Scholars Journal of Applied Medical Sciences (SJAMS) **ISSN 2320-6691 (Online)**
Sch. J. App. Med. Sci., 2014; 2(3C):1045-1052 **ISSN 2347-954X (Print)**

(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com DOI: 10.36347/sjams.2014.v02i03.035

Research Article

Morphometry of the Lumbar Vertebrae and its Clinical Significance

Yael Kapoor*, Anil. R. Sherke, Krishnaiah.M, Suseelamma. D.
Department of Anatomy Kamineni Institute of Medical Sciences, Sreepuram, Narketpally, Nalgonda (Dist.)- 508 254, India

***Corresponding author**
Yael Kapoor
Email: yaelkapoor123@gmail.com

Abstract: Low back pain has attracted the attention of anatomists to do the measurements of lumbar vertebrae. Narrowing of all the diameters of the vertebral foramen could be responsible as a factor which might produce low back pain. The aim of the present study was to estimate the average diameters in the mid-sagittal diameter, interpedicular distance and the lateral recess diameter. 6 sets of30 dried cadaveric bones were taken and studied in the Dept. of Anatomy. Age and sex criteria were not considered. We isolated L_1, L_5 vertebrae and other typical vertebrae. The morphometric analysis was done and compared the results with other authors. Average mid sagittal diameter of vertebral canal ranged from 13.06mm to 14.75mm at L_1-L_5vertebral levels, the interpedicular distance ranged from 18.51mm to 21.50mm at L_1-L_5vertebral levels and the depth of the lateral recess ranged from 7.18mm to 8.95mm at L_1-L_5vertebral levels. There is a slight narrowing occuring at L_3 - L_5levels. The lumbar vertebral foramen is oblong in shape in L_1, triangular in shape inL_2 and L_3 vertebrae with more acute lateral angles in L_3. The present study showed that L_3 remains the centre point for transition in the dimensions and hence more susceptible to stenosis and spinal nerve compression.
Keywords: Low back pain, lumbar canal stenosis, mid-sagittal diameter, interpedicular distance, lateral recess diameters, spinal nerve compression

INTRODUCTION

Low back pain is a major public health problem all over the world.An estimated 75% of all the people will experience back pain at some time in their lives out of which most of them recover without surgery, while 3-5% of the patients present with herniated disc and 1-2% have compression of a nerve root. Treatment can be conservative by physical therapy (or) by surgical decompression also called laminectomy in persons experiencing severe pain, claudication, neurological deficit (or) myelopathy [1]. The transverse diameter was largest at L5, (16.19mm), smallest at L1 (7.05mm), transverse angle at L5 (29°) and smallest at L1(9°). Sagittal angle was largest at L5 and smallest at L1 [2]. The mean pedicle width increased from L1-L5 level, maximum at L5 level. The pedicle height in males decreases from L1-L5, maximum at L1 and minimum at L5.In females it decreases gradually from L3-L5, the height being maximum at L1 andL2 levels [3]. There was an increase in the interpedicular distance from L1-L2 to L2-L3 levels, a decrease from L3-L4 to L4-L5 levels being observed on right side while on left side no change was observed[4].With respect to the patients with lumbar pain, the asymptomatic group proved to have wider foramina from L3-L5 and wider sagittal diameters in S1.The patients with canal stenosis revealed lower figures for all diametres of the central canal, lateral recess of L4 and foramina of L4 and L5[5]. Narrowing of the lumbar vertebral canal referred to lumbar canal stenosis, is most typically due to degenerative changes [6]. The interpedicular distance, the mid-sagittal diameter and the antero-posterior diameter of the lateral recess may be a preliminary but useful aid in the diagnosis of lumbar spinal canal stenosis [6].

Our objective is to determine the morphometry of lumbar canal which predispose to degenerative disorders like disc degeneration, lumbar spondylosis, ankylosing spondylitis, injuries like inter vertebral disc prolapse, deficiency disorders like osteoporosis.

The purpose of this study though not concentrating on the above secondary factors but aims at to study the anatomical background which can initiate the low back pain and lower extremity pain.

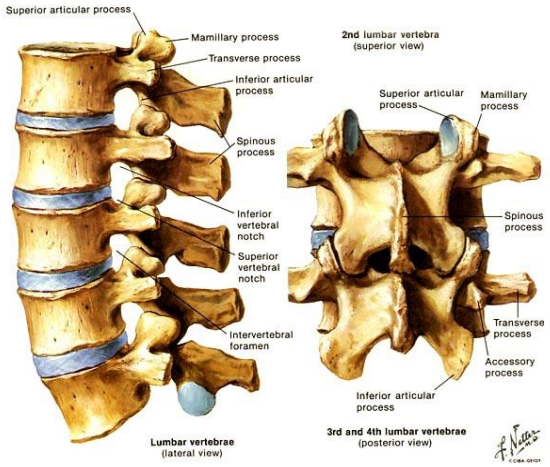

Fig. 1: Shows normal anatomy of the lumbar vertebral column

Anatomy

The lumbar vertebrae are 5 in number designated as L_1 to L_5, out of which L_1 and L_5 are atypical and L_2-L_4 are typical. They differ from the rest of the vertebrae in

(a) Vertebral body is large, wider from side to side and little thicker in front than behind
(b) The pedicles are very strong directed backwards.
(c) The laminas are broad, short and strong.
(d) The vertebral foramen is triangular
(e) The spinous process is thick, broad and somewhat quadrilateral
(f) The transverse processes are long and slender
(g) There are 3 tubercles noticed in the transverse process:
- The lateral costiform process
- The mammillary process is on the back of the posterior articular process
- The accessory process is on the back of the transverse process

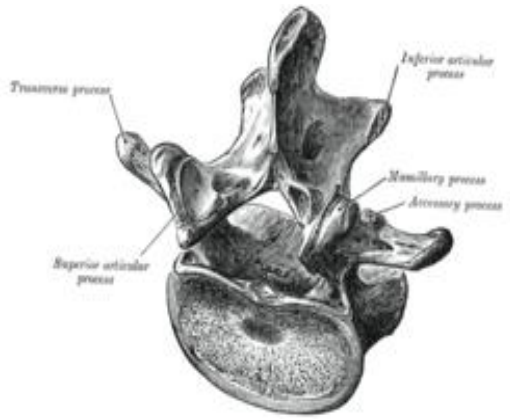

Fig. 2: Shows first lumbar vertebra

(h) The first lumbar vertebra is characterised by strong pedicle which springs from the posterolateral aspect of the body just below its upper border. The spinous process is broader and more in line with the vertebral body and slightly inclined downwards as compared to L_5. Vertebral body is smaller and less thicker than L5 [8].

(i) The fifth lumbar vertebra is characterised by its body being deeper in front than behind, smaller spinous process, thick transverse processes, wide inferior articular processes. This vertebra is a more common site for spondiolysis and spondiolysthesis [8].

Fig. 3: Shows fifth lumbar vertebra

(j) Absence of costal facets.
(k) Absence of foramen transversarium.

Intervertebral Discs

The intervertebral disc which connect the two vertebral bodies are separated from each vertebral body by a hyaline cartilage plate. They are made up of an outer fibrous casing the annulus fibrosis and an inner gelatinous tube the nucleus pulposus.

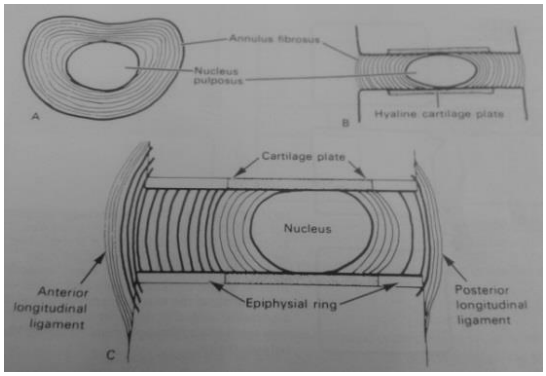

Fig. 4: Shows normal anatomy of the intervertebral disc

The anterior fibres are strengthened by the powerful anterior longitudinal ligament. Posterior longitudinal ligament affords only weak reinforcement especially at L_4-L_5 and L_5-S_1. As the cartilage is avascular it derives its nutrition from the body of the vertebra through the end plates by diffusion. The nucleus pulposus dissipates mechanical stresses. The annulus fibrosis acts as a shock absorber and is

subjected to repeated stress. The first stage of a disc rupture would be detachment if the hyaline cartilage plate, annulus is disrupted, nucleus pulposus escapes out (Fig. 5a). As degeneration continues further and posterior longitudinal ligament gives way and the disc material is extruded into the spinal canal called disc herniation, putting pressure on cord/nerve roots at L_4-L_5 or L_5-S_1 levels. The patient complains of low back pain with radicular pain in the lower limb called sciatica [9] (Fig.5b).

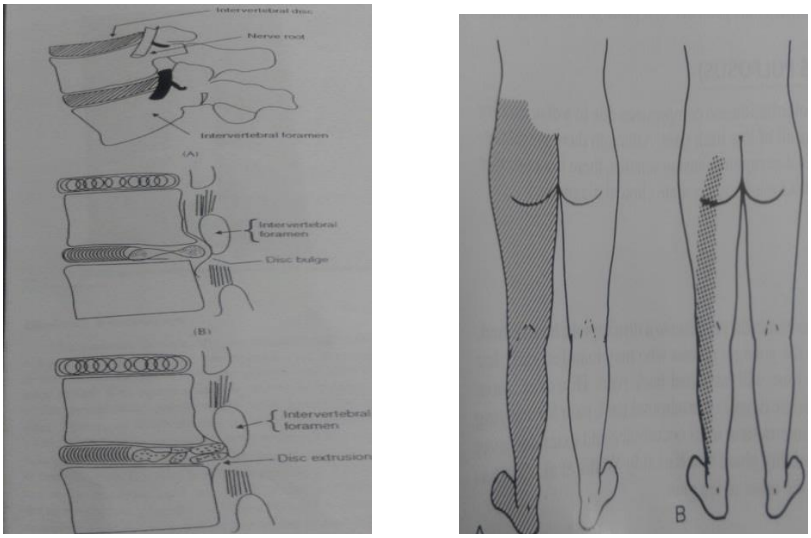

Fig. 5: Shows: a) Prolapse intervertebral disc b) Sciatica

REVIEW OF LITERATURE

According to Dihlmann W [10]; CT of lumbar disc prolapse and vertebral canal stenosis, computed tomography of the herniated lumbar disc, bulging disc and spinal stenosis, represents an investigation of great diagnostic reliability (Fig. 6).

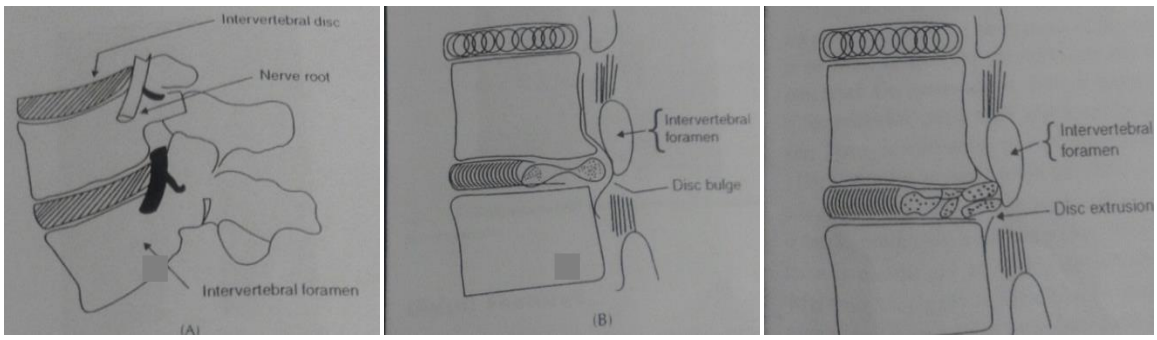

Fig. 6: Shows herniated lumbar disc

Prof. Michael Murphy in his article [17] on "Lumbar canal stenosis", done at the Victorian Brain and Spine Centre, Melbourne, mentioned that lumbar canal stenosis occurs when the bony ring of the lumbar vertebra is affected by degenerative changes of osteoarthritis. Eventually the degenerative changes encroach on the spinal canal and lead to narrowing called stenosis. The excessive degrees of extension, flexion, backward, forward and gliding movements are permitted resulting in the formation of traction spur which differs from osteophytes in that it projects horizontally and develops 1-2mm above the vertebral body edge (Fig. 7).

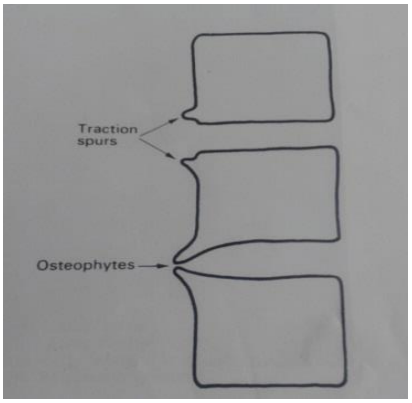

Fig: 7. Shows traction spurs and osteophytes

The next stage of disc degeneration is disc narrowing. The intervertebral discs lose height,

posterior joints override and subluxate, vertebral body shift occurs (Fig: 8)

Fig. 8: Shows subluxation of the vertebrae

According to Justin F Fraser *et al*. [11]; in his article on "Pathogenesis, presentation and treatment of lumbar spinal stenosis associated with coronal (or) sagittal spinal deformities", spondylolisthesis can be caused by congenital, developmental, traumatic, neoplastic (or) degenerative conditions. In degenerative spondylolisthesis, the most common type observed with lumbar stenosis, anteroposterior displacement of a vertebral body results from facet joint erosion and attenuation of the muscular, capsular and ligamentous structures. It occurs most frequently at the L_4- L_5 and L_5-S1levels (Fig. 9).

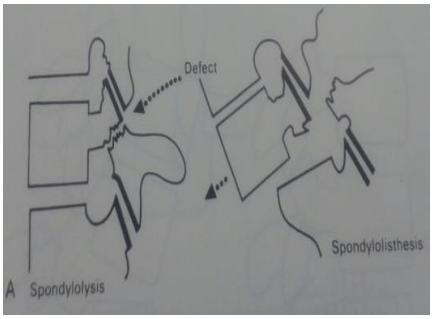

Fig. 9: Shows spondylolysis and spondylolisthesis

According to above author, degenerative scoliosis occurs when one facet joint wears and subluxates more than the other leading to lateral subluxation and development of scoliosis (Fig. 10).

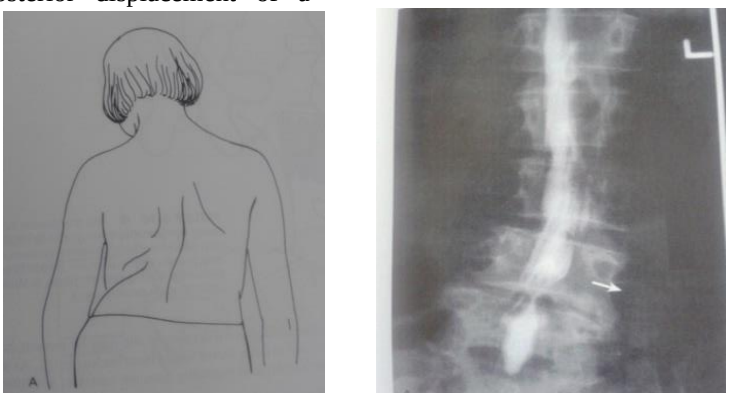

Fig. 10: Shows subluxation leading to scoliosis

In an article by Stig Somme Holm *et al*.; [12], "Lumbar Spondylolysis: A lifelong dynamic condition", studies focussed on young atheletes. Most spondylolytic lesions are considered to be fatigue (or) stress fractures due to repetitive stress (or) microtrauma of the neural arch. The area affected is the pars interarticularis, also called "pars defect", which is the meeting point of the pedicles and thelamina affecting L_5- S_1 (or) L_4-L_5. On X- Ray it gives a classical "Scottish dog with neck belt appearance" (Fig. 11).

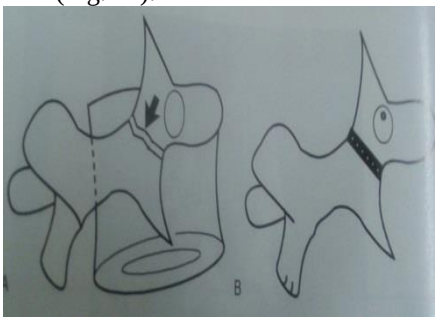

Fig. 11: Shows "pars defect"

In an article by R. Spector *et al*.; [13] stated "CaudaEquina Syndrome", is typically associated with a large space occupying lesion within the canal of the lumbosacral spine (Fig. 12). It is characterised by low back pain, sciatica, lower extremity sensorimotor loss and bowel and bladder dysfunction. It occurs to damage to the nerve roots composing the cauda equine from direct mechanical compression and venous congession (or) ischemia. The syndrome includes urinary retension, perianal (saddle) anaesthesia of the perineum, lower extremity pain and numbness. Decreased rectal tone may be a late finding. Treatment is urgent surgical decompression of the spinal canal. It usually occurs at L_4-L_5 (or) L_5-S_1 spinal segments.

Fig. 12: Shows "Cauda Equina Syndrome"

MATERIALS AND METHODS

Materials

- 30 dried cadaveric lumbar vertebrae
- Vernier calipers

Method

6 sets of dried lumbar vertebrae identified from the Department of Anatomy, KIMS, Narketpally. Among these L_1, L_5 and typical vertebrae (L_2-L_4) are separated. The following measurements were taken with vernier calipers for all these vertebrae and tabulated.

The interpedicular distance is measured as the distance between the inner borders of both the pedicles [6].

Fig. 13: Shows interpedicular distance

The midsagittal diameter is measured as the distance between the posterior border of body of the vertebra and the lamina posteriorly at the midline [6].

Fig. 14: Shows midsagittal diameter

The anteroposterior diameter of lateral recess (depth) is measured from the dorsal surface of the vertebral body to the most ventral segment of the superior articular facet.

Fig. 15: Shows lateral recess

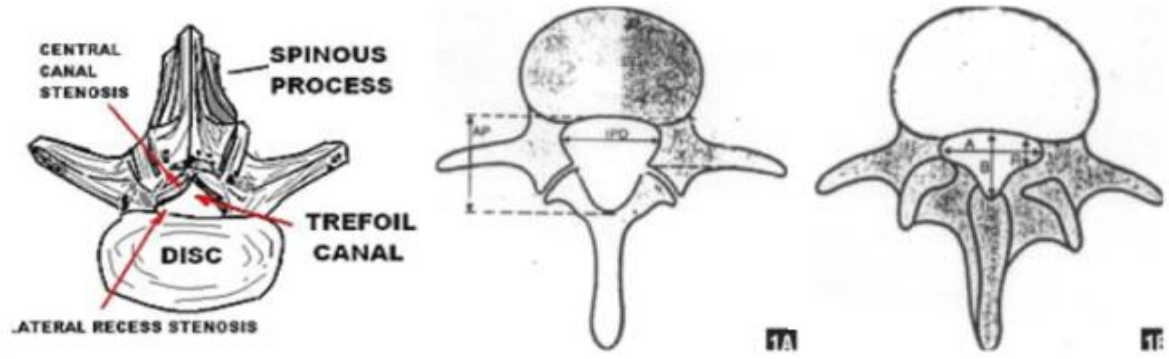

Fig: 16. Showing all the three diameters

OBSERVATIONS

Table 1: Showing sagittal diameter of vertebral canal, interpedicular distance, anteroposterior diameter of lateral recess at L_1, L_5 and typical L_2-L_4 vertebral levels.

Vertebral level	Sagittal diameter of vertebral canal in mm	Interpedicular distance in mm	Anteroposterior diameter of lateral recess in mm
L_1	9.3	16.1	7.1
	13.2	19.3	6.3
	13.3	16.1	7.2
	14.1	20.1	7.1
	15.3	21.3	8.2
	13.3	18.2	7.2
L_5	16.1	24.2	11.3
	17.1	23.2	10.2
	17.3	24.1	11.1
	10.3	18.2	8.1
	14.4	21.1	8.3
	13.3	18.2	7.1
L_2-L_4	13.2	19.3	8.2
	14.3	21.1	9.1
	15.3	23.2	10.2
	14.1	20.3	7.2
	15.2	21.3	8.3
	16.3	22.3	9.1
	15.1	20.3	8.2
	16.3	21.1	9.1
	13.2	22.3	10.3
	16.3	20.3	8.2
	17.3	21.4	9.1
	15.2	20.2	8.3
	16.1	23.2	8.2
	16.3	24.4	10.1
	15.2	22.3	9.2
	13.3	20.3	8.2
	14.2	22.2	9.2
	15.3	21.1	8.3

Table 2: Showing mean diameters at the vertebral levels

Mean sagittal diameter of the canal in mm	Mean interpedicular distance in mm	Mean anteroposterior diameter of the lateral recess in mm
L_1 13.06	18.51	7.18
L_5 14.75	21.50	8.95
L_2-L_4 14.25	21.47	8.79

The average mid sagittal diameter of vertebral canal ranged from 13.06mm – 14.75mmat L_1, L_5 level, at typical level (L_2-L_4) 14.25mm, the average interpedicular distance ranged from 18.51mm – 21.50 mm at L_1, L_5 levels, at typical level L_2 - L_4 21.47mm, the average anteroposterior diameter of the lateral recess ranged from 7.18mm – 8.95mm at L_1, L_5 level at typical level L_2-L_4 8.79mm.

DISCUSSION

Several authors have measured the lumbar vertebral canal. The significance of their data depended on the number of samples, accuracy of their measurements, differences in race & region of the individuals.

According to Mohammed El-Rakhawy *et al*. in 2009 study done on patientsby computed tomography (CT), the inter pedicular distance increased from 21.6 mm at L_1 to 25.1mm at L_5, 21.4mm at L_3, the mid sagittal diameter increased from 14.91mm at L_1 to 15.6mm at L_5 and 13.4mm at L_3 [6].

According to Fernando *et al*. study on patients by CT showed that the asymptomatic group had a wider foramen from L_3 to L_5 than with patients with canal stenosis who revealed lower figures for all diameters of the lumbar canal [5].

In a study done by Tarek Aly *et al*. in (2013) on patients by CT showed that the interpedicular distance ranged from 17.00 to 43.41mm from L_1-L_5levels, mid sagittal diameter from 11.07mm to 26.07 mm from L_1-L_5 levels and lateral recess depth from 4-14mm at L_1-L_5 levels. Narrowing occurred at L_3 [7].

Present study shows the average interpedicular distance, mid sagittal diameter and the anteroposterior diameter of lateral recess at L_1 was 18.51mm, 13.03mm and 7.18mm, at L_5 was 21.50mm, 14.75mm and 8.95mm, and typical vertebral level from L_2-L_4 was 21.47mm, 15.25mm and 8.79mm.

Table 3: Comparison table

Authors	Vertebral levels	Interpedicular distance in mm	Mid sagittal diameter in mm	Antero-posterior diameter of lateral recess in mm
Mohammed El-Rakhawy *et al*. [6] (2009) done by computed tomography	L_1	21.6	14.9	-
	L_2	22.6	15.0	-
	L_3	21.4	13.4	-
	L_4	23.5	15.4	-
	L_5	25.1	15.6	-

Table 4: Comparison table

Authors	Vertebral levels	Interpedicular distance in mm	Mid sagittal diameter in mm	Antero-posterior diameter of lateral recess in mm
Tarek Aly *et al*. [7] (2013) done by computed tomography	L_1- L_5	17.00 – 43.41	11.07-26.07	4-14
	Narrowing occurred at L_3 level			

Table 5: Comparison table

Authors	Vertebral levels	Interpedicular distance in mm	Mid sagittal diameter in mm	Antero-posterior diameter of lateral recess in mm
Present study	L_1	18.51	13.06	7.18
	L_5	21.50	14.75	8.95
	L_2–L_4 (Typical vertebral level)	21.47	14.25	8.79

CONCLUSION

The present dry bone study shows the stenosis of vertebral canal is occurring at a typical vertebral level (L_2- L_4) which is similar to most other studies done on living individuals by CT at L_3 level. There is a narrowing of the vertebral canal occurring at L_2-L_4 level which may lead to compression of the spinal cord and its nerve roots in general population. Some people who are exposed to other factors like osteoporosis, injuries, heavy weight, trauma by carrying heavy loads may become the victims of low back pain.

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