Correlation of body height with thoracic and lumbar vertebral parameters

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Abstract:

With increasing popularity, there has been dramatic improvement in the way the spinal fusion operations are performed as well as in the fixation devices including the pedicle screws. Success among other factors depends on the accuracy of choice of screw, size of the pedicle and quality of the bone.[1]

With the recent increased use of various pedicle screw instrumentations, there is concern about injuries to the pedicle cortex, nerve root, facet joint, and adjacent vital structures by discordant pedicle screw size. Fracture of the pedicle may result from the use of relatively oversized screw. It was also observed that larger screw diameters were stronger and gave better results; therefore choice of the screw for the operation is determined by the minimum diameter of the pedicle.

Introduction

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With the recent increased use of various pedicle screw instrumentations, there is concern about injuries to the pedicle cortex, nerve root, facet joint, and adjacent vital structures by discordant pedicle screw size. Fracture of the pedicle may result from the use of relatively oversized screw. It was also observed that larger screw diameters were stronger and gave better results; therefore choice of the screw for the operation is determined by the minimum diameter of the pedicle .[2]

Morphometric measurements of a particular geographical area will help in proper implant selection during spinal surgeries; designing of best suited implant; understanding the biomechanics and patho-anatomy of the spine; precise clinical diagnosis and management for the population under consideration.

The thoracic and lumbar pedicle morphometry has been studied extensively in different populations using various techniques. Previous studies have shown a significantly smaller size of the thoracic pedicles in women than in men and in Asians than in Caucasians. Some authors postulated that it is the body height that contributes to the variation in the pedicle size. To our knowledge, however, no study has specifically analyzed the relationship between body height and thoracic pedicle parameters in detail.[3]

Weinstein et al[4] (1992) has reported that even within the same population the anatomical variations have been reported on the pedicle shape, size and angulations. Approximately 60% of fixation strength of the thoracic and lumbar pedicles lies in the pedicle, whereas 20-25% of fixation strength is derived from the anterior cortex

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and the rest 15-20% of strength comes from the cancellous bone.

Various authors have studied the thoracic pedicle morphometry and have arrived at differing conclusions regarding the safety of thoracic pedicle screw placement.[5,6]

To our knowledge, however, no study has specifically analyzed the relationship between body height and thoracic and lumbar spine parameters in detail. The parameters measured in the present study were selected considering the growing interest in the thoracic and lumbar spine instrumentation and for better understanding of thoracic and lumbar spine structure in North Indian population.The present study was designed to analyze the detail relationship between body height and thoracic and lumbar vertebral parameters in North Indian population.

Material and methods

The Present study was conducted in the Department of Anatomy, S. P. Medical College, Bikaner. The vertebral columns were obtained from 20 embalmed dissecting-room male cadavers of unknown ages by body donation. Those cases with remarkable alterations of the vertebral columns or evidencing gross pathological lesions of the spine were excluded from study.

The body was placed on the flat surface of dissecting table and measured with the measuring tape keeping it flat on the surface, height was measured in centimeters up to the millimeter level and this was considered as cadaveric body height and taken as such for the statistical calculations. Cadavers were performing spine dissection through posterior approach with the incision performed from C3 to the second dorsal spine of sacrum[7]. The Vertebral column length was measurement before obtaining the dry vertebrae from these columns, from the bony landmarks of the tip of the spine of

first thoracic vertebra to the tip of the spine of fifth lumbar vertebra.

The vertebrae were prepared by trimming off the soft tissue, leaving only the skeletal remains. The specimen was then immersed in 10% sodium hydrochloride solution in warm water for 30 minutes. All the linear measurements of thoracic and lumbar vertebrae were taken using sliding Vernier calipers. Angular measurements were taken in degree by a metallic Goniometer and confirmed after tracing the outline of the vertebrae on to a paper.

Following twelve parameters of vertebrae were measured:-

1. Mid-pedicle width (MPW): The outer cortical transverse distance of the mid pedicle.

2. Pedicle height (PH): The superior inferior outer cortical width of the pedicle measured.

3. Minimal pedicle width (MIPW): After measuring pedicle width and height in transverse and vertical axis respectively the MIPW was measured by turning the vernier caliper until the diameter reading was the smallest.

4. Pedicle length (PL): Distance from the posterior cortex of pedicle to the junction of pedicle with vertebral body in line with the axis of pedicle.

5. Transverse pedicle angle (TPA): It is the angulations of pedicle in transverse plane, the angle between long axis of pedicle and the antero-posterior mid axis of vertebra.

6. Sagittal pedicle angle (SPA): It is the angulations of pedicle in Sagittal plane, the angle between long axis of pedicle and the plane parallel to the superior surface of vertebral body.

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7. Chord length (CL): Measured from the posterior cortical point of the pedicle to the anterior vertebral cortex along the axis of the pedicle.

8. Interpedicular diameter of vertebral canal (IPD): was measured between inner surfaces of right and left pedicles at maximum.

9. Antero-posterior diameter of vertebral canal (APD): was measured in the vertebral canal antero-posteriorly along the mid spine axis at maximum.

10. Vertebral body height anterior (VBHa): Distance between superior and inferior end plates was measured anteriorly.

11. Vertebral body height posterior (VBHp): Distance between superior and inferior end plates was measured posteriorly.

12. Vertebral body width superior (VBWs): The width of vertebral body transversely at superior end plate at maximum.

All the parameters measured thrice and the mean of which was used for the data collection. With the help of SPSS statistical software the mean, standard deviation, student's t test and pearson's correlation test was performed.

Observations & results

Twenty vertebral columns obtained and belonged to all male cadavers. No significant differences were found (p<0.05) between the right and left sides for evaluated parameters of the vertebrae, hence the data were pooled together. The mean cadaveric body height was observed as 170.3 cm with ± 5.7 cm SD. Minimum height was found 160.8 cm and maximum height was found as 178.8 cm. Table 1 & 2 shows the mean values and

standard deviations (±) of the measurements of the thoracic and lumbar vertebrae.

Mid pedicle width (MPW) & Minimum pedicle width (MIPW):- The Mid pedicle width mean value minimum was found at T5 level (4.73 mm) and maximum at T12 level (8.7 mm). The Mid-Pedicle width of pedicles increases from L1 (7.6 mm) to L5 (16.9 mm). The lowest value for Minimum pedicle width was recorded at T5 level (4.42 mm). The highest value of Minimum Pedicle width was found at T12 level (8.3 mm). The Minimum pedicle width of pedicles decreases from T1 to T5 and then increases up to T12 same as in Mid pedicle width .The Minimum pedicle width of pedicles increases from L1(7.2 mm) to L5(11.6 mm); but not that steeply as of the Mid pedicle width. The MIPW was smaller than MPW at all levels in the whole series.

Pedicle height (PH):-The Pedicle height increases from T1 (8.79 mm) to T12 (16.04 mm). The pedicle height is consistently larger than the width. The Pedicle height remains relatively same from L1 (14.8 mm) to L5 (14.3 mm).

Pedicle length (PL):-The greatest Pedicle length was found at the T8 pedicle (12.5 mm) and the smallest at the T2 pedicle (8.3 mm). In the lumbar spine greatest Pedicle length was found at L3 pedicle (9.7 mm) and the smallest at the L5 pedicle (8.7 mm).

Chord Length (CL):-The minimum Chord Length was observed at T1 (24.0 mm). The CL gradually increased to a maximum value at T11 (32.9 mm). The Chord length remained relatively same from L1 to L5.

Transverse pedicle angle (TPA) & Sagittal pedicle angle (SPA):-The maximum Pedicle angle in transverse plane was at T1 level (32.7°). The Pedicle angle in transverse plane gradually decreased to attain minimum value at T12 level (-1.4°). The Sagittal pedicle angle (SPA) was

constant between T1 to T12 vertebrae. The Pedicle angle in transverse plane increase gradually for lumbar spine because pedicles diverge increasingly from L1 (14.0°) to L5(23.8°). Pedicle angle in sagittal plane shows reducing trend caudally, largest Pedicle angle in sagittal plane (SPA) was observed at L1 level (8.2°).

Interpedicular diameter (IPD) & Antero-posterior diameter (APD) of vertebral canal:-
The maximum vertebral canal Interpedicular distance (IPD) was found at T1 (20.1 mm). The IPD gradually decreased to minimum value at T5 (16.1 mm) and then increased till T12 (19.7 mm) and from L1 (21.1 mm) to L5 (26.1 mm). The Antero-posterior dimension (APD) had relatively stable values between T1 to T12 (15.3 mm) and constantly decreasing though slightly, values start at L1(15.9 mm), L5(14.9 mm).

Vertebral body height (VBH):-Vertebral body height anterior and posterior gradually increased to a maximum value at T12 (22.7 mm, 25.3 mm respectively). Vertebral body height anterior shows constant increase from L1 (23.5 mm) to L5 (26.2 mm). Vertebral body height posterior (VBHp) remain almost same up to L3 level (26.5 mm) than gradually decreases up to L5 level (23.2 mm).

Vertebral body width superior (VBWs):-VBWs has minimum value at T3 level (26.8 mm) from T4 it increased to reach maximum value at T12 (39.1 mm) and in lumbar spine increase from L1(41.6 mm) to L5 (50.4 mm).

The pearson's correlation was analyzed between cadaveric body height and pedicle dimensions. The strongest correlation was seen between cadaveric body height with vertebral body height anterior and Pedicle height at higher significance level (p-<0.001, p-<0.015 respectively). Pedicle height correlation was found to be very significant to the vertebral height anterior (p-<0.01) and Mid pedicle width (p<0.01).

Vertebral body width superior shows strong correlation with the Mid pedicle width the r- value is 0.725 and significant value p-<0.001.

Discussion
The previous studies done in India in this regard by Datir and Mitra[8] was based on 18 cadaveric specimens, by Chadha et al[9] on 31 patients and also published study by Acharya et al[10] on 50 patients. All of these studies have focused primarily on pedicle morphometry and except for Datir and Mitra [3] two studies have only studied lower thoracic pedicles. A good knowledge of the pedicle size is therefore essential for proper instrumentation. The MPW gradually decreased from T1 to T5 and started increasing from T6 to T12 in the present study. Similar trend was also seen in almost all studies reported in literature[8,11,16]. We got minimum mean value of 4.7 mm at T5, Datir and Mitra[8], Roopsingh[11]and Zindrick et al[2] also had minimum value at T5 level which were all around 4.5 mm.

In another study by McLain et al[6] 25% of T1 pedicles, 17% of T2 pedicles, 42% of the T3 pedicles, 61% of T4 pedicles, 67% of T5 pedicles and 75% of T6 pedicles were too small to accept a 5.5 mm screw. At all levels the MIPW was almost 0.4-0.5 mm less than the transverse pedicle width in the present study (Table 1). Previous data report the MIPW of T4-T6 levels in female cadavers were less than 4 mm. This result again shows that even the smallest available pedicle screw diameter may be too large for mid thoracic segment[12,13].

In the present study Mid-Pedicle width of pedicles increases from L1 to L5. Vinay K V et al[14] 2012 studied the mid pedical width on X-ray studies and found the same results as of our, they reported the minimum mid pedicle width at L1 level(7.4 mm) and values increase cranio-caudally being maximum at L5 level(11.65 mm). Aruna N et al[1] and Ajay S C et al[15] in two different studies which

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were conducted on dry bones from central and south Indian region have observed the same trend of the increase of Mid pedical width from cranio-caudally but their mean values range from 14.2 mm smallest to 19.2 mm largest at L5 level.

In the present study the PH increased from T1 to T4 and there was a slight fall from T5 to T6 and then it gradually increased till T12 level. Similar trend was also seen in studies of Roopsingh et al[11] but not in the study by Balaji[16] and the computer-tomographic study by Biscevic et al[17] which showed gradual increase from T1 to T12. The MPH of the present study was lower than the above reported studies. The Pedicle height remains relatively same from L1 to L5. For the pedicle height in two different studies performed by Prakash et al[18] and Vinay K V et al[14] on dry bones and X-rays respectively the mean values were close to the findings of present study, but Vinay K V[14] have shown a gradually decrease pattern from L1 to L5 (14.7 mm to 11.7 mm).

The PL in the present study was found in range of around 8.3 mm to 12.1 mm at all levels for thoracic spine. PL in the studies by Roop singh et al[11] were lower (6.4-7.2mm) and in studies conducted by Junhak et al[19] on CT higher (15.9-18.7 mm) compared to the present study. The Pedicle length from body of the vertebra to the transverse process along the long axis of pedicle was not included in majority of the previous works, although it is important for screw fixation techniques. Prakash et al[18] reported that these values were maximum at L2 level (8.3 mm) and minimum at L5 level (6.1 mm) in both left and right pedicle in both the sexes and the pedicle length decreases from L1 to L5 level Short stature of average Indian population compared to the western world can be correlated for the decreased value of all the parameters bilaterally from L1 to L5 in both the sexes. Our

findings were same as above but pedicle length mean values were slightly higher at all levels.

No any previous study have reported the Chord length, which increased gradually from T1 to T9 and than decreased up to T12 level in the present study which is almost consistent with the literature. Compared to the two other, the values in the present study were similar to that of Balaji[16] (cadeveric), Kai[20] (CT), Zindrick[2] (CT) and Junhak et al[19] (CT) except for Roopsingh et al[11] Datir[8] (CD), Balaji[16] (Radiographic) and Biscevic M[17] (CT). Data on the chord length will be help for determination on pedicle fixation screw length.

Transverse pedicle angle (TPA) was more from T1 to T10 in the present study similar to Kai[20] (CT). In another Indian study by Datir[8] the pedicles reached neutral position rather earlier and at no levels the pedicle were facing laterally. The pedicles were sagittaly angulated in cephalad direction with a narrow range between T1-T3 (14.5-19.3°) thereafter it is constant up to T10 and than decreasing upto T12 in the present study Compared to Datir and Mitra[8] the present study group had similar cephalad angulation. Zindrick et al[2] and Roop singh et al[11] had got less value as in the present study. The Pedicle angle in transverse plane (TPA) increase gradually because pedicles diverge increasingly from L1 to L5, Tan H S et al[21] 2004 have reported the pedicle angle in transverse plane increasing from mean value 7.6° to 17.4° at L5 level. Pedicle angle in sagittal plane of the lumbar vertebra was almost parallel to the horizontal plane.

In the present study, IPD decreased from T1 to T5 and then gradually increased from T6 to T12 with mean value of 19.6 mm at T12. The similar trend was observed by Roop Singh et al[11] and Biscevic M[17] (CT). However, the studies by Datir et al[3] showed higher values at all levels. The APD was found relatively stable between T1 (14.4 mm) to T12 (15.2 mm). Roop singh et al[11] and Tan et al[21]

also reported similar findings with mean values of (13.8 mm – 15.8 mm; 11.6 mm- 12.4 mm respectively), but all levels the canal dimensions were wider in the present study.

In the present study a gradual increase in dimensions occurs for the vertebral canal Inter-pedicle distance (IP) from L1 to L5. According to study conducted by Tan S H et al[21] the inter-pedicle distance increases from 19.4 mm at L1 level to 23.4 mm at L5 level. These findings are close to the present study. Antero-posterior (AP) dimension of the vertebral canal constantly decreasing though slightly, start at L1 (15.9 mm) to L4 (14.0 mm), but only to be slightly increased at L5 level (15.2 mm), these mean values of Antero-posterior (AP) dimension of the vertebral canal were found very close to the findings of Tan S H et al[21].

The anterior and posterior VBHa were found to have similar trends with values gradually increasing from T1 (15.1mm) to T12(22.6mm) VBHa were found to have similar results as reported by A. Salim[22] and Roopsingh et al[11]. Vertebral height was more in the present study from that reported by Tan et al[21] and Maria E. Kunkal.[23] We found the posterior Vertebral Height is higher than the Anterior Vertebral Height, except

at L5 level. Anterior Vertebral Height shows constant increase from L1 to L5. Vertebral Height posterior remain almost same up to L3 level than gradually decreases up to L5 level. Gocmen-mas N et al[24] have reported the same pattern of anterior vertebrae height ranging from 22.9 mm to 25.9 mm.

The VBWs had slight decrease from T1 to T4 and started increasing gradually till twelfth vertebrae. Similar trends were also observed by Tan et al[21] However they taken the body width anterio-posteriorly. Vertebral width Superior shows constant increase from L1 to L5. In the observations of Tan S H et al[21] the vertebral superior width increases from L1 to L5 levels and the mean values were found as 36.3 mm to 41.6 mm
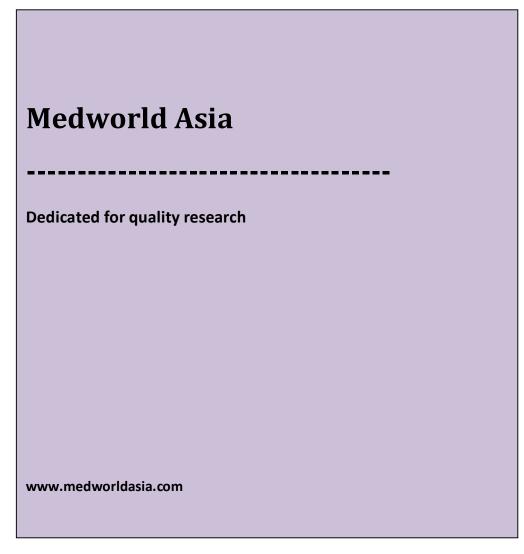
Conclusion

This has been analyzed that the Cadaveric body height and Vertebral body height are good predictors of the Pedicle height. The Vertebral width superior is good predictor of the Mid pedicle width. From this correlation the regression equations can be derived and the pedicle dimensions can be predicted very significantly.

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Table 1 Descriptive statistics of all the parameters for Thoracic vertebrae													
Parameters		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Mid Pedicle Width	Mean	7.72	6.47	5.47	4.77	4.73	4.86	5.03	5.34	6.06	7.34	8.64	8.75
	S.D.	1.19	1.02	1.12	0.98	1.33	1.17	1.27	1.44	1.50	1.83	2.15	2.09
Minimum Pedicle Width	Mean	7.36	6.09	5.13	4.47	4.42	4.44	4.69	4.96	5.49	6.81	8.02	8.30
	S.D.	1.19	0.90	1.16	0.96	1.30	1.21	1.32	1.44	1.44	1.84	2.04	1.95
Pedicle Height	Mean	8.79	10.13	10.77	10.72	10.46	10.68	11.13	11.46	12.28	14.05	15.75	16.04
	S.D.	1.45	1.47	1.08	1.27	1.35	1.36	1.81	1.17	1.02	1.32	1.35	1.82
Pedicle Length	Mean	8.51	8.33	8.92	9.33	10.46	11.06	11.90	12.46	12.07	11.54	11.18	12.16
	S.D.	1.70	1.54	1.64	1.17	1.19	1.05	1.21	1.30	1.23	1.55	1.50	2.19
Transverse Pedicle Angle	Mean	32.67	22.83	18.44	14.53	9.71	7.58	6.39	3.38	4.58	5.43	2.43	-1.35
	S.D.	4.06	7.47	7.37	6.90	6.47	6.43	7.72	6.62	6.24	6.65	8.30	9.52
Saggital Pedicle Angle	Mean	14.53	18.39	19.31	17.58	16.08	16.74	16.03	16.85	17.60	17.13	15.98	15.98
	S.D.	5.47	5.15	3.55	4.06	3.77	4.49	3.73	3.83	3.57	3.92	4.46	5.75
Chord Length	Mean	23.96	25.29	26.24	27.47	28.76	30.65	31.47	33.11	34.71	34.43	32.95	32.34
	S.D.	2.67	2.70	3.16	3.23	3.95	3.93	3.87	4.58	4.22	5.66	6.08	5.91
Vertebral Canal AP	Mean	14.44	13.96	13.97	14.03	14.35	14.92	14.66	14.39	14.19	14.04	14.69	15.29
	S.D.	1.70	1.14	0.63	1.42	1.10	1.55	1.24	1.08	1.14	1.09	1.34	1.64
Vertebral Canal IP	Mean	20.11	18.02	16.62	16.33	16.10	16.22	16.36	16.37	15.85	16.01	17.16	19.66
	S.D.	1.97	2.23	1.71	1.53	1.50	1.61	1.40	1.64	1.19	1.28	1.54	1.93
Vertebral body Height Ant.	Mean	15.11	16.41	16.72	17.02	17.52	17.77	17.93	18.80	19.45	21.01	21.65	22.69
	S.D.	1.40	1.52	1.24	1.34	1.61	1.18	1.53	1.30	1.50	1.67	1.61	2.24
Vertebral Body Height Post.	Mean	16.37	17.09	17.57	18.37	18.72	19.25	19.59	19.91	20.43	21.67	23.85	25.30
	S.D.	1.40	1.71	1.06	2.75	1.51	1.30	1.50	1.28	1.21	1.40	2.98	1.98
Vertebral Body Width Sup.	Mean	28.38	27.88	26.82	26.94	27.62	27.53	28.49	29.51	30.61	32.31	35.61	39.10
	S.D.	2.33	2.17	1.87	1.69	2.19	2.47	2.98	3.27	3.95	3.85	3.29	3.56
All the linear measurements are in millimeters and angles in degrees.													

Table 2 Descriptive statistics of all the parameters for Lumbar vertebrae						
Parameters		L1	L2	L3	L4	L5
Mid Pedicle Width	Mean	7.60	7.88	9.70	12.04	16.93
	S.D.	1.64	1.76	2.00	2.30	2.91
Minimum Pedicle Width	Mean	7.20	7.50	9.19	9.93	11.65
	S.D.	1.53	1.69	2.47	1.85	2.19
Pedicle Height	Mean	14.80	14.31	14.45	13.92	14.37
	S.D.	1.41	1.43	1.43	1.62	1.92
Pedicle Length	Mean	9.61	9.34	9.70	9.05	8.73
	S.D.	2.96	3.06	3.25	3.09	2.88
Pedicle Angle Transverse	Mean	13.98	14.55	15.68	17.95	23.75
	S.D.	5.84	6.54	6.67	6.48	4.83
Pedicle Angle Saggital	Mean	8.20	5.63	2.65	1.25	-0.60
	S.D.	4.87	4.23	3.40	3.69	2.76
Chord Length	Mean	38.07	38.86	39.94	38.94	38.53
	S.D.	5.09	4.37	4.76	4.57	4.77
Vertebral Canal AP	Mean	15.89	15.12	14.34	13.82	14.94
	S.D.	1.44	1.98	1.90	2.19	1.98
Vertebral Canal IP	Mean	21.13	22.00	21.98	22.16	26.13
	S.D.	1.63	2.27	1.42	2.87	2.62
Vertebral Height Ant.	Mean	23.45	24.75	25.64	25.30	26.20
	S.D.	2.39	2.33	2.20	2.49	2.04
Vertebral Height Post.	Mean	26.52	26.55	26.51	25.70	23.23
	S.D.	1.79	2.36	2.03	2.21	2.49
Vertebral Width Sup.	Mean	41.59	44.07	46.28	48.04	50.42
	S.D.	3.02	3.24	3.97	3.37	4.61
All the linear measurements are in millimeters and angles in degrees.						