Journal of Kathmandu Medical College, Vol. 9, No. 1, Issue 31, Jan.-Mar., 2020

A morphometric analysis of pedicles of lumbar vertebrae by using computed tomography scan

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Abstract

Background: The vertebral column is the central pillar of the body which has cervical, thoracic, lumbar, sacral and coccygeal parts. Out of these, the lumbar part is made up of five lumbar vertebrae which lies between the thoracic part above and the sacral part below.

Objectives: The study aimed to measure pedicle dimensions of lumbar vertebrae by using computed tomography scan.

Methodology: This was a descriptive cross-sectional study which was conducted on 115 images of computed tomography scan which were available in the Department of Radio-diagnosis. Pedicle chord length, breadth and thickness of pedicle of lumbar vertebrae were measured in millimeter (mm).

Results: The pedicle chord length and breadth progressively decrease from L1 to L5 vertebral levels and pedicle thickness gradually increases from L1 to L5 vertebrae on both sides in both genders. The pedicle chord lengths were found significantly different whereas breadth and thickness were insignificantly different between males and females at all lumbar vertebral levels except at L1 for breadth.

Conclusions: The pedicle chord length and breadth gradually decreases whereas thickness increases from L1 to L5 vertebral levels amongst Nepalese population.

Key words: Age groups; Lumbar vertebrae; Pedicle screws.

INTRODUCTION

There are five lumbar vertebrae present between the thoracic vertebrae and sacrum in the vertebral column. They are designated as L1 to L5 in cranio-caudal direction. They help in the support of body weight and permit various movements. The pedicles of the lumbar vertebra are short and thick with flattened dorsal projections from the upper part of the body at the junction of its lateral and dorsal surfaces[1].

The lumbar pedicles play an important role in the transfer of body weight from the neural arch to the anterior part of the vertebral column[2]. An accurate knowledge of the lumbar pedicle dimensions has imperative implications for surgical interventions[3]. The majority of clinicians apply anatomical landmarks to guide pedicle screw placement in the lumbar spine[4]. In spite of recent techniques, the incidence of pedicle screw misplacement in the lumbar spine remains an important[5]. Still a study quoted that screw diameter more than 65% of the pedicle may damage its wall in 85% of cases[6].

Though the pedicle screw fixation has developed as a very successful method of spinal fixation[7], it has disadvantages, such as mismatched size of screw and

Access this article online

Website: www.jkmc.com.np

DOI: https://doi.org/10.3126/jkmc.v9i1.33547

HOW TO CITE

Mansur DI, Karki S, Mehta DK, Shrestha P, Maskey S. A morphometric analysis of pedicles of lumbar vertebrae by using computed tomography scan. J Kathmandu Med Coll. 2020;9(1):49-55.

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ISSN: 2019-1785 (Print), 2091-1793 (Online)

pedicle[8]. The knowledge of pedicle dimensions is crucial for the safe placement of pedicle screws. The data is not sufficiently available for Nepalese population. Thus, the present study was aimed to evaluate lumbar pedicle dimensions by using computed tomography (CT) scan images.

METHODOLOGY

A descriptive cross-sectional study was conducted in the Department of Anatomy and data was collected from the Department of Radio-Diagnosis, Dhulikhel Hospital/ Kathmandu University Hospital, Dhulikhel, Nepal by using images of CT scan. A total of 115 images of adult individuals (60 males and 55 females) were included during the period of six months (May-October 2019) for the study after receiving ethical approval from IRC-KUSMS (Ref. no. 159/19). The images of individuals having normal spinal architecture without any obvious fracture and deformity of the vertebrae were included; and having history of spinal surgery, deformities and pre-existing spinal pathology were excluded from the study. Pedicle chord length, breadth and thickness of pedicle of lumbar vertebrae were measured in millimeters. The pedicle dimensions were measured by lines drawn on the CT scan images using options provided in the Digital Imaging and Communications in Medicine software and the values were directly recorded from the monitor screen in millimeter (mm). Pedicle chord length was measured along the long axis of the pedicle from the anterior cortex of the vertebral body to the posterior cortex of pedicle (Figure 1). Breadth of the pedicle was measured as the vertical diameter of the pedicle from the upper margin to lower margin of pedicle in the sagittal plane (Figure 2). Thickness of the pedicle was measured as the transverse diameter of the pedicle perpendicular to the long axis of the pedicle (Figure 3)[9].

All the scans available in the department were taken for the study. Data was collected and entered in Microsoft excel. Point estimate at 95% Confidence Interval was calculated along with frequency and proportion for binary data. The collected data was analyzed by using the Statistical Package for the Social Sciences version 16 (SPSS 16.0) for descriptive statistical analysis. P value was calculated to find the level of significance and p value <0.05 was considered as significant.

RESULTS

Pedicle chord length: In males, the mean values for pedicle chord length was found maximum at L1 (44.72±4.05 mm) and minimum at L5 (42.32±3.78 mm) on right side likewise on left side it was found maximum at L1 (44.71±3.94 mm) and minimum at L5 (42.27±3.76 mm) as shown in table 1. In females, the mean value for pedicle chord length was found maximum at L1 (41.60±3.28 mm) and minimum at L5 (38.29±3.20 mm) on right side similarly on left side it was found maximum at L1 (41.73±3.58 mm) and minimum at L5 (38.20±3.15 mm). Hence, it was found that the pedicle chord length was gradually decreasing from L1 to L5 on both sides in both genders as shown in table 1. It was also reported that the difference in measurements between right and left side was statistically insignificant in both genders except at L4 in males. There was a statistically significant difference between pedicle chord length of males and females at all lumbar vertebral level as shown in table 2.

Breadth: The mean values for breadth of pedicle was found maximum at L1 (14.28±1.63 mm) and minimum at L5 (10.60±2.05 mm) on right side and on left side it was found maximum at L1 (14.63±1.81 mm) and minimum at L5 (10.61±1.59 mm) in males. Similarly in females, these values were found maximum at L1 (13.92±1.93 mm) and minimum at L5 (10.73±1.59 mm) on the right side. On the left side, it was found maximum at L1 (13.94±1.88 mm) and minimum at L5 (10.36±1.59 mm). Hence, it was reported that the breadth was gradually decreasing from L1 to L5 on both sides in both genders as shown in table 1. The difference in breadth between right and left side was statistically insignificant in both genders except at L2 and L4 in males. There was statistically insignificant difference in breadth, between males and females at all lumbar vertebral level except at L1 as shown in table 2.

Thickness: The mean values for thickness of pedicle was found maximum at L5 (10.21±3.75 mm) and minimum at L1 (6.82±1.47 mm) on right side whereas on left side it was found maximum at L5 (10.45±3.79 mm) and minimum at L1 (6.70±1.84 mm) in males. In females, these values were found maximum at L5 (10.19±2.83 mm) and minimum at L1 (6.98±1.83 mm) on right side. On left side it was found to be maximum at L5 (10.09±2.81 mm) and minimum at L1 (6.84±1.43 mm). Hence, it was observed that the pedicle thickness was gradually increasing from L1 to L5 on both sides in both genders as shown in table 1. There was statistically insignificant difference between right and left side in both genders except at L4 in males. There was statistically insignificant difference between males and females at all lumbar vertebral level as shown in table 2.

Table 1: Statistical analysis of right and left pedicles among both genders

Vertebrae	Parameters in millimeter (mm)	Males			Females		
		Right (mean±SD)	Left (mean±SD)	P-value	Right (mean±SD)	Left (mean±SD)	P-value
L1	Chord length	44.72±4.05	44.71±3.94	0.93	41.60±3.28	41.73±3.58	0.47
	Breadth	14.28±1.63	14.63±1.81	0.06	13.92±1.93	13.94±1.88	0.90
	Thickness	6.82±1.47	6.70±1.84	0.53	6.98±1.83	6.84±1.43	0.30
L2	Chord length	44.58±4.04	44.55±3.92	0.58	41.03±3.40	41.04±3.54	0.93
	Breadth	13.60±1.58	13.99±1.84	0.02	13.59±1.62	13.45±1.71	0.40
	Thickness	7.21±1.28	7.23±1.67	0.91	7.04±1.24	7.06±1.36	0.74
L3	Chord length	44.37±3.85	44.30±3.72	0.51	40.23±3.31	40.17±3.25	0.40
	Breadth	13.30±1.89	13.36±1.73	0.70	13.05±2.25	12.92±1.90	0.45
	Thickness	8.67±1.84	8.56±1.82	0.35	8.89±1.65	8.72±1.68	0.20
L4	Chord length	43.46±3.78	43.29±3.76	0.03	39.15±3.17	39.09±3.14	0.29
	Breadth	11.76±1.87	12.25±1.91	0.00	12.31±1.48	12.08±1.57	0.14
	Thickness	9.61±2.23	9.39±2.11	0.05	9.49±1.98	9.66±2.03	0.13
L5	Chord length	42.32±3.78	42.27±3.76	0.75	38.29±3.20	38.20±3.15	0.15
	Breadth	10.60±2.05	10.61±1.59	0.96	10.73±1.59	10.36±1.59	0.07
	Thickness	10.21±3.75	10.45±3.79	0.23	10.19±2.83	10.09±2.81	0.33

Table 2: Statistical analysis of lumbar pedicles among males and females in millimeter (mm)

Vertebrae	Sex	Chord length (mean±SD)	Breadth (mean±SD)	Thickness (mean±SD)
L1	Males	44.72±4.05	14.45±1.72	7.02±1.58
	Females	41.60±3.28	13.93±1.90	7.02±1.60
	P-value	<0.001	0.02	0.98
L2	Males	44.58±4.04	13.60±1.57	7.22±1.48
	Females	41.03±3.40	13.59±1.62	7.05±1.30
	P-value	<0.001	0.95	0.34
L3	Males	44.37±3.85	13.33±1.80	8.61±1.82
	Females	40.23±3.31	12.99±2.08	8.80±1.66
	P-value	<0.001	0.16	0.39
L4	Males	43.29±3.76	12.00±1.90	9.50±2.16
	Females	39.09±3.14	12.19±1.53	9.57±2.00
	P-value	<0.001	0.39	0.79
L5	Males	42.32±3.78	10.61±1.82	10.33±3.76
	Females	38.29±3.20	10.55±1.59	10.14±2.81
	P-value	<0.001	0.78	0.66

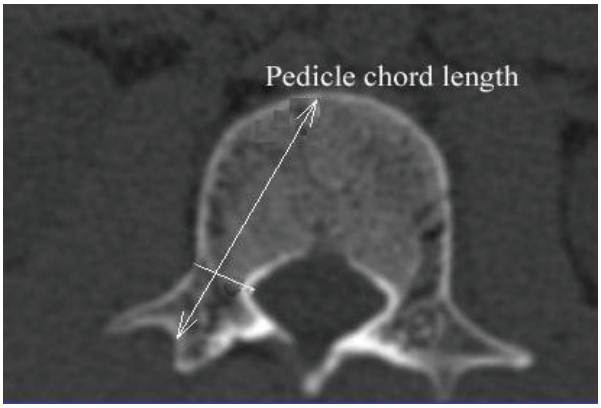

Figure 1: Showing measurement of pedicle chord length

Figure 2: Showing measurement of pedicle breadth (vertical diameter)

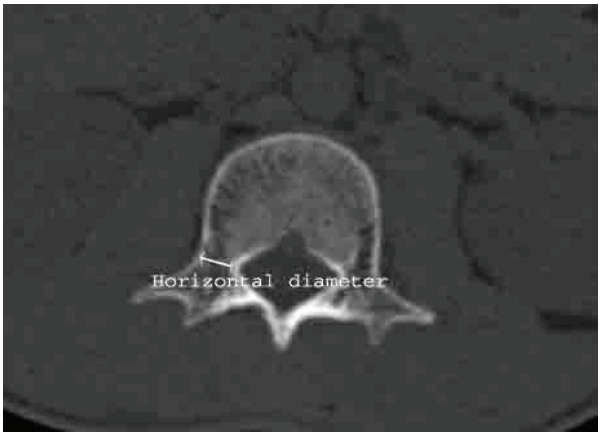

Figure 3: Showing measurement of pedicle thickness (horizontal diameter)

DISCUSSION

The lumbar region is often involved during accidents, degenerative disorders, inborn defects and metastasis. Therefore, artificial fixation may be needed for its activity to be regained. Any structural distortion of the pedicle may interfere the weight transmission mechanism and may compress the neural structures[10]. The pedicle of the vertebra has been used as a fixation site for vertebral implants. Pedicle screw fixation is a method of spine stabilization. It gives rigid, segmental stabilization and also allows maintenance of motion[3]. Therefore, having sharp knowledge the pedicle dimensions is noteworthy for performing a safe surgery[11].

The pedicle chord length determines the safest length of any screw that can be used for pedicular fixation. It is important to prevent vertebral body perforation which may damage the important structures that lie anterior to the vertebral body[12]. A gradual decreasing pattern of pedicle chord length was found in the present study from L1 to L5 vertebral levels which are consistent with the studies in which it was observed that the pedicle chord length decreased gradually from L1 to L5 vertebrae in Egyptian[13] and Mexican populations[14]. This may be due to increasing weight bearing and associated increase in the size of the lumbar body from upper to lower lumbar vertebrae[15].

In contrast to the present study, a study reported the progressive increasing pattern of chord length from L1 to L5 vertebrae[16]. The highest pedicle chord length value was found at L4 while the lowest value was recorded at L5 in western population in both genders[17]. A study of the Indian population found that the mean chord length value was the maximum at L2 and the minimum at L1 irrespective of gender[18]. But few studies reported the maximum chord length at L2[10] and L4[17]. The variations in their results may be due to different ethnicities or regions.

In previous studies[19,20], the chord lengths were found to have statistically insignificant differences between right and left pedicles in both genders which are in accordance with the present study except at L4 among males. The mean chord length in females was lower than in males at all levels[10,12] which is consistent to the result of the present study. A study, among Iranian population, found the chord length values for males were higher than those of females at all vertebral levels[21] which are also supported by the findings of the current study. In a study on Korean population, authors observed that the chord length had no significant difference between males and females[22] whereas in the present study, there are significant gender differences. These differences may be due to many factors such as stature, body build or races[10].

A study revealed that the mean pedicle breadth gradually decreases from L1 to L5 vertebrae[23] which is consistent with the present study. However, a study

amongst Saudi Arabian population had found a gradual increasing pattern of pedicle breadth from L1 to L5 in both genders [8]. A similar trend was also observed by authors who revealed the breadth of pedicles gradually increases from L1 to L5[11]. These findings differ from the present study regarding breadth of the pedicles.

In contrast, a study reported, the pedicle breadth gradually increases from L1 to L3 vertebrae and slightly decreases at L4 and L5 vertebrae among adult Punjabi males[24]. Another study also reported that the breadth of the pedicle gradually increases from L1 to L3 vertebrae and again decreases at L4 and L5[25]. Another study also observed that the breadth of pedicles decreases gradually from L1 to L5 except at L2 where it increased (maximum at L2)[23]. A study in Nepal, observed that the breadth of pedicles increases from L1 to L2 and decreases from L2 to L5[26]. A study done in Mangalore, Karnataka, South India revealed that the breadth of both the pedicles increases from L1 to L2, then decreases from L2 to L3 and again increases from L3 to L5[27]. But a study claimed that the breadth of pedicles decreased from L1 to L5 except at L2 where it was maximum increased at L2[23].

In a study on lumbar vertebrae, the mean pedicle breadth was noticed to have insignificant differences between right and left sides[10] which is consistent with the present study except at L2 and L4. These results are also supported by a study in which the breadth was not found to have significant differences between right and left pedicles[23] which is also consistent with this study. A study also observed that mean pedicle breadth values were found to have significant differences between males and females[8] which is different to this study except at L1.

A gradual increasing pattern of pedicle thickness was found from L1 to L5 vertebrae in Egyptian[13], South Indian[27], Taiwan[28] and West Indian populations[29]. A similar trend was also recorded in Nepalese population. However, a study observed that the thickness of the pedicle decreases from L1 to L5[23]. A study also reported that thickness of the pedicle gradually increased from L1 to L5 vertebrae and thickness was nearly similar in L2 and L3 vertebrae[25]. Another study reported that thickness of the pedicle gradually increases from L1 to L4 vertebrae and less at L5 vertebra among adult Punjabi males[24].

Studies have also claimed that the thickness of right and left pedicles were almost same[23,24] which is also supported by the results of the current study. A significant difference between the pedicle thickness of males and females were also reported in a study[8] which is inconsistent with this study.

Many studies reported that the thickness of pedicles was progressively increasing from L1 to L4 and increased suddenly at L5. This showed that the thickness of the pedicles was gradually increasing towards the caudal vertebrae, which was seen in all the reported studies. The authors mentioned that, load has to pass through the pedicles against gravity at L5 level[7,19,28]. Therefore, the transfer of load from the body to the laminae in L5 will be upwards against gravity, making L5 possess the strongest pedicles with maximum thickness[3]. In the present study also the thickness of pedicles is maximum at L5 level on both sides and in both genders.

The vertebral pedicles are used for placement of screws through them for the management of the unstable lumbar spine and offer potential advantages over anterior instrumentation and hook rod devices[30] and with the help of screws, various devices such as rods, plates or wires can be applied to spine for immobilization or fixation[8]. A misplaced or misdirected pedicle screw may cause injuries to the pedicle cortex, nerve root, facet joint and adjacent vital structures[31,32].

The present study is done in a tertiary hospital which is located in the middle zone of Nepal, therefore the findings of this study can not be generalized. Limited sample size is also the limitations of the present study.

CONCLUSION

This study concludes that the mean values for pedicle chord length and breadth progressively decreases whereas thickness increases from L1 to L5 vertebral levels amongst Nepalese population. Thus, the pedicle dimensions must be considered prior to the selection of a pedicle screw. It is also an essential to understand the pedicle dimensions for the development of techniques and devices for spinal instrumentation for safer pedicle screw placement. It may also generate the baseline data for this population which may help in further research activities.

ACKNOWLEDGEMENTS

Authors would like to thank and acknowledge Dr. Bishal Sah and all staff from the Department of Radio-diagnosis, Dhulikhel Hospital who helped in data collection.

Conflict of interest: None
Source(s) of support: None

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