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**Research Article**

# Morphometry of the Lumbar Vertebrae and its Clinical Significance

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**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 $L_1$-$L_5$vertebral levels, the interpedicular distance ranged from 18.51mm to 21.50mm at $L_1$-$L_5$vertebral levels and the depth of the lateral recess ranged from 7.18mm to 8.95mm at $L_1$-$L_5$vertebral levels. There is a slight narrowing occuring at $L_3$ - $L_5$levels. The lumbar vertebral foramen is oblong in shape in $L_1$, triangular in shape in$L_2$ 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.

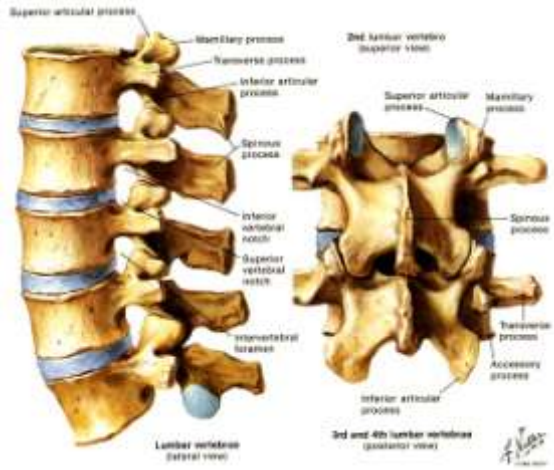

**Fig. 1: Shows normal anatomy of the lumbar vertebral column**

**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

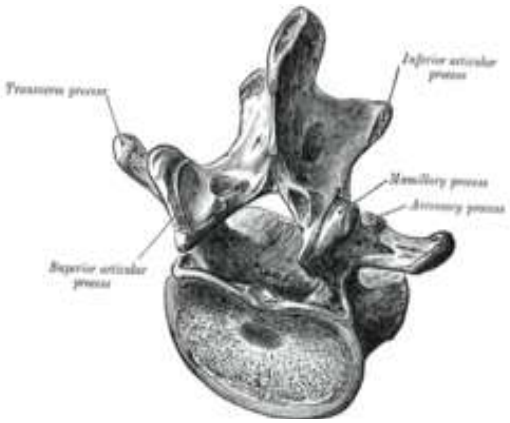

**Fig. 2: Shows first lumbar vertebra**

(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.

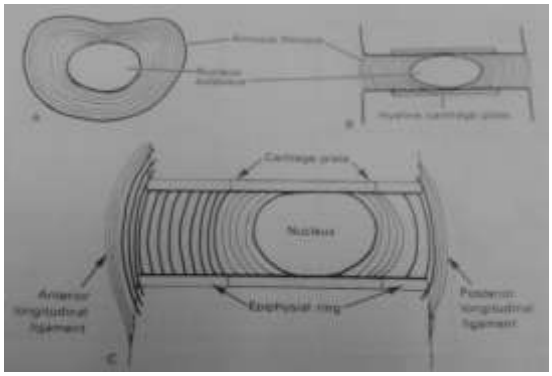

**Fig. 4: Shows normal anatomy of the intervertebral disc**

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).

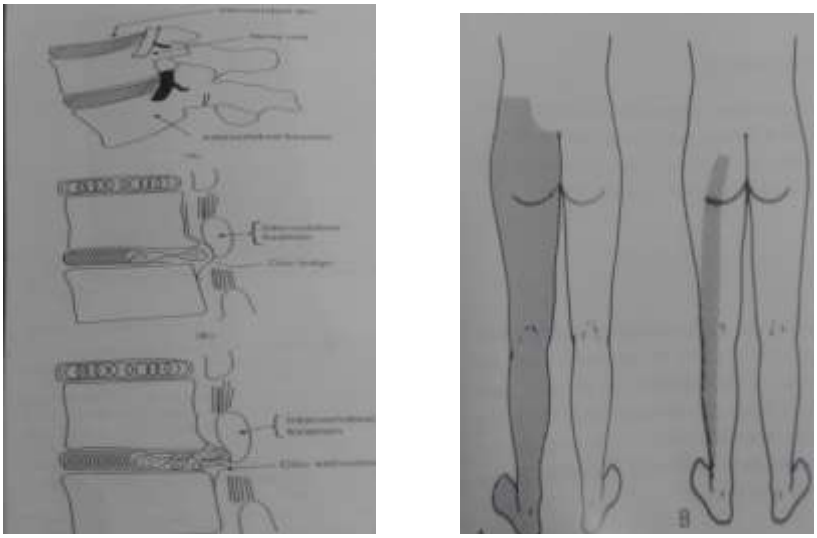

**Fig. 5: Shows: a) Prolapse intervertebral disc b) Sciatica**

**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).

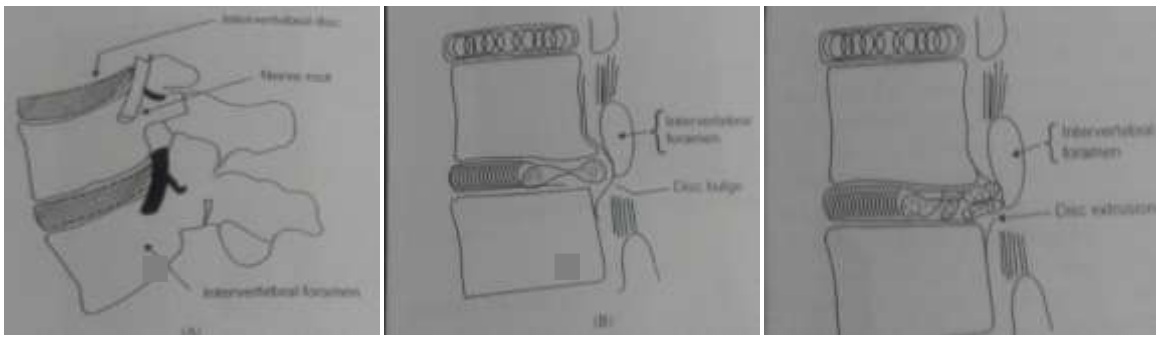

**Fig. 6: Shows herniated lumbar disc**

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).

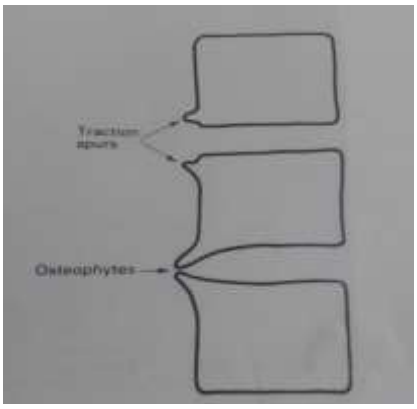


**Fig: 7. Shows traction spurs and osteophytes**

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).

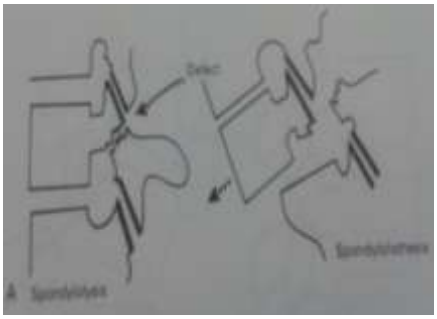

**Fig. 9: Shows spondylolysis and spondylolisthesis**

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).

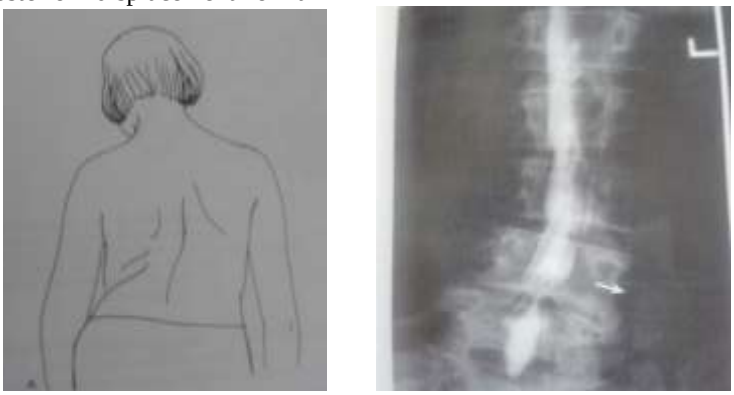

**Fig. 10: Shows subluxation leading to scoliosis**

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).

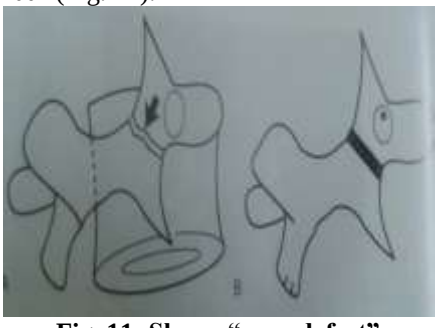

**Fig. 11: Shows "pars defect"**

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**

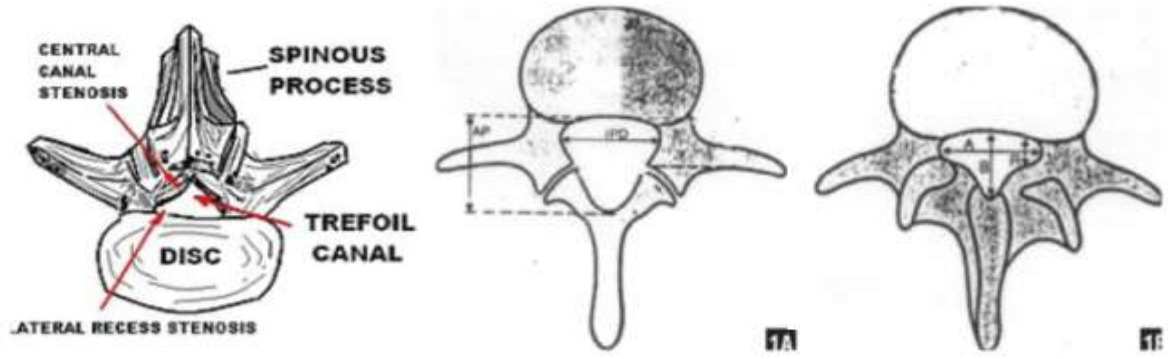


**Fig: 16. Showing all the three diameters**

**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 $L_1$-$L_5$levels, 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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