MORPHOMETRIC STUDY OF LUMBAR SPINE PEDICLES IN A WEST AFRICAN POPULATION AND SURGICAL IMPLICATION IN PEDICULE SCREWS

ETUDE MORPHOMETRIQUE DES PEDICULES LOMBAIRES DU SUJET OUEST-AFRICAIN ET IMPLICATIONS DANS LES VISEES PEDICULAIRES

Konan ML[1,3], Koffi GR[2], Meuga MW[1], Djondé GE[1,3], Diby SS[1], Fatoh E[4] , Kakou M[3],

1. Department of Neurosurgery, Teaching Hospital of Yopougon, University Felix Houphouet Boigny, Abidjan- Ivory Coast
2. Department of Physical Medicine and Rehabilitation, Teaching Hospital of Angre, Abidjan- Ivory Coast
3. Department of Human Anatomy, School of Medicine- University Felix Houphouet Boigny, Abidjan- Ivory Coast
4. Department of Radiology, CHU Cocody, School of Medicine- University Felix Houphouet Boigny, Abidjan- Ivory Coast

ABSTRACT

Background: Lumbar pedicles are usually used as screw insertion sites for stabilization of degenerative and traumatic lesions of lumbar spine. In preoperative planning, the dimensions of screw (length and diameter) and their orientation must be matched to the pedicle morphometry. The aim of this study was to provide lumbar pedicle morphometric characteristics of sub-Saharan African subjects for direct surgical application.
Methodology: A radio-anatomical study was done on the lumbar pedicles of 42 adults (17 male and 25 female) representing 420 pedicles ,from June 1 to October 26, 2021 at the radiology department of the University Hospital of Cocody. The data were collected from the axial and sagittal section scans and measurements were made. A Student's t-test was performed to compare pedicle morphometric data by gender.
Results: The pedicle transverse angle ranged from 24.0 to 35.7 degrees in male and from 23.3 to 34.4 degrees in female, with a significant gender difference. Pedicle diameters ranged from 7.06 to 13.4 mm in male and from 6.53 to 12.4mm in female. Pedicle height ranged from 9.07 to 13.5 mm in male and 9.46 to 13.4 mm in female ,decreasing caudally. The maximum length of a lumbar pedicle screw ranged from 10.1mm to 12.2mm in male versus 11.2 to 12.4mm in female and was significantly different according to gender at L1 (p=0.0337) and L2 (0.0419).
Conclusion: This study provides important pedicle morphometric data to spine surgeons for selection of pedicle screws.

Key words: Morphometry, Pedicle, Lumbar spine, Radio-Anatomy, West Africa

Correspondant :
Konan Meleine Landry ,
landrix07@gmail.com

Soumis : 14/11/2022
Accépté : 04/01/2023

Citation : *Morphometric study of lumbar spine pedicles in a west african population and surgical implication in pedicule screws.*
Konan ML, Koffi GR, Meuga MW, Djondé GE, Diby SS, Fatoh E, Kakou M.
JAMO 2023; 8 (1): 8-17.

RESUME

Contexte/ Justification *: Les pédicules lombaires sont fréquemment utilisés comme site d'insertion de matériel d'ostéosynthèse (vis pédiculaires) pour la stabilisation des lésions dégénératives et/ ou traumatiques du rachis lombaire. Dans la planification pré opératoire, les dimensions (longueur et diamètre) des vis et leur orientation doivent correspondre à la morphométrie du pédicule. Le but de ce travail était d'analyser les caractéristiques morphométriques des pédicules du rachis lombaire chez les sujets d'Afrique sub-saharienne dans un but chirurgical.*
Méthodologie *: Une étude radio-anatomique a été réalisée à partir des données*

scannographiques de rachis lombaire chez 42 patients adultes (17 hommes et 25 femmes) soit 420 pédicules, pendant la période allant du 1er juin au 26 octobre 2021 dans le service de radiologie du CHU Cocody Abidjan. La mesure et la collection des dimensions pédiculaires ont été faites sur les coupes axiales et sagittales suivie d'une étude comparative (t-test) selon le genre.
***Résultats** : L'angle transversal pédiculaire de L1 à L5 variait de 24 à 35,7 degrés chez l'homme contre 23,3 à 34,4 degrés chez la femme. Le diamètre pédiculaire variait de 7.06 to 13.4 mm degrés chez l'homme contre 6.53 to 12.4mm chez la femme. La hauteur pédiculaire des vertèbres variait entre 9,07 et 13,5 mm chez l'homme et entre 9,46 et 13,4 mm chez la femme, décroissant dans le sens caudal. Le diamètre pédiculaire variait entre 7,06 et 13,4 mm chez l'homme et entre 6,53 et 12,4 mm chez la femme La longueur maximale de vis pédiculaires variait entre 10,1 et 12,2 mm chez l'homme et entre 11,2 et 12,4 mm chez la femme et était significativement différente selon le genre en L1 (p=0.0337) et L2 (0.0419).*
***Conclusion** : Cette étude a permis de fournir des données morphométriques importantes aux chirurgiens dans le choix des dimensions de vis pédiculaires.*

***Mots-clés :** Morphométrie, Pédicule, Rachis lombaire, radio-anatomie, Sujet ouest Africain*

INTRODUCTION

Pedicle screwing was a major innovation in spine surgery [1].Prior to the development of this technique by Raymond Roy-Camille in 1963 [2], the fixation of the dorso-lumbar spine was based on using the posterior vertebral arch [3]. These were plate fixation, screwed into the spinous processes, proposed by Wilson in 1945, and notched rod osteosynthesis supported by laminar hooks, published in 1962 by Harrington . These techniques had disadvantage of being biomechanically flimsy and could not be performed when a laminectomy was done at the same level. Over the years, the transpedicular screwing has been widely used by spine surgeons because it has demonstrated a superior biomechanical advantage over lateral mass and hook fixation techniques [2, 4]. Screw diameter and length are important parameters in preoperative planification. A too thick screw may damage the pedicle or adjacent nerves, while a small diameter screw relative to the pedicle offers little resistance to spinal biomechanical stresses and is more prone to dislocation [5]. A screw that is too long may drill the vertebral anterior periosteum and damage the retroperitoneal vessels of the abdomen and pelvis. Numerous morphometric studies of the lumbar spine have reported pedicle dimensions. These studies have been conducted in Asian, European, Mediterranean, and North American countries [6-8].
The aim of this study was to provide morphometric data of lumbar spine pedicles in a West African population.

MATERIALS AND METHODS

A cross-sectional study was made on of adult patients (aged 21 years and older) who underwent a lumbar spine scan during the period from June 1 to October 26, 2021, at the radiology department of the University Hospital of Cocody, in Abidjan. We did not include the patients with congenital malformations of vertebral development and patients with vertebral pedicles destroyed by osteolytic tumor processes or by trauma. The data were collected from the axial and sagittal section scans. The measurements were

made with RADIANT Dicom viewer software and collected on a Microsoft excel 2013 workbook. Statistical analysis was performed with Graph Pad Prism 9.11 software. The student's t test was used to compare the measured means by gender, with the threshold of significance alpha inferior or equal to 0.05 used.

- The pedicular transverse angle (a) was defined as the angle formed by the intersection of a sagittal line passing through the apex of the spinous process and the middle of the vertebral body and an oblique line passing through the middle of the pedicle joining the middle of the anterior edge of the vertebral body (Figure 1).

- The pedicle diameter (d) was defined as a line perpendicular to the medial and lateral edges of the pedicle at its most constricted area (Figure 1).
- The pedicle length (lp) was defined as the distance between the vertebral entry point of the pedicle (on the facet joint) and the posterior edge of the vertebral body (Figure 2).
- The ideal screw length (lv) was measured as the distance from the posterolateral edge of the pedicle (screw entry point) to the middle of the pedicle and ending at the middle of the anterior edge of the vertebral body (Figure 2).
- The pedicle height (h) was defined as the vertical distance corresponding to the insertion point of the pedicle on the vertebral body (Figure 3).

We obtained consent from the hospital authority. Patients were contacted for verbal consent. We explained to them the objectives and interests of our study. Confidentiality of data was respected by assigning an anonymity number. There were no conflicts of interest.

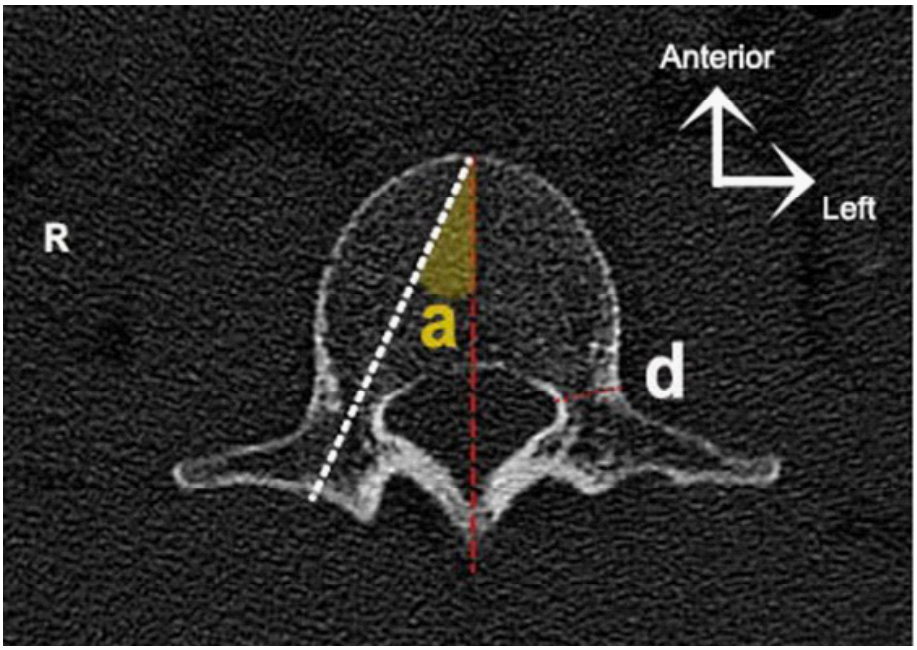

Figure 1: the method of measuring the diameter (d) and the transverse angle of the pedicle (a) at a vertebra

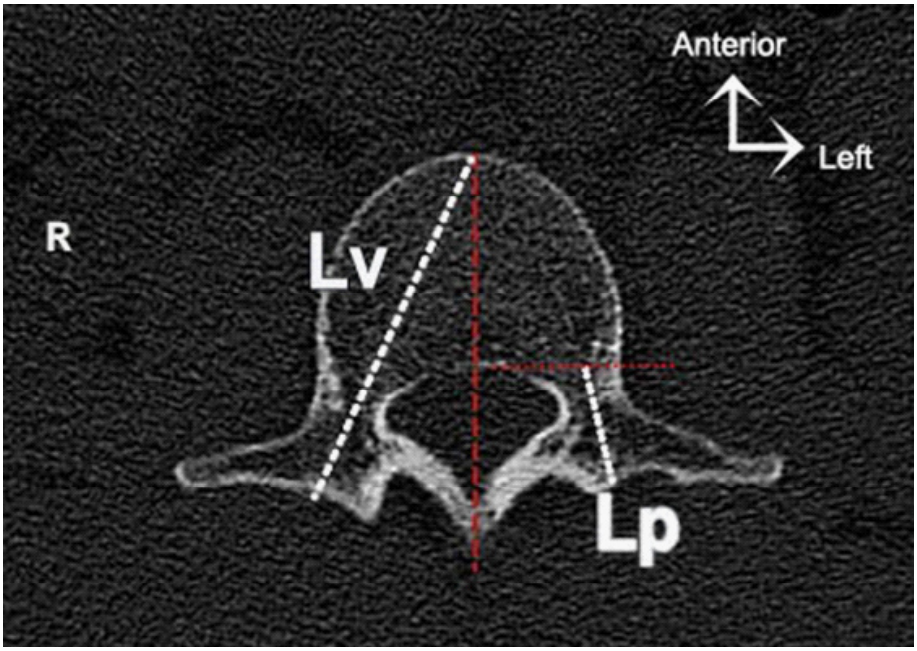

Figure 2: the method for measuring the pedicle length (lp) and the maximum length of a transpedicular screw (lv)

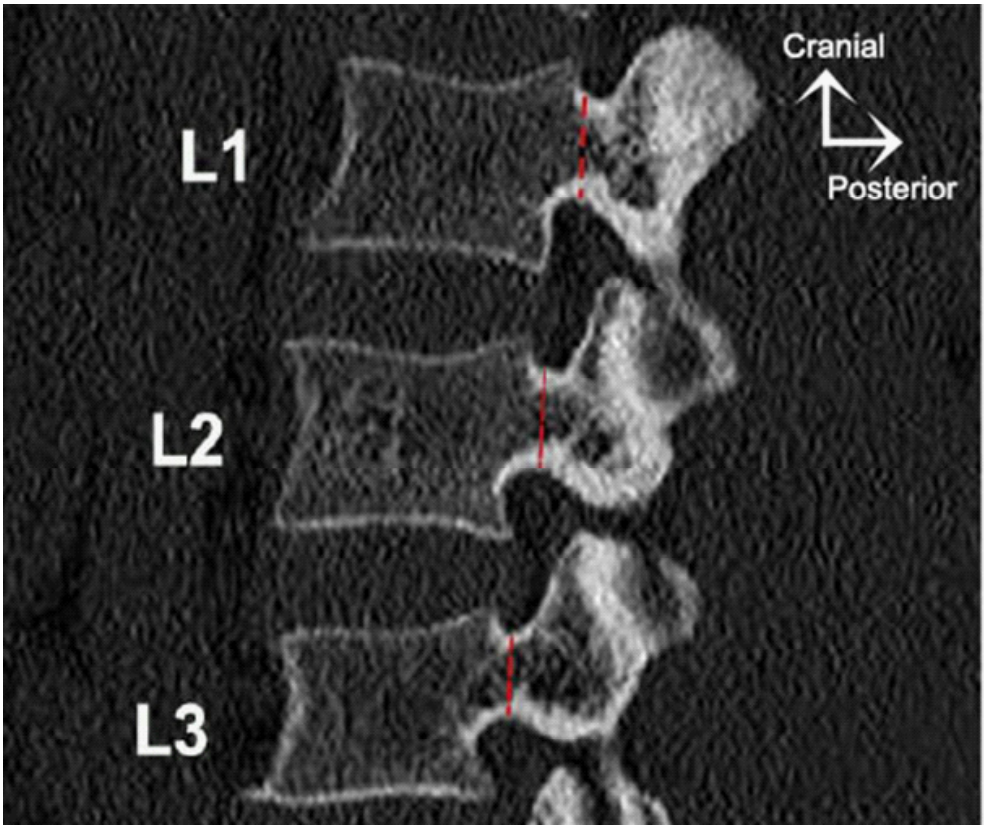

Figure 3: method of measuring pedicle height (h)

RESULTS

42 patients were studied, representing 420 lumbar pedicles. The patients ranged from 21 to 65 years with an average age of 39 years. Female were the most represented with a sex ratio of 0.68.

The transverse pedicle angle refers to the degree of obliquity of the lumbar pedicle. It ranged from 24.0 to 35.7 degrees in male and from 23.3 to 34.4 degrees in female. However, the comparison between male and female did not show any significant difference except at the L3 vertebral level (Table I). It was also noted that this angle had minimal values at the L1 and

L2 vertebrae.

Table I: morphometry of the transverse angle of the lumbar pedicles according to gender and vertebral level
Transverse pedicle angle L1 - L5 (in degrees)

Vertebra	Male (n=34) Mean (SD)	Female (n=50) Mean (SD)	Male vs Woman P
L1	24.0 (2.26)	23.3 (2.14)	0.1668
L2	24.8 (2.24)	23.7 (2.82)	0.0620
L3	26.9 (2.80)	25,5 (3,05)	(*) 0.0307
L4	28.6 (3.05)	27.5 (3.41)	0.1364
L5	35.7 (4.64)	34.4 (5.02)	0.2321

Pedicle diameter ranged from 7.06 to 13.4 mm in male and from 6.53 to 12.4 mm in female. The minimum values were at the L1 and L2 vertebrae. Although the pedicle diameters were higher in male, there was no statistically significant difference at any level (Figure 4).

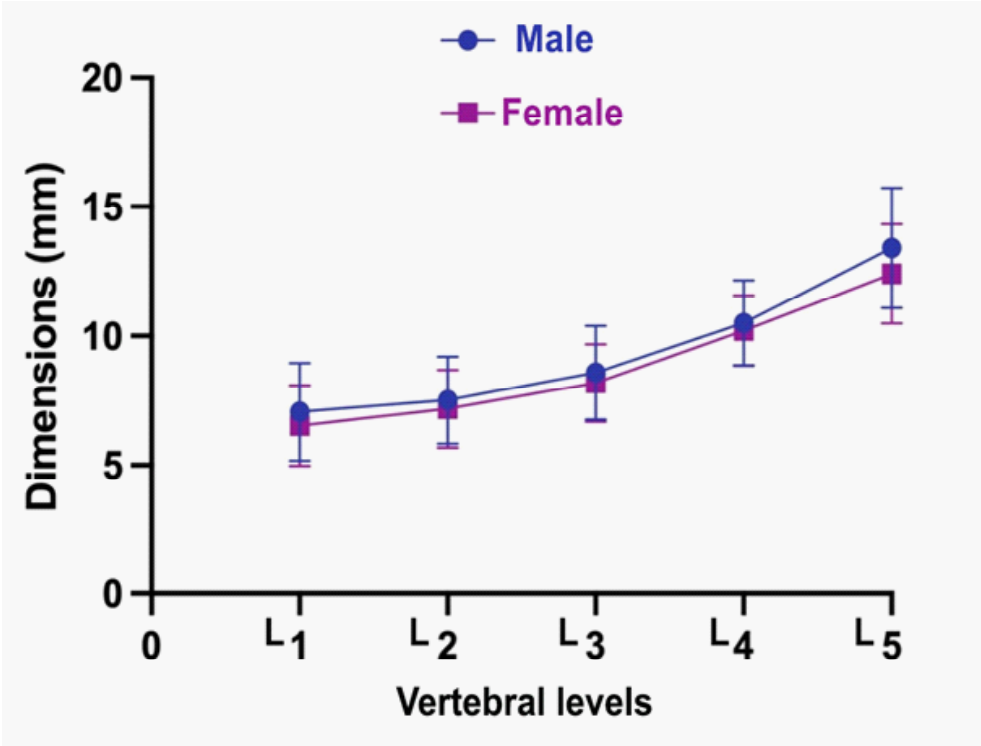

Figure 4: Pedicle diameter according to gender and vertebral level

The maximum length of a lumbar transpedicular screw was significantly different by gender at L1 and L2 (Table II). At these levels, the measured maximum length was greater in men than in female. From these results, we deduce that an ideal lumbar transpedicular screw length is 40 mm for all levels.

Table II : maximum length of trans-pedicular screws according to gender and vertebral level

The maximum length of a trans-pedicular screw L1 - L5 (length in mm)			
Vertebra	Male (n=34) Mean (SD)	Female (n=50) Mean (SD)	Male vs Female P
L1	49.6 (04.14)	47.7 (03.78)	(*) 0.0337
L2	50.3 (03.63)	48.6 (03.92)	(*) 0.0419
L3	49.9 (03.56)	48.2 (04.13)	0.0570
L4	48.5 (04.37)	47.9 (03.08)	0.4490
L5	49.9 (04.37)	48.3 (04.10)	0.0964

In male, pedicle height had mean values that ranged from 9.07 to 13.5 mm, whereas in female, it ranged from 09.46 to 13.4 mm. This measurement decreased in the caudal direction of the lumbar vertebrae. The height of the lumbar vertebral pedicles was higher in female without any statistically significant difference being found (Table III).

Table III: The height of the pedicles according to gender and vertebral level

The height of the pedicles L1 - L5 (height in mm)			
Vertebra	Male (n=34) Mean (SD)	Female (n=50) Mean (SD)	Male vs Female P
L1	13.5 (2.16)	13.4 (1.92)	0.6665
L2	12.6 (1.87)	12.6 (1.72)	0.9939
L3	11.9 (2.03)	12.1 (1.39)	0.5663
L4	10.5 (1.55)	11.0 (1.68)	0.1426
L5	09.07 (1.47)	09.46 (1.80)	0.0964

Pedicle length ranged from 1.01 to 1.22 cm in male. In female, the values ranged from 1.12 to 1.24 cm. We observed that no difference in length of the lumbar pedicles in male versus female except for L5 vertebral level, where there was a statistically significant difference (Figure 5).

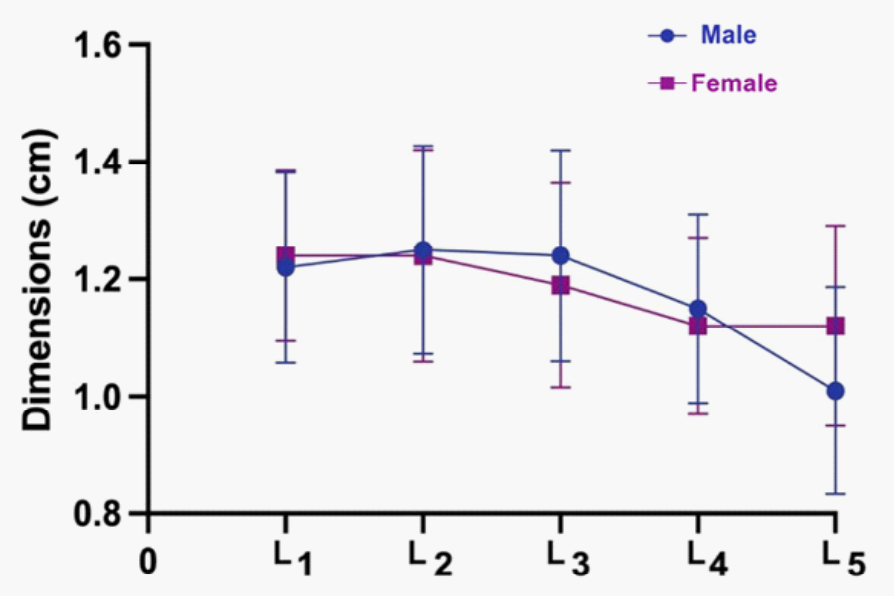

Figure 5: Pedicle length according to gender and vertebral level

The height decreases in the caudal direction while the diameter increases in the same direction. Comparative analysis of these two elements (t-test) did not find any statistically significant difference between these two parameters, from one vertebral level to another (p = 0.3382 for male; p = 0.180 for female; α = 5%).

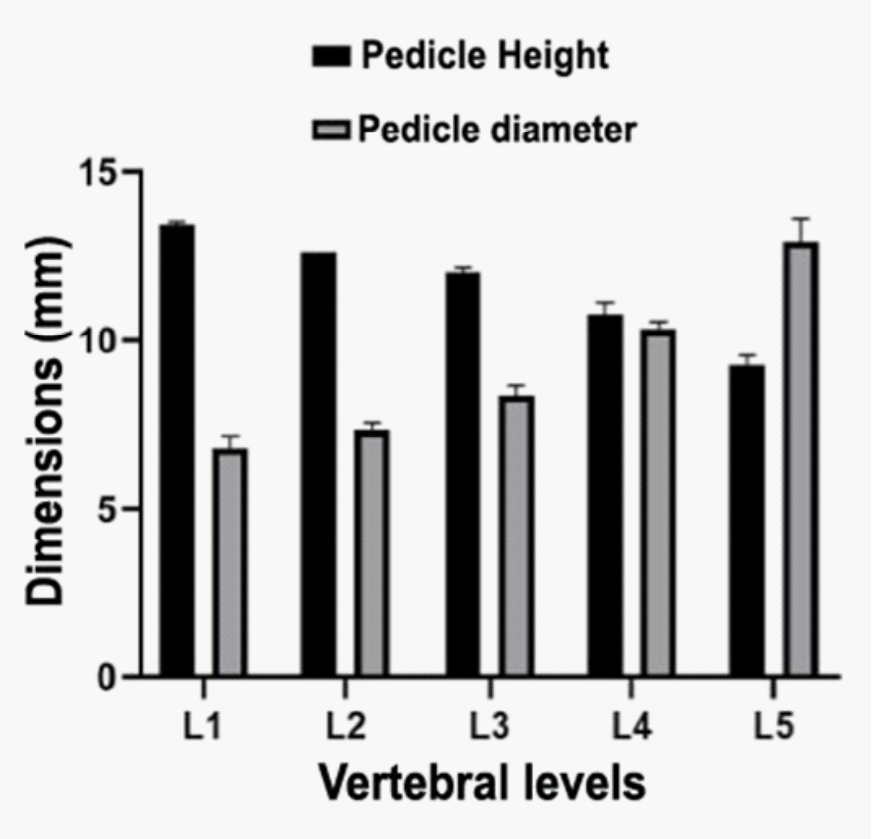

Figure 6: diameter and height of the pedicle according to the vertebral level

DISCUSSION

The morphometry of lumbar pedicles has aroused a lot of interest in the scientific community. Indeed, knowledge of the anatomical characteristics of the lumbar pedicles has a direct surgical application for the placement of pedicle implants in the treatment of vertebral instabilities [9, 10].

This radio-anatomical study is the first morphometric study of the lumbar spine pedicles in West African melanoderma population and the second of its kind conducted on a sub-Saharan African population. It allowed to specify the orientation and the pedicle dimensions in the sagittal and axial (transverse) planes. In addition, the morphological data collected can help local surgeons in the choice of the dimensions of the pedicle screws according to the different vertebral levels.

Our measurements of pedicle diameter are similar with Mohanty et al, carried out on an Indian population [11], who found a minimum value of pedicle diameter of 7.2 ± 0.87 mm, and to that of Hou, carried out on a Chinese population [12]. However, they are lower than the data of Goyal et al and Panjabi et al [9, 13] .Notably for these authors, the pedicle diameters at L4 and L5 were particularly high (L4=13.4 mm, L5=18.0mm) and (L4=15.51 mm, L5=19.51mm) respectively.

Of all the studies of the same type found in the literature, the study by Zindrick et al found the highest values with a minimum value of 8.7 mm at L1 and a maximum of 18 mm at L5 [10]. This difference could be explained

by the racial difference. One component remains unchanged when these different studies are analyzed, and that is the growth of the pedicle diameter in the cranio-caudal direction [11].

The pedicle height (measured in the sagittal plane) represents the safety margin that should not be violated at the risk of damaging the intervertebral foramina and running the risk of injury to the lumbar nerve roots. Nerve root and spinal cord injuries are rare with an incidence of between 0.6% and 11%. The incidence of a permanent motor deficit is rare. However, a transient motor deficit related to neurapraxia is common when the pedicle height is not correctly estimated [14]. In our study, in male, the mean values ranged from 9.07 to 13.5 mm, whereas in female, they ranged from 09.46 to 13.4 mm. This measurement decreases in the caudal direction of the lumbar vertebrae. The height of the lumbar vertebral pedicles was higher in female without any statistically significant difference being found. It is classically observed that this dimension is greater than the pedicle diameter. In our study, this finding was also found. Our measured values are similar to those of Goyal et al, and lower than those of Panjabi. In the work of Goyal, the population studied was that with degenerative lesions of the spondylolisthesis type [9, 13]. Although the reasons for performing lumbar spine scans were not included in the data collected, it is likely that the scans in our study sample were performed in this context.

The pedicle transverse angle is a very important measured angle that determines the degree of medial obliquity during insertion of a lumbar transpedicular screw, i.e., the pedicle transverse angle is used by the surgeon to gauge the optimal course of pedicle screw placement. In our study, this angle ranged from 24.0 to 35.7 degrees in male and from 23.3 to 34.4 degrees in female, with a maximum at L4. It was also noted that this angle had minimal values at the L1 and L2 vertebrae; in other words, the pedicles at L1 and L2 were the least oblique. There was a tendency for this angulation to increase in the caudal direction from L1 to L5. The comparison between male and female showed no significant difference at any vertebral level except at L3 ($p=0.0307$). This difference could be due to morphological variability related to the female gender. Our results were close to those of Dzierżanowski et al. who found an angle varying between 20 and 32 degrees [6]. Moreover, our results were identical to those of Stockton et al who found a similar evolution of this angle with a statistically significant difference at the level of the L2 and L3 vertebrae according to racial origin [15]. However, our results were different from those of Panjabi who found angles varying between 14 and 25 degrees [9].

The measurement of the maximum length of a transpedicular screw allowed us to deduce the ideal length of a lumbar pedicle screw. This measurement, in addition to the measurement of the transverse diameter, provides the 2 elements necessary for the appropriate choice of the dimensions of a lumbar screw for a given vertebral segment. Ideally, the length of the pedicle screw should not cross the anterior cortex of the vertebral body, which would avoid injury to the large retroperitoneal anterior vessels.

Our results suggest that the ideal length of a lumbar screw is 48 mm and does not exceed 50 mm, with a length of pedicle screws that is significantly greater in men than in female. Nojiri et al and Dzierżanowski et al found this same superiority in male over female in terms of screw length [6, 16] . However, Dzierżanowski et al. found a longer screw length (ranging from 51 to 53.9 mm) than that found in our study. Nojiri et al. on the other hand, found a smaller one.

For all these variables measured, there was no significant morphometric difference according to gender except for the transverse pedicle angle at the L3 vertebra.

One of the interests of our study is to demonstrate the absolute necessity or otherwise of measuring the two main parameters of pedicle height and diameter in preoperative planning. The second part of the research question is to know if these parameters are influenced in one way or another by gender.

Considering the results obtained from this study, we claim that the measurement of only one of these two main parameters, in particular the pedicle diameter, associated with the other parameters, namely the transverse angle of the pedicle and the maximum length of a transpedicular screw, is sufficient for the selection of screws in preoperative planning, regardless of gender. Indeed, the height decreases in the caudal direction while the diameter increases in the same direction. Although these two parameters are highly correlated, comparative analysis of these two elements (t-test) did not find a statistically significant difference between these two parameters, from one vertebral level to another and regardless of gender ($p = 0.3382$ for male; $p = 0.180$ for female; $\alpha = 5\%$).

Regarding pedicle targeting and the choice of transpedicular screws, our study provides us with data similar with the literature with respect to the maximum length of a transpedicular screw [6, 16]. Indeed, in most studies, the length of transpedicular screws is greater in male than in female. This parameter is also important for the surgeon to consider in preoperative planning.

CONCLUSION

We investigated the morphometric data of the lumbar spine pedicles in a West African population through a radio-anatomical study that took place at the radiology department of the CHU of Cocody. The results of this work provide the spine surgeon with practical numerical data for the choice of lumbar pedicle screws in preoperative planning. Furthermore, this work emphasizes the need to have scans in digital form. The morphometric data of the melanoderma West African population in this work is consistent with the literature on populations of other races. A future research area will be to evaluate the accuracy of lumbar pedicle screw and the incidence of screw malposition.

REFERENCES

1. Abdel-Malek K, McGowan D, Goel V, Kowalski D, Smith S. 1997. Bone registration-method for robot assisted surgery: pedicle screw insertion. Proceedings of the Institution ofMechanical Engineers, Part H: Journal of Engineering in Medicine. 211(3):221-233.

2. Buckenmeyer L. 2013. Optimization of Pedicle Screw Depth in the Lumbar Spine:Biomechanical Characterization of Screw Stability and Pullout Strength.[Master's thesis,University of Toledo]. OhioLINK Electronic Theses and Dissertations Center. URL:http://rave.ohiolink.edu/etdc/view?acc_num=toledo1365099627

3. Catonné Y, Laville C, Saillant G. 2018. Pedicle Sight in Spine Surgery: A Raymond Roy-Camille's. E-Mem Acad Natle Chir. 17 (2): 011

4. Dzierżanowski J, Skotarczyk M, Baczkowska-Waliszewska Z, Krakowiak M, Radkowski M, Łuczkiewicz P, et al. 2019. Morphometric Analysis of the Lumbar Vertebrae Concerning the Optimal Screw Selection for Transpedicular Stabilization. In: Advances in Medicine and Medical Research. Advances in Experimental Medicine and Biology (1133). Springer, Cham. p83-96. URL: http://link.springer.com/10.1007/5584_2018_324

5. Garg RK, Somvanshi DS. 2011. Spinal tuberculosis: a review. J Spinal Cord

Med;34(5):440-454.
6. Goyal D, Tarazona D, Segar A, Sutton R, Motto M, Divi S et al. 2021. Lumbar Pedicle Morphology and Vertebral Dimensions in Isthmic and Degenerative Spondylolisthesis-A Comparative Study. International Journal of Spine Surgery ;15(2):243-250
7. Güleç A, Kaçıra BK, Kütahya H, Özbiner H, Öztürk M, Solbaş ÇS, et al. 2017. Morphometric analysis of the lumbar vertebrae in the Turkish population using three-dimensional computed tomography: correlation with sex, age, and height. Folia Morphologica;76(3):433-439.
8. Hou S, Hu R, Shi Y. 1993. Pedicle morphology of the lower thoracic and lumbar spine in a Chinese population. Spine 18(13):1850-1855.
9. Hsieh M-K, Liu M-Y, Chen J-K, Tsai T-T, Lai P-L, Niu C-C, et al. 2019. Biomechanical study of the fixation stability of broken pedicle screws and subsequent strategies. Plos one 14(6):e0219189.
10. Maaly MA, Saad A, Houlel MEE. 2010. Morphological measurements of lumbar pedicles in Egyptian population using computerized tomography and cadaver direct caliber measurements. Egypt J Radiol Nucl Med. 41(4):475-481.
11. Makino T, Kaito T, Fujiwara H, Yonenobu K. 2012. Morphometric analysis using multiplanar reconstructed CT of the lumbar pedicle in patients with degenerative lumbar scoliosis characterized by a Cobb angle of 30° or greater: Clinical article. J Neurosurg Spine. 17(3):256-62
12. Mohanty SP, Pai Kanhangad M, Bhat SN, Chawla S. 2018. Morphometry of the lower thoracic and lumbar pedicles and its relevance in pedicle fixation. Musculoskeletal surgery 102(3): 299-305.
13. Nojiri K, Matsumoto M, Chiba K, Toyama Y. 2005. Morphometric analysis of the thoracic and lumbar spine in Japanese on the use of pedicle screws. Surg Radiol Anat.27(2):123-128.
14. Panjabi MM, Goel V, Oxland T, Takata K, Duranceau J, Krag M et al. 1992. Human lumbar vertebrae. Quantitative three-dimensional anatomy. Spine; 17(3): 299-306
15. Stockton R, Albano J, Lentz J, Ganz M, Grewal K, Katsigiorgis G. 2019. A comparison of lumbar transverse pedicle angles between ethnic groups: a retrospective review. BMC musculoskeletal Disorders;20(1):1-7
16. Zindrick M R, Wiltse L L, Doornik A, Widell E H, Knight G W, Patwardhan A G et al. 1987. Analysis of the morphometric characteristics of the thoracic and lumbar pedicles. Spine;12(2): 160-166.