Original Article

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A Cross-sectional Study of Third to Seventh Cervical Vertebral Bodies, Pedicles, and its Relevance to Screw Size used in Clinical Practice

Anatomy Section

KISHORE CHANDRA THAKUR[1], SUNDER LAL JETHANI[2]

ABSTRACT

Introduction: To provide stability to the unstable cervical spine, the usage of transpedicular screws is very common due to their success in providing good results in terms of fixation, stability, and strength. The size of the transpedicular screw used must be in accordance with the morphology of the pedicle of the vertebra in a particular region or group of the population. This helps avoid pedicle wall damage along with nearby neurovascular structures.

Aim: The aim of the present study was to measure the body and pedicle of cervical vertebrae (third to the seventh) and to understand their morphology in relation to the need for a uniform screw size.

Materials and Methods: A cross-sectional study was conducted from May 2019 to March 2023, using a total sample of 102 adult human dry cervical vertebrae collected from the bone bank of the Anatomy Department at the Himalayan Institute of Medical Sciences, SRHU, Dehradun. Only cervical vertebrae from the third to the seventh were included. Digital vernier calipers were used to measure the parameters, including the Transverse Diameter (TD), Anteroposterior Diameter (APD), and Vertical Height (VH) of the vertebral body, as well as the Pedicle Width (PW), Pedicle Height (PH), and Pedicle Length (PL) of the pedicle. Statistical analysis was performed using Microsoft® Excel® 2019 MSO (Version 2209 Build 16.0.15629.20200) 64-bit software (Microsoft Office Home and Student 2019, Washington, USA). The parameters of the right and left sides of the pedicle (PW, PH, PL) were compared using the student's t-test, and Pearson correlation test was used to find correlations among them. A p-value of 0.05 or lower was considered statistically significant.

Results: For the vertebral body, the mean APD was 16.6 mm, VH was 11.6 mm, and TD was 25.6 mm. For the pedicle, the mean PW was 5.1 mm, PH was 6.5 mm, PL was 8 mm, and Axial Length (AXL) was 30.4 mm. No significant difference was found between the right and left sides of PW (p=0.7), PH (p=0.2), PL (p=0.7), and AXL (p=0.2). A weak correlation (0.31-0.40) was observed among the parameters of the vertebral body (APD, TD, VH), whereas a moderate to strong correlation (0.60-0.89) was noticed among the parameters of the cervical vertebrae pedicle (PW, PH, PL, and AXL).

Conclusion: The size of the screw used for spinal fixation in one region of the Indian population may not always be compatible with other regions. This morphological study of the cervical vertebral body and pedicle suggests its clinical relevance in the use of a cervical transpedicular screw with a diameter of less than 4 mm and a length of less than 30 mm. Additionally, using a screw along the sagittal plane of the vertebral body with a length of less than 16 mm may reduce bone breach and prevent neurovascular damage.

Keywords: Pedicle screw, Spinal disease, Vertebrae

INTRODUCTION

The seven cervical vertebrae are identified by the presence of the foramen transversarium in the transverse process through which important vessels like the vertebral artery pass, except in the seventh cervical vertebra. Altogether, the cervical vertebral column has a secondary curvature, i.e., an anterior convex curvature. The vertebral body and pedicle are stronger components of the third to seventh cervical vertebrae and are thus widely used for instrumentation. The pedicle on each side is a short cylindrical bony part that projects posterolaterally from the body of the vertebra, and after joining the lamina of the vertebra, it completes the neural arch. Morphometry of the vertebral body and the pedicle plays a role in providing stability post-fixation by screws or wires. Variability in the morphometric data has been reported regarding the vertebral body and pedicle of each cervical vertebra and in different populations [1,2].

The procedure of introducing a cervical screw carries a risk of neurovascular damage if the screw violates its course while traversing the pedicle [3-6]. A transpedicular screw is commonly utilised in spinal surgeries, either by an anterior or posterior approach, to stabilise an unstable spine due to trauma or pathological conditions [7]. No complications were documented in a study when the transpedicular cancellous screw was used in accordance with pedicle size [8]. However, in different studies, higher medial wall damage of the pedicle was noted due to maladaptation between the pedicle and the screw size used, even after using intraoperative imaging techniques [8-13]. One study concluded that although the strength of the pedicle of the cervical vertebra is similar to that of the thoracic and lumbar areas, the use of a screw there carries an unacceptable risk [14].

The research has been undertaken with the variability of morphological dimensions of the cervical vertebral body and pedicle in mind, and its usefulness during vertebral column fixation. The available data either focus on individual cervical vertebrae numbers or adhere to pedicle dimensions. However, the present study aimed to estimate the morphological dimensions of different parameters in collaboration with all parameters required for vertebral instrumentation. Additional knowledge of anatomical measurements of the required parameters will encourage the use of more compatible screws with the aim of reducing neurovascular damage during spinal surgeries. Thus, the aim of the study was to measure the body and pedicle of cervical vertebrae

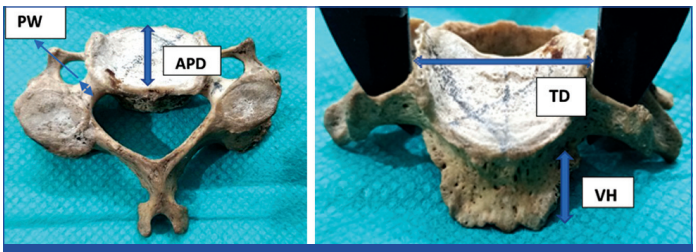
(third to the seventh) and to understand their morphology in relation to the need for a uniform screw size. The secondary objective is to compare the parameters required for screw fixation and determine the correlation among those necessary parameters.

MATERIALS AND METHODS

The protocol for this cross-sectional study, conducted from May 2019 to March 2023 over a duration of four years, was approved by the research and ethical committee (LOA: Anatomy/2019/01) of the Himalayan Institute of Medical Sciences, SRHU, Dehradun. A total number of 102 dry human cervical vertebrae from the bone bank of the anatomy department were collected. The sample excluded the atlas (C1) and axis (C2) due to their lower frequency of surgeries. Damaged and malformed cervical vertebrae were excluded. The specific age and sex of the bones could not be confirmed due to the unavailability of specific records.

The dimensions of parameters such as the pedicle and vertebral body could be helpful for surgeons during spine fixation using transpedicular screws. However, it is not practical to apply the data from each specific number of cervical vertebrae in all scenarios. To address this issue and make the data more practically applicable and less cumbersome, we used the mean of each parameter for the third to seventh cervical vertebrae.

The parameters measured included the following: for the cervical vertebral body, the authors measured the Anteroposterior Distance (APD), Transverse Distance (TD), and VH (distance between the mid of the anterosuperior and anteroinferior margin of the vertebral body) [Table/Fig-1-4]. For the pedicle of each side of each cervical vertebra, we measured PH (distance between the superior and inferior border of the pedicle), PW (distance between the medial and lateral border of the pedicle from the superior aspect), and PL (distance between the vertebral end and laminar end of the pedicle from the inferior aspect) [Table/Fig-1,5-7].



[Table/Fig-1]: PW: Pedicle width, APD: Anteroposterior diameter.
[Table/Fig-2]: TD: Transverse diameter, VH: Vertical height. (Images from left to right)

[Table/Fig-3]: Anteroposterior Diameter (APD).
[Table/Fig-4]: Vertical Height (VH). (Images from left to right)

All measurements were performed according to the method used in previous studies by Prameela MD et al., and Bazaldua CJJ et al., [12,15].

APD: Anteroposterior Distance across the vertebral body [Table/Fig-1,3].

TD: Transverse Distance across the vertebral body [Table/Fig-2].

VH: Distance between the mid of the anterosuperior and anteroinferior margin of the vertebral body [Table/Fig-2,4].

PH: Distance between the superior and inferior border of the pedicle [Table/Fig-5].

PW: Distance between the medial and lateral border of the pedicle from the superior aspect [Table/Fig-1,6].

PL: Distance between the vertebral end and laminar end of the pedicle from the inferior aspect [Table/Fig-7].

AXL: Distance from the mid of the anterosuperior margin of the vertebral body to the mid of the superior and inferior articular process posteriorly [Table/Fig-8].

[Table/Fig-5]: Pedicle Height (PH).
[Table/Fig-6]: Pedicle Width (PW). (Images from left to right)

[Table/Fig-7]: Pedicle Length (PL).
[Table/Fig-8]: AXL-Axial Length of pedicle. (Images from left to right)

The APD and TD of the vertebral body were measured from the superior aspect, while VH was measured from the anterior aspect. Digital Vernier Caliper SAFESEED (ASIN B01GV06XQM) was used with a resolution of 0.1 mm/0.1" and an accuracy of ±0.2 mm/0.01" to take all measurements in mm to one decimal point. Each measurement was taken twice by a single observer, and the average of both measurements was considered.

STATISTICAL ANALYSIS

The Mean (M), Standard Deviation (SD), and Standard Error (SE) of different parameters were calculated. A t-test was applied to compare right-left parameters, and Pearson correlation test was used to analyse the relationships between variables. A graph was plotted using Microsoft® Excel® 2019 MSO (Version 2209 Build 16.0.15629.20200) 64-bit (Microsoft Office Home and Student 2019, Washington, USA). A p-value of <0.05 or lower was considered statistically significant.

RESULTS

A total of 102 dry cervical vertebral bodies were measured. The mean TD was 25.6 mm ±2.6, APD was 16.6 mm ±2.2, and VH was 11.6 mm ±1.4 [Table/Fig-9].

Parameters	Sample number (n)	Mean	Median	Mode	SD	SE
Vertebral body	102					
TD		25.6	25.1	26.2	2.6	0.2
APD		16.6	16.4	17.7	2.2	0.2
VH		11.6	11.6	11.7	1.4	0.1

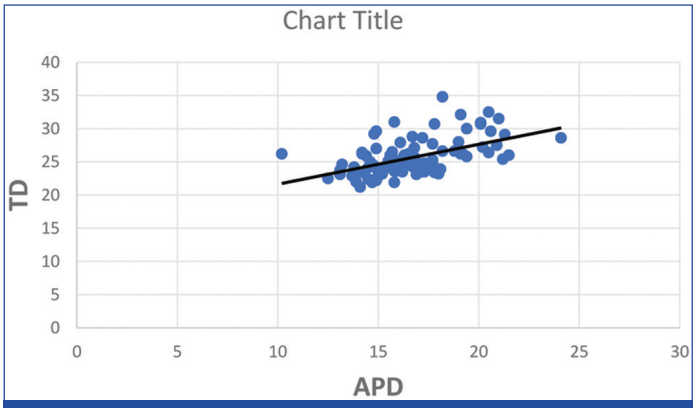
Right pedicle	102					
RPW		5.1	5.1	5.5	0.9	0.09
RPH		6.5	6.5	6.3	0.9	0.09
RPL		8.0	8.1	8.1	2.0	0.2
RAXL		30.4	30.1	28.3	2.6	0.2
Left pedicle	102					
LPW		5.1	5.1	5.5	0.9	0.09
LPH		6.6	6.5	6.5	1.0	0.1
LPL		8.0	7.6	9.8	2.2	0.2
LAXL		30.3	30.2	29.0	2.6	0.2
Total pedicle	204					
PW		5.1	5.1	5.5	0.9	0.06
PH		6.5	6.5	6.5	0.9	0.06
PL		8.0	7.8	8.1	2.1	0.1
AXL		30.3	30.1	28.7	2.6	0.1

[Table/Fig-9]: Result of measured parameters of cervical vertebrae (in mm).

When Pearson correlation was applied, a weak positive correlation (less than 0.45) was observed between APD and TD, TD and VH. However, no correlation was observed between APD and VH [Table/Fig-10]. [Table/Fig-11] shows a the weak positive correlation graphically.

S. No.	Correlation of APD with	r-value	Strength of correlation
1	TD	0.40	Weak (+ve)
2	VH	0.08	NO
	Correlation of TD with		
1	VH	0.31	Weak (+ve)

[Table/Fig-10]: Correlation of cervical vertebral body parameters.



[Table/Fig-11]: Correlation between APD and TD.

A total of 204 cervical vertebrae pedicles were measured, with 102 on each side. The mean values of the pedicle parameters were as follows: PW 5.1 mm ±0.9, PH 6.5 mm ±0.9, PL 8.0 mm ±2.1, and AXL 30.3 mm ±2.6 [Table/Fig-9]. When measuring the pedicle of each side of each vertebra, the mean values were as follows: RPW 5.1 mm ±0.9, RPH 6.5 mm ±0.9, RPL 8.0 mm, RAXL 30.4 mm ±2.6 on the right side, and LPW 5.1 mm ±0.9, LPH 6.5 mm ±1, LPL 8.0 mm ±2.2, LAXL 30.3 mm ±2.6 on the left side. No significant difference ($p>0.05$) was found between RPW/LPW, RPH/LPH, RPL/LPL, and RAXL/LAXL [Table/Fig-12]. Moderate strength of correlation ($0.45<r<0.75$) was observed between the right and left sides of each parameter [Table/Fig-12].

S. No.	Parameters	p-value	Remarks	r-value	Strength of correlation
	Pedicle				
1.	RPW/LPW	0.7	Not significant	0.71	Moderate (+ve)
2.	RPH/LPH	0.2	Not significant	0.60	Moderate (+ve)
3.	RPL/LPL	0.7	Not significant	0.70	Moderate (+ve)
4.	RAXL/LAXL	0.2	Not significant	0.89	Strong (+ve)

[Table/Fig-12]: Comparison of p-values and correlations of right and left pedicle parameters.
Test applied: t-test

DISCUSSION

In the present study, the parameters of the vertebral body showed a higher mean TD (25.6 mm) than the mean APD (16.6 mm), while the mean VH of the body was the lowest among the three, which is consistent with the known characteristic feature of the cervical vertebral body. The parameters of the pedicle in the cervical vertebrae of the present study showed a higher mean PH (6.5 mm) compared to the mean PW (5.1 mm). The mean values of the pedicle parameters on the right side were equal to those on the left side. In a study by Ebraheim NA et al., it was found that the anteroposterior length of the vertebral body increased from top to bottom, and the mean value was higher in males [10]. The mean value of APD in the present study (16.6 mm) was consistent with a study by Rao EVK et al., on Indians, which reported an APD of 15.9 mm [11].

Higher vertebral body parameters were noted in the present study compared to a study on the South Indian population by Prameela MD et al., [Table/Fig-13] [12]. In comparison with a study on the Nigerian population [13], the mean APD of Nigerians was much higher, which could be due to variations in ethnicity or environmental factors. However, the vertebral body parameters in the present study were closer to those of the Turkish [14], Mexican [15], and Singaporean [16] populations.

S. No.	Author	Year	Population	APD (mm)	TD (mm)	VH (mm)
1	Present study	2022	Indian	16.6	25.6	11.6
2	Rao EVK et al., [11]	2016	Indian	15.9	21.4	12.3
3	Prameela MD et al., [12]	2020	Indian	14.7	23.2	10.9
4	Udoaka AI and Chisom E [13]	2016	Nigeria	20.4		12.8
5	Polat S et al., [14]	2019	Turkish	14.0	24.4	10.6
6	Bazaldúa CJJ et al., [15]	2011	Mexican	16.4	20.7	
7	Bosbuga M et al., [16]	2004	Singapore	14.1	14.8	10.0

[Table/Fig-13]: Comparative study of the vertebral body of cervical vertebrae [11-16].
All units are in mm

Chen ZW and Cao SJ concluded in their study that lower-level cervical spine instability can be corrected using pedicle screws, taking into account the available cervical pedicle dimensions for effective fixation [17]. Xu R et al., also support this statement, emphasising the risk of penetration during screw insertion [18]. Therefore, the anteroposterior dimension of the vertebral body [Table/Fig-13] and the various parameters of the pedicle should not be neglected, considering the potential risk of damage to nearby neurovascular structures [3-6,19].

When comparing the data [Table/Fig-14], pedicle parameters such as PL, PW, and PH in the present study were closer to the means of similar parameters in the Egyptian population [20], but not in accordance with other studies on the Indian population. In the present study, PL (8.0 mm) was measured from the inferior aspect, while in the study by Prameela MD et al., on the Indian population, PL was 5.41 mm and measured from the superior aspect. This could be the most probable reason for the significant difference in the mean value of PL between the two studies [12].

For the cervical vertebrae from C3-C7, the pedicle AXL range was 30.0 to 36.5 mm in the study by Eldin MMM, and the mean pedicle AXL measured in the present study was 30.38 mm [20]. The present study's mean value of pedicle AXL was consistent with a study by Kumar S et al., on the Indian population [21].

When comparing pedicle dimensions of the third to seventh cervical vertebrae in different studies on the Indian population [Table/Fig-15], it can be inferred that a safer pedicle screw diameter could be

S. No.	Author	Year	Population	PL	PW	PH	AXL
1	Present study	2022	Indian	8.0	5.1	6.5	30.3
2	Ugur HC et al., [4]	2000	Turkish		4.9-5.7	6.3-6.6	
3	Prameela MD et al., [12]	2020	Indian	5.41	4.52	5.98	29.26-32.22
4	Polat S et al., [14]	2019	Turkish	5.65	3.66		
5	Bazaladua CJJ et al., [15]	2011	Mexican	4.75	4.75	6.95	
6	Bozbuga M et al., [16]	2004	Singaporean		4.76	6.37	
7	Eldin MMM [20]	2014	Egyptian	7.06	5.18	6.65	30-36.5
8	Kumar S et al., [21]	2021	Indian		4.71-6.14	6.22-6.64	29.2-32.2
9	Farrooque K et al., [23]	2018	Indian	5.2-5.7	4.3-5.7	5.5-6.1	29.6-33.4
10	Gupta R et al., [27]	2013	Indian		4.9	6.5	
11	Liu J et al., [28]	2010	American		5.26-6.63	6.7-7.6	
12	Kayalioglu G et al., [29]	2007	Turkish		4.1-5.2	5.9-6.2	

[Table/Fig-14]: Comparative study of pedicle dimensions of cervical vertebrae (in mm) [4,12,14-16,20,21,23,27-29].

less than 4 mm, considering that the mean PW and height were in the range of 4.3 to 6.1 mm and 5.2 to 7.1 mm, respectively. At C3 [Table/Fig-15], there was a minimum PW of 4.3 mm and a PH of 5.2 mm, suggesting that a screw with a diameter less than 4 mm may provide better fixation without breaching the bone bridge required [22,23].

S. No.	Author	Year	Parameter	C3	C4	C5	C6	C7
1	Kumar S et al., [21]	2021	PH	6.2	6.4	6.0	6.1	6.6
			PW	4.7	4.7	5	5.1	6.1
2	Panjabi MM et al., [22]	2000	PH	6.7	7.1	6.3	6.2	-
			PW	4.3	4.4	4.9	5.1	
3	Farooque K et al., [23]	2018	PH-Males	5.7	6	6.2	6.4	6.3
			PH-Females	5.2	5.5	5.7	6.1	5.9
			PW-Males	4.7	5	5.4	5.7	6
			PW-Females	4.3	4.6	4.8	5	5.4
4	Sharma D et al., [24]	2022	PW	4.7	4.8	5.26	5.41	
5	Patwardhan AR et al., [25]	2011	PW-Males	5.3	5.3	5.6	5.6	6.1
			PW-Females	4.6	4.7	4.7	5.3	5.6
6	Banerjee PS et al., [30]	2012	PH	6.4	6.5	6.7	6.4	6.7
			PW	4.8	4.8	5	5.3	6.1

[Table/Fig-15]: Comparative study of a pedicle from C3 TO C7 [21-25,30].

A variety of cortical and cancellous screws are available in diameters ranging from 2.7 to 4.5 mm. For safer insertion of the pedicle screw, a bony bridge of approximately 0.5 mm on either side is required [23,24]. Some studies recommend a 0.75 mm bony bridge on each side of the screw for added safety [25].

During the introduction of the pedicle screw, there is a higher risk of breaching the bony margin on the lateral side, approximately 10%, due to the mismatch in screw size [26]. The foramen transversarium contains the vertebral artery, which is related to the lateral aspect of the pedicle. According to a study by Sharma D et al., the lateral distance from the pedicle to the vertebral artery ranges from 0.97 mm to 1.15 mm [24]. Considering the high likelihood of neurovascular complications during pedicle breach, Patwardhan AR et al., recommended the use of a 2.7 mm diameter transpedicular screw [25].

Eldin MMM found pedicle AXL within the range of 30 to 36.5 mm in the Egyptian population [20], while studies on the Indian population showed axial PL in the range of 29.2-33.4 mm [21,27]. The mean axial PL in the present study was 30.38 mm, consistent with other studies conducted on Indians [21,27]. [Table/Fig-13-15] displays comparative studies of vertebral bodies, pedicle dimensions, and a comparative study of the pedicle from C3 to C7, respectively [4,12,14-16,20-25,27-30].

No significant difference was observed after applying the t-test among the pedicle parameters of the right and left sides [Table/Fig-12]. A moderate correlation was observed among the pedicle parameters. The right and left axial PL showed a strong correlation when applying Pearson correlation, but the p-value was not significant (p=0.58). Based on the available data [Table/Fig-14] on the AXL of the pedicle, it can be suggested that the length of the pedicle screw should not exceed 30 mm [4,12,14-16,20,21,23,27-29]. A similar view was presented by Kumar S et al., in the context of Indian cervical vertebrae, where they recommended a screw length of 20-30 mm for surgeries [21]. The present study's data on various parameters indicate that a compatible screw may have a diameter of less than 4 mm and a length of less than 30 mm. Additionally, a screw used in the sagittal plane of the vertebral body with a length of less than 15 mm may be more compatible and safe.

Limitation(s)

The non availability of data regarding the age and sex of the bones is a limitation of this study.

CONCLUSION(S)

Knowledge of these variations in parameters adds additional safety measures during surgeries. As there were no significant differences observed in the right and left pedicle parameters, with weak and moderate correlations among other parameters, it would help surgeons use more uniform and compatible screws safely at all levels from C3-C7. This may reduce the occurrence of neurovascular complications that commonly arise from breaching the bony boundaries of pedicle in cervical vertebrae.

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PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Anatomy, Himalayan Institute of Medical Sciences, Swami Rama Himalayan University, Dehradun, Uttarakhand, India.
2. Professor, Department of Anatomy, Himalayan Institute of Medical Sciences, Swami Rama Himalayan University, Dehradun, Uttarakhand, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Kishore Chandra Thakur,
Flat No. 33, Ground Floor, Lane-2, Madhu Vihar, Haripur, Kanwali, GMS Road,
Near Jewel Residency, Dehradun-248001, Uttarakhand, India.
E-mail: bestthakur@hotmail.com

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