

Lumbar Pedicle Morphometry in a Sample of the Egyptian Population, Parameters and Measures to Safe Screw Placement

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Abstract

Background: One of the leading causes of disability worldwide is degenerative degeneration of the lumbar spine. The process of fixation in lumbar fusion requires screw insertion into the vertebrae. The pedicle is crucial to postoperative healing and spinal biomechanics. Our goal is to compute the Egyptian population's lumbar spine pedicle morphometry.

Aim of Study: The goal is to determine how the Egyptian population's lumbar spine pedicles are shaped. This would serve as a straight forward manual for Egyptian surgeons to use for determining the pedicle screw's length, diameter, and trajectory before doing surgery on Egyptian patients.

Patients and Methods: From November 20, 2023, until February 20, 2024, Cairo University Hospitals will conduct a prospective study. When acquiring a multi-slice volumetric CT scan of the belly and pelvis OR the lumbar spine, the thinnest slice thickness (≤ 1 mm) is used, and there is no space between the slices. after choosing the proper display window, multi-planar reconstruction in several orthogonal planes (i.e. bone window). Next, measurements of the pedicle's height and transverse diameter, encompassing the L1–L5 vertebrae, will be made. Additionally, the posterior portion of the pedicle up to the anterior two thirds of the vertebral body will be measured bilaterally as the antero-posterior dimension of the L1–L5 vertebrae. Repeated measurements compared by side and level will yield mean values.

Results: Males generally have larger right side lumbar vertebrae (L1 to L5) than females do. The discrepancies are found in all the vertebrae, with L2 (1.367925) exhibiting the largest variance and L5 (0.46226) exhibiting the smallest. This implies that the average size of male vertebrae is greater. Similar to the right side, the data for the left side of the lumbar vertebrae demonstrates that. In addition, males tend to have longer axial lengths than females on both the right and left sides.

Conclusion: Measurements of the lumbar region's pedicles in a sample of Egyptian citizens. These data are thought to be crucial for spine surgeons in planning the precise sizes of the plates and screws used in internal fixation during lumbar fixation and fusion procedures. The anatomical measurements of that specific sample population should be taken into consideration while manufacturing the implants.

Key Words: Lumbar pedicle morphometry – Parameters and measures to safe screw placement.

Introduction

LUMBAR spine degenerative disease, which includes spondylolisthesis, disc degeneration, and lumbar spinal stenosis, is one of the leading causes of disability worldwide. Lumbar degenerative spine disease can impair quality of life since it is linked to a range of clinical symptoms, such as weakness, lower extremity discomfort, and low back pain (LBP) of different intensities [1].

A frequent surgical method for treating spinal diseases such as degenerative disk disease, lumbar stenosis, trauma, deformities, and neoplasms is lumbosacral spine fusion [2].

The process of fixation in lumbar fusion requires screw insertion into the vertebrae. The conventional method for achieving this has been the posterior lumbosacral spine pedicle screw (PS) augmentation, which was initially documented by Boucher in 1959 [3].

The pedicle produced 60% axial pullout resistance and 80% screw stiffness in a study on the pullout resistance of screws, indicating that the pedicle is crucial to spinal biomechanics and postoperative recovery. The majority of academics concur that the two most significant anatomical characteristics of the pedicle are its breadth and height [4].

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In this study we aim to Calculate the morphometry of lumbar spine pedicles in the Egyptian population. This would form a simple guide for the Egyptian surgeons on planning the length, diameter and trajectory of pedicle screws when operating on Egyptian patients.

Material and Methods

CT scans for either abdomen and pelvis or lumbar spine will be collected on PACS system. L1–L5 vertebrae from 106 adults both sexes separated into individual vertebrae.

Each scan will be evaluated by a radiologist with good experience to calculate the morphometric values of pedicle.

Multi-slice volumetric CT scan acquisition of the abdomen & pelvis OR for the lumbar spine is done using the thinnest slice thickness ($\leq 1\text{mm}$) and with no gap in between the slices. Followed by multi-planar reconstruction in different orthogonal planes after selecting the appropriate display window (i.e. bone window). Then the transverse diameter and height of the pedicle will be measured including L1–L5 vertebrae. Furthermore, the antero-posterior dimension of (L1–L5 vertebrae) will be measured from the posterior aspect of the pedicle up to the anterior two thirds of the vertebral body bilaterally.

Mean values will be derived from repeated measurements compared by level and side.

This is done to provide the anatomic orientation of the pedicle in relation to the vertebral body

The study will take place in Cairo University Hospitals in the period from 11/2023 to 2/2024.

Inclusion and exclusion criteria:

Inclusion criteria:

- Adult patients >18 years old.
- Egyptian population
- Both genders

Exclusion criteria:

- Pediatric patients <18 years old.
- Patient who already had spine surgery.
- Patients with history of lumbar spine fractures.

Sample size calculation: Using PASS 11 sample size calculator with 0.05 alpha error and power of study 0.80, after applying test of difference of proportions; Calculating minimal sample size needed to detect Lumbar pedicle Morphometry in the Egyptian Population for the sensitivity based on literature , the total sample size will be 106 patients. Stat Data analysis: Data analysis packages will be SPSS version 21. Qualitative data will be presented by number and percentage, quantitative data will be

presented by mean, standard deviation, and median. Statistical tests will be done for parametric and non-parametric data accordingly.

SPSS version 21 data analysis packages will be used. Quantitative data will be provided as mean, standard deviation, and median; qualitative data will be presented as number and percentage. Accordingly, statistical tests for both parametric and non-parametric data will be conducted. A *p*-value of 0.05 or less will be taken into consideration for the level of significance.

Results

Results were noted independently for male and female vertebrae. The height, width, and length of the left and right pedicles of the L1 to L5 vertebrae in both sexes are the mean values with standard deviation.

Pedicle width:

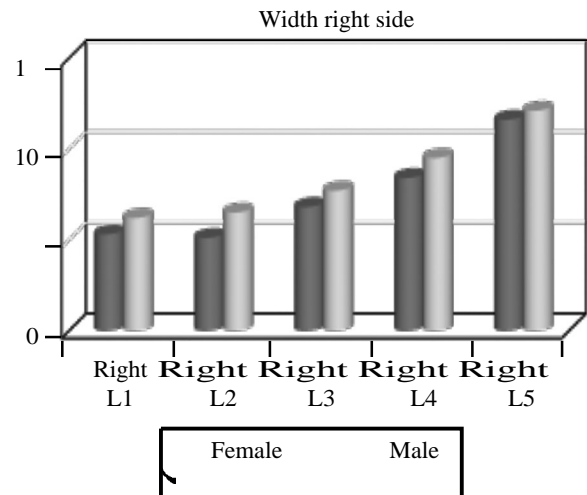


Fig. (1): Width right side.

Table (1): Width Right side.

Diameter	Female	Male
Right L1	5.375472	6.25283
Right L2	5.186792	6.554717
Right L3	6.837736	7.70566
Right L4	8.456604	9.5
Right L5	11.68868	12.15094

The above bar chart and tabulated data indicates that the diameters of the right side of the lumbar vertebrae (L1 to L5) are consistently larger in males compared to females. The differences vary across the vertebrae, with the most significant difference observed at L2 (1.367925) and the smallest difference at L5 (0.46226). This suggests that male vertebral dimensions are generally larger.

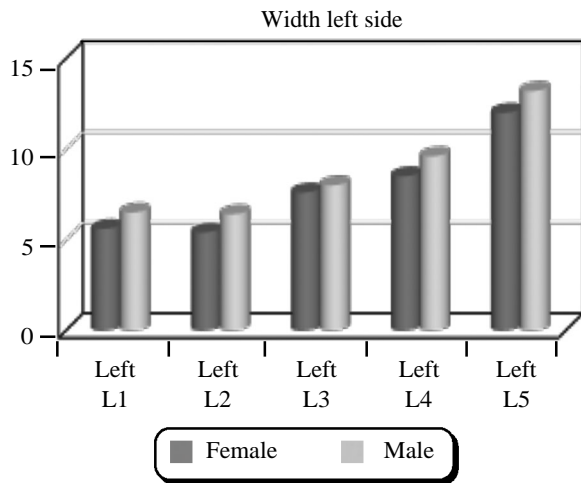


Fig. (2): Width left side.

Table (2): Width Left side.

Diameter	Female	Male
Left L1	5.639623	6.549057
Left L2	5.458491	6.467925
Left L3	7.601887	8.05283
Left L4	8.503774	9.632075
Left L5	11.99057	13.21698

The data for the left side of the lumbar vertebrae shows that, similar to the right side, the diameters are consistently larger in males compared to females across all lumbar levels (L1 to L5). The differences in diameter range from 0.450943 at L3 to 1.22641 at L5, indicating a noticeable difference with males having larger vertebral dimensions. The most significant difference is seen at L5, while the least difference is at L3.

Pedicle height:

The following illustrated data indicates that females tend to have greater pedicle height at the upper lumbar levels (L1 and L2), whereas males have greater height at the lower lumbar levels (L3 to L5). The most significant difference is observed at L4, where male pedicle height exceeds female pedicle height by 0.905656.

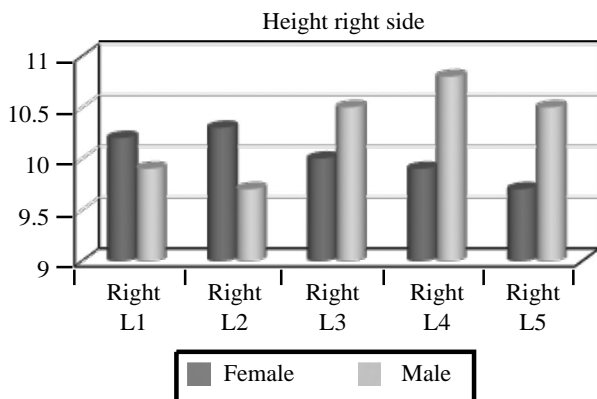


Fig. (3): Height Right side.

Table (3): Height Right side.

Height	Female	Male
Right L1	10.24528	9.909434
Right L2	10.31132	9.777358
Right L3	10.00943	10.53208
Right L4	9.962264	10.86792
Right L5	9.735849	10.54717

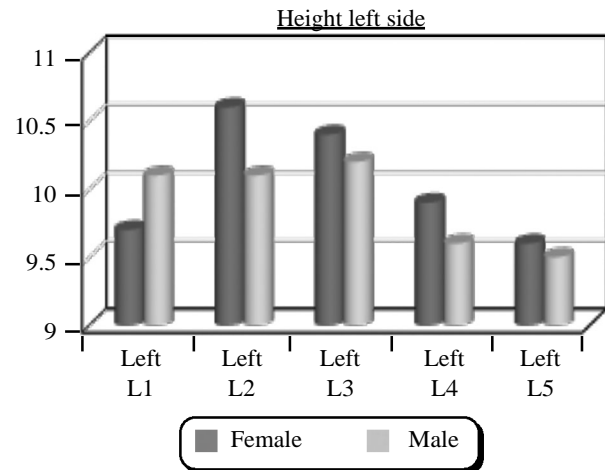


Fig. (4): Height Left side.

Table (4): Height Left side.

Height	Female	Male
Left L1	9.764151	10.19057
Left L2	10.62264	10.12264
Left L3	10.41509	10.24528
Left L4	9.924528	9.641509
Left L5	9.603774	9.588679

Comparing the average pedicle height between male and female vertebrae on the left side, we can observe that the average pedicle height for females (10.064 mm) is slightly higher than that for males (9.958 mm). However, the differences are not substantial.

Axial length:

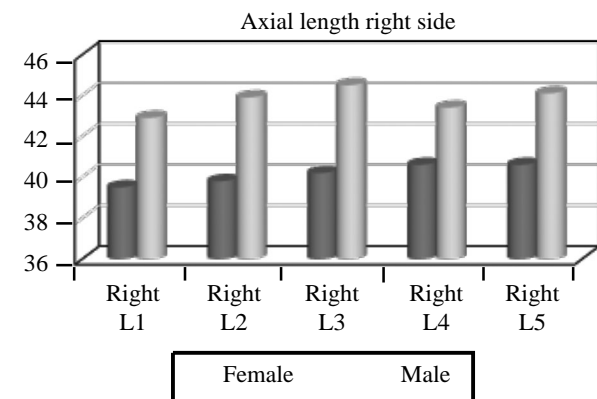


Fig. (5): Axial length right side.

Table (5): Axial Length right side.

Axial length	Female	Male
Right L1	39.5283	42.90566
Right L2	39.86792	43.90566
Right L3	40.22642	44.50943
Right L4	40.69811	43.41509
Right L5	40.62264	44.11321

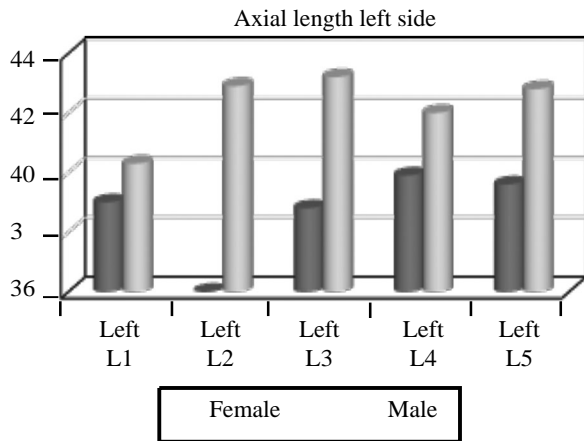


Fig. (6): Axial length left side.

Table (6): Axial Length left side.

Axial length	Female	Male
Left L1	39.0566	40.33962
Left L2	38.49057	42.90566
Left L3	38.83019	43.20755
Left L4	39.9434	42.00214
Left L5	39.64151	42.83019

Average Axial Length - Right Side:

- Female average axial length (Right side) = $(39.53 + 39.87 + 40.23 + 40.70 + 40.62) / 5 \approx 40.39$ mm
- Male average axial length (Right side) = $(42.91 + 43.91 + 44.51 + 43.42 + 44.11) / 5 \approx 43.572$ mm.

Average Axial Length - Left Side:

- Female average axial length (Left side) = $(39.06 + 38.49 + 38.83 + 39.94 + 39.64) / 5 \approx 39.392$ mm.
- Male average axial length (Left side) = $(40.34 + 42.91 + 43.21 + 42.00 + 42.83) / 5 \approx 42.658$ mm.

Across both right and left sides, males generally have longer axial lengths compared to females. This difference is consistent across all vertebrae levels measured.

Discussion

The pedicle is an irregular polymorphous tubular structure that forms the transition between the vertebral body and the lamina when viewed from the coronal plane. Panjabi characterizes the pedicle's shape as being akin to an irregular dumbbell [5].

However, anatomic variations of the lumbar pedicle can make screw placement challenging in posterolateral lumbar fixation and fusion procedures, and retrospective studies have demonstrated that even in experienced hands, pedicle wall violations can occur in up to 29% of cases [6]. Thus, one of the keys to a successful transpedicular procedure is knowledge of the lumbar pedicle morphometry [7].

Transverse pedicle width (TPW):

Since it dictates the size of the pedicle screw to be utilized during surgery, TPW is a crucial metric for pedicle screw insertion. Males had larger dimensions than females in every previous study that measured transverse pedicle diameter.

Males showed higher dimensions than females in a research by Muhammad M. Alam (2014) et al. [8] utilizing CT scans on a sample of the Pakistani population [8]. In a different study, male cadaveric specimens had greater dimensions than female cadaveric specimens, and TPW gradually increased from L1 to L5 vertebrae in the North American population, according to Charles C. Yu (2015) et al. [9]. Research on the Indian populace also revealed that men had larger dimensions than women [10].

Because the TPW dimensions measured by CT in this study are somewhat smaller than those of the western and Indian populations, a little smaller size screw may be needed, especially in females [9].

Pedicle height:

According to our research, males have higher pedicle heights at the lower lumbar levels (L3 to L5), whereas females have higher pedicle height values at the upper lumbar levels (L1 and L2). With the exception of L5, where the Chinese population has a higher value than other populations (20.5mm), the values for American populations are, nevertheless, greater at all levels than those for Asian [11,12]. As the values are more than the pedicle width at all lumbar levels, the pedicle height in the current study most closely approaches that in the Pakistan study, where the pedicle height has no bearing on choosing the proper diameter pedicle screw [8].

Pedicle axial length:

Knowing the PAL value before operation is very important to prevent breach of the anterior cortex. It is evident from our study that the length of pedicles is around 4cm of all lumbar levels. Across both right and left sides, males generally have longer axial lengths compared to females, also axial lengths on the right side are greater for both males and females. In males, the largest values were at L3, while the highest values for females were at L4. The values were similar to data from western populations. This also agrees with Li et al., who stated that pedicle length decreased gradually from L1 to L5 and co-

incided with weight increasing and weight bearing [13].

L2 was measured as 53.3 ± 0.6 mm, L3 as 53.3 ± 3.2 mm, L4 as 55.4 ± 3.0 mm, and L5 as 52.0 ± 4.5 mm in men, and 49.7 ± 4.7 mm, L3 as 47.0 ± 3.4 mm, L4 as 50.2 ± 4.7 mm, and L5 as 46.0 ± 5.7 mm in females, according to a CT study of PAL in western populations. The greatest value was at L4 for both sexes, and the lowest value was at L5 [12]. L1 47 ± 3.39 mm, L2 49.03 ± 3.39 mm, L3 47.21 ± 3.95 mm, L4 47.48 ± 5.38 mm, and L5 48.91 ± 4.42 mm were the PAL values found in a 50 patient CT investigation of the Indian population without regard to sex, with L2 having the greatest value and L1 having the lowest value. The male values were greater at all levels than the female values, and there was a direct drop from L1 to L5, according to the Iranian population study that evaluated the CT scans of 25 males and 25 females. The male PAL values were L1 49.88 mm and 45.08 mm while the female PAL values were L5 50.2 mm and 46.4 mm [14,15].

Conclusion:

We present the measures of the lumbar region's pedicles in a sample of Egyptian citizens. These data are thought to be crucial for spine surgeons in planning the precise sizes of the plates and screws used in internal fixation during lumbar fixation and fusion procedures. The anatomical measurements of that specific sample population should be taken into consideration while manufacturing the implants.

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قياس شكل العنق القطني فى عينة من السكان المصريين، المعلومات والتدابير اللازمة لوضع المسمار بشكل آمن

الخلفية: أحد الأسباب الرئيسية للإعاقة فى جميع أنحاء العالم هو تنكس العمود الفقرى القطنى. تتطلب عملية التثبيت فى الدمج القطنى إدخال المسمار فى الفقرات. يعتبر العنق أمرًا بالغ الأهمية للشفاء بعد العملية الجراحية والميكانيكا الحيوية للعمود الفقرى. هدفنا هو حساب قياس شكل عنق العمود الفقرى القطنى للمصريين.

الهدف: الهدف هو تحديد كيفية تشكيل عنقات العمود الفقرى القطنى لدى السكان المصريين. سيكون هذا بمثابة دليل مباشر للجراحين المصريين لاستخدامه فى تحديد طول مسمار العنق وقطره ومساره قبل إجراء الجراحة على المرضى المصريين.

الطرق: فى الفترة من ٢٠ نوفمبر ٢٠٢٣ حتى ٢٠ فبراير ٢٠٢٤، ستقوم مستشفيات جامعة القاهرة بإجراء دراسة استطلاعية. عند إجراء فحص مقطعى حجمى متعدد الشرائح للبطن والحوض أو العمود الفقرى القطنى، يتم استخدام أنحف شريحة بسمك (١ مم)، ولا توجد مسافة بين الشرائح. بعد اختيار نافذة العرض المناسبة، إعادة البناء متعدد المستويات فى عدة مستويات متعامدة (أى نافذة العظام). بعد ذلك، سيتم إجراء قياسات لارتفاع العنق والقطر العرضى، الذى يشمل الفقرات L1-L5. بالإضافة إلى ذلك، سيتم قياس الجزء الخلفى من العنق حتى الثلثين الأماميين من الجسم الفقرى بشكل ثنائى كالبعد الأمامى الخلفى للفقرات L1-L5. القياسات المتكررة مقارنة بالجانب والمستوى سوف تسفر عن قيم متوسطة.

النتائج: الذكور بشكل عام لديهم فقرات قطنية فى الجانب الأيمن أكبر (من L1 إلى L5) مقارنة بالإناث. تم العثور على التناقضات فى جميع الفقرات، حيث تظهر L2 (١,٣٦٧٩٢٥) أكبر تباين وL5 (٠,٤٦٢٢٦) تظهر أصغرهما. وهذا يعنى أن متوسط حجم فقرات الذكور أكبر. وكما هو الحال فى الجانب الأيمن، فإن البيانات الخاصة بالجانب الأيسر من الفقرات القطنية توضح ذلك. بالإضافة إلى ذلك، يميل الذكور إلى أن يكون لديهم أطوال محورية أطول من الإناث على الجانبين الأيمن والأيسر.

الاستنتاج: قياسات عنقات المنطقة القطنية فى عينة من المواطنين المصريين. يُعتقد أن هذه البيانات مهمة لجراحي العمود الفقرى فى تخطيط الأحجام الدقيقة للمسامير المستخدمة فى التثبيت الداخلى أثناء إجراءات التثبيت والدمج القطنى. ينبغى أن تؤخذ فى الاعتبار القياسات التشريحية لتلك العينة المحددة أثناء تصنيع المسامير.