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Original Article

Three-Dimensional Computed Tomography Measurements of Pedicle Diameters and Angles for the Safety of Posterior Cervical Spinal Instrumentation

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ABSTRACT

Objective: The cervical pedicle screw fixation technique ensures rigid stabilization by offering superior correction capability for the restoration of the sagittal alignment of the cervical spine. Given the technical complexity of this procedure and its proximity to critical neurovascular structures, it is imperative for surgeons to thoroughly assess the patient's anatomy before undertaking pedicle instrumentation in the lower cervical spine. This comprehensive evaluation is crucial for minimizing risks and ensuring optimal surgical outcomes.

Methods: In the present study, the widths, heights, transverse angles, and maximum lengths of pedicle screws of the vertebral pedicles between C3 and C7 in posterior cervical spinal instrumentation were bilaterally evaluated in 50 adult patients using preoperative four-way direct radiographs, thin-section computed tomography (CT) scans, and 3-dimensional CT (3D-CT) images.

Results: The results revealed that pedicle height, pedicle width, and maximum screw length increased gradually as we descended caudally from the C3 vertebra to the C7 vertebra, whereas the transverse pedicle angle increased between C3 and C5 and decreased between C5 and C7. The mean maximum screw length varied between 29.7 mm and 33.1 mm.

Conclusion: The findings of this study emphasize the importance of the widths, heights, transverse angles, and maximum lengths of pedicle screws for their appropriate placement into the pedicle in surgical procedures.

INTRODUCTION

Abumi et al.[1] proposed lower cervical vertebrae stabilization with pedicle screws in 1994. Further research by Ito et al.[2] found that pedicle screws are more biomechanically stable than lateral mass screws for cervical fixation from C3 to C6. More specifically, pedicle screws were four times more resistant to rotational pressures and twice as robust against flexion and extension stresses than lateral mass screws. However, cervical vertebrae pedicle screw insertion is technically tough. Although morphological studies have established landmarks and angulation standards for placing cervical pedicle screws, these anatomical markers have proven to be unreliable when dealing with specific diseases such as rheumatic cervical spine disorders and degenerative cervical myelopathy. Due to the heterogeneity in architecture, researchers are now relying more on preoperative computed tomography (CT) scans and personalized guidelines to ensure precise screw placement that is suited to each patient's particular anatomy.[3]

In the present study, the widths, heights, and transverse angles of the vertebral pedicles between C3 and C7 and the maximum lengths of the pedicle screws that could be inserted in posterior cervical spinal instrumentation were bilaterally evaluated in 50 adult patients using preoperative four-way direct radiographs, thin-section CT scans, and 3-dimensional CT (3D-CT) images to produce a database. The findings of this study highlight the importance of these variables for the appropriate placement of pedicle screws into the pedicle in surgical procedures.

MATERIALS AND METHODS

Data from a cohort of 50 patients, comprising 25 female and 25 male individuals, aged between 25 and 65 years, who underwent 3D cervical computed tomography (CT) scans for various indications between 2000 and 2011 at the Department of Neurosurgery, were systematically analyzed utilizing the Novapacs system. Pedicle parameters were meticulously measured. Exclusion criteria included patients with infectious, neoplastic, traumatic, or congenital spinal anomalies. Axial and sagittal images of the C3-C7 cervical vertebral pedicles were selected for analysis, and the following parameters were measured:

1. Craniocaudal Height of the Pedicle: This parameter, also known as the rostrocaudal dimension, was obtained from sagittal images.

2. Pedicle Width: This refers to the mediolateral diameter of the pedicle isthmus.

3. Transverse Angle of the Pedicle: This is the angle between the pedicle axis and the midline of the vertebral corpus.

4. Maximum Screw Length: This measurement represents the distance from the posterior cortex of the lateral mass to the anterior wall of the vertebral corpus along the pedicle axis.

RESULTS

The C3 vertebral level had the lowest mean pedicle height, measuring 6.5 mm in males and 5.6 mm in females. Conversely, the C7 vertebral level had the highest pedicle height, measuring 7.6 mm in men and 6.7 mm in women (Table 1). The height of the pedicle exhibited a tendency to progressively rise towards the distal extremity.

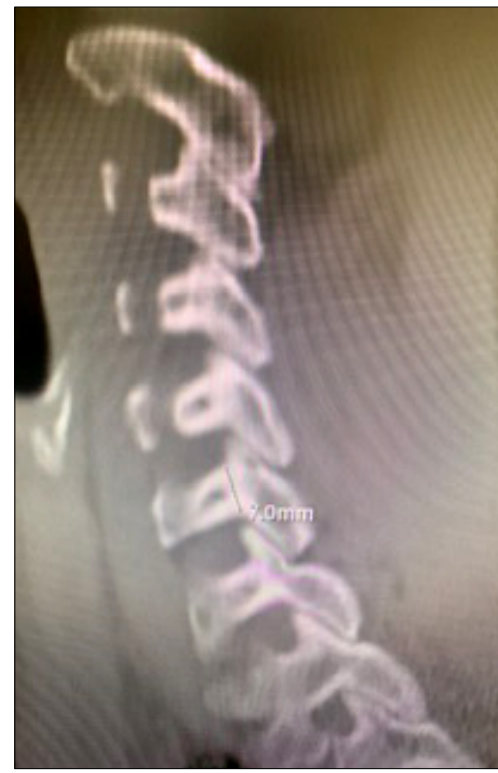

Figure 1. Pedicle height.

In both men and women, the smallest average pedicle width was found at the C3 vertebral level, measuring 5.0 mm for men and 4.0 mm for women. Conversely, the largest average pedicle width was seen at the C7 vertebral level, measuring 7.1 mm for males and 6.1 mm for females (Table 1). There was a tendency for the breadth of the pedicle to expand as one moved from the C3 to C7 vertebrae.

In both men and women, the smallest average transverse

Table 1. Mean values and standard deviations of measurements of cervical pedicle

		Pedicle Width (mm)	Pedicle Height (mm)	Transvers Pedicle Angle (degree)	Maximum Screw Length (mm)
C3	Mean	4.5+-1.0	6.2+-1.1	43.1+-4.8	29.7+-3.6
	Man	5.0+-1.1	6.5+-1.0	42.3+-4.9	30.0+-3.7
	Woman	4.0+-0.8	5.6+-1.0	44.2+-4.9	28.2+-3.3
C4	Mean	4.9+-1.1	6.3+-1.1	45.0+-4.6	29.9+-3.6
	Man	5.3+-1.0	6.7+-1.2	44.3+-4.8	31.2+-3.4
	Woman	4.3+-0.9	5.9+-1.1	45.1+-4.1	28.7+-3.5
C5	Mean	5.4+-1.1	6.5+-1.1	45.4+-4.5	31.1+-4.2
	Man	5.8+-1.1	6.8+-1.2	44.4+-4.1	32.3+-4.1
	Woman	4.9+-0.8	6.0+-1.1	45.8+-4.1	29.7+-3.6
C6	Mean	5.6+-1.0	6.8+-1.1	42.5+-4.8	32.0+-4.3
	Man	6.0+-1.1	7.1+-1.0	42.1+-4.8	32.9+-4.4
	Woman	5.1+-1.0	6.2+-1.1	42.9+-4.8	30.9+-4.0
C7	Mean	6.7+-1.2	7.2+-1.2	37.6+-4.9	33.1+-5.3
	Man	7.1+-1.0	7.6+-1.0	37.4+-4.9	34.4+-5.4
	Woman	6.1+-0.9	6.7+-1.1	38.3+-5.0	31.6+-4.8

Figure 2. Pedicle width (Medio-Lateral Width of the Pedicle Isthmus).

Figure 3. Transverse pedicle angle (Angle between the pedicle axis and the midline of the vertebral corpus).

pedicle angle was found at the C7 vertebral level, measuring 37.4 degrees for men and 38.3 degrees for women. On the other hand, the largest average transverse pedicle angle was observed at the C5 vertebral level, measuring 44.4 degrees for males and 45.8 degrees for females (Table 1).

The mean screw length varied between 29.7 mm and 33.1 mm. The smallest mean maximum screw length was obtained at the C3 vertebral level in men (30.0 mm) and women (28.2 mm), and the largest maximum screw length was obtained at the C7 vertebral level in both men (34.4 mm) and women (31.6 mm) (Table 1).

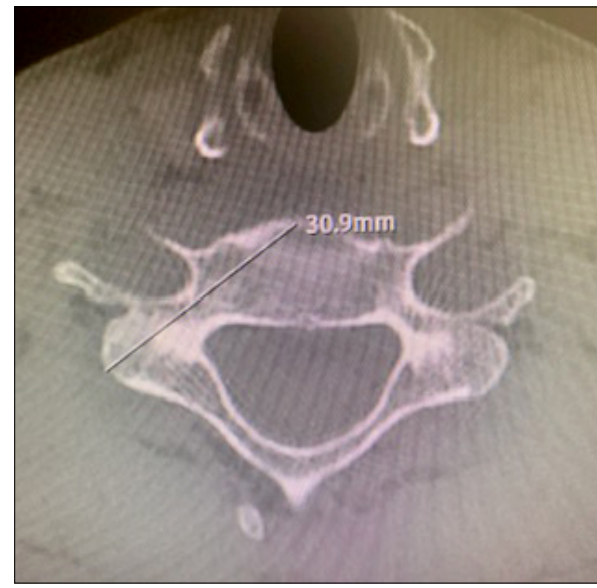

Figure 4. Maximum Screw Length (Distance from the Posterior Cortex of the Lateral Mass to the Anterior Wall of the Vertebral Corpus along the Pedicle Axis).

DISCUSSION

One significant peril associated with cervical pedicle screw insertion is the potential harm to the vertebral arteries. Injuries to the dominant side of the vertebral arteries can lead to significant and potentially severe effects. To reduce the chances of vertebral artery injury, it is important to have a better understanding of the morphological features. In a prior study conducted by Yang et al.,[4] it was discovered that the cervical pedicles on the same side as the dominant vertebral artery had a reduced size. Pedicle screws should not be used at the C3 and C4 vertebrae if the pedicle width is less than 4 mm and the total breadth and distance from the outer cortex to the vertebral artery is less than 5 mm. According to Liu et al.,[5] the third cervical vertebra pedicle was the smallest in the study. The pedicles covered the third to seventh cervical vertebrae.

Previous investigations found that cervical pedicles have a smaller transverse diameter than sagittal width.[6,7] According to Yusof et al.,[8] the pedicles of the lower cervical vertebrae have a greater width in the sagittal direction compared to their width in the transverse direction. A morphometric research study was conducted on the subaxial vertebrae of a Malaysian population using CT scans to determine the key factor affecting the feasibility of employing the pedicle screw procedure on these vertebrae, which is the transverse diameter of the pedicles. The findings from the study showed that the widest pedicle was found at the C7 vertebra for both male and female participants. On the other hand, the narrowest pedicle was seen at the C4 vertebra for male participants and at the C3 vertebra for female individuals. Additionally, they stated that a minimum pedicle width of 4.5 mm is necessary for the insertion of a 3.5-mm cervical pedicle screw.[8] According to

the existing literature, the findings from this study showed that the lowest diameter of the pedicle was found at the C3 vertebra, while the maximum diameter was seen at the C7 vertebra. Furthermore, the pedicle diameter tended to grow as it moved towards the distal end. The pedicle height values were similar to those reported in prior investigations and exceeded the pedicle width values in both males and females.

In a previous study performed using CT, Dong et al.[9] reported that the optimal medial angulation for cervical pedicle screw placement was 45-55 degrees at C3-6 and 30-45 degrees at C7 vertebrae. Liu et al.[5] reported that the pedicle transverse angle was the highest at C4 and lowest at C7. In the present study, the smallest medial angulation was at the C7 vertebra in both male and female patients, whereas the largest medial angulation was at the C5 vertebra.

Abumi posited that the optimal entry point for the insertion of a pedicle screw is located just inferior to the facet joint, approximately 1-2 mm lateral to the midpoint of the superior articular process.[1] The lateral margin of the cervical vertebrae's lateral mass features a notch that is approximately at the same level as the pedicle. Specifically, the pedicles are situated slightly inferior to this notch at the C2 vertebral level, at the level of the notch between C3 and C6, and at or superior to the notch at the C7 level.[10] Pan et al.[11] delineated this notch, which is considerably lateral to Abumi's prescribed entry point and proximate to the pedicle projection, as their designated entry point. Consequently, they positioned the screw at a significantly higher angle, closely aligning with the true pedicle transverse angle, which they postulated likely mitigated the risk of the proximal medial cortex deflecting the screw laterally.[11] In our clinical practice, we have adopted this notch as the entry point. Our measurements of the maximum feasible screw length from this reference point revealed that the average screw length ranged from 29.7 mm to 33.1 mm. Correspondingly, Mohi Eldin et al.[12] reported the minimum pedicle axis length as 29.5 mm.

Conclusion

Prior to performing pedicle instrumentation in the lower cervical spine, surgeons should thoroughly assess the patients' anatomy. Identifying the locations where the pedicle screws will be inserted, as well as the angles at which they will be placed, and their size prior to surgery might help minimize potential difficulties.

Informed Consent

Retrospective study.

Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept: A.B., T.H.; Design: A.B., T.H.; Supervision: A.B., T.H.; Fundings: A.B., T.H.; Materials: A.B., T.H.; Data: A.B., T.H.; Analysis: A.B., T.H.; Literature search: A.B., T.H.; Writing: A.B., T.H.; Critical revision: A.B., T.H.

Conflict of Interest

None declared.

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Posterior Servikal Spinal Enstrümantasyonda Uygulama Güvenliği İçin Pedikül Çapları ve Açılarının Üç Boyutlu Bilgisayarlı Tomografi İle Ölçümleri

Amaç: Servikal pedikül vida tekniği omurganın sagital diziliminin restorasyonu için yüksek korreksiyon kabiliyeti sağlayarak rijit fiksasyona olanak sağlar. Tekniğin zorluğu ve önemli nörovasküler yapılara komşuluğundan dolayı, cerrahlar alt servikal omurgada pedikül enstrümantasyonu yapmadan önce hastanın bireysel anatomisini ayrıntılı olarak değerlendirmelidir.

Gereç ve Yöntem: Bu çalışmada, posterior servikal spinal enstrümantasyonda C3-C7 arası vertebral pediküllerin genişlikleri, yükseklikleri, transvers açıları ve pedikül vidalarının maksimum uzunlukları, preoperatif dört yönlü direkt grafi, ince kesit bilgisayarlı tomografi (BT) ve 3 boyutlu bilgisayarlı tomografi (3B-BT) görüntüleri ile 50 erişkin hastada iki taraflı değerlendirilerek veritabanı elde edildi.

Bulgular: Elde edilen verilere göre C3 vertebrasından C7 vertebrasına doğru kaudale doğru inildikçe pedikül yüksekliğinin, pedikül genişliğinin ve yerleştirilebilecek maksimum vida boyunun giderek arttığı; transvers pedikül açısının ise C3-5 arası artıp, C5-7 arası azaldığı belirlendi. Ortalama maksimum vida uzunluğu 29.7 mm ile 33.1 mm arasında bulundu.

Sonuç: Bu değişkenlerin cerrahi uygulamalarda pedikül vidalarının pediküle uygun yerleştirilebilmesi için önemi vurgulandı.

Anahtar Sözcükler: Bilgisayarlı tomografi; servikal pedikül vidası; servikal pedikül morfometrisi.