Analysis of the spinal nerve roots in relation to the adjacent vertebral bodies with respect to a posterolateral vertebral body replacement procedure

ABSTRACT

Objective: This study aims to improve the understanding of the anatomic variations along the thoracic and lumbar spine encountered during an all-posterior vertebrectomy, and reconstruction procedure. This information will help improve our understanding of human spine anatomy and will allow better planning for a vertebral body replacement (VBR) through either a transpedicular or costotransversectomy approach.

Summary of Background Data: The major challenge to a total posterior approach vertebrectomy and VBR in the thoracolumbar spine lies in the preservation of important neural structures.

Methods: This was a retrospective analysis. Hundred normal magnetic resonance imaging (MRI) spinal studies (T1–L5) on sagittal T2-weighted MRI images were studied to quantify: (1) mid-sagittal vertebral body (VB) dimensions (anterior, midline, and posterior VB height), (2) midline VB and associated intervertebral discs height, (3) mean distance between adjacent spinal nerve roots (DNN) and mean distance between the inferior endplate of the superior vertebrae to its respective spinal nerve root (DNE), and (4) posterior approach expansion ratio (PAER).

Results: (1) The mean anterior VB height gradually increased craniocaudally from T1 to L5. The mean midline and posterior VB height showed a similar pattern up to L2. Mean posterior VB height was larger than the mean anterior VB height from T1 to L2, consistent with anterior wedging, and then measured less than the mean anterior VB height, indicating posterior wedging. (2) Midline VB and intervertebral disc height gradually increased from T1 to L4. (3) DNN and DNE were similar, whereby they gradually increased from T1 to L3. (5) Mean PAER varied between 1.69 (T12) and 2.27 (L5) depending on anatomic level.

Conclusions: The dimensions of the thoracic and lumbar vertebrae and discs vary greatly. Thus, any attempt at carrying out a VBR from a posterior approach should take into account the specifications at each spinal level.

Key words: Expandable cage; magnetic resonance imaging; posterior approach expansion ratio; thoracolumbar spine; vertebral body replacement; vertebroplasty.

Introduction

The thoracolumbar spine is susceptible to tumors (both primary and metastatic), traumatic and osteoporotic fractures, degenerative deformities, and infections.[1-8] All these can subsequently threaten spinal stability and lead to impingement of critical neural structures. The purpose of a surgical intervention focuses on pain control, spinal decompression, and mechanical stabilization.[9] Vertebrectomy and vertebral body replacement (VBR) with a

Access this article online	
Website: www.jcvjs.com	Quick Response Code
DOI: 10.4103/0974-8237.199869	

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How to cite this article: Awwad W, Bourget-Murray J, Zeiadin N, Mejia JP, Steffen T, Algarni AD, *et al.* Analysis of the spinal nerve roots in relation to the adjacent vertebral bodies with respect to a posterolateral vertebral body replacement procedure. J Craniovert Jun Spine 2017;8:50-7.

prosthetic cage offer significant structural support, allowing anterior and middle column decompression, and restoration of normal height and sagittal alignment[6,10] Vertebrectomy and VBR have been shown to increase mobility and decreased need for narcotics when compared to radiation alone when treating patients for metastatic epidural compression.[11] Although not all fractures require VBR, radical debridement and reconstruction of the anterior column (with or without posterior fixation) are sometimes indicated in severely comminuted fractures. Several studies have demonstrated the advantage of using VBR cages for anterior column reconstruction in this population,[7,8] whereby a safe and reliable decompression could be achieved.

Currently, VBR expandable cages are designed for placement from an anterior approach for optimal fit and *in situ* expansion. The anterior approach allows for good access to the vertebral body (VB) and relatively easy vertebrectomy. VBR cages are not inherently stable and as such typically require additional stabilization. While fixation systems exist that can be applied from the anterior approach, clinical and biomechanical studies have shown that these systems are not as stable as the posterior-based pedicle screw system or combined anterior/posterior systems.[12-14] In general, this necessitates the repositioning of a patient during surgery, and placement of hardware from a separate surgical approach.

Some authors have described a one-stage posterior (transpedicular) surgical approach to vertebrectomy and VBR (we call this the posterior approach vertebrectomy [PAV]), with relatively low morbidity.[15-23] Although these studies suggest that an all-posterior approach can be considered in select cases, the literature still varies significantly at this point. Some authors dispute that an all-posterior approach has the advantage of fewer complications when compared to the anterior approach.[24-26] However, an anterior approach can be followed by a separately staged posterior approach to optimize spine stabilization. These two-staged approaches are traditionally used in radical resection of spinal tumors followed by reconstruction and stabilization.[16,27] By carrying out a posterior only approach, the additional anterior approach can be avoided in many cases. Yet, the major challenge to total PAV in the thoracolumbar spine with expandable cage reconstruction lies in the preservation of the important neural structures found in the access path to the VB.

The size of the entry portal (EP) for placement of a VBR cage through a PAV is limited to the space lateral to the spinal cord or cauda equina and between adjacent nerve roots. Based on our current understanding of spine anatomy, the EP to the anterior column, through a posterior incision, is dependent on the space between the spinal nerve and the posterior border of the inferior endplate of the superior VB (DNE). The space created after vertebrectomy and adjacent discectomies (VB and adjacent discectomies (2D)) is the largest height to which a cage must expand when implanted. The ratio between the VB and 2D and the DNE is referred to as the posterior approach expansion ratio (PAER) [Figure 1]. This ratio represents the relative change in height; an implant must adopt from the EP (DNE) before it is implanted (A) to its expanded height (VB and 2D) (B).

Advances in imaging have greatly improved the ability to visualize vertebral and spinal nerve root anatomy. Plain radiographs, computed tomography (CT), and magnetic resonance imaging (MRI) are imaging modalities regularly used for normal referencing of spine morphology.[28-33] The use of radiographs, however, is limiting due to (1) variability in the film–focus distance, (2) rotation of the spine and parallax effect, and lastly, and (3) harmful effects of ionizing radiation, as noted by Gallagher *et al*.[30] MRI, on the other hand, has been used to analyze the normal anatomy and variants of vertebrae and neural structures[28,32-34] and has comparable accuracy and reproducible measurements compared to CT.[35,36] CT does retain some advantage over MRI with regard

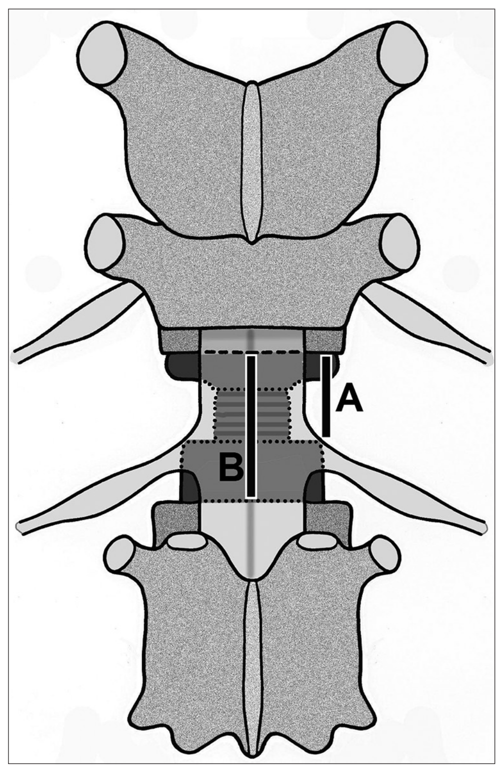

Figure 1: Schematic diagram of the relative anatomy for the entry portal to a posterior approach vertebrectomy. The vertebral body replacement expandable cage must be small enough to travel between upper endplate and adjacent spinal nerve root (DNE) (A) and able to expand sufficiently to restore anterior column height (vertebral body and 2D) (B). The posterior approach expansion ratio is the ratio between the vertebral body and 2D and the entry portal

to bone detail; however, MRI was shown to reliably evaluate the volume and area of vertebrae,[28] in addition to having high-quality soft tissue visualization and good inter- and intra-tester reliability.[37,38]

Although MRI is often used to image spine pathology before surgical procedures, there is currently no published data describing MRI measurements of the thoracic and lumbar spine and associated neural structures. Despite the effectiveness of VBR from an anterior approach, the detailed anatomy variations from level to level have not been described for the PAV. There is thus a need to have adequate information on the normal morphology of the thoracic and lumbar spine to adequately carry out a PAV and reconstruction. This study is to analyze the anatomical features of the thoracolumbar spinal nerve roots in relation to the adjacent vertebral bodies on MRI scans. Results should allow better planning for a VBR through a transpedicular vertebrectomy or costotransversectomy and guide engineers in designing VBR cages specific to an all-posterior approach.

Methods

Study cohort

The retrospective review of MRI scans was approved in accordance to the Institutional Review Board of our institution (No. 11-767 GEN). Thoracolumbar MRI scans obtained from a total of 100 patients (63 female and 37 male); age range, 18–65 years with a mean of 41.2 years (standard deviation [SD] =13.3) were analyzed. All patients had T2-weighted MRI images in the supine position to rule out significant spinal pathology. None of the participants were found to have any significant spine pathology based on the radiologist report. For the MRI images to be eligible for the study, the patients needed to meet the following additional inclusion/exclusion criteria:

Patient inclusion criteria as follows:

1. Patients were between 18 and 65 years of age
2. MRI studies were from preexisting sagittal imaging of the thoracic and lumbar spine (T1–L5), done for clinical purposes not associated with this study
3. The quality and clarity of the MRI images were sufficiently adequate for measurement of vertebrae parameters in the mid-sagittal view.

Patient exclusion criteria as follows:

1. Patients with significant deformity of the spine, such as excessive kyphosis (>6°), significant scoliosis (>20°), lordosis >80°, significant fractures, tumors, or degenerative disease of the spine. Determination of significant disease was based on radiologist's reports.

Data collection

Patients were found through the PACS (Intelerad Inc, Montreal, Quebec, Canada) database system of a single institution. All measurements were made using Inteleviewer PACS software. Patients were not contacted for the purposes of this study, and patient confidentiality was maintained. The search parameters were limited to studies that were conducted during 2011. None of the authors acted as treating physicians for any of the study participants. All MRI reports were reviewed to ensure that appropriate inclusion/exclusion criteria were met.

Measurement technique

Standard sagittal T2 fast relaxation fast spin echo images of the spine were used to make measurements of the thoracolumbar vertebrae. The relevant anatomy features we aimed to measure included VB and intervertebral disc height and distance between exiting segmental nerve roots. Mid-sagittal frames were used to measure: anterior, middle and posterior VB heights [Figure 2a - A-C], heights of the VB with superior and inferior intervertebral discs [Figure 2a - D], the anteroposterior width of the mid-vertebral bodies [Figure 2a - E], and endplates [Figure 2a - F]. The distance between spinal nerves and the posterior edge of the inferior endplate of the overlying vertebrae [Figure 2b - G] and between adjacent exiting nerve roots [Figure 2b - H] were measured in the mid-pedicular sagittal plane. These measurements were collected for every spinal level within the thoracolumbar spine (T1–L5).

Statistics

Descriptive statistics for patient characteristics will be provided as medians and ranges for continuous variables (i.e., age) and as proportions for categorical variables (i.e., gender). The PAER at each spinal level was calculated as a ratio of the distance between VB and 2D and the DNE [Equation in Figure 1]. This

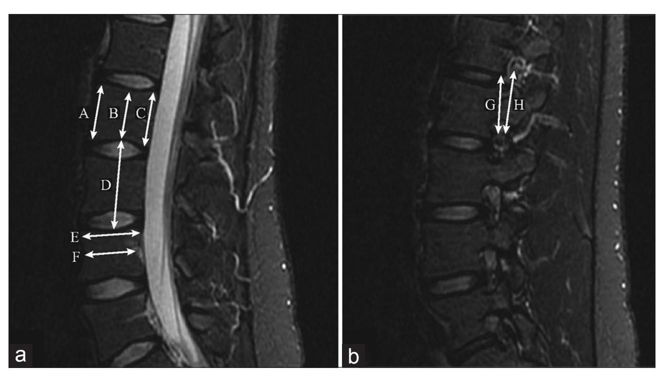

Figure 2: Example of thoracolumbar measurements recorded: (a) A - Anterior vertebral body height; B - Midline vertebral body height; C - Posterior vertebral body height; D - Vertebral body and associated intervertebral discs height; E - Antero-posterior endplate diameter; F - anteroposterior vertebral waist diameter; (b) G - Distance between superior endplate and spinal nerve; H - Distance between spinal nerves

ratio represents the relative size a VBR cage must change from before it is implanted between the inferior endplate of superior adjacent vertebra and nerve root and the size (i.e., height) it must finally expand to fill the defect left by the resection of the VB and the adjacent two discs.

Results

Vertebral body morphology

The mean, SD, and range (minimum and maximum) of the anterior, midline and posterior VB heights, midline VB and 2D height, and the anteroposterior endplate and VB diameter are listed in Table 1. The mean anterior VB heights showed a gradual increase craniocaudally; with T1 having the smallest mean anterior VB height (1.39 ± 0.16 cm) and L5 the largest (2.76 ± 0.23 cm). The mean midline and posterior VB height showed a similar increase in height up to L2, with T1 having the smallest height (midline = 1.32 ± 0.14 cm, posterior = 1.43 ± 0.15 cm) and L2 having the largest (midline = 2.37 ± 0.19 cm, posterior = 2.64 ± 0.20 cm). The mean midline and posterior VB height were larger than the mean anterior VB height between T1 and L2; this is consistent with anterior wedging. Moving further caudally past L2, the mean midline and posterior VB heights measured less than the mean anterior VB height, indicating posterior wedging [Figure 3]. The mean midline VB and 2D (VB and associated intervertebral discs height) increased gradually from T1 (2.6 cm) to L4 (4.74 cm) [Figure 4].

Spinal nerve anatomy

The mean distance between adjacent spinal nerves (DNN) and between the inferior endplate of the superior vertebrae and the spinal nerve (DNE) are shown in Figure 5 and Table 2. Both followed a similar pattern: the mean gradually increasing from T1 (1.36 ± 0.19 cm for DNN and 1.25 ± 0.17 cm for DNE) to a maximum at L3 (2.45 ± 0.32 cm for DNN and 2.45 ± 0.29 cm for DNE).

The mean DNE was found to be generally smaller (1.25 ± 0.17 cm at T1 - 2.04 ± 0.34 cm at L5) than the mean DNN (1.36 ± 0.19 cm at T1 - 2.20 ± 0.36 cm) at almost all spinal levels, except for at the L1 and L2 levels, where the mean DNN was generally smaller (L1 = 2.23 ± 0.32 cm; L2 = 2.40 ± 0.33 cm) than the DNE (L1 = 2.36 ± 0.26 cm; L2 = 244 ± 0.26 cm).

Posterior approach expansion ratio

The mean, SD, and range of the PAER are listed in Table 3. The mean PAER was generally constant among all spinal levels and averaged 1.98, being lowest at T12 (1.69 ± 0.21), and highest at L5 (2.27 ± 0.40). The PAER values ranged from as low as 1.31 (at T11) to as high as 3.48 (at L5).

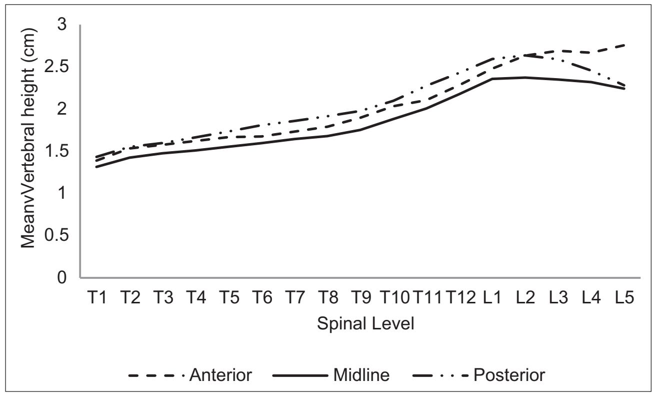

Figure 3: Mean anterior, middle and posterior vertebral body height

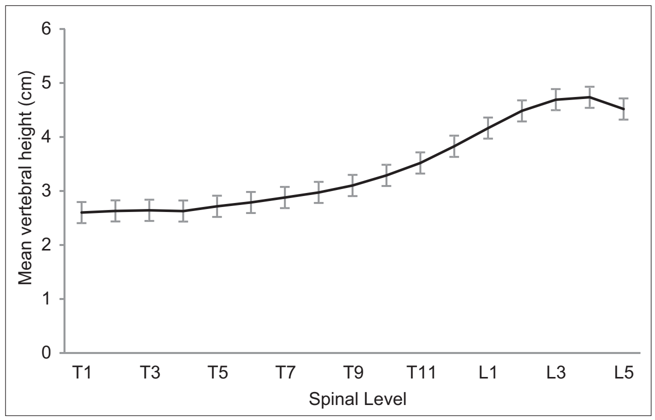

Figure 4: Mean middle height of vertebral body and associated intervertebral discs. These gradually increase from T1 (2.6 cm) to L4 (4.74 cm)

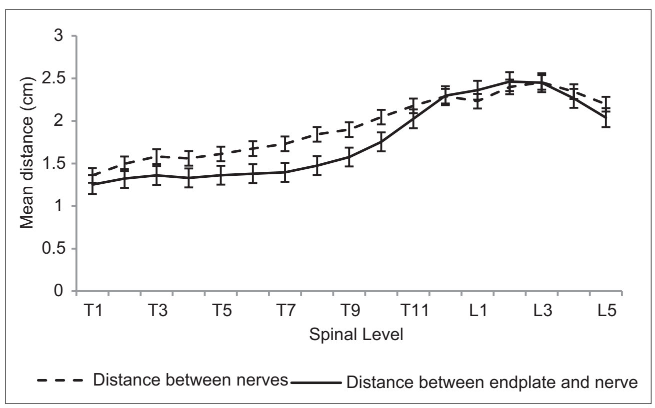

Figure 5: Comparison between distances of adjacent spinal nerves (DNN) versus distances between inferior endplate of superior vertebrae and spinal nerve (DNE)

Discussion

The current study aimed to investigate the anatomy of the thoracolumbar spine and associated neural structures. To the best of our knowledge, it is the first study to analyze the anatomical features of the thoracolumbar spine and exiting nerve roots. MRI has been shown to offer reliable images with high-contrast resolution and better precision for

Table 1: Vertebral body morphology data

Spine level	Anterior VB height (cm)			Midline VB height (cm)			Posterior VB height (cm)		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
T1	1.39±0.16	1.08	1.75	1.32±0.14	1.02	1.80	1.43±0.15	1.14	1.86
T2	1.53±0.17	1.12	1.97	1.42±0.14	1.05	1.83	1.55±0.15	1.14	1.90
T3	1.58±0.15	1.26	2.02	1.48±0.15	1.10	1.85	1.60±0.16	1.24	1.98
T4	1.62±0.16	1.29	2.05	1.51±0.16	1.19	2.03	1.66±0.17	1.27	2.08
T5	1.67±0.17	1.27	2.14	1.55±0.16	1.20	2.04	1.73±0.18	1.31	2.21
T6	1.67±0.17	1.03	2.06	1.60±0.17	1.23	2.16	1.81±0.18	1.13	2.33
T7	1.73±0.18	1.20	2.23	1.64±0.17	1.37	2.31	1.86±0.19	1.26	2.50
T8	1.79±0.16	1.50	2.42	1.68±0.16	1.37	2.32	1.92±0.20	1.56	2.69
T9	1.90±0.17	1.50	2.57	1.75±0.17	1.30	2.37	1.98±0.20	1.16	2.69
T10	2.03±0.20	1.56	2.75	1.88±0.18	1.56	2.40	2.10±0.19	1.69	2.80
T11	2.11±0.19	1.63	2.80	2.01±0.18	1.59	2.54	2.28±0.24	1.81	3.37
T12	2.28±0.21	1.45	2.88	2.18±0.20	1.19	2.62	2.43±0.22	1.91	3.02
L1	2.48±0.20	2.05	3.16	2.36±0.19	1.96	2.84	2.59±0.21	2.09	3.17
L2	2.63±0.21	2.22	3.35	2.37±0.19	1.88	2.81	2.64±0.20	2.16	3.31
L3	2.69±0.21	2.29	3.25	2.35±0.18	1.80	2.89	2.59±0.21	1.72	3.15
L4	2.67±0.20	2.03	3.29	2.32±0.20	1.92	2.80	2.46±0.22	1.99	3.08
L5	2.76±0.23	2.21	3.37	2.24±0.22	1.75	2.86	2.28±0.22	1.80	2.82

Contd...

Table 1: Contd...

Spine level	VB and associated intervertebral discs height (VB and 2D), cm			AP endplate diameter (cm)			AP VB diameter (cm)		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
T1	2.60±0.18	2.24	2.98	1.45±0.18	0.98	1.90	1.43±0.19	1.01	1.86
T2	2.63±0.17	2.25	3.33	1.56±0.20	1.09	2.02	1.57±0.20	1.06	2.02
T3	2.64±0.20	2.28	3.52	1.73±0.22	1.20	2.39	1.73±0.20	1.28	2.32
T4	2.63±0.18	2.06	3.16	1.92±0.26	1.34	2.66	1.90±0.23	1.35	2.65
T5	2.72±0.17	2.32	3.17	2.07±0.25	1.51	2.76	2.04±0.24	1.44	2.76
T6	2.79±0.18	2.29	3.22	2.22±0.27	1.66	3.01	2.19±0.26	1.49	3.12
T7	2.88±0.19	2.26	3.44	2.39±0.30	1.72	3.10	2.35±0.29	1.78	3.14
T8	2.98±0.20	2.62	3.65	2.54±0.31	1.88	3.44	2.49±0.31	1.91	3.43
T9	3.10±0.20	2.80	3.65	2.64±0.33	2.05	3.59	2.55±0.31	1.89	3.35
T10	3.29±0.21	2.83	3.91	2.70±0.31	2.09	3.35	2.59±0.30	1.96	3.30
T11	3.52±0.25	2.86	4.25	2.76±0.30	2.05	3.45	2.60±0.29	1.92	3.40
T12	3.83±0.30	2.90	4.58	2.81±0.33	2.05	3.66	2.60±0.30	1.95	3.44
L1	4.17±0.31	3.54	4.99	2.94±0.32	2.24	3.67	2.67±0.32	2.02	3.68
L2	4.49±0.31	3.54	5.30	3.09±0.33	2.42	4.04	2.82±0.34	2.09	3.73
L3	4.69±0.31	3.80	5.33	3.23±0.32	2.51	4.09	2.93±0.32	2.13	3.97
L4	4.74±0.35	3.75	5.47	3.23±0.31	2.40	3.97	2.96±0.32	2.06	3.83
L5	4.52±0.36	3.71	5.41	3.20±0.33	2.03	3.98	2.87±0.33	1.54	3.77

SD - Standard deviation; VB - Vertebral body; AP - Antero-posterior

quantifying both vertebral and neural anatomy.[28,34-37] More importantly, these results aim to improve our understanding of the anatomic variations along the thoracic and lumbar spine encountered when considering an all-posterior vertebrectomy procedure, given that the major difficulty in performing a vertebrectomy by a posterior approach is the preservation of the delicate neural structures during surgical dissection. Any VBR device designed for the posterior surgical approach should be designed keeping these specific anatomic features in mind.

The measurements of this study, from 100 adults from the general population on sagittal T2 weighted images, showed that sagittal vertebral height dimensions tend to increase from T1 to L3. There is a decrease in the sagittal vertebral height from L3 to L5. The DNN, DNE (approach height), and VB and 2D tend to follow this same pattern becoming greatest at L3. In addition, the mean posterior VB height was larger than the mean anterior VB height from T1 to L2, consistent with anterior wedging. From L3 to L5, the mean posterior VB height was shown to be smaller than the mean anterior

Table 2: Spinal nerve anatomy data showing the DNN and DNE

Spine level	Distance between adjacent spinal nerves (DNN), cm			Distance between inferior endplate of superior vertebrae and adjacent spinal nerve (DNE), cm		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
T1	1.36±0.19	0.90	1.90	1.25±0.17	0.83	1.74
T2	1.50±0.21	1.17	2.10	1.32±0.19	0.85	1.90
T3	1.58±0.20	1.22	2.06	1.36±0.18	0.90	1.83
T4	1.56±0.20	1.19	2.18	1.34±0.20	0.82	1.88
T5	1.61±0.20	1.09	2.40	1.36±0.17	0.89	2.01
T6	1.68±0.22	1.09	2.30	1.38±0.19	0.95	1.86
T7	1.73±0.23	1.25	2.30	1.40±0.21	0.95	2.08
T8	1.84±0.25	1.18	2.50	1.48±0.20	1.09	1.96
T9	1.90±0.24	1.31	2.41	1.58±0.22	1.09	2.18
T10	2.05±0.27	1.46	2.69	1.75±0.25	1.01	2.35
T11	2.18±0.28	1.48	2.75	2.02±0.27	1.23	2.74
T12	2.29±0.32	1.60	3.32	2.30±0.29	1.65	3.29
L1	2.23±0.32	1.37	3.15	2.36±0.26	1.80	3.21
L2	2.40±0.33	1.41	3.41	2.44±0.26	1.90	3.07
L3	2.45±0.32	1.70	3.27	2.45±0.29	1.31	3.10
L4	2.34±0.32	1.49	3.30	2.27±0.30	1.31	3.23
L5	2.20±0.36	1.31	3.30	2.04±0.34	1.35	3.00

SD - Standard deviation

Table 3: Mean, standard deviation, and range of posterior approach expansion ratio

Spinal level	PAER		
	Mean±SD	Minimum	Maximum
T1	2.11±0.28	1.52	2.98
T2	2.02±0.26	1.42	3.18
T3	1.97±0.27	1.60	3.11
T4	2.00±0.30	1.50	3.16
T5	2.02±0.24	1.47	2.96
T6	2.05±0.27	1.50	2.88
T7	2.10±0.29	1.43	3.02
T8	2.05±0.26	1.66	2.88
T9	2.00±0.27	1.51	2.88
T10	1.91±0.30	1.40	3.30
T11	1.76±0.23	1.31	2.94
T12	1.69±0.21	1.19	2.25
L1	1.78±0.19	1.43	2.35
L2	1.85±0.18	1.52	2.23
L3	1.94±0.25	1.48	3.17
L4	2.12±0.29	1.46	3.17
L5	2.27±0.40	1.49	3.48

PAER - Posterior approach expansion ratio; SD - Standard deviation

VB height, indicating posterior wedging. These results agree with findings from a study by Masharawi *et al*.,[39] whose work aimed at characterizing thoracic and lumbar (T1–L5) VB shape, focusing on vertebral wedging, using a 3D digitizer. Their findings show that VB was anteriorly wedged from T1 to L2, nonwedged at L3, and posteriorly wedged at L4 and L5.

With regard to the anatomy of the neural structures relevant to posterior VBR, we found that the space between adjacent spinal nerves (DNN) gradually increase in the caudal direction similar to the VB height, with the shortest distance at T1, and the largest distance at L3. The mean distance for the approach height ranged from 1.25 cm at T1 to 2.45 cm at L3, but there was a considerable variation (0.82–3.29 cm). The gradual increase in approach height is best explained by the gradual increase in vertebral height over the same segments. The variability in approach height stresses the need for a surgical technique that can adapt to significant anatomic variability.

With this in mind, it is typically assumed that the smallest access to the anterior column from the posterior access would be the corridor between the spinal nerve and the inferior endplate of the superior VB (DNE) and not the space between adjacent spinal nerves (DNN). Our findings supported this clinical finding for all spinal levels except for that at L1 and L2, where the distance between the adjacent nerves was smaller than between the spinal nerve and the inferior endplate. This can be explained by recognizing that L2 is at the apex of the lumbar lordosis. The lordosis of the lumbar spine probably brings the posterior part of the spine (foramina and nerve roots) closer than the more anterior adjoining endplates, making the distance between nerve roots the smallest, rather than the distance from endplate to nerve root.

Our decision to report the PAER ratio in the current study is based on our desire to provide researchers with concrete information on the extent a VBR device must expand to safely pass through the EP and subsequently expand to efficiently replace the injured VB an adjacent discs. The mean PAER varied between 1.69 (T12) and 2.27 (L5) depending on anatomic level. If we apply the PAER to an expandable VBR fixation device, the ideal expandable VBR cage would need to achieve expansion ratios covering the largest PAER. However, the average PAER reported contained significant variation, indicating that at some spinal levels, VBR devices would have to expand beyond 200% after implantation to fill the vertebral defect left from the vertebrectomy. Taking this into account, it would be empirical to design VBR cages of different size to accommodate for these parameters, and thus optimize fit and stability of the expandable cage.

The previous studies have found that inserting a traditional expandable cage through the posterior approach required complex maneuvers risking nerve injury.[40] In the context of fractured vertebrae, some vertebral height may be lost even before surgery; thus, the expansion ratios may be different than for an intact vertebra. However, in many cases, the pedicles remain intact and therefore the EP (DNE) for a PAV will remain accurately represented in this cohort of patients.[41] For these cases, the method for quantifying spinal parameters presented here may still be utilized for preoperative planning, the major difference being that the cage might be expected to expand less to fill the already collapsed vertebral defect.

A limitation of the current study is a lack of standardization based on patient gender and height. The previous studies have found correlations between VB dimensions and patients' height[42] as well as gender-based differences in vertebral morphology.[30,43] Yet, some have shown that the VB size was independent of age or ethnicity,[39] while others have published on VB and nerve root anatomy without taking all these parameters into account.[28,30,33,34] Gender differences are simply of size and scale, but not form. Meaning that female vertebra are generally smaller versions of male vertebrae. The range of data shown in this study contains all the parameters needed to know about both female and male patient differences. Future studies will be required for anatomical verification of radiological findings: are they correlated to cadaveric and intraoperative surgical findings.

The posterior approach to the spine provides a unique opportunity to treat spine pathology using a standard single approach. As we have demonstrated in this study, the dimensions to the thoracic and lumbar spine can vary greatly. Thus, any attempt at designing VBR for posterior implantation should take into consideration the anatomical variations across spinal segments, as well as differences among patients.

Conclusions

The posterior approach to the spine provides a unique opportunity to treat spine pathology and performs vertebrectomy using a standard single approach. As we have demonstrated in this study, the dimensions of the thoracic and lumbar vertebrae and discs vary greatly. Thus, any attempt at carrying out VBR from a posterior approach should take into account the specific variations at the different spine levels as outlined in this paper.

Acknowledgment

This work was supported in part by a grant from the Canadian Institute of Health Research to PFJ. The study was undertaken at the Orthopedic Research Laboratory at the Montreal General Hospital, McGill University Health Center, McGill University, Montreal, Canada.

Financial support and sponsorship

This work was supported in part by a grant from the Canadian Institute of Health Research to PFJ.

Conflicts of interest

There are no conflicts of interest.

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