Research Article

Morphological and morphometrical analysis of lumbar vertebrae in relation to pedicle and its clinical implications

S. Priyadharshini, Karthik Ganesh Mohanraj*

ABSTRACT

Introduction: Vertebral column is piled-up vertebrae that present on the dorsal side of the human body which extends from the base of the skull to the coccyx. Spine includes cervical, thoracic, lumbar, and sacral regions comprising respective vertebrae. Pedicle screw on lumbar system is a popular technique for instrumentation to treat spinal disorders as it provides a stable fixation and corrects the spinal deformities. Morphometry of the pedicle and the adjacent neural structures should be understood to decrease the risk of post-operative complications. **Materials and Methods:** A total of 40 dry human disarticulated lumbar vertebrae were obtained from the Department of Anatomy, Saveetha Dental College and Hospitals and Madras Medical College, Chennai. Using a vernier caliper, the length, breadth, height of spinous process, vertebral foramen, and pedicle of lumbar vertebrae are measured. **Results:** In the study, the mean horizontal diameter of pedicle (HDP) ranges from 8.12 mm to 13.66 mm. The mean HDP increases from L1 to L5 vertebrae. The mean vertical diameter of pedicle (VDP) ranges from 17.78 mm to 18.95 mm. Maximum vertical diameter of vertebral pedicle was measured at L2 (18.95 mm), and the minimum diameter was at L5 (17.78 mm). **Conclusion:** The choice of the pedicle screw is determined by the minimum diameter of the pedicle. The success rate of pedicle screw fixation completely relies on the ability of the screw in maintaining the anchorage within the fixed site in the body of the vertebrae.

KEY WORDS: Lumbar vertebrae, Morphometry, Pedicle, Transpedicular screw fixation, Vertebral column

INTRODUCTION

Vertebrae are small irregular bone that present on the dorsal side of the human body which extends from the base of the skull to the coccyx. Spine or the vertebral column is composed of stacked vertebrae along with the intervertebral discs. Spine includes cervical, thoracic, lumbar, and sacral regions. Spinal nerve passes through the space created by the intervertebral discs along with the laminae, pedicle, and articulation process of adjacent vertebrae. Lordotic curve is produced by the lumbar vertebrae as a group.[1,2] The lumbar intervertebral disc height is between that of cervical and thoracic intervertebral discs. All five lumbar vertebrae that present in the human body are typical except L5 which is atypical due to its shape. L5 has the largest body and transverse processes of all vertebrae. The anterior aspect of the body has a greater height compared to the posterior. This creates the lumbosacral angle between the lumbar region of the vertebrae and the sacrum.[3,4] The lumbar vertebrae have the largest bodies of the entire spine and an increase in size as the spine descends. The support of the entire upper body is the responsibility of the lumbar vertebrae due to its distinct feature of marked increase in size. The curvature of articular facets is thought to assist in the stabilization and weight-bearing capacity of lumbar vertebrae.[5]

The most familiar disease associated in the spinal region is osteoporosis. Osteoporosis is a condition which is involved in decreased bone mass and gradual decline in the architectural makeup of bone tissue which results in diminution of bone strength and increases the risk of occurrence of bone fractures.[6,7]

Pedicle screw fixing on lumbar system is a popular technique for instrumentation to treat spinal disorders as it provides a stable fixation and corrects the spinal deformities. This pedicle screw system, often referred to as the bilateral pedicle screw system, has become

Access this article online	
Website: jprsolutions.info	ISSN: 0975-7619

Department of Anatomy, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Corresponding author:** Karthik Ganesh Mohanraj, Department of Anatomy, Saveetha Dental College, Saveetha Institute of Medical And Technical Sciences, Saveetha University, 162, Poonamallee High Road, Chennai - 600 077, Tamil Nadu, India. Phone: +91-9940545168. E-mail: karthikganesh.0446@gmail.com

Received on: 20-03-2019; Revised on: 26-05-2019; Accepted on: 28-05-2019

the gold standard technique for spinal fusion.[8,9] The application of pedicle screw fixing on the lumbar vertebrae also depends on the size, shape, and dimensions of the pedicle. This anatomy of the bone varies most often on various conditions. Thus, a proper morphological and morphometrical study on lumbar vertebrae throws light upon the variations found on this bony structure and its working space and applicability of screws in several medical interventions. Thus, the morphometry and anatomy of the pedicle and the adjacent neural structures should be understood to decrease the risk of post-operative complications.[10] The objective of the present study is focused on the morphological and morphometrical analysis of lumbar vertebral pedicle and its application on pedicle screw placement in dry human lumbar vertebrae.

MATERIALS AND METHODS

A total of 40 dry human disarticulated lumbar vertebrae were obtained from the Department of Anatomy, Saveetha Dental College and Hospitals and Madras Medical College, Chennai. Using a Vernier caliper, the length, breadth, height of spinous process, vertebral foramen, and pedicle of lumbar vertebrae are measured. Vertical diameter was taken as a maximum diameter in the sagittal plane, and horizontal diameter was taken as a maximum diameter in a plane right angle to the vertical. In anteroposterior aspect, the limits of the pedicle are marked with pencil, and the diameters were measured in two perpendicular planes, such as vertical and horizontal diameters. All the lumbar vertebrae measurements are depicted in Figure 1. Each lumbar vertebra was measured on right and left pedicles at each parameter. The values of the diameters of all lumbar vertebrae observed were noted, and the average is expressed as mean ± standard deviation.

RESULTS

In the study, the mean horizontal diameter of pedicle (HDP) ranges from 8.12 mm to 13.66 mm. The average HDP of L1 was 8.12 mm ± 0.35, L2 was 8.95 mm ± 0.19, L3 was 11.45 mm ± 0.34, L4 was 12.17 mm ± 0.28, and L5 was 13.66 mm ± 0.32. The mean HDP increased gradually from L1 to L5 vertebrae. The mean vertical diameter of pedicle (VDP) ranges from 17.78 mm to 18.95 mm. Maximum VDP was measured at L2 (18.95 mm), and the minimum diameter was at L5 (17.78 mm). The average VDP of L1 was 18.12 mm ± 0.22, L2 was 18.95 mm ± 0.49, L3 was 18.63 mm ± 0.54, L4 was 18.5 mm ± 0.28, and L5 was 17.78 mm ± 0.53. The diameter of right pedicle and left side pedicle was measured and compared separately in all parameters. Diameter of right and left sides was obtained to have little variation, but the difference was found significant not statistically. All the observed values are represented graphically in Figures 2 and 3.

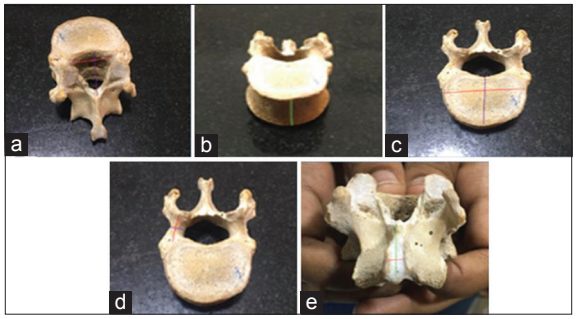

Figure 1: All the lumbar vertebrae measurements are shown in the figure a, b, c, d and e

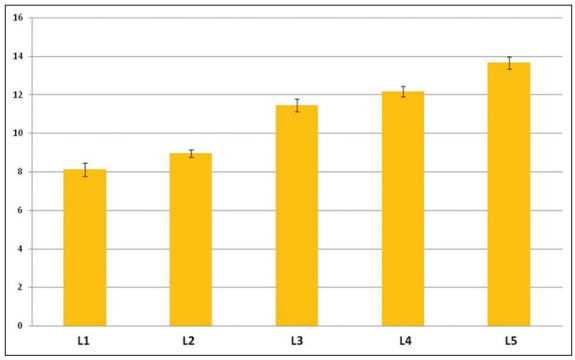

Figure 2: Horizontal diameters of lumbar vertebrae as mean ± standard deviation

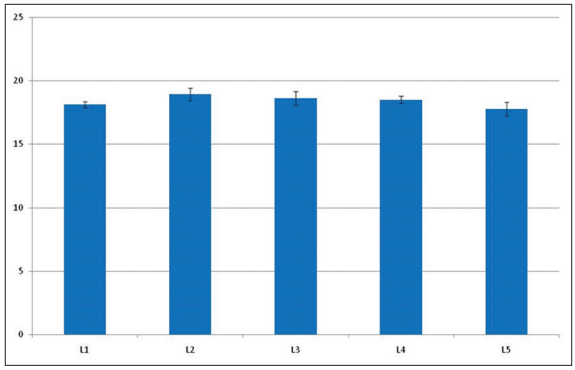

Figure 3: Vertical diameters of lumbar vertebrae as mean ± standard deviation

DISCUSSION

In the present study, the detailed relationship between the lumbar vertebrae and the pedicle in terms of their length, breadth, and height was analyzed. The pedicle width and height varied between individuals and between levels. However, there were no significant differences between the right and left side. The pedicle width of the lumbar segment increased gradually from L1 to L4 and increased sharply at L5. The pedicle height of the lumbar segment gradually decreased from L2 to L5, and the pedicle height of L1 was slightly smaller than that of L2. The pedicle heights of our study were smaller compared with the results from the other similar studies. With respect to the pedicle length, it has been observed that the pedicle length

decreases from L1 to L5. This corresponds to the study that reported that the pedicle length was longest at L1 and shortest at L5. The lumbar region due to its large size of vertebral canal has a lesser incidence of neurological fractures as compared to those in the thoracic region. Spinal taps are performed inferior to L2 as the roots forming the cauda equina, suspended in the cerebrospinal fluid, move out of the way of the spinal needle due to their relative resilience cauda equine nerve roots.[11]

Vertebral pedicle forms an important part in weight transmission. For a number of procedures performed inside the vertebral body such as biopsies and vertebroplasties, vertebral pedicle is used as an access port.[12] Complications related to the placement of the pedicel screw were reported by several authors. Complications related to surgery, infection either superficial or deep, pulmonary thromboembolisms are some of the related complications. The safest site for the placement of the pedicel screw is at the axis of the pedicel.[13-15]

Pedicle screw placement is preferred in the lumbar vertebrae instead of the thoracic region due to its defects such as small size, varying entry points, and proximity to neurovascular structures. Maximum diameter and length of the pedicle are essential so that the pedicle screw placement does not intrude the pedicle cortical layer and the vertebral body. The size of the screw should be determined by the compatibility of the entry point with the anatomical guides. During spinal instrumentation, the screw insertion must be done without damaging the neurological and vascular structures adjacent to the pedicle and vertebral body.[16-18]

Lumbar vertebral pedicles are widely used as a placement site for various surgical procedures such as vertebroplasties, biopsies related with vertebral bodies, and kyphoplasties.[19] Variations and differences in the dimensions of the lumbar vertebral pedicles at various levels have clinical inferences for neurosurgeons to carry out safe surgical procedures in this site.[20]

CONCLUSION

A detailed knowledge of the potential safe zones of the pedicle and the potential safe zone between the pedicle and the adjacent neural structures is mandatory while performing surgery in the pedicle region. Technically, the pedicle screw fixation is a demanding procedure that requires understanding the spinal anatomy and helps to reduce the risk of defect in zygapophyseal joint. The choice of the pedicle screw is determined by the minimum diameter of the pedicle. Success of the pedicle screw depends on the ability of the screw to get fixed and to maintain anchorage within the body of the vertebrae.

REFERENCES

1. DeSai C, Agarwal A. Anatomy, Back, Vertebral Column StatPearls. Treasure Island (FL): StatPearls Publishing; 2018.
2. Lafian AM, Torralba KD. Lumbar spinal stenosis in older adults. Rheum Dis Clin North Am 2018;44:501-12.
3. Berven S, Wadhwa R. Sagittal alignment of the lumbar spine. Neurosurg Clin N Am 2018;29:331-9.
4. Patel EA, Perloff MD. Radicular pain syndromes: Cervical, lumbar, and spinal stenosis. Semin Neurol 2018;38:634-9.
5. Shin EH, Cho KJ, Kim YT, Park MH. Risk factors for recurrent lumbar disc herniation after discectomy. Int Orthop 2019;43:963-7.
6. Kanis JA, Melton LJ 3rd, Christiansen C, Johnston CC, Khaltaev N. The diagnosis of osteoporosis. J Bone Miner Res 1994;9:1137-41.
7. Cheng ML, Gupta V. Premenopausal osteoporosis. Indian J Endocrinol Metab 2013;17:240-4.
8. Gertzbein SD, Robbins SE. Accuracy of pedicular screw placement *in vivo*. Spine (Phila Pa 1976) 1990;15:11-4.
9. Roy-Camille R, Saillant G, Mazel C. Internal fixation of the lumbar spine with pedicle screw plating. Clin Orthop Relat Res 1986;203:7-17.
10. Lien SB, Liou NH, Wu SS. Analysis of anatomic morphometry of the pedicles and the safe zone for through-pedicle procedures in the thoracic and lumbar spine. Eur Spine J 2007;16:1215-22.
11. Waxenbaum JA, Futterman B. Anatomy, Back, Lumbar Vertebrae. Island, FL: StatPearls Publishing; 2018.
12. Standring S. Gray's Anatomy, The Anatomical Basis of Clinical Practice. 40th ed. London: Churchill Livingstone, Elsevier Publications; 2008.
13. Vanichkachorn JS, Vaccaro AR, Cohen MJ, Cotler JM. Potential large vessel injury during thoracolumbar pedicle screw removal. A case report. Spine (Phila Pa 1976) 1997;22:110-3.
14. Blumenthal S, Gill K. Complications of the Wiltse pedicle screw fixation system. Spine (Phila Pa 1976) 1993;18:1867-71.
15. Lonstein JE, Denis F, Perra JH, Pinto MR, Smith MD, Winter RB. Complications associated with pedicle screws. J Bone Joint Surg Am 1999;81:1519-28.
16. McCormack BM, Benzel EC, Adams MS, Baldwin NG, Rupp FW, Maher DJ, *et al.* Anatomy of the thoracic pedicle. Neurosurgery 1995;37:303-8.
17. Cho W, Cho SK, Wu C. The biomechanics of pedicle screw-based instrumentation. J Bone Joint Surg Br 2010;92:1061-5.
18. Korkmaz MF, Erdem MN, Ozevren H, Sevimli R. Determining the optimal length and safety of pedicle screws in the T12 vertebra: A morphometric study. Cureus 2018;10:e2156.
19. Canale TS, Beaty JH, Campbell's Operative Orthopaedics. 11th ed., Vol. 2. United States: Mosby Publishers; 2008. p. 1346.
20. Sreevidya J, Dharani V, Savithri K, Seshayyan S. Study of lumbar vertebrae with respect to the dimensions of the pedicle in South Indian population. Indian J Basic Appl Med Res 2017;6:523-30.

Source of support: Nil; Conflict of interest: None Declared