tried to determine normal reference values of different dimensions regarding cervical spinal canal. Lee HM et al [17] in their analysis determined the average mid-sagittal canal diameters from C3 through C7 in the normal Korean was 13.2 +/- 1.3 millimeters in male and 13.1 +/- 2.6 millimeters in female. Ryan T. Tierney et al [12] deducted that the SAC ranged from 2.5 to 10.4 mm and was greatest at C7 and least at C3 or C5 level in their study population. KK Gour et al [13] did their study in Indian population in the locality of Jabalpur and found that mid sagittal diameter of cervical vertebral canal, the mean values were 14.38 (±1.43) mm, 14.40 (±1.31) mm, 14.36 (±1.32) mm and 14.55 (±1.21) mm respectively at 3rd, 4th, 5th, and 6th cervical vertebral levels. Michael J. Lee et al [21] in their study done on cadavers found that the average anterior-posterior canal diameter (and standard deviation) in all specimens at all levels was 14.1 ± 1.6 mm. The canal diameters ranged from 9.0 to 20.9 mm, with a median diameter of 14.4 mm. Men had significantly larger cervical spinal canals than women at all of the levels that were evaluated.In our study, we analyzed 100 asymptomatic subjects by MRI study (T2 weighted sagittal and axial images) for determination of normal reference values of canal diameter and space available for cord in C3 to C7 vertebral body level. The values of canal diameter (mean +/- 2SD) in different levels were 12.0±3.3mm (C3); 12.0±2.32mm (C4); 12.0±2.32mm (C5); 12.0±2.3mm (C6); 12.6±2.62mm (C7) and the corresponding space available for cord values were 5.0±2.76mm (C3); 5.1±1.92mm (C4); 5.3±2.14mm (C5); 5.6±2.08mm (C6); 6.3±2.54mm (C7) levels.Values of both CAD and SAC were greatest at C7 level and were least at C3 level. The values are also lower than the values obtained by the previous workers, possibly indicating the importance of racial factors. Whereas the same measurement of canal diameter (CAD) in symptomatic subjects (n=50) were at C3 = 10.9±1.84mm; C4 = 10.8± 1.88mm; C5 = 10.5±2.14mm; C6 = 10.6±2.52mm; C7 = 11.1± 2.26mm and Space available for cord at C3 = 4.3±1.78mm; C4 = 4.1±1.94mm; C5 = 3.8±1.58mm; C6 = 4.2±1.76mm; C7 = 4.8± 2.3mm. So the values in symptomatic subjects were significantly lower than the corresponding values of same variables at same level in asymptomatic subjects (p ranging from 0.0001 to 0.001).

Conclusion

After analyzing all of my data statistically we determined the lower range of normal values of the canal diameter (CAD) & space available for cord (SAC) at all the levels from C3 to C7 of cervical vertebrae. The Lower margin of normal values (mean – 2SD) of CAD & SAC calculated from my data set was lowest at C3 level (8.7 mm for CAD & 2.2 mm for SAC) and was highest at C7 level (10 mm for CAD & 3.8 mm for SAC). The values are lower than the values obtained in other studies done on different study population in other countries, even compared to the population of central part of India (Jabalpur). However it matched the inter-level variation established in the previous studies, that the values are least in C3 level, and are highest in C7 level. It is well recognized that mid sagittal spinal canal diameter and space available for the cord (SAC) in cervical vertebrae (C3 to C7) varies considerably in normal adult population of both the sexes and decrease in them will result in cervical stenosis symptoms. Knowledge of normal reference values of these two parameters in Indian population will be helpful for concerned researchers and the normal acceptable range of values will be very helpful for the clinicians to predict spinal canal stenosis and to decide for the necessity of surgical intervention.

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