Original Research Article

The diagnostic value of magnetic resonance imaging measurements for assessing cervical spinal canal stenosis in relationship with the 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 Indian adults

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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. 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. **Materials & Methods:** In the present study, for asymptomatic subjects selected from 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 selected from 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. **Results:** Sensitivity of cervical canal diameter as a marker of canal stenosis in predicting symptoms was 62% (95%CI 47.17-75.35) with specificity 91%, positive predictive value (PPV) 77.5% and negative predictive value (NPV) 82.73%. Sensitivity of SAC as a maker of cervical canal stenosis in predicting symptoms was 66 % (51.23-78.79) with specificity 93%, PPV 82.5 %, and NPV 84.55%. Finally at C7 level, r is>0.8 so strong +ve correlation between canal diameter (CAD) & space available for cord (SAC) at C7 cervical level. Sensitivity of cervical canal diameter & SAC both as the marker of canal stenosis in predicting symptoms was 82% (68.56- 91.42) with specificity 87%, PPV 75.93 % and NPV 90.60 %. **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. We know that when sensitivity more than 70%, it indicates predictability. In present study we find that sensitivity is 82%. So we may conclude that in case of patient having symptoms of cervical stenosis, canal diameter and space available for cord both measurements are important.

Keywords: Spinal canal diameter, spinal canal space, cervical spine, mid sagittal level, cervical stenosis, magnetic resonance imaging (MRI), sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV)

Introduction

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Cervical canal stenosis can result from a multitude of causes and can cause spinal cord compression leading to substantial morbidity. It requires prompt diagnosis and treatment to prevent long-term disabilities secondary to irreversible spinal cord injury [1]. Spinal cord compression affects the cervical cord in 10% cases and its prevalence is reported to be 24.4% [2]. Narrowing of the cervical canal can be caused by several conditions including tumors, infections, trauma, degenerative changes like intervertebral disc herniation, osteophytes, and ossification of posterior longitudinal ligaments [3, 4]. Cervical spinal canal narrowing can lead to injury of the spinal cord and neurological symptoms including neck pain, headache, weakness and parasthesisas [5]. Diagnosis is made with clinical history, neurological signs and radiological investigations including plain radiographs, computed tomography (CT) scans, myelography and magnetic resonance imaging (MRI). MRI is a more sensitive modality than CT scan and is the gold standard for imaging cervical cord. MRI of the spine not only helps in diagnosing but also gives an idea of the possible treatment options [6, 7] Although spinal stenosis is a disease mostly associated with the elderly, cases of developmental cervical spinal stenosis, occurrence of stenosis in children and cervical stenosis associated with Down's syndrome are also documented. Correct diagnosis of cervical spinal stenosis is the single most important factor for quick and accurate treatment of the associated pathology and to ensure optimal treatment and procedural outcome [8]. Undiagnosed cervical spinal stenosis may have severe complications as was cited by Fujioka et al. [9], 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) [10-13]. However, as described in the study of many other workers, observed among different ethnic groups in the western population the 12mm guideline dividing stenotic spinal canals from non-stenotic spinal canals (that is currently universally applied) may have to be reconsidered, as high proportions of their study sample had mean sagittal diameters of less than 12mm. Significant variation in the dimensions of the cervical spinal canal in different ethnic groups precludes the usage of universal definitions to determine the presence of spinal stenosis in individuals as a general rule. It is important to assess the degree of canal stenosis for the better management of patients. The space available for the cord (SAC) measurement has been performed previously using MRI. The SAC 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.Previous studies have described various methods of assessing the degree of cervical canal stenosis. Early studies were based on radiographs; Edwards and Larocca [15] measured the sagittal diameter of the cervical spinal canal on a plain lateral radiograph, whereas Pavlov et al. [16] and Torg et al. [17] used the ratio of the sagittal diameter of the cervical canal divided by the corresponding diameter of the vertebral body. However, MRI is currently by far the most commonly used imaging method for the accurate evaluation of spinal canal stenosis. MRI visualizes not only the width and length of the spinal canal but also depicts in detail the spinal cord, intervertebral disks, osteophytes, and ligaments, all of which are potential causes of spinal canal stenosis [18]. 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 stenotic symptom. 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 necessity of surgical intervention. 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.

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 symptomtic 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 are mid sagittal spinal canal diameter and the space available for the cord (SAC), which will be 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.

Study Techniques-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 and the patients referred for MRI of cervical spine due canal stenotic manifestations were selected for symptomatic population. Patient's particulars were recorded and detailed written consent was taken from each of them. Relevant clinical history was taken for confirmation/ exclusion of stenotic symptoms. Then the T2 weighted mid-sagittal sections and the axial sections at mid-sagittal levels of C3 to C7 spinal segments of the asymptomatic and symptomatic subjects were thoroughly examined in the viewing console of the MRI machine and the canal diameter and space available for the cord (SAC) were measured with the measuring software under the supervision of a radiologist. At last all the data was statistically analyzed to determine the normal reference range of cervical spinal Canal Diameter and SAC at mid-sagittal level from C3 to C7 in males and females and their range of values for predicting spinal canal stenosis. A comparative analysis was also be done from the MRI of the patients clinically diagnosed to have spinal stenosis in between these two parameters to determine relative importance of each of them for detecting cervical spinal canal stenosis.

Results

Study of selected cervical spine dimensions in normal and symptomatic adults [Software used-Statistica version 6 [Tulsa, Oklahoma: Stat Soft 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: Comparison of numerical variables between Groups Normal and Symptomatic – Student's unpaired t test

	Mean Mean	t-value	df	p	Valid N	Valid N	Std.Dev.	Std.Dev.	
	N	S				N	S	N	S
	39.4	42.1	-1.202	148	0.231	100	50	13.38	12.55
C3-CAD	12.0	10.9	4.148	148	0.000	100	50	1.65	0.92
C3-COD	6.9	6.6	2.275	148	0.024	100	50	0.82	0.64
C3-SAC	5.0	4.3	3.445	148	0.001	100	50	1.38	0.89
C4-CAD	12.0	10.8	6.185	148	0.000	100	50	1.16	0.94
C4-COD	6.9	6.7	1.245	148	0.215	100	50	0.83	0.78
C4-SAC	5.1	4.1	5.946	148	0.000	100	50	0.96	0.97
C5-CAD	12.0	10.5	7.856	148	0.000	100	50	1.16	1.07
C5-COD	6.7	6.6	0.750	148	0.454	100	50	0.83	0.71
C5-SAC	5.3	3.8	8.406	148	0.000	100	50	1.07	0.79
C6-CAD	12.0	10.6	6.862	148	0.000	100	50	1.15	1.26
C6-COD	6.5	6.4	0.258	148	0.797	100	50	0.75	0.66
C6-SAC	5.6	4.2	8.055	148	0.000	100	50	1.04	0.88
C7-CAD	12.6	11.1	6.703	148	0.000	100	50	1.31	1.13
C7-COD	6.3	6.3	-0.096	148	0.924	100	50	0.68	0.62
C7-SAC	6.3	4.8	6.847	148	0.000	100	50	1.27	1.15

Table 4: Comparison of numerical variables between Groups Normal Male and Normal Female- Student's unpaired t test

	Mean M	Mean F	t-value	df	p	Valid N M	Valid N F	Std.Dev. M	Std.Dev. F
	38.4	41.6	-1.105	98	0.272	69	31	12.46	15.21
C3-CAD	11.9	12.1	-0.339	98	0.735	69	31	1.87	1.02
C3-COD	7.0	6.8	1.217	98	0.227	69	31	0.85	0.74
C3-SAC	4.9	5.3	-1.129	98	0.262	69	31	1.58	0.74
C4-CAD	12.0	12.0	-0.189	98	0.851	69	31	1.19	1.11
C4-COD	6.9	6.7	1.007	98	0.316	69	31	0.87	0.76
C4-SAC	5.0	5.3	-1.101	98	0.274	69	31	1.03	0.80
C5-CAD	12.0	12.0	0.293	98	0.770	69	31	1.17	1.15
C5-COD	6.8	6.6	1.284	98	0.202	69	31	0.81	0.88
C5-SAC	5.2	5.4	-0.674	98	0.502	69	31	1.22	0.64
C6-CAD	12.1	12.0	0.331	98	0.741	69	31	1.19	1.07
C6-COD	6.6	6.3	1.813	98	0.073	69	31	0.77	0.67
C6-SAC	5.5	5.7	-0.921	98	0.359	69	31	1.06	0.98
C7-CAD	12.6	12.4	0.805	98	0.423	69	31	1.42	1.02
C7-COD	6.3	6.1	1.405	98	0.163	69	31	0.64	0.77
C7-SAC	6.3	6.3	0.080	98	0.936	69	31	1.37	1.07

We know that if p value<0.01, then it is significant, here pvalue>0.01.So it is not significant. Thus, no sexual dimorphism is apparent [Table 4].

Table 5: Comparison of numerical variables between Groups Symptomatic Male and Symptomatic Female – Student's unpaired t test

Mean	Mean	t-value	df	p	Valid N	Valid N	Std.Dev.	Std.Dev.	
	M	F				M	F	M	F
Age	41.3	44.2	-0.756	48	0.453	35	15	12.63	12.56
C3-CAD	10.9	11.0	-0.248	48	0.805	35	15	0.95	0.88
C3-COD	6.7	6.5	0.847	48	0.401	35	15	0.71	0.44
C3-SAC	4.2	4.5	-0.865	48	0.392	35	15	0.91	0.86
C4-CAD	10.8	10.9	-0.287	48	0.775	35	15	0.99	0.83
C4-COD	6.8	6.5	1.283	48	0.206	35	15	0.75	0.82

C4-SAC	4.0	4.4	-1.311	48	0.196	35	15	0.95	1.01
C5-CAD	10.4	10.6	-0.734	48	0.467	35	15	1.11	0.98
C5-COD	6.7	6.6	0.412	48	0.683	35	15	0.67	0.81
C5-SAC	3.7	4.1	-1.380	48	0.174	35	15	0.71	0.93
C6-CAD	10.6	10.6	0.058	48	0.954	35	15	1.23	1.37
C6-COD	6.5	6.3	0.950	48	0.347	35	15	0.63	0.72
C6-SAC	4.1	4.3	-0.622	48	0.537	35	15	0.84	0.99
C7-CAD	11.1	11.2	-0.398	48	0.692	35	15	1.16	1.10
C7-COD	6.4	6.1	1.082	48	0.285	35	15	0.58	0.71
C7-SAC	4.7	5.1	-0.976	48	0.334	35	15	1.20	1.05

Here also p value >0.01, so it is not significant. Thus, no sexual dimorphism is apparent, even in symptomatic subjects [Table 5].

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

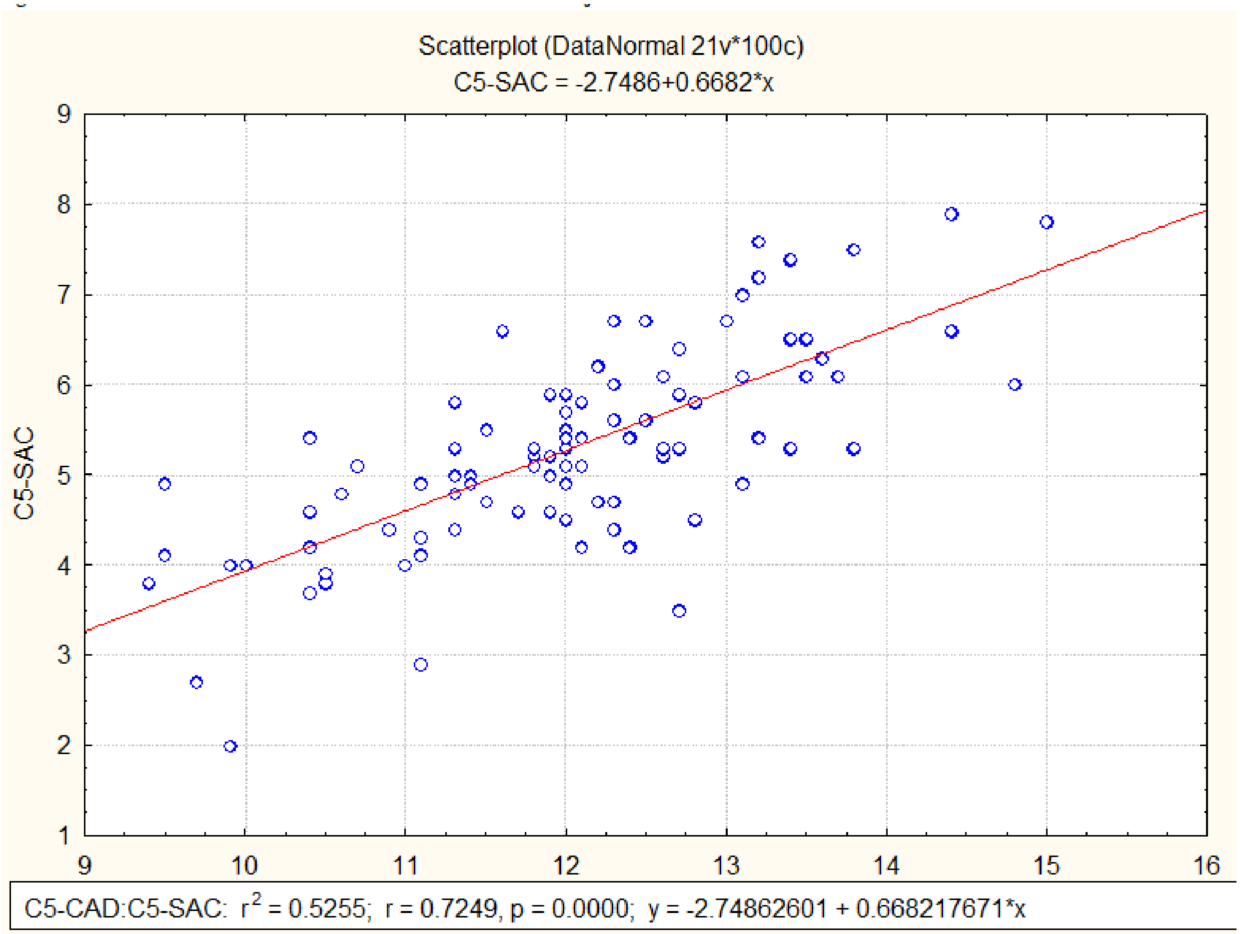

Fig 1: Correlation of CAD with SAC at C5 level in normal subjects

So, as before, +ve correlation between CAD & SAC at C5 cervical vertebral level is seen [Fig. 1].

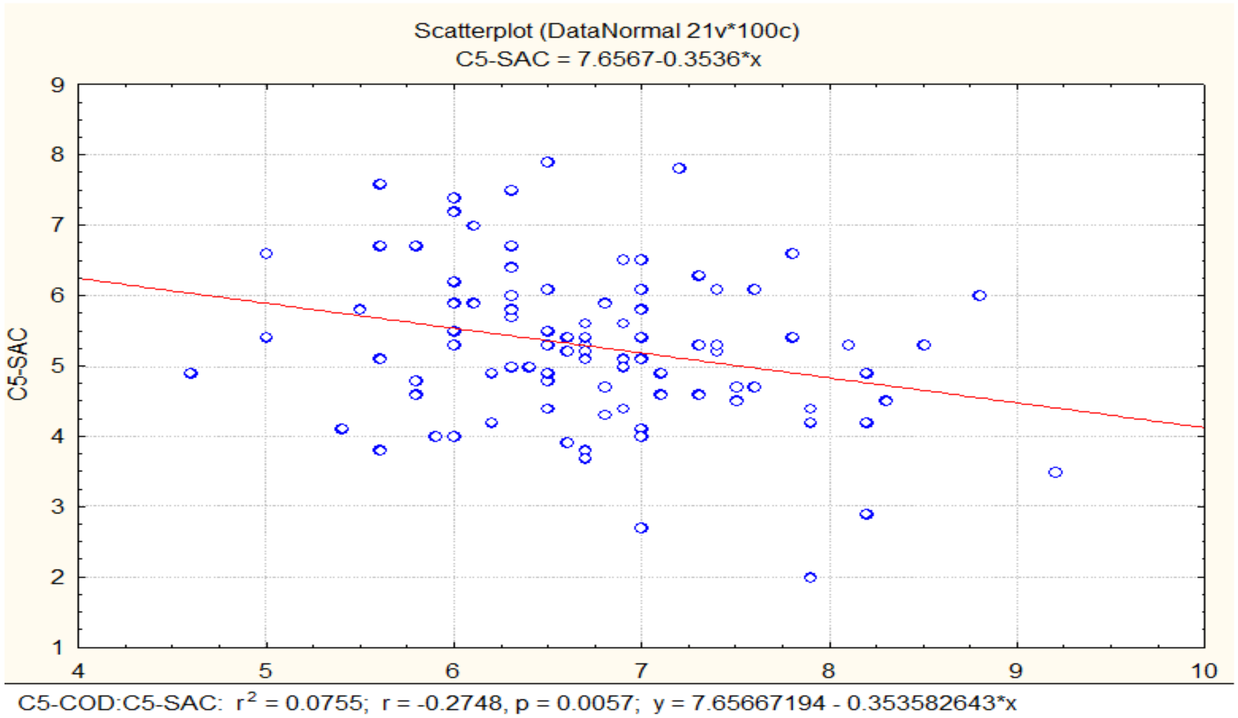

Fig 2: Correlation of COD with SAC at C5 level in normal subjects

In this table we find that r <0.5 & r^2 nearer to 0, so at C5 level there is very weak - ve correlation b/w COD & SAC [Fig. 2].

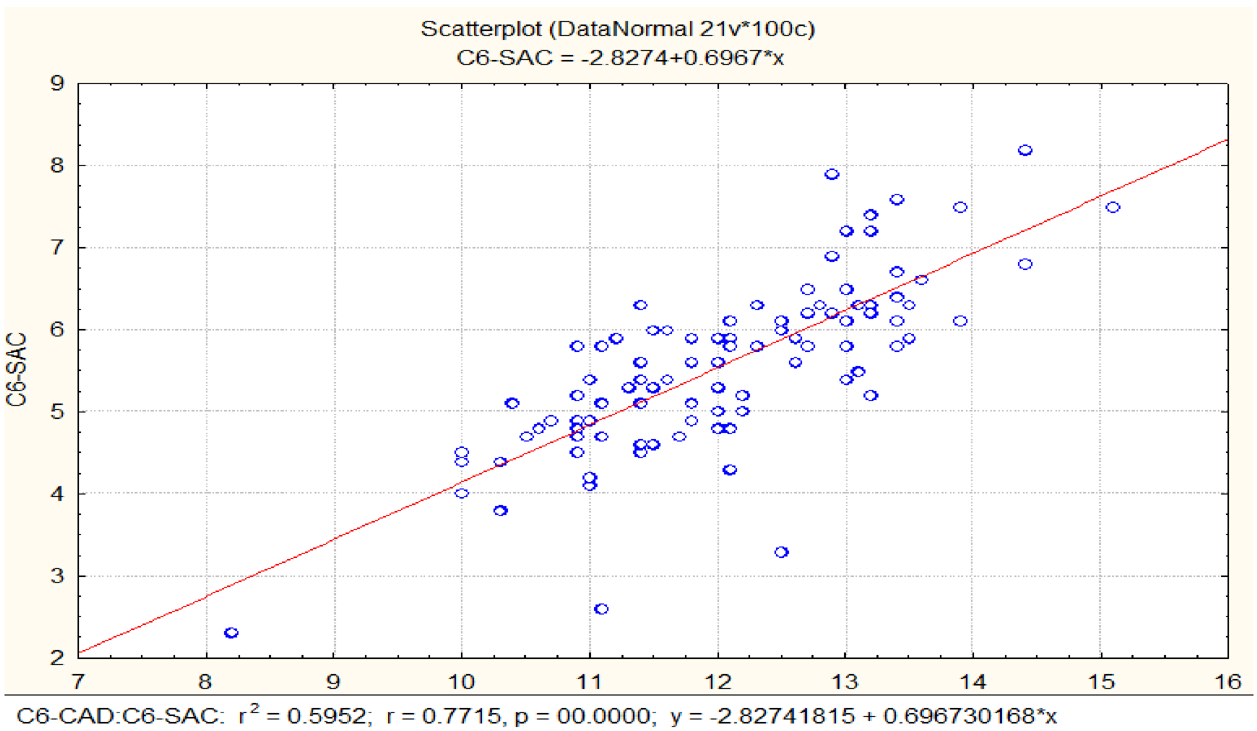

Fig 3: Correlation of CAD with SAC at C6 level in normal subjects

Here also we find that r is nearer to 1 & so there is +ve correlation between CAD & SAC at C6 level [Fig. 3].

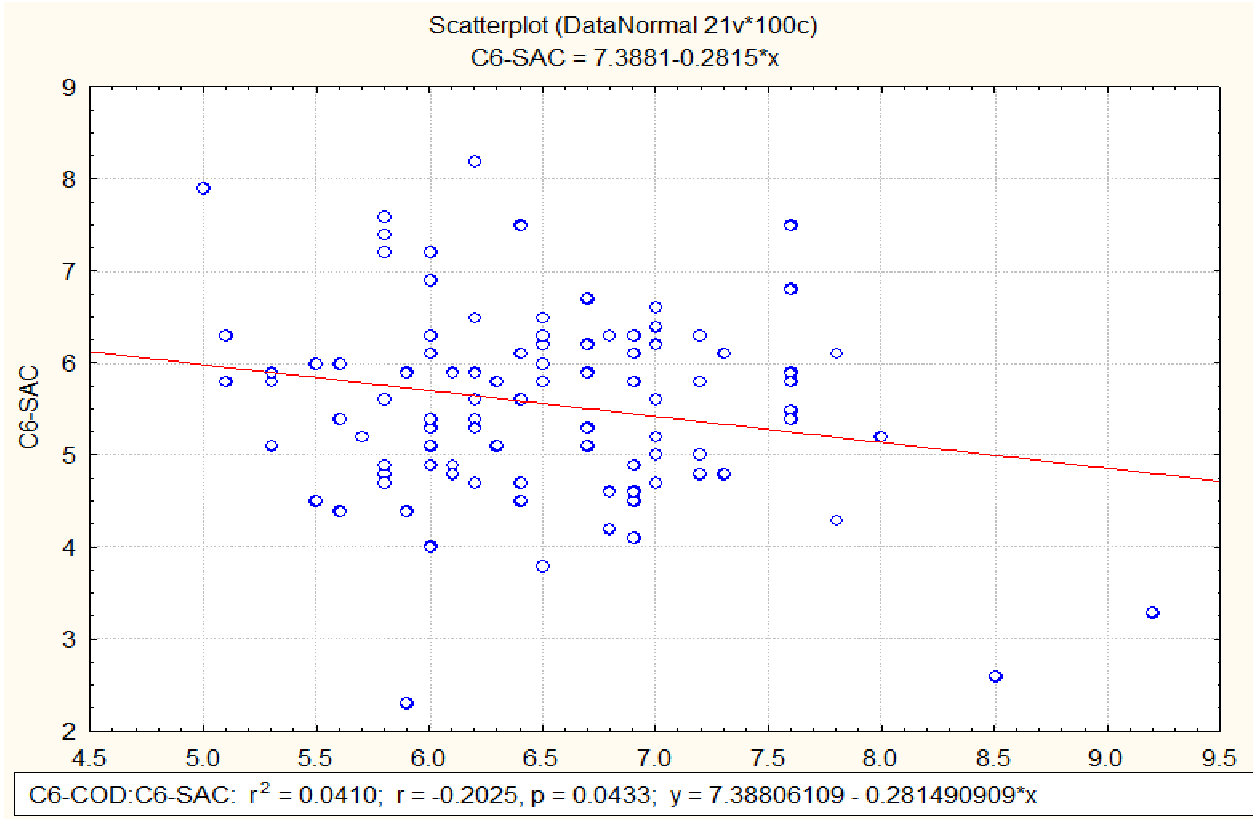

Fig 4: Correlation of COD with SAC at C6 level in normal subjects

In this table also we find that r <0.5 & r^2 nearer to 0 so at C6 level also there is very weak - ve correlation b/w COD & SAC [Fig. 4].

And finally at C7 level, r is>0.8 so strong +ve correlation between canal diameter (CAD) & space available for cord (SAC) at C7 cervical level [Fig. 5].

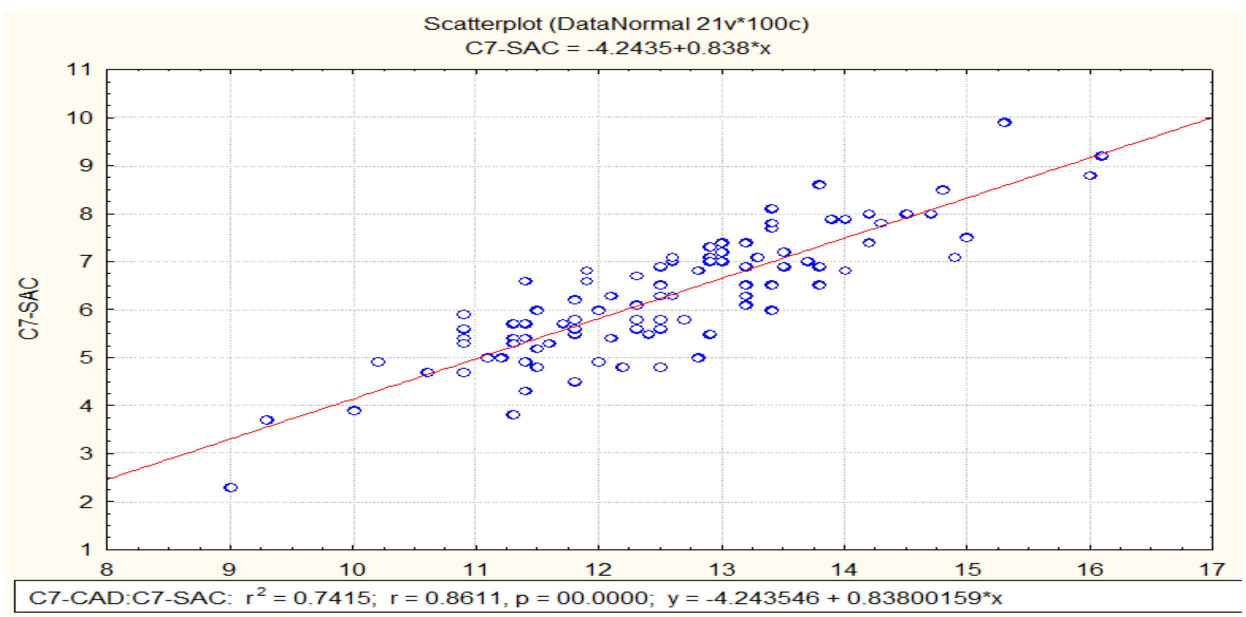

Fig 5: Correlation of CAD with SAC at C7 level in normal subjects

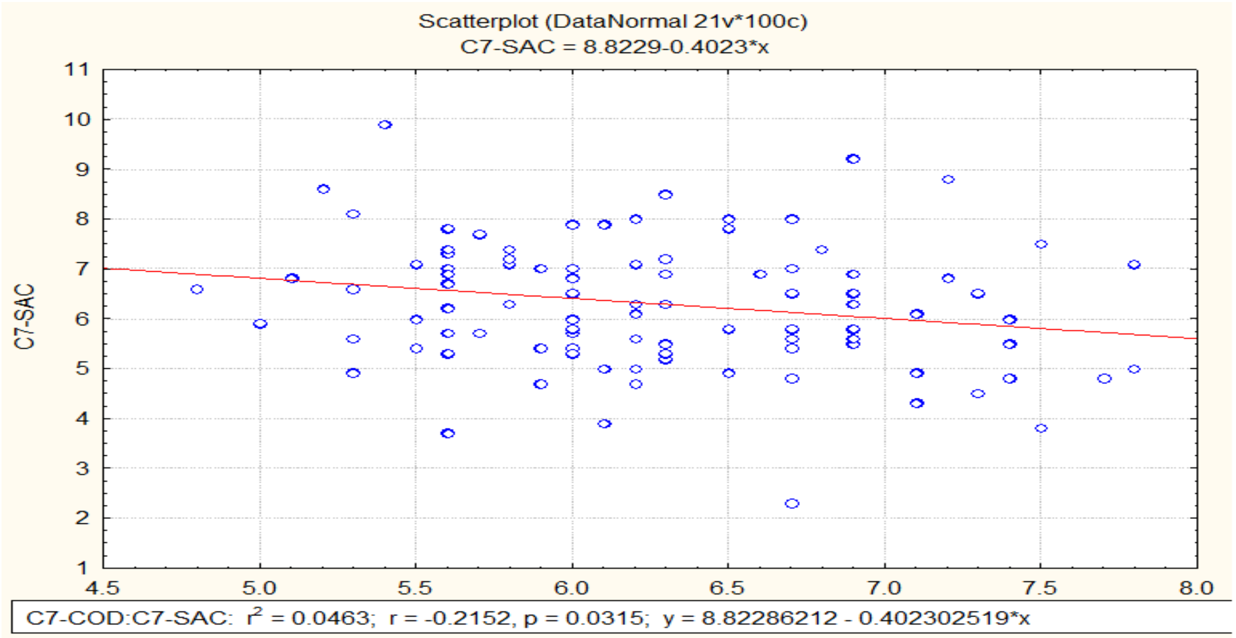

Fig 6: Correlation of COD with SAC at C7 level in normal subjects

And finally for COD also we find that r <0.5 & r^2 nearer to 0 so at C7 level also there is very weak -ve correlation b/w COD & SAC [Fig. 6].

Table 6: Evaluations According to Cervical Canal Diameter (CAD)

Characteristics	Symptomatic	Asymptomatic
Stenotic	31	9
Nonstenotic	19	91

Using the software-MedCal version11.6 (Mariakerke, Belgium:MedCal software, 2011) we get- Sensitivity of cervical canal diameter as a marker of canal stenosis in predicting symptoms— 62% (95%CI 47.17-75.35), specificity 91% (83.6-95.8), positive predictive value (PPV) 77.5% (61.55- 89.16) and negative predictive value (NPV) 82.73% (74.35- 89.7) [Table 6].

Table 7: Evaluations According to Space Available for Cord (SAC)

Characteristics	Symptomatic	Asymptomatic
Stenotic	33	7
Nonstenotic	17	93

Sensitivity of SAC as a maker of cervical canal stenosis in predicting symptoms- 66 % (51.23-78.79), specificity 93% (86.11-97.14), PPV 82.5 %(67.22-92.66), and NPV 84.55% (76.41-90.73) [Table 7].

Table 8: Evaluations According to Both CAD & SAC

Characteristics	Symptomatic	Asymptomatic
Stenotic	41	13
Nonstenotic	9	87

Sensitivity of cervical canal diameter & SAC both as the marker of canal stenosis in predicting symtoms—82% (68.56- 91.42), specificity - 87% (78.80- 92.89), PPV 75.93 % (62.36-86.51) and NPV 90.60 % (82.95- 95.62) [Table 8]. We know that when sensitivity more than 70%, it indicates predictability. Here at table 8 we find that sensitivity is 82%. So we may conclude that in case of patient having symptoms of cervical stenosis, canal diameter and space available for cord both measurements are important.

Fig 1: Measurement of canal diameter

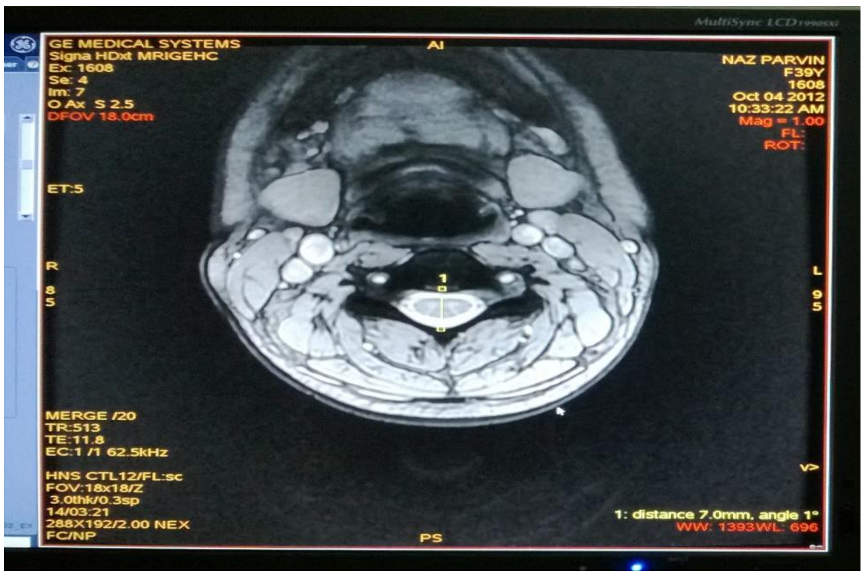

Fig 2: Measurement of cord diameter

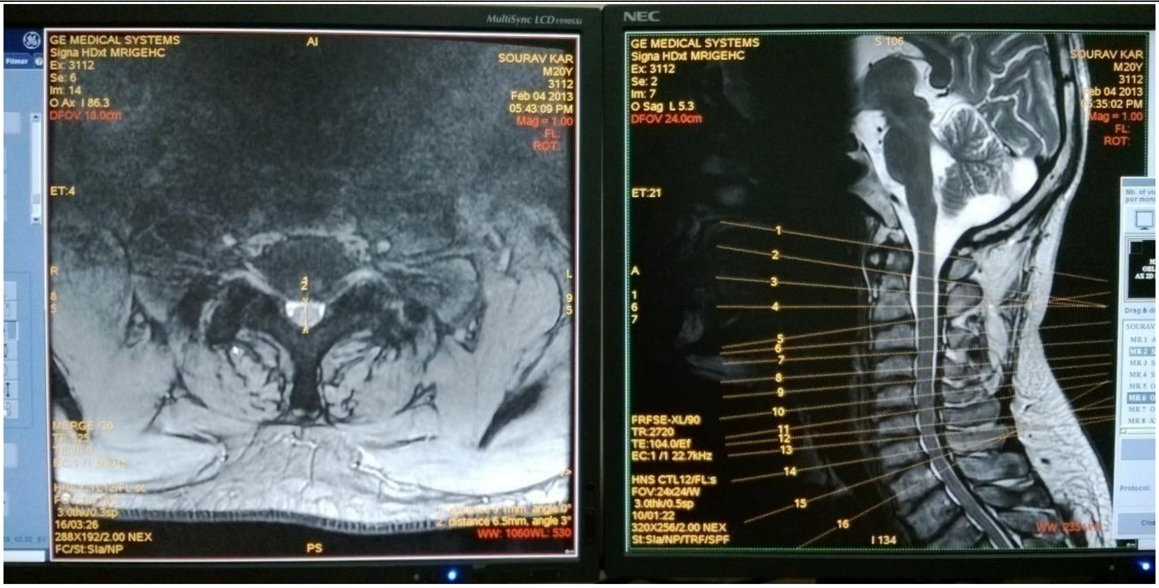

Fig 3: Assessment of stenosis in C7 vertebral level

Fig 4: Measurement of canal and cord diameter in a patient with stenotic symptoms

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 my study; I have measured Canal Diameter & Space Available for Cord at the level of cervical vertebrae, i.e., C3 to C7 level [Fig 1-4] Each vertebra has two main parts — a body in front & vertebral arch behind. Both of them enclose a vertebral canal for the lodgment & 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 [19]. 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 [19]. 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 [20] 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 [20]. 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 [21] 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 [21]. Kyung-Jin Song, et al study [22] 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.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 [23].In this background, 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.In the present 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). Comparison of the data in the normal population between male (n=69) and female (n=31) and also in symptomatic population (male, n=35 and female, n=15) revealed no sexual dimorphism between the observed values of CAD and SAC (in normal group, p value varying from 0.262 to 0.936 and in symptomatic group, p value varying from 0.174 to 0.954). When the CAD values and SAC values were compared at each level from C3 to C7 the data revealed positive correlation at all levels. (At C3 level $r = 0.8686$, $r^2 = 0.7544$; at C4 level $r = 0.7081$, $r^2 = 0.5014$; at C5 level $r = 0.7249$, $r^2= 0.5014$; at C6 level $r = 0.7715$, $r^2 = 0.5952$; at C7 level $r = 0.8611$, $r^2= 0.7414$) revealing inter relationship between these two parameters. Whereas when cord diameters at different level were compared with SAC value at the same level they show poor linear correlation, (at C3 level $r = 0.0633$, $r^2= 0.0040$; at C4 level $r = - 0.1681$, $r^2 = 0.0282$; at C5 level $r= - 0.2748$, $r^2 = 0.0755$; at C6 level $r = - 0.2025$, $r^2 = 0.0410$; at C7 level $r = - 0.2152$, $r^2 = 0.0463$.), thus proving that cord diameter is not of any statistical importance accounting for the variability of the SAC values.When the values of canal diameter (CAD) and SAC were analyzed by Chi square test for their relative importance in differentiating normal asymptomatic population from the symptomatic groups both of this parameter were found significant. The sensitivity of canal diameter for differentiating symptomatic population was 62% with specificity of 91%, whereas for the SAC the sensitivity was 66 % and the specificity was 93 %. When both of these parameters considered together the sensitivity increased to 82 %, specificity being 87%. This indicates importance of both the parameters while predicting the cervical canal stenosis in normal clinical practice.Zhong YM et al [24] study revealed that 30 cases of cervical stenosis included 13 male and 17 female with an average age of 39 years ranging from 28 to 66 years. The sagittal diameter of cervical spinal canal were below 10 mm (absolute stenosis) in 12 cases,within 10 to 12 mm (correspondence stenosis) in 18 cases. MRI scans in neutrality, flexion, extension performanced and the degree of cervical spinal canal stenosis and the changes of spinal cord compression were evaluated after MRI scans obtained. Narrow sagittal cervical canal diameter brings about an increased risk of neurological injuries in traumatic, degenerative and inflammatory conditions and is related with extension of cervical spine, gender, as well as ethnicity [25]. The cord-canal-area ratio (> 0.8) or the space available for the cord (< 1.2 mm) measured on MR images can be used to reliably identify patients at risk for acute CSCI after a minor trauma to the cervical spine [26].

Conclusion

Sensitivity of cervical canal diameter as a marker of canal stenosis in predicting symptoms was 62% (95%CI 47.17-75.35) with specificity 91%, positive predictive value (PPV) 77.5% and negative predictive value (NPV) 82.73%. Sensitivity of SAC as a maker of cervical canal stenosis in predicting symptoms was 66 % (51.23-78.79) with specificity 93%, PPV 82.5 %, and NPV 84.55%. Finally at C7 level, r is>0.8 so strong +ve correlation between canal diameter (CAD) & space available for cord (SAC) at C7 cervical level. Sensitivity of cervical canal diameter & SAC both as the marker of canal stenosis in predicting symptoms was 82% (68.56- 91.42) with specificity 87%, PPV 75.93 % and NPV 90.60 %. 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.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 of margin of error, specifically in the situations where decisions of interventional procedures are to be taken.

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