Information regarding the precise dimensions of the lumbar vertebrae is essential for spinal surgery and instrumentation. When stenosis of the vertebral canal or the intervertebral foramen exists, the neural structures in them can be affected and cause symptoms such as low back or radicular pain. Accurate and comprehensive spinal canal measurements in the lumbar vertebrae are incomplete. The purpose of this study was to collect data on the dimensions of the lumbar spinal canal from computed tomography scans.

Three hundred patients (162 men and 138 women) were studied. Computed tomography scans were obtained to determine the normal values of the midsagittal diameter, interpedicular distance, and lateral recess depth in the normal Egyptian population. The narrowest level was L3. The range of the midsagittal diameter was 11.07 to 26.07 mm at all levels. The range of the interpedicular distance was 17.00 to 43.41 mm at all levels. In all patients at all levels, mean lateral recess depth was 6.7 mm (range, 4-14 mm). The narrowest lateral recess depth was at L5. Few patients (3.3%) had a statistically stenotic midsagittal diameter measurement. The canal shape was not uniform along the 5 lumbar vertebrae; it ranged from being circular or rounded in the upper lumbar vertebrae to triangular in the midlumbar vertebrae to trefoil in the lower lumbar vertebrae, especially at L5. Trefoil canals existed mainly in the lower lumbar vertebrae at L5, followed by L4.

Data from computed tomography scans combined with accurate measurements are the basis for anatomical studies, clinical research, and the development of implants suitable for a group of patients with measurements different from the population standard.

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The authors have no relevant financial relationships to disclose.

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Accurate and comprehensive data on spinal canal measurements in the lumbar vertebrae are incomplete. However, the precise dimensions of the lumbar vertebrae are essential to spinal surgery and instrumentation, such as pedicle screws. Previous studies depended on direct measurements from plain radiographs\(^1\,\text{a}\,\text{b} \) or computed tomography (CT) scans.\(^3\) Few reports have analyzed cadaver specimens.\(^3\,\text{a} \,\text{b}\) The value of the data has depended on the number of samples and the accuracy of the measurements. Panjabi et al\(^5\) reported a comprehensive study of human cadaver lumbar vertebrae, but because of their difficulty in obtaining specimens, the study was limited to 12 specimens. Fang et al\(^5\) reported data applicable to the Asian lumbar spine that were also obtained from CT scans, but these measurements do not necessarily apply to the spine in the normal Egyptian population.

The purpose of the current study was to collect data on the dimensions of the midsagittal diameter and interpedicular distance of the lumbar spinal canal from CT images in the normal adult Egyptian population.

**Materials and Methods**

**Study Population**

Three hundred consecutive patients who presented between 2009 and 2011 underwent CT scans of the abdomen. Inclusion criteria were: (1) CT scan, including images from L1 to S1; (2) patient age of 18 years or older; and (3) lumbar spine appearing normal on CT scans, although minor degenerative changes were allowed if no evidence existed of encroachment on the spinal canal. Exclusion criteria were: (1) accompanying symptoms (eg, low back pain and lower-extremity pain); (2) vertebral abnormalities; (3) gross spinal pathology (eg, spondyloolisthesis, retrolisthesis, and disk space collapse); and (4) previous spinal surgery.

One hundred sixty-two (54%) men with a mean age of 44.3 years (range, 8-74 years) and 138 (46%) women with a mean age of 51.6 years (range, 22-78 years) were included (Table 1). Mean patient height was 170 cm for men and 160 cm for women.

**Measurement Method**

Computed tomography scans were obtained using a Vision GX (Toshiba, Tokyo, Japan). Sequential 3-mm continuous axial images were obtained parallel to the upper and lower endplates for each vertebra and were studied from L1 to L5. Fifteen hundred lumbar vertebrae from L1 to L5 of the 300 patients were examined. Midsagittal diameter, interpedicular distance, and lateral recess depth were measured to determine the normal values of these measurements in the normal Egyptian population.

The images were stored in a computerized system that allowed enhancement, magnification, and rotation and had a measuring tool. To measure the distance between 2 points, a cursor is positioned using the mouse over an initial reference point. The cursor is then moved to the second reference point by dragging the mouse. When the mouse button is released, the distance between the 2 points is displayed in the information box, reflecting a measurement from the CT image and the actual size of the lumbar spinal canal in the plane of the slice. Three parameters were measured from the cross-sectional images in each lumbar vertebra. Statistical analysis was performed using the mean, SD, standard error, and Student’s t test. A P value less than .05 was considered statistically significant.

![Table 1](https://healio.com/Orthopedics/images/orthopedics энергия тепло нуно.png)

**RESULTS**

**Midsagittal Diameter**

Three hundred patients underwent CT scanning. Midsagittal diameter was measured and analyzed statistically (Figure 3). Data are presented as mean±SD (range) for each level for all patients (Table 2). The narrowest level was L3. The range of these measurements at all levels was 11.07 to 26.07 mm.

**Interpedicular Distance**

Interpedicular distance was measured, and data are presented as mean±SD (range) from L1 to L5 for all patients. Mean interpedicular distance was 23.83±2.58 mm (range, 17.00-30.59 mm) in L1, 24.30±2.78 mm (range, 17.08-34.33 mm) in L2, 25.72±3.23 mm (range, 19.10-36.65 mm) in L3, 27.29±3.82 mm (range, 18.00-39.79 mm) in L4, and 31.46±4.69 mm (range, 21.10-43.41 mm) in L5 (Table 3). The range at all levels was 17.00 to 43.41 mm. The measurement of the lumbar vertebrae showed a steady increase in the interpedicular distance from L1 to L5.

**Lateral Recess Depth**

In all patients at all levels, mean lateral recess depth was 6.7 mm (range, 4-14 mm). No significant difference existed between the right and left sides. The narrowest lateral recess depth was at L5.
Canal Shape

Canal shape was not uniform among the 5 lumbar vertebrae; it ranged from circular or rounded in the upper lumbar vertebrae to triangular in the midlumbar vertebrae to trefoil in the lower lumbar vertebrae, especially at L5. The incidence of the trefoil canal shape at L5 was 20%. Patient height had no effect on the measurements.

Discussion

Computed tomography is a validated, simple, standardized method for precise measurement of the spinal canal directly from a CT scan. It is used to measure the normal values of the anteroposterior diameter and interpedicular distance of the lumbar spinal canal. A study of canal configuration should allow the CT to help diagnose lumbar spinal stenosis with a high level of confidence.11

Several authors3,5,7,8,10,12 have measured human vertebrae. The significance of their data depended on the number of samples and the accuracy of their measurements.

Assessing a few samples cannot provide adequate and representative information, and a larger series is required. In addition, the methods used in the past affected the accuracy of the information. It is difficult to obtain several cadaver specimens and to provide appropriate information concerning the dimensions from these specimens because they undergo postmortem changes. Early studies performed with plain radiographs were difficult to interpret, and errors were frequent.

Table 2

<table>
<thead>
<tr>
<th>Vertebra</th>
<th>Mean Midsagittal Diameter (Range), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>16.75 (12.62-26.07)</td>
</tr>
<tr>
<td>L2</td>
<td>15.85 (12.09-20.41)</td>
</tr>
<tr>
<td>L3</td>
<td>15.09 (11.88-20.42)</td>
</tr>
<tr>
<td>L4</td>
<td>15.46 (11.79-22.73)</td>
</tr>
<tr>
<td>L5</td>
<td>16.36 (11.01-24.22)</td>
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Table 3

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</table>
A comparison exists between the study by Zhou et al,7,13,16,17 and the current study. In the current study, the midsagittal diameter of the lumbar spinal canal from L1 to L5 had an hourglass shape. This was also seen in Korean patients in whom the narrowest diameters were found at L3 and L4.16 These findings are consistent with the data reported by Hinck et al.18 The hourglass shape was explained by the fact that the lower end of the lumbar enlargement of the spinal canal is located at L1, which is the transitional area from the thoracic spine to the thin lumbar spine.19 L1 coincides with the region of functional transition between the relatively immobile thoracic spine and the mobile lumbar segment. Therefore, the diameter of the spinal canal at this level may be a reflection of the size of its contents and an adaptation to ensure the protection of those contents during complex movements of this transitional region.17

Few patients (3.3%) who underwent midsagittal diameter measurement had bony stenosis.20 The stenotic vertebrae were marginally below the lower limit of the normal midsagittal diameter of the scanned lumbar vertebrae at each level. The shortest midsagittal diameter in the current study was 11.01 mm, whereas the lower limit of normal is 12 mm.3 Eisenstein7 reported that this marginal skeletal stenosis might predispose patients to cauda equina compression, which may be caused by minimal degenerative changes in bony and soft tissue structures bordering the spinal canal. He reported a slightly lower (1.3 %) incidence.7

In the current study in all lumbar vertebrae (ie, L1 to L5), the interpedicular distance ranged from 17.03 to 43.41 mm; the interpedicular distance showed a steady increase from L1 to L5. This coincides with the reports by Lee et al16 and Zhou et al.13 The minimum normal interpedicular distance values in the current study were slightly lower than those reported by Lee et al.16

Table 4

<table>
<thead>
<tr>
<th>Vertebral Level</th>
<th>Mean Midsagittal Diameter, mm</th>
<th>Akl &amp; Zidan15</th>
<th>P</th>
</tr>
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<tbody>
<tr>
<td>L1</td>
<td>16.75</td>
<td>16.5</td>
<td>&lt;.01*</td>
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<tr>
<td>L2</td>
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Akl and Zidan15 and the current study. In the study by Akl and Zidan,15 L1 had the largest midsagittal diameter in all measured lumbar vertebrae, which matched the current results. Also, a reduction occurred in the value of the midsagittal diameter of the lumbar vertebrae from L1 to L3 and then increased again until L5, which also occurred in the current study (Table 4). When comparing the midsagittal diameter values from the current study with those from the study by Akl and Zidan,15 a statistically significant P value was found (Table 4). This can be explained due to the difference in the instrument used for measurement (CT vs plain radiographs, respectively) and because the current measurements were performed on living humans using CT, whereas Akl and Zidan15 measured the lumbar vertebrae in nonliving specimens that may have undergone postmortal changes. Many morphologic studies of the lumbar spinal canal have been conducted according to race.7,13,16,17

Lee et al,16 Eisenstein,7 and Amonoo-Kuofi17 reported that L1 has the largest midsagittal diameter and that reduction of the midsagittal diameter occurred until L3, followed by an increase again until L5. In correlation with the current study and the study by Lee et al16 on Korean patients, P values were significant. The study performed by Eisenstein,7 which was performed on South African Negroses and Caucasoids, showed a significant P value for the White population. The difference in this outcome may be due to racial and environmental factors or to different measurement methods. The P values of the Black population in the study by Amonoo-Kuofi17 in Nigeria were insignificant (Figure 4).

The introduction of CT provided the first opportunity for an appropriate cross-section assessment, including vertebral body dimensions, in living patients. Computed tomography combined with available digitized measuring tools provides more accurate measurement and can be obtained with comparative ease, allowing a thorough assessment of various vertebral measurements in several patients. Accurate measurement is also allowed on CT by the availability of contrast adjustment for the optimization of image quality and distance measurement. Nevertheless, a potential source of error due to interobserver error, which was 5% in a study by Zhou et al,13 was excluded from the current study because 1 investigator (O.A.) performed all measurements. The axial plane on CT is ideal for assessing the size and configuration of the spinal canal because the entire bony circumference of the spinal canal can be directly visualized.14 In the current study, CT was performed on all patients, and bony encroachment on the spinal canal was well demonstrated. Computed tomography is superior to plain radiography in obese and demineralized patients.

Akl and Zidan15 reported a morphologic study of the lumbar spinal canal on the postmortal lumbar vertebrae of Egyptians. A comparison exists between the study by Lee et al16 and the current study. In the study by Akl and Zidan,15 L1 had the largest midsagittal diameter in all measured lumbar vertebrae, which matched the current results. Also, a reduction occurred in the value of the midsagittal diameter of the lumbar vertebrae from L1 to L3 and then increased again until L5, which also occurred in the current study (Table 4). When comparing the midsagittal diameter values from the current study with those from the study by Akl and Zidan,15 a statistically significant P value was found (Table 4). This can be explained due to the difference in the instrument used for measurement (CT vs plain radiographs, respectively) and because the current measurements were performed on living humans using CT, whereas Akl and Zidan15 measured the lumbar vertebrae in nonliving specimens that may have undergone postmortal changes. Many morphologic studies of the lumbar spinal canal have been conducted according to race.7,13,16,17

Tables 5 through 8 present comparisons between different racial populations and the current study.7,13,16,17

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*Significant.
et al.16 The shape of the spinal canal in the current study was not uniform throughout the 5 lumbar vertebrae. It is not simply a truncated cylinder. In L1, the cross-section is rounded or oval. When it is transverse oval, the transverse diameter is greater than the anteroposterior diameter. In the mid and lower lumbar regions, the spinal canal is triangular, with the apex directed posteriorly with a larger transverse than anteroposterior dimension. In the lower lumbar region, the lamina bows inside with some indentation toward the canal. This finding coincides with the report by Naheedy.21 In the current study, trefoil canals were mainly seen in the lower lumbar vertebrae at L5 and L4, which coincides
with the report by Dorwart et al. The alteration of the shape of the lumbar spinal canal is due to anatomical variation, not to pathological conditions. This view was shared by Eisenstein, who referred to this alteration in the usual triangular shape of the lower lumbar vertebral canal, mostly at L5, as a variation of the normal anatomy and not a pathological state causing compression. The lumbar canal at this level only has to accommodate L5 and the sacral nerve roots.

CONCLUSION
Data from CT scans combined with accurate measurements are the basis for anatomical studies, clinical research, and the development of implants suitable for a group of patients with measurements different from the population standard.

REFERENCES