ORIGINAL ARTICLE

Morphometric study on the 12th thoracic vertebrae which is most frequently exposed to trauma and the closest vertebra to thoracic aorta

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ABSTRACT

BACKGROUND: To describe gender-related differences in the length of the left chord and pedicle at the level of 12th thoracic vertebrae and appropriate length of the screw to be applied so as to decrease the perforation risk of anterior cortex of the corpus and preventable injury of major vascular vessels.

METHODS: Axial bone window computed tomography images of T12 vertebral pedicles of 60 patients (30 males and 30 females, age >25 years) without any sign of spinal trauma were obtained and morphometric data were analyzed.

RESULTS: Mean ages of the female (n=30) and male (n=30) patients were 32.17±4.24 and 31.70±3.60 years, respectively. The left chord lengths of T12 of the male (38.17±2.54 mm) and female (36.62±2.27 mm) patients were compared and a statistically significant difference was found between these two measurements (p=0.016). A statistically significant difference between the length of the left chord (37.40±2.51) (range, 32–44 mm) and age (31.93±3.91) (range, 25–40 years) and also a moderate degree of correlation were observed (p=0.002), (r=0.401). A statistically significant difference and a moderate degree of correlation were found between the lengths of the left chords (37.40±2.51; range, 32–44 mm) and the left pedicles (12.12±1.34; range, 10.0–15.80 mm) (p=0.001), (r=0.577).

CONCLUSION: Significant differences and correlations exist between the left pedicle and the left chord in male and female patients and patients with different ages. The data obtained can be used as a guide to determine the implant size and intraoperative management of T12 vertebral pedicle.

Keywords: Anatomy; aorta; pedicle morphology; pedicle screw; thoracic vertebra.

INTRODUCTION

Because of its mechanical mobility due to its function as a transition zone, thoracolumbar region is the most frequently affected site of the spine. These pathologies involve trauma, degenerative diseases, osteoporotic compression fractures, instabilities, neoplastic diseases, and infections.[1–4] Thoracolumbar instrumentation consists of an important part of the treatment alternatives of these pathologies. Although complete consensus has not been arrived at applicability of thoracic posterior transpedicular screws (TPTSs) and their long-term outcomes, this procedure has been used widely as a stabilization method.[5,6] No matter which advanced technique is used, much experience about spine anatomy is needed.[1] If appropriate screws are not selected and inserted at a correct angle, serious complications as pedicle fracture, nerve injury, and neurologic and vascular injury can occur.[7]

Fixation with TPTS has become a popular method in the management of traumatic instability, tumors, deformities, and degenerative diseases. When compared with the lumbar vertebra, placement of the thoracic pedicle screw is very challenging because of its small size, variable entry point, and closeness to neurovascular structures and spinal cord.

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[8,9] Despite technical advances within the past few decades, implantation of the pedicle screw carries high risk of complication. Malposition of the screw is the prevalently reported complication with an incidence rate varying between 0% and 42%.[10] Despite serious neurological, visceral, or vascular complication rates with screw fixation are relatively lower, various studies have indicated higher pedicular perforation rates (41–54%).[11–13]

Many studies have demonstrated that the success rates of stabilization with TPTS have been effected by depth of the penetration and size of the screw, technical factors, and patient-related factors as scoliosis, anemia, tobacco use, and lower bone mineral density.[14,15]

In surgical applications, surgeon selects pedicle screw with appropriate caliber and length based on his/her previous experiences, however, insertion angle of the screw is not determined according to certain criteria. Closeness to neurological structures scares the surgeon while screwing and encourages the surgeon to be more aggressive so as to achieve necessary screw length and thickness for effective stabilization. Detailed information about the pedicle morphology is important for safe TPTS fixation. Vertebral pedicle and body have different morphometric characteristics in each population.

MATERIALS AND METHODS

This is a study performed using information on pedicle morphologies of 60 successive patients aged over 25 years of age. The study was approved by the University Clinical Studies Ethics Committee.

To describe differences between pedicle lengths of male and female patients, left pedicles and left chords of 12th thoracic vertebrae were measured with the aid of computed tomography (CT). Thin-slice (0.5 mm slice thickness) three-dimensional tomograms of thoracic 12 vertebrae of 60 patients were evaluated (Philips Brilliance CT, Eindhoven, Holland).

The patients in this group had not any spinal disease; however, they suffered from thoracic and abdominal diseases. Patients with spinal deformities, tumors, past or current spinal fractures, infection, congenital anomalies, and cases who had undergone lumbar surgery were excluded from the study.

For the present study, thoracic vertebrae were examined in addition to the affected vertebral regions as the source of patients' complaints. First of all, 2 mm thick axial images were obtained. Then, bone window was reformatted and three images of maximum thickness were obtained and among them the thickest pedicle section was selected. Then using the image of this section, digital measurements of the pedicle and the screws were performed (Philips Brilliance CT, Eindhoven Holland). The measurements were done by the authors of this article (i.e., orthopedists, neurosurgeon, and radiologist) with the aid of a CT technician. "Middle segment pedicle" was defined as the largest transverse image of the right and the left pedicles.[6]

Length of the Pedicle

The distance measured between the posterior screw entry point and posterior vertebral cortex entry point was defined as the length of the pedicle at the mid-pedicle axis (Fig. 1a and 1c).

Length of the Chord

The distance measured between the posterior entry point of the screw and anterior vertebral cortex was defined as the length of the pedicle at the mid-pedicle axis (Fig. 1b and 1d).

Statistical Analyses

Statistical analyses were performed with Student's t-test and Pearson correlation analysis, using PASW v18 statistical package.

RESULTS

Mean ages of the female (n=30) and male (n=30) patients were 32.17±4.24 and 31.70±3.60 years, respectively. The left chord lengths of T12 of the male (38.17±2.54 mm) and female (36.62±2.27 mm) patients were compared and a statistically significant difference was found between these two measurements, p=0.016 (p<0.05) (Table 1). A statistically significant difference between the length of the left chord (37.40±2.51)

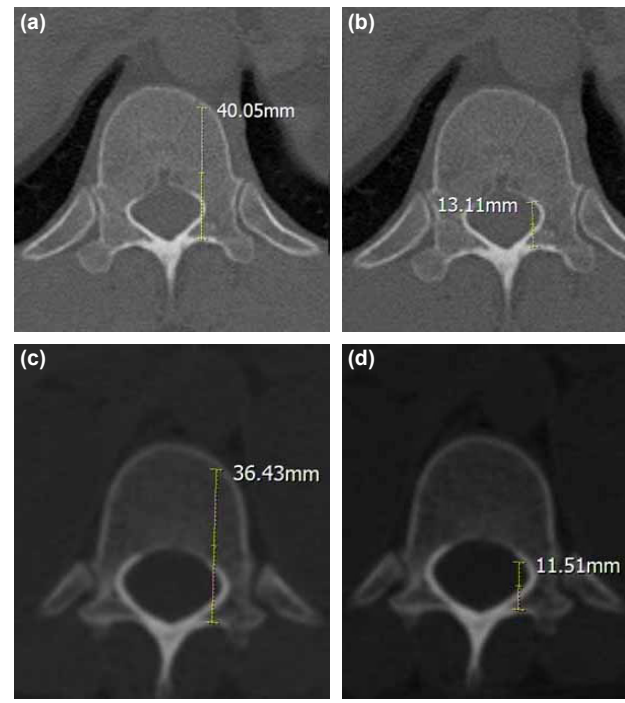

Figure 1. (a, b) Axial computed tomography measurement of the left T12 vertebrae and length of the pedicle in male patients. **(c, d)** Axial computed tomography measurement of the left T12 vertebrae and length of the pedicle in female patients.

Table 1. Correlation between gender and the length of the left chord, the length of the left pedicle

	Mean±SD	Min-Max	p
Length of the left pedicle (mm)			
Male (n=30)	12.30±1.27	10.0–15.80	0.276
Female (n=30)	11.94±1.40		
Length of the left cord (mm)			
Male (n=30)	38.17±2.54	32–44	0.016
Female (n=30)	36.62±2.27		
Age (years)			
Male (n=30)	32.17±4.24	25–40	0.648
Female (n=30)	31.70±3.60		

SD: Standard deviation; Min: Minimum; Max: Maximum.

Table 2. Correlation between the length of the left chord and age

	n	Mean±SD (min-max)	p
Age (years)	60	31.94±3.91 (25–40)	0.002
Length of the left cord (mm)	60	37.40±2.51 (32–44)	

SD: Standard deviation; Min: Minimum; Max: Maximum.

Table 3. Correlation between the length of the left pedicle and age

	n	Mean±SD (min-max)	p
Age (years)	60	31.94±3.91 (25-40)	0.092
Length of the left cord (mm)	60	12.12±1.37 (10.0–15.80)	

SD: Standard deviation; Min: Minimum; Max: Maximum.

Table 4. Correlation between the length of the left chord and the length of the left pedicle

	n	Mean±SD (min-max)	p
Length of the left cord (mm)	60	37.40±2.51 (32–44)	0.001
Length of the left pedicle (mm)	60	12.12±1.37 (10.0–15.80)	

SD: Standard deviation; Min: Minimum; Max: Maximum.

(range, 32–44 mm) and age (31.93±3.91) (range, 25–40 years) and also a moderate degree of correlation were observed (p=0.002), (r=0.401) (Table 2). The left pedicle lengths of T12 were not statistically significantly different between male (12.30±1.27 mm) and female (11.94±1.40 mm) patients (p=0.276) (Table 1). The correlation between the length of the left pedicles (12.12±1.34; range, 10.0–15.80 mm) and age (31.93±3.91 years) was not statistically significant (p=0.092) (Table 3). A statistically significant difference and a moderate degree of correlation were found between the lengths of the left chords (37.40±2.51; range, 32–44 mm) and the left pedicles (12.12±1.34; range, 10.0–15.80 mm) (p=0.001), (r=0.577) (Table 4).

DISCUSSION

During application of TPTS, fluoroscopy has been used frequently, morphometric information of the vertebral pedicle and corpus offers important advantages to the surgeon during operation. As a known fact, malposition rate using standard open technique has been reported in higher percentage (up to 40%) of the cases.[16] Determination of the optimal length of the screw decreases the risk of injury of the anterior cortex of the vertebral body and major vascular injury can be prevented. With the introduction of screw fixation of the pedicle during spinal surgery, the choice of appropriate sized screw for the intervened pedicle has gained importance. Complex structure of the thoracic vertebral pedicle and anatomical location of the adjacent neurovascular structure together with the potential risk of injury limit indications of this fixation method.[17] CT is the most reliable imaging modality for the determination of the pedicle length and axis and length of the screw.[18]

Prevention is the best treatment modality for every type of complication. Perfect knowledge of the anatomy, attention to anatomic markers, careful evaluation of preoperatively obtained images, and use of modern auxiliary systems can decrease the risk of pedicle screw malposition. Many vascular structures including azygos vein in the thoracic region, intercostal artery, inferior vena cava and aorta, in the lumbar region primarily aorta, and common iliac vessels are under jeopardy.[7]

Since vascular injuries can be life threatening for the patient, they should be recognized at an early stage. In emergency conditions, after application of direct vascular suturing or embolization, repositioning can be performed. In asymptomatic patients with malpositioned screws close to vascular structures, repositioning is debatable. Some authors find revision procedure very risky. Foxx et al.[19] detected that 33 of 680 screws implanted in the thoracolumbar region were in contact with a major vessel. In none of the patients, any symptom and sequela were not found because of vascular contact. Some other authors have emphasized that because of persistent bumps of the screw on the vessel, secondary lesions might develop at the site of contact (i.e., lacerations and pseudoaneurysms) which necessitate implementation of revision procedures.[7]

To minimize the development of such complications which might resist treatment and cause problems, accurate evalua-

tion of the pedicle morphology and selection of the appropriate screw before the operation convey importance.

We combined our data with those of the literature and demonstrated that for the mid-thoracic spine level, 4 mm and for upper and lower thoracic spine levels 4 mm screws can be used safely. Because of very small sagittal and transverse angles at the levels of middle and lower thoracic spine, pedicular screws should be placed in nearly vertical planes. Entry point of the pedicle is on the middle transverse line at upper thoracic levels and near the upper edge of the transverse process for lower thoracic levels. For upper and lower thoracic levels, implantation of 25–30 mm screw appears to be a safe procedure. If possible, pre-operative determination of the screw size using computer-assisted software programs compatible with morphologic characteristics of patient's thoracic vertebra will decrease complication rates.

Conclusions

Because of its small size and closeness to neurovascular structures, screw fixation of thoracic pedicle has a narrow safety margin. Pedicular morphometric characteristics differ between genders. Significant differences and correlations exist between the left pedicle and the left chord in male and female patients and patients with different ages. Screw fixation of thoracic pedicles is frequently performed under fluoroscopy. If possible, preoperatively, acquisition of computer-assisted morphometric analysis is recommended so as to refrain from unwanted complications and also plan placement of the implant and determine its appropriate dimensions. The data obtained can be used as a guide to determine the implant size and intraoperative management of T12 vertebral pedicle.

Ethics Committee Approval: This study approved by the İstanbul Medeniyet University Goztepe Training and Research Hospital Ethics Committee (Date: 20.11.2019, Decision No: 2019/0412).

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ORİJİNAL ÇALIŞMA - *ÖZET*

Torasik aortaya en yakın ve travmaya en fazla maruz kalan 12. torasik vertebranın morfometrik çalışması

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AMAÇ: Korpusun anterior korteksinin perforasyon riskinin ve önlenebilir büyük vasküler zedelenmelerin azaltılması amacıyla 12. torakal vertebra seviyesinde sol kord uzunluğu, sol pedikül uzunluğu ve uygun vida uzunluğunun cinsiyetler arası farklılıklarını tanımlamak.
GEREÇ VE YÖNTEM: Çalışmada 25 yaşından büyük (25–40 yıl), spinal travma bulgusu olmayan 60 hastanın (30 erkek, 30 kadın) T12 vertebra pediküllerinin torakal aksiyel kemik pencere BT görüntüsü alınarak morfometrik verileri analiz edildi.
BULGULAR: T12 sol kord uzunlukları erkek (38.17±2.54 mm) ve kadınlarda (36.62±2.27 mm) karşılaştırılarak, istatistiksel anlamlı bir fark bulunmuştur (p=0.016). Sol kord uzunluğu (37.40±2.51) (32–44 mm) ile yaş (31.93±3.91) (25–40 yıl) arasında istatistiksel olarak anlamlı bir fark ve orta derecede korelasyon görülmüştür (p=0.002, r=0.401). Sol kord uzunlukları (37.40±2.51) (32–44 mm) ile sol pedikül uzunlukları (12.12±1.34) (10.0–15.80 mm) arasında istatistiksel açıdan anlamlı farklılık ve orta düzeyde korelasyon saptanmıştır (p=0.001, r=0.577).
TARTIŞMA: Sol pedikül ve sol kord uzunluğu ile yaş ve cinsiyet arasında anlamlı farklılıklar ve ilişkiler mevcuttur. Elde edilen bilgiler implant boyutu ve intraoperatif T12 vertebra pedikülünün yönelimi için bir yol gösterici olarak kullanılabilir.
Anahtar sözcükler: Anatomi; aorta; pedikül morfolojisi; pedikül vidası; torasik omurga.

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