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Original Research Article

A STUDY OF TRANSMISSION OF WEIGHT THROUGH PEDICLES OF CERVICAL AND UPPER THORACIC REGION IN MAN OF SOUTH KARNATAKA REGION, INDIA

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ABSTRACT

Introduction: The pedicles act as struts and reinforce the vertical system of columns. The pedicle as this is the site where vertebral column fixation surgeries are most frequently implemented.

Objective: This study has been attempted to find out the transmission of weight through pedicles in man of South Karnataka region, India so that this knowledge could be applied to explain some of the clinicopathological conditions of the spine.

Materials and Methods: The 6 cervical and upper 5 thoracic vertebrae of 30 human adult male columns were selected for the study. The various parameters of inferior body surface area, pedicle index, body-pedicle angle and the ratio pedicle index to inferior body surface area were measured for each of the 6 cervical and upper 5 thoracic vertebrae of 30 columns.

Results: The area of the inferior surface of T_5 vertebra was more than double that of the body of C_2 vertebra. The mean pedicle index was greater at C_2, T_1, and T_2 levels, while it was smaller at the remaining levels. At C_2 level, in relation to the body, pedicles were directed backwards, downwards and laterally while, at C_4 level, pedicles were almost directed horizontal. From C_6 level downwards, pedicles were directed upwards and backwards. Their lateral deviation gradually diminished and at T_5, it was directed completely backwards.

Conclusion: The measurements obtained by the present study reveals the importance of pedicle in understanding the mechanics of spinal anatomy and its applications with respect to transmission of weight.

KEY WORDS: Pedicle, Cervical Region, Thoracic region, South Karnataka.

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INTRODUCTION

The pedicle is strongest part of vertebrae. They are made of entirely cortical bone with a small core of cancellous bone [1]. The upper margins form the superior vertebral notch, and lower margins form the inferior vertebral notch, and both contribute to corresponding intervertebral foramen [2]. Previously morphometric studies of the cervical, thoracic, and lumbar vertebrae have been undertaken and majority of these studies focus exclusively on the pedicle as this is the site where vertebral column fixation surgeries are most frequently implemented [3-5]. However, the pedicle screw has its own disadvantages also. Because of mismatched size of screw and pedicle the instrumentation may fail. This may result in cortex perforation of pedicle or fracture of pedicle. Sometimes pedicle screw may loosen. As seen above the pedicle screw fixation has its own advantages and disadvantages.

The horizontal diameter of pedicle decides the screw diameter. For this reason, the detail of pedicle morphometry becomes important as it helps in the selection of most suited pedicle screw. Almost all the previous workers have reported the data on morphometry of the pedicle based on a common pool of vertebrae (male and female vertebrae were pooled together) [6,7]. However, Scoles [8] have reported statistically significant sex differences in pedicle morphometry. Most of previous studies of the morphometry of pedicle are based on white populations [5,8,9]. Thus according to Krogman [10]; as the racial variations in skeleton are well known, hence the morphometry of the pedicle may vary from population to population. Even within the same population the anatomical variations have been reported on the pedicle shape, size and angulation [11]. Therefore, the present study was conducted to find out the transmission of weight through pedicles in man of South Karnataka region, India so that this knowledge could be applied to explain some of the clinico-pathological conditions of the spine.

MATERIALS AND METHODS

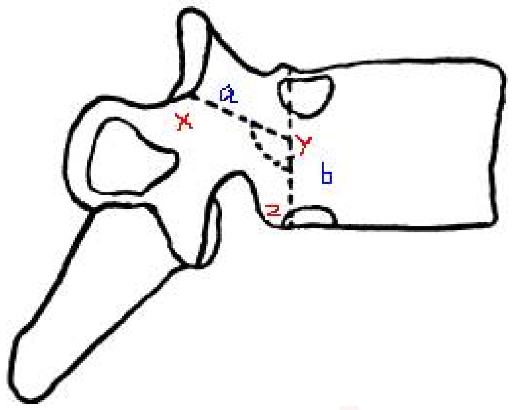
Present study was done on dry vertebral bones procured from the collection of Bangalore Medical College, Bengaluru, Karnataka, India. A total of 330 vertebrae were measured. Anatomical measurements were taken of the six cervical and upper five thoracic vertebrae of thirty columns using a vernier calliper (0-150mm with a precision of 0.02mm), sharp pencil, tracing paper, graph sheet and carbon paper. Adopting the various mechanical principles and ideas of Pal GP and Routal RV [4], the body pedicle angle, mean pedicle indices (represent the strength of the pedicle) and its ratio to the mean inferior body surface area were taken in the present study for each of the six cervical (C_2 - C_7) and upper five thoracic vertebrae (T_1 - T_5) of thirty columns. To overcome personal errors in judgment, the following procedures were adopted: Initially, all the measurements were taken by the author and criteria were established till the observations made individually coincided fully. Then the observations were repeated by a double blind method. Almost all the observations and measurements which were made at the second or subsequent attempts were identical to those made at the first time a maximum difference of one millimeter. Sexing of the vertebral column was established by observing the respective pelvis including the sacrum by the criteria laid down in the text books of anatomy such as subpubic angle, ischiopubic rami, ischial spine, greater sciatic notch, preauricular sulcus, acetabular cavity, obturator foramen, ischium-pubis index, breadth and curve of sacrum, articular surface of S_1 and sacral index. Those columns in which the sex could be established unequivocally only have been included.

Inferior body surface area: The area of the inferior surface of the body in each vertebra was measured using graph paper method. The outline of the inferior surface of the vertebral body was, traced on to a thin tracing sheet which was then transferred on to a graph sheet with the help of a tracing paper and the area was measured in square centimeters by counting the number of squares covered. This represents the parameter of the anterior column.

Pedicle index: The pedicle index is the product of the greatest and smallest diameters of a pedicle at its most slender portion [12]. This was determined as an indicator of the size of the pedicle. The mean of the indices of the two sides was then calculated to give the mean pedicle index for each vertebra.

Body-pedicle angle: The pedicles connect the anterior and posterior columns whose inclination and strength vary at different levels. The inclination and the strength of pedicles suggest the direction of transfer of the compressive forces between two columns in a curvilinear vertebral column, in par with the line of gravity. This angle was measured by projecting the long axis of the pedicle and the vertical axis of the body on the lateral aspect of the vertebra (Figure 1). In the cervical region, the long axis of the pedicle was drawn after detaching the transverse process. Mean body-pedicle angle ± S.D. (standard deviation) for each vertebral level was calculated.

Fig. 1: Body-pedicle angle (x,y,z), long axis of pedicle (a), long axis of body (b).



RESULTS

The area of the inferior surface of T_5 vertebra was more than double that of the body of C_2 vertebra (Table 1).

The mean pedicle index was greater at C_2, T_1, and T_2 levels, while it was smaller at the remaining levels (Table 1).

Table 1: Inferior body surface area, pedicle index and their ratio at each vertebral level.

Vertebral Levels	Mean Pedicle index	Mean Inferior body surface area (cm2)	Pedicle index / Inferior body surface area
C_2	0.56±0.10	2.28±0.65	0.25
C_3	0.31±0.08	2.69±0.62	0.12
C_4	0.30±0.07	3.15±0.74	0.1
C_5	0.32±0.08	3.62±0.70	0.09
C_6	0.33±0.05	4.02±0.69	0.08
C_7	0.43±0.08	4.90±0.62	0.08
T_1	0.63±0.09	5.40±0.92	0.11
T_2	0.63±0.11	5.81±1.06	0.11
T_3	0.50±0.17	5.99±1.15	0.08
T_4	0.43±0.11	6.36±1.28	0.07
T_5	0.40±0.08	6.86±1.66	0.06

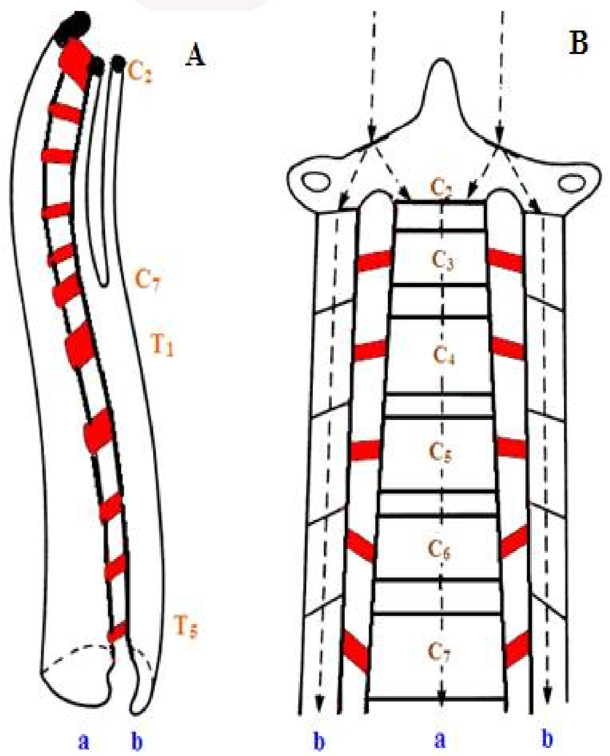
Each value is Mean ± standard deviation.

Angles between body and pedicle at various levels are given in Table 2 (Figure 2). At C_2 level, in relation to the body, pedicles were directed backwards, downwards and laterally while, at C_4 level, pedicles were almost directed horizontal. From C_6 level downwards, pedicles were directed upwards and backwards. Their lateral deviation gradually diminished and at T_5, it was directed completely backwards.

Table 2: Body-pedicle angle at each vertebral level.

Vertebral levels	Range (in degree)	Mean Body-pedicle angle (in degree)
C_2	45°-69°	57.3°
C_3	47°-69°	59.5°
C_4	62°-87°	74.0°
C_5	65°-92°	79.5°
C_6	84°-111°	99.6°
C_7	102°-114°	107.5°
T_1	104°-117°	110.4°
T_2	103°-119°	111.8°
T_3	104°-118°	111.3°
T_4	106°-118°	111.4°
T_5	107°-120°	115.1°

Fig. 2: Diagram to indicate weight transmission through the cervical and upper thoracic regions of the vertebral column (A); weight transmission through the cervical region of the vertebral column (B); a, column formed by bodies and intervertebral discs; b, column formed by articular processes in the cervical and by laminae in the thoracic region. Pecked lines and arrows indicate the path of weight transmission. Thick red bars connecting the columns represent the pedicles. Note the thickness and direction of inclination of the pedicles.



DISCUSSION

At the cervico thoracic junction transfer of weight from posterior to anterior column probably occurs through the pedicles [4,13]. The positions of weight bearing columns relative to each other is important, when columns are placed away from the centre of the load it can resist bending or buckling forces and are more stable than columns which are placed closer to each other.

The idea concerning weight transmission in the thoracic region is similar to the concept of the posterior column of Denis [14]. However, Louis [15] described a 'three column spine' concept for the thoracic as well as the cervical regions, in spite of the absence of distinctive bar-like articular processes in the thoracic region. The posterior two columns in the cervical region and the single posterior column in the thoracic region are connected by the pedicles to the anterior column. According to Louis [15] these pedicles act as struts and reinforce the vertical system of columns.

According to the hypothesis presented here, the pedicles play an important role in the transfer of the load from one column to the other and can be considered as mechanical beams. However, the transfer of load is effective only when the pedicles are inclined towards the vertical direction (Figure 2). At C_2 level, the inclination of the pedicles is such that it effectively transfers part of the load from anterior to posterior columns. Similarly, the position of the columns in relation to one another is also important. According to the study of Pal and Routal [4] a similar trend was observed in their study of the cervical and upper thoracic vertebrae (Table 3).

Table 3: Review of inferior body surface area and Pedicle index and their ratio with other studies [4].

Vertebral Levels	Inferior body surface area		Pedicle index		Pedicle index / Inferior body surface area	
	Study of Pal & Routal	Present Study	Study of Pal & Routal	Present Study	Study of Pal & Routal	Present Study
C_2	2.41	2.28	0.61	0.56	0.25	0.25
C_4	2.75	3.15	0.27	0.3	0.09	0.1
C_6	3.28	4.02	0.33	0.33	0.1	0.08
C_7	3.69	3.25	0.38	0.45	0.1	0.09
T_1	4.25	5.4	0.65	0.63	0.15	0.11
T_2	4.76	5.81	0.65	0.63	0.13	0.19
T_5	5.34	6.86	0.4	0.4	0.07	0.06

The cancellous structure of vertebrae has been studied to investigate the direction of trabeculae and thus the lines of stress [16]. The trabecular bone of the pedicle, connecting the body to the laminae, differed in different regions of the vertebral column. At C_2 level, it was found that trabeculae are involved in transfer of the column. At C_2 level, it was found that trabeculae are involved in transfer of the compressive forces from the superior articular surface to the inferior articular process and body [16]. Throughout the thoracic region, trabeculae in the pedicle were inclined anteriorly towards the body, indicating that compressive forces in the thoracic spine are transferred from the neural arch to the body.

Louis [15] on the basis of vertebral morphological study of dry skeleton claimed that descending forces from second cervical to fifth lumbar are transmitted through three columns. An anterior formed by bodies and intervertebral discs and to posterior formed by successive articular processes. He opines that this vertebral system of column is reinforced by horizontal stress, namely the pedicles and laminae, which at the level of each vertebra firmly joins the columns to each other.

J Maheshwari [17] states that recent biomechanical studies from the view point of stability have shown that the spine can be divided into three columns anterior, middle and posterior. The anterior column consists of anterior longitudinal ligaments and anterior part of annulus fibrosus along with anterior half of the vertebral body. The middle column consists of the posterior longitudinal ligaments and posterior part of annulus fibrosus along with posterior half of the vertebral body. The posterior column consists of the posterior bony arches along with the posterior ligamentous complex. In the different spinal injuries, the integrity of one or more these columns may be disrupted resulting in threat to stability of the spine. When only one column is disrupted e.g. wedge compression fracture of the vertebrae the spine is stable. When two columns are disrupted e.g. burst fracture of body of the vertebrae, the spine is considered unstable. When all the three columns are disrupted, spine is always unstable e.g. dislocation of one vertebrae over other.

On serial measurements of cervical and upper thoracic vertebrae, found that at the second cervical level, the compressive force acting on the superior articular surfaces where transmitted to the inferior surface of the body and the two inferior articular facets [18]. From second cervical to seven cervical vertebrae, compressive forces are transmitted through three parallel columns, an anterior formed by the bodies and intervertebral discs and two posterior, formed by successive articulations of the articular processes on either side. Due to the posterior curvature in the cervical region, the posterior columns here sustain more of the compressive force. From seven cervical level downwards, the compressive force is transmitted through two columns, one anterior formed by the bodies and intervertebral discs and one posterior formed by successive articulations of the laminae at their articular facets because of the incorporation of bar-like articular processes into the laminae at the level of C_7 and below in the upper thoracic region, due to anterior curvature, the main part of the compressive force is transmitted through the interior column. Below the seventh cervical level, compressive force from the posterior column is partly transferred to the anterior column through the pedicles of first and second thoracic vertebrae.

On the basis of the measurement of the lower thoracic and lumbar vertebrae deduce that the compressive forces were transmitted through two parallel columns in thoraco lumbar region one anterior (formed by vertebral bodies and intervertebral discs) and one posterior (formed by successive articulations of laminae with each other at their articular facets). These two columns are connected to each other by pedicles whose inclination and strength vary at different levels [19].

They stated that a considerable part of the weight of the upper limbs and the thoracic cage is transmitted through the ribs to the posterior columns (laminae) through the costotransverse articulations and its ligaments. Because of the anterior concavity of the spine in the thoracic region, weight is transferred from the posterior to the anterior column through the inclined pedicles. In the lumbar region where the concavity is posterior apart of the compressive force of the anterior column is transmitted to the posterior. Thus the compressive force in the curvilinear vertebral columns tends to deviate towards the line of gravity.

CONCLUSION

The present study had observed, at C_2 level, the inclination of the pedicles is such that it effectively transfers part of the load from anterior to posterior columns. Below C_7 level, compressive force from the posterior column is partly transferred to the anterior column through the pedicles at T_1 and T_2. In the upper thoracic region, due to the anterior curvature, the main part of the compressive force is transmitted through the anterior column, which sustains even greater compressive force than is suggested by body area, with resulting increased stress. The measurements obtained by the present study reveals the importance of pedicle in understanding the mechanics of spinal anatomy and its applications with respect to transmission of weight. This knowledge could be applied to explain some of the clinicopathological conditions of the spine.

Conflicts of Interests: None

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