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Evaluation of Lumbar Canal Diameter and Areas by Computed Tomography

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Abstract: Determining normal ranges of spinal canal diameters, we can make initial diagnosis in persons who have lower diameters of spinal canal. These persons are predisposed to spinal canal stenosis that is a major cause of spinal radiculopathies. In different studies performed in several countries, minimum and maximum ranges of spinal canal diameters were different for each population. In this study, we tried to determine the mean values of normal spinal canal diameters and areas in Tabriz and its suburb. Thirty nine healthy, young to mid-age cases were selected. Our study was focused on L3-L4 and L4-L5. The following parameters were measured: the area of cross-section of the vertebral body, the area of cross-section of the dural sac, interarticular diameter, interligamentous diameter, antero-posterior diameter of the lumbar canal, inter-pedicular diameter and the area of cross-section of the vertebral canal. A correlation between the parameters studied and the height of subjects was significant for interligamentous diameter (for L3/L4 and L4/L5) and interarticular diameter (only at L3/L4), cross-section area of the vertebrae (both L3 and L4), cross-section area of vertebral canal (only at L5 level), area of dural sac (at L3/L4 and L4). It was suggested that these diameters and areas should be interpreted as unction of height of the subject. Most of diameters studied had smaller means than those in previous studies. This can be attributed to differences between populations and it can be interpreted as predisposition to spinal canal stenosis in our population.

Key words: Lumbar canal, diameter, areas, computed tomography, diagnosis, spinal canal

INTRODUCTION

In different studies performed in several counties, minimum and maximum ranges of spinal canal diameters were different for each population. By determining normal ranges of spinal canal diameters we can make initial diagnosis in persons who have lower diameters of spinal canal. These persons are predisposed to spinal canal stenosis, which is the major cause of spinal radiculopathies. Low back pain is the major cause of disability, poor quality of life and societal costs. For example, in the United States (Amonoo-Kuofi *et al*., 1990) the annual societal cost of back pain is estimated to be between $20 and $50 billion (Borenstein and Wiesel, 1995) back symptoms are the most common cause of disability in patients under 45 years of age (Moss *et al*., 1992) approximately 1% of the U.S. population is chronically disabled because of back pain.

The structure of the lumbar spine is complex. To diagnose and treat this area effectively, one must have a clear knowledge of the normal anatomy. Following is an introduction of anatomy of lumbar spine.

Spinal canal stenosis may involve the central spinal canal, its lateral recess (neural canal), the intervertebral foramina, or all three components. Spinal canal stenosis may be developmental or, as is more common, an acquired disease from numerous causes (Moss *et al*., 1992; Rao *et al*., 1994) (Table 1).

Congenital lumbar spinal canal stenosis is more often seen in males than in females; usually in their 2nd or 3rd decade (Amonoo-Kuofi *et al*., 1990). Spinal stenosis syndrome affects mainly patients at their 5-6th decades of life. There is a strong debate in the literature whether patients with spinal stenosis should be operated or treated conservatively (Shabat *et al*., 2006).

Differences in dimensions of male and female specimens were not found to be statistically significant (Ebraheim *et al*., 1996). At all levels (L1-L5) the transverse diameters of the lumbar spinal canal were approximately 1-1.5 mm higher in males than in females (Tacar *et al*., 2003).

Pathological changes can occur in the diameters of the lumbar spinal canal. Therefore, assessing the canal size is an important diagnostic procedure (Tacar *et al*., 2003).

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Table 1: Spinal canal stenosis

Congenital
Idiopathic
Achondroplasia
Morquio's disease
Bone dysplasias
Acquired
Degenerative changes in disk
Spondylolysis
Spondylolisthesis
Facet arthropathy
Posttraumatic
Postsurgical
Ankylosing spondylitis
Ossification of posterior longitudinal ligament (OPLL)
Ossification or hypertrophy of ligamentum flavum
Diffuse idiopathic skeletal hyperosis (DISH)
Metabolic causes:
Paget's Disease
Acromegaly
Epidural lipomatosis
Florosis

(Combination of one or more of the above entities may account for the spinal canal stenosis)

The patients without lumbar symptoms had wider foramina and sagittal diameters in S1 than those with lumbar symptoms (Santiago *et al*., 2001).

In this study, we tried to determine the mean values of normal spinal canal diameters and areas in a healthy, young to mid-age population from Tabriz and its suburb. There are many studies (using different modalities) about measurement of spinal canal diameters in foreign populations (Amonoo-Kuofi *et al*., 1990; Gouzien *et al*., 1990; Lee *et al*., 1978, 1995; Wilmink *et al*., 1988). As to our knowledge, there is no report of normal spinal canal diameters in Iranian populations.

MATERIALS AND METHODS

The subjects: This study was performed on 39 subjects (16 males and 23 female) with age ranging from 18-40. Study cases were selected from patients referred to perform CT scan of other parts of the body and had no low back pain or other problem attributable to lumbar spine.

Technique: Examinations were made using a GE CT-MAX II scanner. Our study was focused on L3-L4 and L4-L5 levels because these levels are studied most frequently in CT-scan examinations. Meanwhile, examination of L5-S1 level is difficult because of technical limitations (angle of gantry in our scanner was limited to 20°). For each, we took a lateral scout view of lumbar spinal canal. Then cuts were made perpendicular to the posterior wall of the vertebral body at each level. About 2 mm thickness was used. For each level (L3-L4 and L4-L5) we acquired a cut through highest part of intervertebral foramen, a cut through the disc and a cut through the middle 3rd of the lower vertebral body. Images were reconstructed in high resolution and printed on film with a window for bony structures (level: 300, width: 1500) and a window for soft tissues (level: 80, width: 1000) and transferred to a PC using an HP transparent flatbed scanner. Measurements were made in adobe Photoshop and converted to actual sizes (mm) using the scale printed with each image.

Parameters studied: Cuts below the pedicles. These cuts were made through the highest part of the intervertebral foramina. The following parameters were measured: the area of cross-section of the vertebral body (SCV-L3 and SCV-L4); the area of cross-section of the dural sac (SF-L3 and SF-L4).

These cuts were made at the level of the middle of the disc and are concerned with the intervertebral articulation. The following parameters were measured: interarticular diameter (DIA-L3/L4 and DIA-L4/L5); interligamentous diameter (DIL-L3/L4 and DIL-L4/L5); area of cross-section of the dural sac (SE-L3/L4 and SF-L4/L5). Measurements were made as greatest diameter between the internal limits of 2 articulations for DIA and the distance between internal borders of the soft parts of the articulations (capsules and ligament flavum) on the line joining the articulations for DIL.

These cuts were made through the third of the vertebral body and show a complete vertebral body ring. The following parameters were measured: antero-posterior diameter of the lumbar canal (DAP-L4 and DAP-L5); inter-pedicular diameter (DIP-L4 and DIP-L5); the area of cross-section of the vertebral canal (SC-L4 and SC-L5). Measurements were made as the distance from the mid-point of the posterior wall of the vertebral body to the anterior border of the point of union of the 2 laminae DAP and the greatest distance between the inner borders of the 2 pedicles for DIP. Measurements of SCV, DAP, DIP, SC and DIA were made on images printed using bony structures window and level, whereas those for SF and DIL were made on images with soft tissue window.

Statistical method: The presence of any significant correlation between the parameters that were measured and the height of the subjects was sought. Coefficients of correlation and p-values corresponding to these coefficients were calculated using SPSS Windows software. A coefficient of correlation was considered significant (not occurring by chance) when the corresponding $p \leq 0.050$ (5%).

RESULTS

Mean age and height of patients were 30±6 year and 167±9.15 cm, respectively. Mean area of vertebral body of L3 and L4 was 1515±254.6 mm^2 and 1470±255.4 mm^2, respectively. Mean area of dural sac of L3 and L4 was 142±30.7 mm^2 and 128±36.4 mm^2, respectively (Table 2).

Mean of interarticular diameter (DIA), interligamentous diameter (DIL), antero-posterior diameter (DSP), interpedicular ciameter (DIP) and area of Spinal of Canal (SC) were showed in Table 2.

Significant liner correlation was found between height and area of vertebral body of L3 (p = 0.008) and L4 (p = 0.007), area of spinal canal of L5 (p = 0.012), interarticular diameter of L3/L4 (p = 0.011), area of dural sac of L3/L4 (p = 0.033), interligamentous diameter of L3/L4 (p = 0.001) and L4/L5 (p = 0.046), respectively (Table 3).

Table 2: Normal measurements of the lumbar canal (39 cases)

Parameters	Mean	SD	Minimum value	Maximum value
Age (year)	30	6.0	18	40
Height (cm)	167	9.15	155	187
Subpedicular cut				
SCV-L3 (mm^2)	1515	254.6	1133	2164
SCV-L4 (mm^2)	1470	255.4	1123	2139
SF-L3 (mm^2)	142	30.7	87	218
SF-L4 (mm^2)	128	36.4	39	221
Cut through disc				
DIA-L3/L4 (mm)	20	3.2	11	28
DIA-L4/L5 (mm)	22	3.7	12	28
DIL-L3/L4 (mm)	12	2.9	4	17
DIL-L4/L5 (mm)	13	3.3	7	20
SF-L3/L4 (mm^2)	133	39.2	68	247
SF-L4/L5 (mm^2)	133	41.6	49	256
Cut through pedicles and lamina				
DAP-L4 (mm)	14	2.7	8	23
DAP-L5 (mm)	15	2.5	10	23
DIP-L4 (mm)	23	2.1	20	27
DIP-L5 (mm)	30	4.7	22	44
SC-;4 (mm^2)	229	45.8	120	322
SC-L5 (mm^2)	281	70.0	137	490

SCV: Area of vertebral body; SF: Area of dural sac; DIA: Interarticular diameter; DIL: Interligamentous diameter; DSP: Antero-posterior diameter; DIP: Interpedicular ciameter; SC: Area of spinal of canal

Table 3: The significant correlation between the measured parameters and the height of subject

Parameters	Mean	SD	p-value
SCV-L3 (mm^2)	1515	254.6	0.008
SCV-L4 (mm^2)	1470	255.4	0.007
SC-L5v	281	70.0	0.012
DIA-L3/L4 (mm)	20	3.2	0.011
SF-L4 (mm^2)	133	39.2	0.033
SF-L4 (mm^2)	128	36.4	0.050
DIL-L3/L4 (mm)	12	2.9	0.001
DIL-L4/L5 (mm)	13	3.3	0.046

SCV: Area of vertebral body; SC: Area of spinal canal; DIA: Interarticular diameter; SF: Area of dural sac; DIL: Interligamentous diameter

DISCUSSION

The diameters: A correlation between the diameters studied and the height of subjects was significant for interligamentous diameter (DIL-L3/L4 and DIL-L4/L5) and interarticular diameter only at L3/L4 level (DIA-L3/L4) (Table 3). This is in contrary with previous studies. Gouzien *et al*. (1990) concluded that there is a significant correlation between height and only interpedicular diameter (Table 4). In our study there was not a significant correlation between interpedicular diameter and height of subjects.

Although it is stated in previous literature that measurement of interligamentous diameter is important in the study of a canal narrowed by degenerative disease, previous studies were not able to demonstrate a significant correlation between height and DIL (Gouzien *et al*., 1990). In our study this significant correlation was present for both levels (DIL-L3/L4 and DIL-L4/L5).

Most of diameters studied had smaller means than those in previous studies (Table 5) (Amonoo-Kuofi *et al*., 1990; Gouzien *et al*., 1990; Lee *et al*., 1995; Wilmink *et al*., 1988). The anteroposterior diameter (DAP) which is essential in diagnosis of canal stenosis, has greater mean in some of previous studies (Gouzien *et al*., 1990). It is stated that the lowest possible normal limit for DAP appears to be 12 mm (Gepstein *et al*., 1991; Gouzien *et al*., 1990), but we had a minimum value of 8 mm for DAP-L4, 10 mm for DAP-L5 and 6 cases had DAP value <12. This can be due to differences between populations in our study and previous studies, or differences between techniques of measurement (less probable particularly for the study performed by Gepstein *et al*. (1991).

Table 4: Significance of correlation between the measured parameter and the height of subjects

Parameters	Our series (1998) (p-value)	Gouzien *et al*. (1990) (p-value)
SCV-L3 (mm^2)	Significant (0.008)	-
SCV-L4 (mm^2)	Significant (0.007)	Significant (0.010)
SF-L3 (mm^2)	Non-significant (0.139)	-
SF-L4 (mm^2)	Significant (0.050)	-
DIA-L3/L4 (mm)	Significant (0.011)	-
DIA-L4/L5 (mm)	Non-significant (0.069)	-
DIL-L3/L4 (mm)	Significant (0.001)	Non-significant (0.100)
DIL-L4/L5 (mm)	Significant (0.046)	Non-significant (0.500)
SF-L3/L4 (mm^2)	Significant (0.033)	Significant (0.010)
SF-L4/L5 (mm^2)	Non-significant (0.347)	-
DAP-L4 (mm)	Non-significant (0.494)	Non-significant (0.670)
DAP-L5 (mm)	Non-significant (0.241)	Non-significant (0.100)
DIP-L4 (mm)	Non-significant (0.133)	Non-significant (0.001)
DIP-L5 (mm)	Non-significant (0.127)	Non-significant (0.001)
SC-L4 (mm^2)	Non-significant (0.155)	Non-significant (0.001)
SC-L5 (mm^2)	Significant (0.012)	Significant (0.010)

SCV: Area of vertebral body; SF: Area of dural sac; DIA: Interarticular diameter; Dil: Interligamentous diameter; DAP: Atero-posterior diameter; DIP: Interligamentous diameter; SC: Area of spinal canal

Table 5: Comparison between mean measurements from the present study and previous reports and significantly

Parameters	Our study 1998-Iran (p-value)	Gouzien *et al.* (1990)-France (p-value)	Hwan-Mp Lee (1995)-Korea	Wilmink *et al.* (1988)-Netherlands
SCV-L4 (mm^2)	1470 (0.007)	1318 (0.010)	-	-
SF-L4 (mm^2)	142 (0.139)	169	-	-
SF-L4 (mm^2)	128 (0.050)	168	-	-
DIA-L3/L4 (mm)	20 (0.011)	22	-	-
DIA-L4/L5 (mm)	22 (0.069)	24	-	-
DIL-L3/L4 (mm)	12 (0.001)	12 (0.100)	-	10
DIL-L4/L5 (mm)	13 (0.046)	15 (0.500)	-	14
SF-L3/L4 (mm^2)	133 (0.033)	155 (0.010)	-	-
SF-L4/L5 (mm^2)	133 (0.347)	157	-	-
DAP-L4 (mm)	14 (0.494)	17 (0.670)	14	14
DAP-L5 (mm)	15 (0.241)	18 (0.100)	14	14
DIP-L4 (mm)	23 (0.133)	26 (0.001)	23	22
DIP-L5 (mm)	30 (0.127)	31 (0.001)	26	25
SC-L4 (mm^2)	229 (0.155)	288 (0.001)	-	-
SC-L5 (mm^2)	281 (0.012)	350 (0.010)	-	-

SCV: Area of vertebral body; SFC: Area of dural sac; DIA: Interarticular diameter; DIL: Interligamentous diameter; DAP: Antero-posterior diameter; DIP: Interpedicular diameter; SC: Area of spinal canal

The areas: A significant correlation was present between cross-sectional area of the vertebrae (both SCV-L3 and SCV-L4) and height of subjection. For cross-section area of vertebral canal there was a significant correlation only at L5 level (SC-L5) (Table 3).

Relationship between area of canal and that of vertebral body have been established in previous literature. Jones and Thomson (1968) have found a ratio with mean value of 0.16 and SD of 0.033 (by conventional radiology). Gouzien *et al.* (1990) have found a mean value of 0.22 and SD of 0.05 (by CT scan). In our series, we found a mean value of 0.158 and a SD of 0.033 ($p = 0.033$) (Jones and Thomson, 1968).

The area of dural sac was significantly correlated with height at L3/L4 and L4 levels (SF-L3/L4 and SF-L4) (Table 3). It has a fundamental importance in the examination of spinal canal. It is more logical to consider the area of dural sac in relation to the size of the canal, because a small sac within a canal that is narrow may be asymptomatic but a large sac in a normal size canal may be pathological.

The ratio between area of dural sac and area of canal has been studied previously. Gouzien *et al.* (1990), has found a mean value of 0.58 and SD 0.10. We found a mean value of 0.558 and a SD of 0.103 ($p<0.001$). It must be mentioned that measurements made by CT scan are static and do not take into account any changes that results from alteration in position and posture. In addition there are other soft tissue structures within spinal canal such as epidural fat and ligament flovum and the joint capsules.

CONCLUSION

A study of lumbar spinal canal at L3-5 level was performed on 39 cases. A significant correlation was found between height of subjects and cross-sectional areas of vertebral body, spinal canal and dural sac and interligamentous and interarticular diameters.

Some diameters that are important in examination of spinal canal stenosis were not significantly correlated with height of subjects (DAP-L4 and DAP-L5). It is important to note that in our study antero-posterior diameter of spinal canal had a mean value slightly lesser than previous studies in other populations (Gouzien *et al.*, 1990). Meanwhile (and may be more important) in our series we had a considerable number of subjects with DAP value lesser than accepted minimum value in other populations. This can be attributed to differences between populations and it can be interpreted as predisposition to spinal canal stenosis in our population. Most of the other parameters had a lesser mean value than other population. This can also be attributed to differences between populations. It is suggested that there can be significant correlation between diameters and areas of spinal canal at upper levels and height of subjects.

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