Original Article

Pedicle Dimensions of the Thoracic Vertebrae in the Zimbabwean Adult Male Population: A Cadaveric Study

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Author's Contribution

[1,2,3] *Conception of study*
[1,2,3] *Experimentation/Study conduction*
[1,2,3] *Analysis/Interpretation/Discussion*
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Abstract

Objective: To record the dimensions of thoracic-vertebrae pedicles in the grown-up community of Zimbabwe.

Study design: A cross-sectional descriptive study.

Place and Duration of study: A six-month study was carried out in the Anatomy Department (Gross Anatomy Laboratory), University of Zimbabwe, College of Health Sciences, Harare (from May 2019 to November 2019).

Materials and Methods: The thoracic vertebrae from 15 adult male cadavers were dissected out and Pedicle External Sagittal Diameter (PESD), Pedicle External Transverse Diameter (PETD), and chord length were measured using a vernier caliper and compared (on right and left sides). The statistical analysis was done using SPSS version 23, with data expressed as means, standard deviation, and ranges. The student's t-test was used to estimate the difference in pedicle dimensions of the right and left sides of the thoracic vertebrae.

Results: There was a significant difference between the right and left pedicle dimensions in chord length at the level of T_9, PESD at levels T_6 and T_7, and PETD at levels T_2, T_6, T_7, and T_{11}. PESD values were noted to be increasing from thoracic vertebrae T_1 to T_{12} with a plateau phase noted from T_2-T_7. PETD values decreased from T_1-T_5 and then gradually increased to T_{12}. Chord length increased gradually from T_1-T_{12}.

Conclusion: Pedicle dimensions differ between the Zimbabwean population and other ethnic groups of earlier investigations. Furthermore, there was a significant difference between the right and left pedicles in terms of PETD, PESD, and Chord length.

Keywords: Chord-length, Pedicle dimensions, Thoracic vertebrae.

Introduction

The thoracic vertebral column comprises twelve vertebrae numbered T_1 to T_{12}, articulating at inter-vertebral joints. These vertebrae have a heart-shaped body for support and are weight-bearing. A typical thoracic vertebra possesses pedicles that project posteriorly from the superior part of the body. Each pedicle has an upper and lower border. The lower border forms the upper boundary of the intervertebral foramen. This foramen accommodates the thoracic nerve of the same number as the vertebra.[1]

Thoracic vertebrae are mostly typical vertebrae having independent bodies, vertebral arches, and seven processes for muscular attachment and articular connections. The processes include two superior articular facets, two inferior articular facets, two transverse processes, and a single spinous process. The T_1, T_{10}, T_{11} and T_{12} vertebrae are examples of atypical vertebrae.[2] The body bears the majority of the force applied to the vertebrae. The bodies increase in size from above going downwards.[3]

The pedicle is the strongest part of the vertebra. About 80 percent of the hold of the pedicle screw is contributed by the pedicle.[4] The lateral borders of the vertebral foramen and superior and inferior margins of the intervertebral foramen are formed by the pedicle.[5] Pedicles provide side protection for the spinal cord and nerves. The dural sac is a medial relation of the pedicle and the nerve roots via the intervertebral foramina. These structures are susceptible to injury during pedicle screw placement.[6] They also serve as a bridge (between the front part and back part of the vertebrae). The pedicle is clinically important in thoracic pedicle screw placement and it acts as an important radiographic marker. The pedicle is used as an entry point in kyphoplasty and vertebroplasty procedures.[7]

Thoracic pedicles are generally long and stout. There is a difference in pedicle size among different individuals, populations, and ethnic groups.[8] However, the right and left sides of the same vertebrae are usually similar.[9] Pedicles are stronger in thoracic vertebrae and increase in length from T_1-T_{12}.[10] The lower thoracic region has larger pedicles when compared to the upper lumbar vertebra.[11]

The fourth thoracic vertebra (T_4) has the narrowest pedicles whereas the pedicles of T_5-T_{12} become increasingly wider.[12] T_{11} has the widest pedicle external sagittal diameter (PESD) with T_1 having the narrowest.[13] Furthermore, T_5 has the narrowest pedicle external transverse diameter (PETD). Due to the oval shape of the pedicle, the sagittal plane width is generally larger than the transverse plane width.[14]

Previous studies have concluded that thoracic spine T_5-T_8 is the most common site for a breach. A lateral breach is more common than a medial breach. Upper thoracic vertebrae, the third to sixth thoracic vertebrae pose to be of greater risk due to the narrowness of their pedicles.[15] For proper fixation without complications, a detailed study of pedicle dimensions of thoracic vertebrae is thus essential. Hence, the main objective of the present study was to measure the PESD, PETD, and chord length in male adult cadavers from the Zimbabwean population.

Materials and Methods

This descriptive cross-sectional study was conducted in the Department of Anatomy, University of Zimbabwe College of Health Sciences Harare, Zimbabwe. The duration of the study was 6 months from May 2019 to November 2019. The sample consisted of 15 adult black Zimbabwean male cadavers.[16]

Sample Size Calculation:

Level of significance = 5%, Power = 80%, $Z\alpha = Z$ is constant set by convention according to accepted α error and $Z\ (1-\beta) = Z$ is constant set by convention according to the power of study which is calculated from the following table:

Z values for conventional values of alpha (α)	
Alpha	Zα
0.05	1.96
0.01	2.58
Z values for conventional values of beta (β)	
Beta	Z (1-β)
0.20	0.842
0.10	1.28
0.05	1.64
0.01	2.33

$\alpha = 0.05\ \beta = 0.05$

$Z\alpha = 1.96$, $Z\ (1-\beta) = 1.64$, Standard Deviation (SD) = 15, d (effect size) = 20

Formula for sample size $n = 2\ (Z\alpha + Z\ [1-\beta])^2 \times SD^2 / d^2$

So $n = 2\ (1.96 + 1.64)^2 \times 15^2 / 20^2 = 14.58$

Therefore, sample size was taken as 15.

Non-probability convenience sampling was used and cadavers were selected according to their accessibility and proximity to the researcher. Approval of the Joint Research Ethics Committee of the University of Zimbabwe was taken before conducting the

experiment. Adult black male cadavers between the age group of 22 to 40 years with no obvious vertebral deformities were included in the study. Male cadavers with kyphosis, scoliosis, or other gross vertebral malformations, injuries of thoracic vertebrae, Caucasians, females, and children were excluded from this study. Osteoporotic changes were ruled out since only male cadavers aged between 25 to 40 years were considered in this study.

Embalmed human cadavers were dissected using the posterior approach to the thoracic spine. The cadavers were put in the prone position and the subcutaneous vertebra prominence of C_7 was felt and marked. One mid-line longitudinal incision was made over spinous processes and laminae of C_7 to the lumbosacral angle. Using a scalpel, blunt probe, and finger, muscles of the posterior thoracic wall were mobilized and reflected laterally as far as possible to expose the vertebral arches, transverse processes as well as the ribs from T_1-T_{12}. The vertebral column was then resected by cutting through the ribs and inter-vertebral disks at the lumbosacral angle, between C_6 and C_7. Following the removal of the vertebral column, the vertebral bones were heated for 72 hours in a maceration heater in order to remove the soft tissues attached to the bone.

The remaining soft tissues were removed by manual dissection and the vertebrae were air-dried. The PESD, PETD, and chord length were measured on both sides of the thoracic vertebrae by using a vernier caliper. Statistical analysis was done by IBM SPSS version 23. Means and standard deviations were calculated. An independent sample t-test was used to estimate the difference in pedicle dimensions of the right and left sides. P-value ≤ 0.05 was taken as the level of significance.

Results

There was a gradual increase in PESD from T_1-T_{12} (Figure 1 and Table 1). A plateau phase was noted from vertebral levels T_2-T_7 (Figure 1). The least mean PESD values were at T_1 (right 9.89±1.27mm and left 10.02±0.98mm) and the largest was at T_{12} (right 17.50±2.04mm and left 17.97±1.78mm). T_6 and T_7 showed significant differences between the right and left values.

The largest PETD was observed at T_1 (8.33mm) and the least PETD was observed at vertebral level T_5 (4.05mm) (Table 2). A sharp decrease was noted in vertebral levels T_1-T_5 followed by a gradual increase in vertebral level T_6-T_{12} which also showed significant differences ($p<0.05$) between the right and left side values (Table 2).

Chord length increased gradually from T_1-T_{12} with the largest chord lengths observed at T_{12} (right 44.57±2.16mm and left 45.02±2.34mm) and the least chord lengths observed at T_1 (right 31.14±2.11mm and left 31.29±2.38mm) (Table 3 and Figure 2). There was a significant difference between right and left values at T_9 (Table 3).

Table 1: Comparison of right and left mean PESD

Vertebral level	*Right Mean PESD±SD(mm)*	*Left Mean PESD±SD(mm)*	*P-value*	*Mean PESD(mm) {(right+left)/2}*
T_1	9.89±1.27	10.02±0.98	0.470	9.96
T_2	11.81±1.09	11.38±1.10	0.290	11.60
T_3	11.56±1.21	11.87±0.91	0.152	11.72
T_4	11.77±0.85	11.69±0.49	0.651	11.73
T_5	11.77±0.96	11.62±0.86	0.442	11.70
T_6	11.69±1.26	11.15±1.17	0.0100	11.42
T_7	11.83±0.96	11.23±1.20	0.001	11.53
T_8	12.11±0.96	12.11±1.14	1.000	12.11
T_9	13.72±0.83	13.52±0.87	0.100	13.62
T_{10}	15.11±1.65	14.86±1.46	0.162	14.99
T_{11}	16.54±1.69	16.87±1.42	0.161	16.71
T_{12}	17.50±2.04	17.97±1.78	0.142	17.74

Table 2: Comparison of right and left mean PETD

Vertebral level	*Right Mean PETD±SD(mm)*	*Left Mean PETD±SD(mm)*	*P-Value*	*Mean PETD(mm) {(right+left)/2}*
T_1	8.23±0.74	8.42±1.19	0.481	8.33
T_2	6.71±1.13	6.44±1.17	0.041	6.58
T_3	5.29±0.77	5.29±0.73	0.970	5.29
T_4	4.26±1.43	4.19±0.67	0.820	4.23
T_5	4.13±1.01	3.97±0.98	1.210	4.05
T_6	4.44±1.05	4.06±0.98	0.001	4.25
T_7	4.76±0.89	4.60±0.90	0.021	4.68
T_8	5.11±1.10	5.02±0.93	0.261	5.07
T_9	5.53±0.97	5.57±1.11	0.773	5.55
T_{10}	6.43±1.07	6.37±1.15	0.552	6.40
T_{11}	7.73±0.82	7.34±1.19	0.041	7.54
T_{12}	7.70±1.30	7.79±1.49	0.551	7.75

Table 3: Comparison of right and left mean chord lengths

Vertebral level	*Right Mean Chord Length±SD(mm)*	*Left Mean Chord Length±SD(mm)*	*P-value*	*Mean Chord length(mm) {(right+left)/2}*
T_1	31.14±2.11	31.29±2.38	0.610	31.22
T_2	32.55±2.87	32.36±3.02	0.310	32.46
T_3	33.97±2.74	34.35±2.65	0.141	34.16
T_4	36.90±2.73	36.76±2.99	0.703	36.86
T_5	37.05±3.10	37.12±3.29	0.733	37.09
T_6	39.41±3.06	39.81±3.36	0.062	39.61
T_7	41.61±4.38	41.66±4.58	0.951	41.62
T_8	42.42±3.62	42.69±3.65	0.120	42.56
T_9	43.76±3.87	44.40±3.63	0.037	44.08
T_{10}	43.79±3.61	44.37±3.57	0.112	44.08
T_{11}	43.84±3.27	44.02±3.24	0.551	43.93
T_{12}	44.57±2.16	45.02±2.34	0.160	44.8

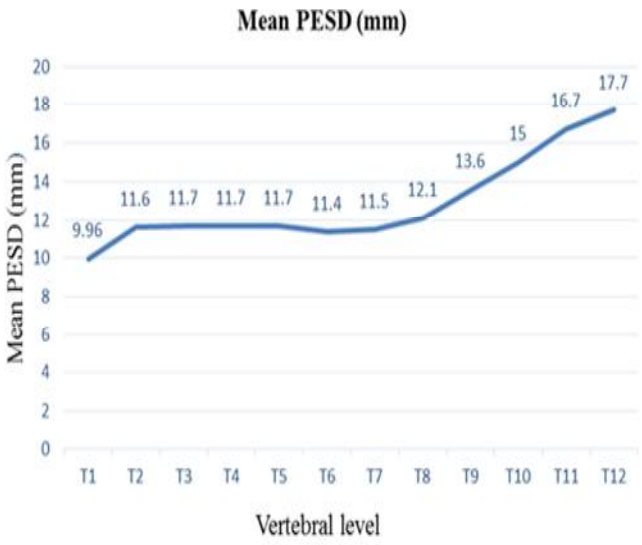

Figure 1: Graph of Mean PESD against thoracic level

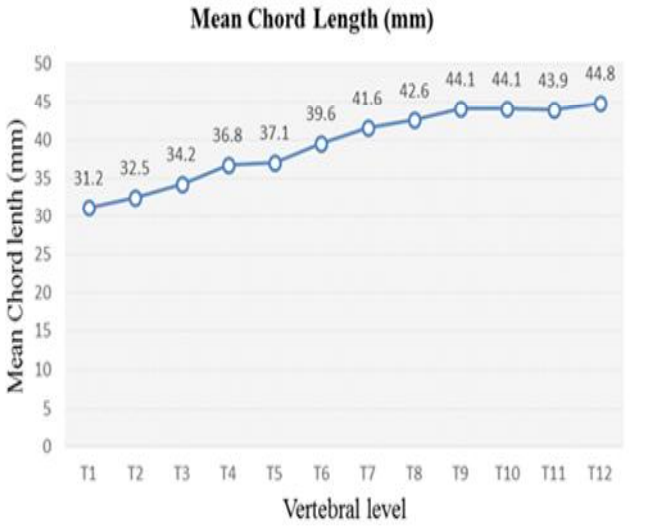

Figure 2: Graph of Mean Chord Length against vertebral level

Discussion

The thoracic segment is the longest part of the human vertebral column. The costo-vertebral articulations provide stability to thoracic vertebrae and are important for the structural and functional integrity of the thorax. The thoracic spinal column plays a main role in certain motions such as lateral flexion, axial rotation, and flexion/extension of the trunk. Significant variations have been seen in the pedicle shape and size between individuals and between thoracic vertebral levels within the same individual.[17] The use of pedicle screws in the thoracic spine is on increase to correct the various abnormal clinical conditions. The current study was designed to determine the accurate dimensions in the Zimbabwean adult male population to prevent vascular as well as spinal cord injury due to screw mal-placement.

The PESD values obtained in the American and Indian populations were larger than those reported in the present study.[18] The study on the Thai population had shown smaller values of PESD.[19] However, the trend regarding PESD seen in the present study was similar to previous research with slight variation in the last two vertebrae, i.e. T_{11} and T_{12}. American population had its largest PESD at T_{11} (17.4mm)[20] whereas, in this study, the highest PESD was at T_{12}. Also, there were significant differences between the right and left sides at levels T_6 and T_7 in the present study which was in contrast to the experiments done on other ethnic groups.[21]

PETD is the most critical anatomical variable in pedicle screw placement. Similar to the PESD, the values of the mean PETD examined in the present study were smaller compared to those reported in the American and French populations.[22] However, the trends were seen in PETD (where the mid-thoracic levels (T_4 to T_7) showed the lowest mean PETD values) were similar to the ones in the American, Indian, and French populations.[23] This trend is further supported by other researchers who stated that the mid-thoracic levels were the most susceptible site for a breach due to the narrowness of their pedicles.[24] This study on the Zimbabwean population suggests that to avoid medial and lateral breaches during pedicle screw placement, screws with a diameter of 5mm or less are used from T_2-T_{10} while screws with a diameter of 7mm or less are used elsewhere (T_1, T_{11}, and T_{12}).

The pedicle screw length can be determined by the chord length of the thoracic vertebrae.[25] In the current study, it was determined that there was a gradual increase in chord length at each vertebral level and it was consistent with the observation of the Indian population.[26]

For the ideal screw placement to occur, the screw length should include 50% of the vertebral body to minimize screw failure.[27] The present study on the Zimbabwean population suggests that screws of length 25mm be used in the upper thoracic level and screws of length 30mm be used elsewhere (mid and lower thoracic levels). These screw lengths are safer and avoid perforation of the anterior cortex of the body. However, the screws with a diameter of 5mm or less can be used from T_2-T_{10} thoracic levels, and screws with a diameter of 7mm or less are used elsewhere (T_1, T_{11}, and T_{12}).

Conclusion

Zimbabwean population had smaller pedicle dimensions as compared with other ethnic groups and the mid-thoracic region (T3 - T7) was most susceptible to pedicle screw breach due to small PETD. Significant differences in the right and left pedicle dimensions at the same vertebral level in terms of PESD, PETD, and chord length were also seen in the current study.

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