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Anatomic bases for anterior spinal surgery: surgical anatomy of the cervical vertebral body and disc space

J. Lu[1], N. A. Ebraheim[1], H. Yang[1], J. Rollins[1] and R. A. Yeasting[2]

[1] Departments of Orthopedic Surgery and [2] Anatomy, Medical College of Ohio, Toledo, Ohio, USA

Summary: Twenty adult cadaveric cervical spines were sectioned longitudinally through the midline to display longitudinal sections of the vertebral bodies and disc spaces from C3 to T1. Computer-assisted anatomic images were obtained for measurements of the disc spaces and vertebral bodies. Anteroposterior (AP) depth gradually increased from 16.56 ± 2.21 mm at C3 to 19.32± 2.30 mm at C7. Greater values of AP depth at the inferior endplate were found at C5 (20.75 ± 2.87 mm) and C6 (20.56 ± 2.31 mm) compared with the values at C3 (18.26 ± 1.82 mm), C4 (19.27 ± 2.88 mm) and C7 (19.21 ± 3.22 mm). The AP depth at the superior endplate was greater than that at the inferior endplate. The height of the disc space was found to be lowest at the posterior disc space from C2-3 to C7-T1 (2.95 ± 0.86 mm at C2-3, 2.78 ± 0.93 mm at C3-4, 2.45 ± 0.79 mm at C4-5, 2.92 ± 0.64 mm at C5-6, 2.46 ± 0.59 mm at C6-7, 2.93 ± 1.05 mm at C7-T1), when compared to the height of the disc space at the anterior disc space from C2-3 to C7-T1 (4.07 ± 0.85 mm at C2-3, 4.34 ± 1.18 mm at C3-4, 3.95 ± 1.37 mm at C4-5, 3.55 ± 1.37 mm at C5-6, 3.55 ± 0.76 mm at C6-7, 3.67 ± 1.17 mm at C7-T1). The mid-axis of the disc space was situated at approximately 3 mm above the anterior midpoint of the annulus fibrosus at the level of the lower cervical spine. To reach the posterior portion of the disc space from the anterior midpoint of the annulus fibrosus, a 5° cephalad angulation of the drill relative to the mid-axis of the disc space is necessary. All these original data from cadavers may be helpful during anterior approach for discectomy, vertebrectomy and anterior screw-plate placement.

Correspondence to : *N.A. Ebraheim*

Bases anatomiques de la chirurgie vertébrale cervicale par voie antérieure. Anatomie chirurgicale du corps vertébral et du disque intervertébral cervicaux

Résumé : 20 colonnes cervicales issues de cadavres d'adultes ont été sectionnées longitudinalement sur la ligne médiane pour fournir des coupes longitudinales des corps vertébraux et des disques intervertébraux de C3 à T1. Les images anatomiques obtenues ont été traitées à l'aide d'un ordinateur pour fournir des mesures des disques intervertébraux et des corps vertébraux. L'épaisseur antéro-postérieure (AP) augmentait progressivement de 16,56 ± 2,21 mm en C3 à 19,32 ± 2,30 mm en C7. Les valeurs les plus importantes de l'épaisseur AP au plateau vertébral inférieur ont été relevées en C5 (20,75 ± 2,87 mm) et C6 (20,56 ± 2,31 mm) alors qu'elles étaient plus faibles en C3 (18,26 ± 1,82 mm), C4 (19,27 ± 2,88 mm), et C7 (19,21 ± 3,22 mm). L'épaisseur AP mesurée au plateau vertébral supérieur était plus importante que celle mesurée au plateau inférieur. La hauteur du disque intervertébral était moins élevée à la partie postérieure des disques intervertébraux de C2-C3 à C7-T1 (2,95 ± 0,86 mm en C2-C3, 2,78 ± 0,93 mm en C3-C4, 2,45 ± 0,79 mm en C4-C5, 2,92 ± 0,64 mm en C5-C6, 2,46 ± 0,59 mm en C6-C7, et 2,93 ± 1,05 mm en C7-T1) en comparaison avec celles relevées à la partie antérieure de l'espace de C2-C3 à C7-T1 (4,07 ± 0,85 mm en C2-C3, 4,34 ± 1,18 mm en C3-C4, 3,95 ± 1,37 mm en C4-C5, 3,55 ± 1,37 mm en C5-C6, 3,55 ± 0,76 mm en C6-C7, et 3,67 ± 1,19 mm en C7-T1). L'axe moyen du disque intervertébral était situé environ 3 mm au-dessus du point moyen antérieur de l'annulus fibrosus au niveau de la partie inférieure de la colonne cervicale. Pour atteindre la partie postérieure de l'espace intervertébral, à partir du point moyen antérieur de l'annulus fibrosus, il faut donner à la mèche une angulation de 5° vers la tête par rapport à l'axe moyen du disque intervertébral. Toutes ces données cadavériques originales peuvent rendre service au cours des abords antérieurs pour discectomie, vertébrectomie, et mise en place de plaque et de vis.

Key words: Cervical spine — Discectomy — Anterior approach — Fusion — Anatomy

Direct decompression by resection of osteophytes in front of the spinal canal may place the spinal cord at risk of iatrogenic injury [12]. Although the risk of serious neurologic damage via the anterior approach is small, of the order of 0.7% in Graham's study [12], this risk is not negligible. Any neurologic damage via the anterior procedure can be catastrophic. Reported complications of the anterior approach have included quadriplegia [20], dural injury [2] and excessive bleeding due to laceration of the epidural venous plexus [10]. Thus, anterior fusion without decompression has a potentially lower risk of serious complications, but may not directly provide immediate or complete relief of spinal cord compression.

Anterior cervical discectomy or vertebrectomy with bone graft, especially in the lower cervical spine, has been routinely performed for degenerative and traumatic lesions [5, 17-19]. However, anatomic studies of the cervical disc space and vertebral body relevant to anterior cervical discectomy and bone grafting are not well addressed in the literature. Understanding the quantitative anatomy of the cervical disc space and vertebral body not only enhances the accuracy of anterior cervical discectomy but also allows adequate decompression of the cervical canal.

Additionally, stabilization of the unstable cervical spine with anterior screw-plate fixation has been commonly used [1, 3, 4]. However, regarding the screws violating the anterior spinal canal or damaging the spinal cord, we believe that a knowledge of the margins of the anteroposterior depth of the vertebral body may minimize the risk of spinal cord injury.

Material and methods

Twenty adult embalmed cadavers (8 males and 12 females) with a mean age of 67.8 years (range 61-89) were obtained from the Department of Anatomy for the present study. All specimens were frozen in a neutral position and cut longitudinally through the midline with an electric saw to show longitudinal sections of the vertebral bodies and disc spaces from C3 to T1. Specimens with midline longitudinal-sectional surfaces of the intervertebral discs and vertebral bodies were directly scanned into a computer (Apple-Power Macintosh 7100/66) along with a reference metric scale. The software program used for the scanning procedure was the "Adobe Photoshop limited edition 2.5.1", developed by Adobe Systems Inc., with the "ScanMaker Plug-In 2.10" feature. The surfaces of the specimen were kept in close contact with the surface of the scanner to maintain consistency and accuracy. The scans obtained on the "Adobe Photoshop" were then subjected to the program entitled "Color Image 1.31" for measurements. The calibration factor for the measurement software was obtained by scanning a ruler with the specimens. This procedure ensured that the dimensions of the scanned image were consistent with those of the actual specimens. Several parameters were determined from C3 to C7 levels. The midline anteroposterior (AP) depths of the vertebral bodies were measured at the levels of the superior and inferior endplates and at the middle of the vertebral bodies. The midline heights of the intervertebral discs were measured at the anterior and posterior disc space, and midpoint of the disc space. The mid-axis of the intervertebral disc space was defined as a reference line passing between the midpoints of the superior and inferior endplates. The anterior insertions of the annulus fibrosus at the superior and inferior adjacent vertebral bodies were identified. The midpoint of the annulus fibrosus was determined, and then a line was drawn between the midpoint of the anterior annulus fibrosus and the midpoint of the posterior disc space. The distance between the above two lines was measured at the anterior border of the disc space. The angle between these two lines was also determined (Fig. 1). All values of parameters were expressed in mean ± standard deviation. The differences among different levels were analyzed with Student's t-test.

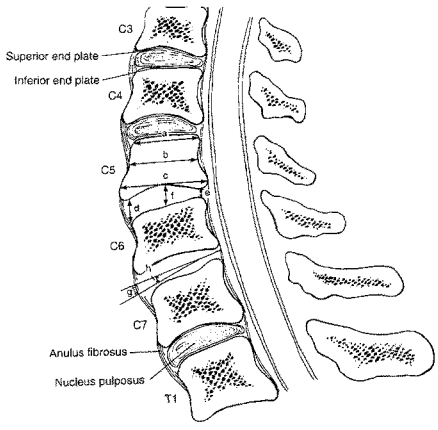


Fig. 1.
Schematic illustration of measurements on the midline longitudinal sections of the subaxial cervical spine. *a*, midline AP depth of vertebral body at the level of the superior endplate ; *b*, midline AP depth of vertebral body at the middle of the vertebral body ; *c*, midline AP depth of vertebral body at the level of the inferior endplate ; *d*, midline height of the intervertebral disc at anterior border of the disc space ; *e*, midline height of the intervertebral disc at posterior border of the disc space ; *f*, midline height of the intervertebral disc at median of the disc space ; *g*, distance at anterior annulus fibrosus between mid-axis of the intervertebral disc space and a line passing through the anterior midpoint of the annulus fibrosus and the midpoint of the posterior disc space ; *h*, angle between mid-axis of the intervertebral disc space and a line passing through the anterior midpoint of the annulus fibrosus and the midpoint of the posterior disc space

Results

AP depth at the superior endplate increased from 16.56 ± 2.21 mm at C3 to 19.32 ± 2.30 mm at C7 ($P < 0.05$). AP depth at the middle of the vertebral body varied minimally (16.8 ± 1.98 mm at C3 to 17.93 ± 2.55 mm at C7) ($p > 0.05$) with the greatest value of 18.14 ± 2.31 mm at C6. Greater values of AP depth at the inferior endplate were found at C5 (20.75 ± 2.87 mm) and C6 (20.56 ± 2.31 mm), compared with the values at C3 (18.26 ± 1.82 mm) ($p < 0.005$), C4 (19.27 ± 2.88 mm) and C7 (19.21 ± 3.22 mm) (Fig. 2A). The height of the disc space was found to be lowest at the posterior disc space from C2-3 to C7-T1 (2.95 ± 0.86 mm at C2-3, 2.78 ± 0.93 mm at C3-4, 2.45 ± 0.79 mm at C4-5, 2.92 ± 0.64 mm at C5-6, 2.46 ± 0.59 mm at C6-7, 2.93 ± 1.05 mm at C7-T1), when compared to the height at the anterior disc

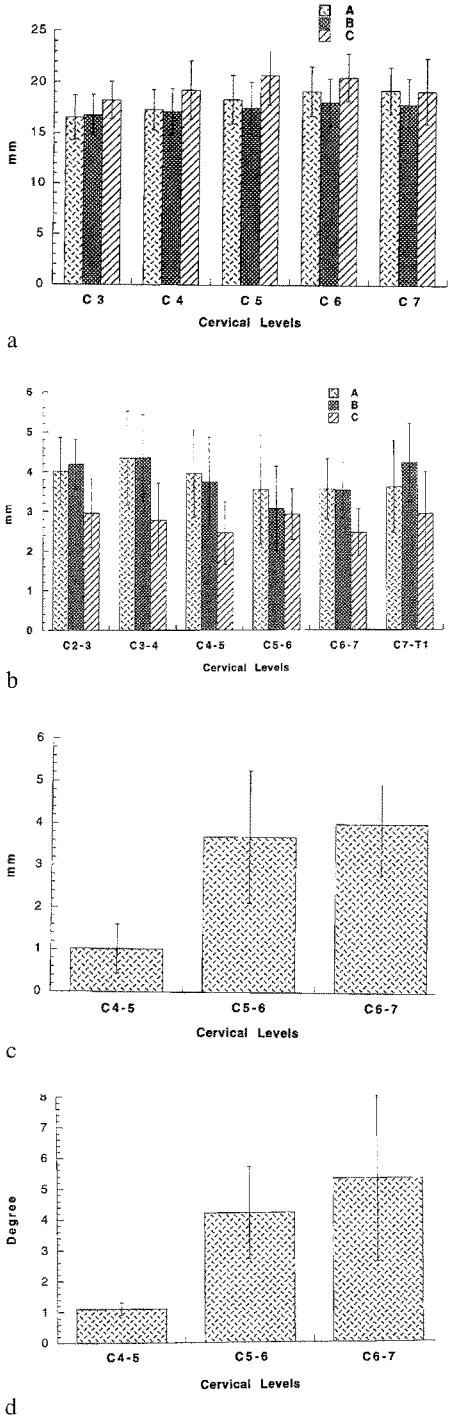


Fig. 2a-d
Error bar graphs showing results of measurements at different levels. **a** Comparison of AP depths of the vertebral body at the superior endplate (*A*), middle of the vertebra (*B*) and inferior endplate (*C*) ; **b** Comparison of the heights of the disc space at the anterior margin (A), midpoint (*B*) and posterior margin (*C*) ; **c** Distance at anterior annulus fibrosus between mid-axis of the intervertebral disc space and a line passing through the anterior midpoint of the annulus fibrosus and the midpoint of the posterior disc space ; **d** Angle between mid-axis of the intervertebral disc space and a line passing through the anterior midpoint of the annulus fibrosus and midpoint of posterior disc space

space from C2-3 to C7-T1 (4.07 ± 0.85 mm at C2-3, 4.34 ± 1.18 mm at C3-4, 3.95 ± 1.37 mm at C4-5, 3.55 ± 1.37 mm at C5-6, 3.55 ± 0.76 mm at C6-7, 3.67 ± 1.17 mm at C7-T1) ($p < 0.05$). The height of the disc space at the midpoint of the disc spaces from C2-3 to C7-T1 was 4.17 ± 0.62 mm at C2-3, 4.35 ± 1.08 mm at C3-4, 3.74 ± 1.12 mm at C4-5, 3.06 ± 1.06 mm at C5-6, 3.52 ± 0.71 mm at C6-7 and 4.21 ± 0.98 mm at C7-T1 (Fig. 2B). The mid-axis of the disc space passed through the midpoint of the anterior annulus fibrosus at the levels of C2-3, C3-4, and C7-T1. However, the angle between the mid-axis of the disc space and a line connecting the anterior midpoint of the annulus fibrosus and the midpoint of the posterior disc space was 1.1 ± 0.2° at C4-5, 4.2 ± 1.5° at C5-6 and 5.3 ± 2.7° at C6-7 (Fig. 2C). The distance between the mid-axis of the disc space and the midpoint of the anterior annulus fibrosus was 1.02 ± 0.58 mm at C4-5, 3.69 ± 1.57 mm at C5-6 and 4.01 ± 1.22 mm at C6-7 (Fig. 2D).

Discussion

Disc degeneration is inevitable, especially in the elder population. The intervertebral disc is composed of an outer annulus fibrosus, the nucleus pulposus contained within, and the cartilaginous end-plates. Degenerative disc disease most frequently involves the C5-6, C6-7, and C4-5 levels, in decreasing order of occurrence [9, 11]. Anterior cervical discectomy with interbody arthrodesis is the procedure of choice in cervical spondylosis. The risk of spinal cord injury with anterior discectomy and fusion has been calculated to be approximately 2 per 1000 [20]. In order to effectively and thoroughly remove the disc material, it is necessary to know the anatomy of the cervical disc and vertebral body. The present study may not only provide guidelines for discectomy and interbody bone graft on the anterior cervical spine, but also facilitate adequate removal of the disc material and decompression of the spinal canal.

Robinson and Smith first performed cervical discectomy and fusion by an anterior surgical approach [17-19]. They described removal of the cartilaginous endplate and subchondral bone at the top and bottom of the intervertebral disc space. With removal of the endplate, the volume of the recipient site averaged 10 to 15 mm in height, 10 to 15 mm in width, and 10 to 15 mm in depth. The present study demonstrated that AP depth of the vertebral body at the levels of the superior and inferior endplates and at the middle of the vertebral body was shortest at C3 (16 mm) and greatest at C5 and C6 (20 mm). In general, the AP depth of the vertebral body gradually increased from C3 to C6. The depth of the vertebral body at the inferior endplate was consistently larger than the depth at the superior endplate of the next caudal vertebral body from C3 to C6. To reach the posterior longitudinal ligament, more disc material can be removed. However, our current study showed that anteroposterior drilling of the vertebral body and the AP depth of the bone graft cannot exceed 20 mm. Therefore, all the above measurements are useful for determining the depth of the trough in the vertebral body, the size of the interbody bone graft, and for placing vertebral body screws in anterior plate fixation.

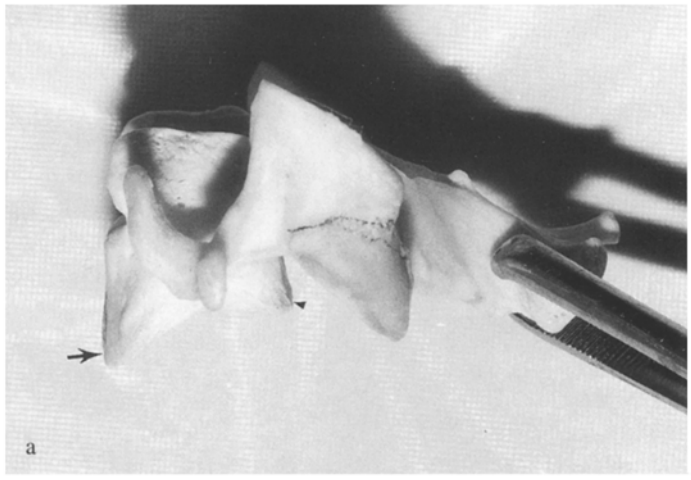
Cloward advocated using a dowel-type graft placed into a prepared site with special instrumentation [5]. All soft tissue (disc and ligament) has to be removed to maximise the rate of fusion. The current study demonstrated that the height of the disc spaces was found to be lowest at the posterior disc space from C2-3 to C7-T1. The inferior margin of the vertebral body is lower anteriorly than posteriorly, especially in the lower cervical spine. The axis of the anterior disc space was lower than that of the posterior disc space in the lower cervical spine (Fig. 3). If a drill hole is placed at the center of the midline at the disc level for discectomy, a 5° cephalad inclination of the drill may enable the posterior portion of the disc space to be reached easily. Furthermore, a distance of 3 mm above the midpoint of the annulus fibrosus and perpendicular to the anterior surface of the annulus is recommended for hole drilling at the lower cervical levels. This may allow precise removal of the posterior disc and vertebral endplates on the caudad and cephalad aspects of the vertebral body.

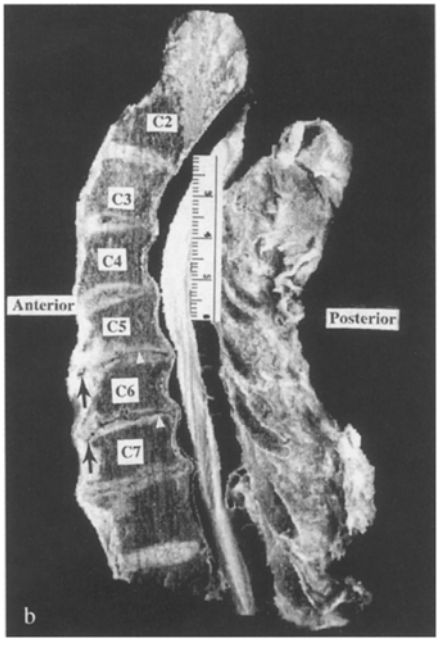
Panjabi et al [16] reported that the mean area of the superior articular surface of the uncovertebral joint is 44 mm^2, approximately twice that of the inferior articular surface, and is inclined from the apex of the uncinate process laterally to the disc space medially. The angle of inclination of the uncovertebral joint increases from C5 to C7 in the frontal plane [16]. Because the interface of the uncovertebral joint is angled approximately 30° cephalad from the horizontal line of the intervertebral disc, removal of disc material can be carried out laterally to the uncovertebral joints, 3-5 mm cephalad to the midpoint of the anterior disc space at the midline, which avoids excessive bone removal (Fig. 3C).

The width of the vertebral body gradually increased from C3 level (19.2 ± 1.8 mm) to C7 level (25.6 ± 2.0 mm) [6, 7]. The distance between the medial and lateral margins of the uncinate process was approximately 20-25% of vertebral body width. The distance between the medial and lateral margins of the uncinate process gradually increased from the C3 (4.9 ± 0.7 mm) to the C7 (6.3 ± 0.7 mm) level [13]. The height of the uncinate process was 5.8 mm to 6.1 mm at the C4-6 levels [6]. The anterolateral window for decompression of the neural foramen could be determined by the height and width of the uncinate process. The size of the window made by drilling the base of the uncinate process is approximately 5 to 6 mm wide transversely and 5 to 6 mm above the midpoint of the anterior disc space at the midline vertically.

The AP depth at the superior endplate increased from 16.56 ± 2.21 mm at C3 to 19.32 ± 2.30 mm at C7. Little variation was found for AP depth at the middle of the vertebral body (16.8 ± 1.98 mm at C3 to 17.93 ± 2.55 mm at C7) with the greatest value of 18.14 ± 2.31 mm at C6. Greater values of AP depth at the inferior endplate were found at C5 (20.75 ± 2.87 mm) and C6 (20.56 ± 2.31 mm) compared with the values at C3 (18.26 ± 1.82 mm), C4 (19.27 ± 2.88 mm) and C7 (19.21 ± 3.22 mm). However, the anteroposterior diameter of the medial margin of the uncinate process was greater at the C5 and C6 levels (12.5 ± 1.5 mm and 12.3 ± 1.4 mm) than at the C7 level (11.6 ± 1.3 mm) [13]. These variations should be considered during resection of the vertebral body or uncinate process and as determining the size of the bone graft. Therefore, the use of fixed values for anterior decompression from C3 to C7 levels may not be appropriate and may lead to inadequate decompression at the lower cervical vertebrae [6-8, 13].

Anterior plating, in conjunction with cervical arthrodesis, provides excellent stability with optimal alignment and posture and is an important technique for the treatment of cervical trauma. AP depths of the cervical vertebrae from C3 to C7 have been reported in the literature [8,14-16]. However, our data was quite close to





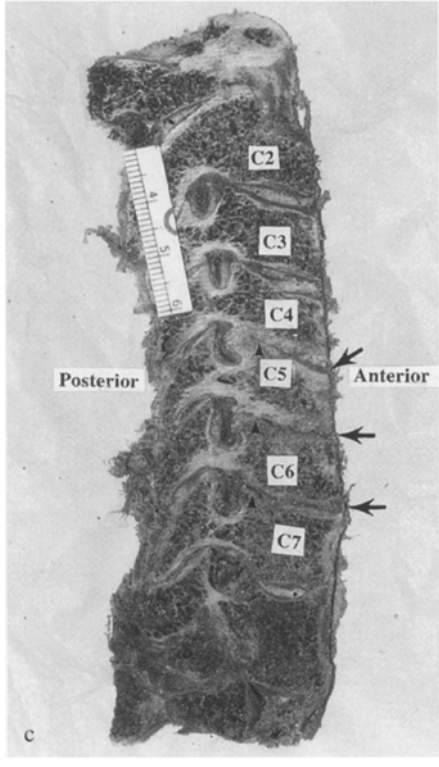


Fig. 3a-c
a A dried C5 vertebral body in lateral view showing that the inferior margin of the vertebral body anteriorly (*arrow*) was lower than that posteriorly (*arrowhead*) ; **b** A midline longitudinal section of the cadaveric specimen showing that the axis of the anterior disc space (*arrows*) was lower than that of the posterior disc space (*white arrowheads*) in the lower cervical spine ; **c** An oblique longitudinal section of the cadaveric specimen showing the lateral portion of the vertebral body and disc space. The anterior disc spaces (*arrows*) were much lower than the posterior spaces (*arrowheads*), especially in the lower cervical levels

that of Pait et al [15], which gave the shortest at C3 and the greatest at C5-7.

The placement of a screw into the superior half of the vertebral body should be shorter than into the inferior half ; this is especially important when bicortical screws are inserted.

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