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Research Article
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CT Evaluations for C2 Pedicle Screw Fixation: Multiplanar Computerized Tomography Measurements in 100 Moroccan Patients

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Abstract

Background: Transpedicular screw fixation in the Axis is difficult due to its relation with adjacent anatomic features. Successful placement requires a sufficient understanding of axis pedicle.

Objective: The aim was to assess length and width of the C2 pedicle in Moroccan population in order to evaluate the safety of pedicle screw fixation.

Patients and methods: We evaluated the C2 pedicle morphology using computed tomography (CT) imaging in 100 patients (30 females and 70 males; age range, 18–70; mean, 36,2 ± 11,9 years). Axial CT cutting was made at 1.25 mm intervals**.** The measurements of C2 pedicles were performed on CT images using its measurement tools. The pedicle transverse width was defined as the mediolateral diameter of the pedicle isthmus. Pedicle length (distance from the posterior cortex of the lateral mass to the middle of the vertebral body).

Results: The overall mean pedicle transverse widths (PTW) were 5.3 mm (4.1 to 7.1 mm), in males were 5.2 ± 0.5 mm and 5 ± 0.4 mm in females. The overall mean pedicle lengths (PL) were ranged from 19,7 to 26.7 mm with average 22.5 mm. The mean PL in female was 21.8 ± 1.4 mm and 22.8 ± 1.7 mm in male. The mean PTW and PL were greater in males than in females at both sides, and this difference was statistically significant. On the other hand, they were not correlated to age in our adult patients.

Conclusion: Our findings suggest that there were significant differences between individuals and ethnics. The preoperative CT scans undergoing cervical transpedicular fixation should be thoroughly analyzed for successful pedicle screws placement.

Keywords: Anatomy; Axis; Computed tomography; Transpedicular fixation

Introduction

There are many causes of cervical spine or occipito-cervical instability, such as trauma, degenerative disease, neoplasm, malformation, and infection. C2 transpedicular screw fixation (TPSF) is one of the most advanced procedures currently used to treat spinal instabilities. But successful placement of pedicle screws in C2 requires a sufficient three-dimensional understanding of pedicle morphology especially it length and weight to ovoid neural or vascular complications. Several cadaveric and radiological anatomical studies of the cervical pedicle have been reported in European, American in addition to Asian populations [1-3]; but no study of C2 pedicle was reported in Africa in our knowledge. It reported possible ethnic differences in pedicle dimensions, which in turn may have impeded the development of consistent methodologies for assessing the feasibility of TPSF placement among different ethnic populations.

The goal of the present study was to evaluate assess length and width of C2 pedicle, calculated from computed axial tomography examinations for surgical application, in Moroccan population and we then analyzed these data for ethnic similarities and disparities.

Patients and Methods

This study involved evaluation of C2 pedicle CT of 100 Moroccan patients admitted to our institution between Marsh and October 2015, for the assessment of the cranio-cervical spine. The patients included in this study aged 18 years and older, including 33 (33%) females and 67 (67%) males. Overage was 36,2 ± 11,9 years (range, 18–70 years) of all the patients. Mean age was 42 years (18 – 70 years) in females and 32 years (18 – 57 years) in males. CT cutting was made at 1.25- mm intervals in axial plan.

The pedicle transverse width (PTW) was defined as the out medial-lateral diameter of the pedicle, taken perpendicular to the axis of the C2 pedicle and measured in millimeters +/- 0.1 mm. The levels measured were the mild of C2 pedicle bilaterally (Figure 1). The mean diameter was taken as the mean diameter of the right and left pedicles of the 100 patients studied.

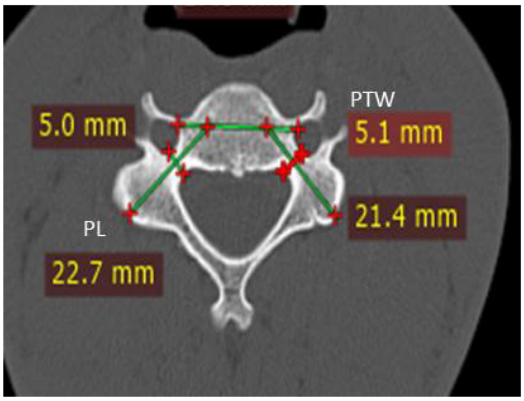

Figure 1: CT image of horizontal planar reconstruction through the C2 pedicle. (PL: Pedicle Axis Length, PTW: Pedicle Transverse Width).

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C2 pedicle length (PL) was determined from the posterior cortex of the lateral mass to the middle of vertebral body along the pedicle axis (Figure 2), corresponding to usually used screw length.

Axial CT images were obtained using 1.25 mm thickness slices. All those pedicle parameters were determined using bony windows which providing the most detailed osseous anatomy. We measured the dimensions of the pedicles from images of multiplanar reformations by Radian Dicom Viewer software. The measurements were performed by confirmed radiologist.

Statistical analysis

Statistical analysis was performed using SPSS software (version 22; SPSS IBM, Inc., Chicago, IL). Continuous variables were analyzed using t test and categorical variables were analyzed using Chi-square test.

Paired t test was used to compare the parameters in males and females and between the right and left. The level of significance was fixed at 0.05.

Exclusion criteria

The no Moroccan patients and who had cervical abnormalities were excluded from this study.

Ethics

No ethical approval was required for this study. The patients were informed of the exam subject and all information was used with confidentiality.

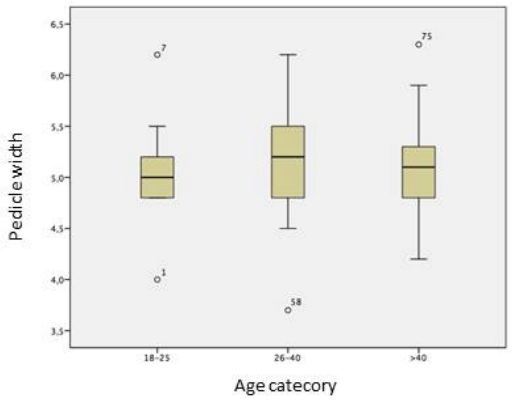

Figure 2: Pedicle width distribution according to age.

Pedicle Length			
Gender	**Right (mean)**	**Left (mean)**	**P**
Female	19.7-24.5 mm (21,788)	18.7-25.1 mm (22,073)	0.09 NSD§
Male	19.7-26.7 mm (21,800)	19.7-26.7 mm (22,948)	0.09 NSD§
P	0.004 SSD*	0.016 SSD*	
• SSD: Statistically Significant Difference, § NSD: No Significant Difference			

Table 1: Pedicle transverse length based on CT measurement.

Pedicle Width			
Gender	**Right (mean)**	**Left (mean)**	**P**
Female	4.0-5.6 mm (5,006)	4.1-5.9 mm (5,121)	0.002*
Male	3.7-6.7 mm (5,213)	4.1-7.1 mm (5,343)	0.002*
P	0.04*	0.052§	
* SSD: Statistically Significant Difference, § NSD: No Significant Difference			

Table 2: Pedicle width based on CT measurement.

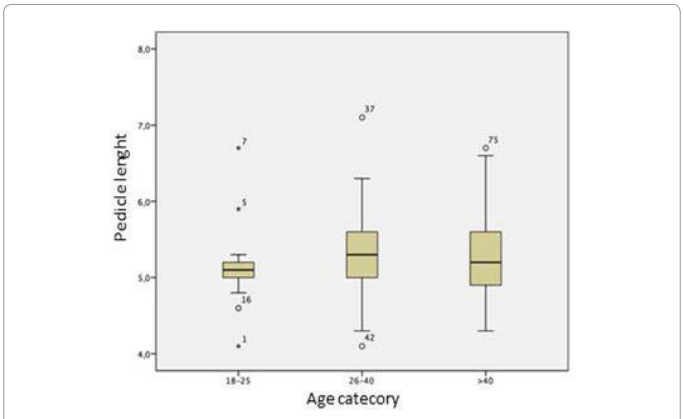

Figure 3: Pedicle length distribution according to age.

Results

One hundred patients comprising 200 C2 pedicles were evaluated (i.e., 200 right and left pedicles). The means standard deviations (SD) of the diameter and length parameters were calculated at both sides for male and female patients separately. The results are summarized in Tables 1 and 2.

PL

The overall mean PL ranged from 19.7 to 26.7 mm with average 22.5 mm (Table 1). The mean PL in female was 21.8 ± 1.4 mm (SD is 1.4 mm; 95% confidence interval is 12.1- 1 mm), and 22.8 ± 1.7 mm in male (SD is 1.7 mm; 95% confidence interval is 12.1- 13 mm) in the right and 22.1 ± 1.4 mm (SD is 1.4 mm; 95% confidence interval is 12.1-13 mm) and 22.9 ± 1.8 mm (Standard deviation is 1.8 mm; 95% confidence interval is 12.1- 13 mm) in the left respectively. There were statistically significant differences (*P:* 0.004) in PL between males and females.

PTW

The overall mean PTW ranged from 4.1 to 7.1 mm with average 5.3 mm (Table 2). The mean right PTW in female was 5 ± 0.4 mm (SD is 0.4 mm; 95% confidence interval is 12.1- 13 mm) and 5.2 ± 0.5 mm in male (SD is 0.5 mm; 95% confidence interval is 12.1- 13 mm). It was 5.1 ± 0.5 mm (Standard deviation is 0.4 mm; 95% confidence interval is 12.1- 13 mm) and 5.3 ± 0.5 mm (SD is 0.6 mm; 95% confidence interval is 12.1- 13 mm) in the left respectively. The mean PTW was greater in males than in females. The difference was statistically significant (P value: 0004). It's also significantly greater in the left (5.3 ± 0.5 mm) than in the right (5.1 ± 0.5 mm) (P value: 0.002).

We have analyzed pedicle width and length according to age patients and we found that they were not correlated to age in our adult patients and does not undergo a normal distribution going from one age group to another (Figures 2 and 3).

Discussion

Transpedicular instrumentation is a standard way to stabilize the spine in degenerative conditions, trauma treatment, tuberculous spondylitis, and tumor reconstruction as well as in occipito-cervical deformities. The cervical pedicle is a very narrow and precise anatomical structure that demands its morphological study and extreme care when targeted for procedure. Leconte in 1964 was the first to describe the use of C-2 pedicle screws in the management of traumatic Spondylolisthesis [1]. Their work demonstrated that using the C-2 pedicle as an anchor for the stabilization of occipito-cervical

instability could be performed safely and provide excellent results. This technique did not gain widespread attention until Roy-Camille and colleagues [4] reported its use in the treatment of C-2 related instability in 1989. Several methods have been used to stabilize the upper spine but the pedicle is the principal element which provides the strongest point of attachment to the spine, with the best bony purchase [5].

However, transpedicular screw fixation placement in the Axis is difficult and not widely performed because of its complex morphologic features which allows for very limited screw space. This technic has certain risks due to C2 relation with many adjacent vulnerable neural and vascular structures adjacent to the narrow cervical pedicle, leading to an increased risk of complications from pedicle violation. Additionally, anatomic variations between ethnics and individuals in the size and shape of cervical pedicles limit the application of pedicle screws.

Morphologic studies of the cervical spine have been reported as a way to evaluate the feasibility and safety of the technique. Both cadaveric and radiologic studies showed that the diameter of the cervical spines is adequate for screw fixation [1,6,7]. In contrast to the manual measurement data from cadaver specimens, the ability of CT to perform measurements in living subjects offers the prospect of acquiring information that is more accurate. The anatomic measurements can be different to those with CT as reported by Okuyama K et al. [8]. In addition, that CT studies are easier, more feasible and bellow several samples evaluation. Our CT study was performed in this aim to evaluate C2 pedicle dimensions.

Pedicle length depends on measurement methods. This accounts for the difference pedicle length reported in those studies. In previous anatomical [9-11] as CT evaluation [6,12] reports investigators defined the length as the distance from the posterior surface of the C-2 inferior articulating process to the anterior surface of the vertebral body (range 25.4 mm – 28.8 ± 3.4 mm). Howington JU et al. [1] chose to define the length as the distance from the posterior surface of the inferior articulating process to the junction of the pedicle with the vertebral body (mean 7.9 mm, range 6.4 to 9 mm). We chose to define the length as the distance from the posterior surface of the inferior articulating process to the middle of vertebral body (mean 22.5 mm, range 19.7-26.7 mm).

The average length of the C2 pedicles measured in this study do not differ significantly from those reported in Asian population which used the same criterias. It was 22.6 ± 1.7 mm in our African population and 23.5 ± 2.3 mm published by King NK et al. [13]. But differ significantly from European/American studies with greater length (25.4 mm – 28.8 ± 3.4 mm) [14,15].

Many articles that we reviewed showed, as in our study, that mean PL was significantly greater in males than in females [14,16]. The mean PL was in males (22.8 ± 1.7 mm) and in females (21.8 ± 1.4 mm). However no significantly differences were reported in studies of Naderi et al. [15] and Xu et al. [11].

Outer pedicle width dimensions of C2 in this study (average, range of 5.2 ± 0.5 mm) were similar in both as in females to those in Asian [13] and European [17] studies who reported an average range of 5.2 to 5.4 mm and 5.18 ± 1.25 mm respectively. It showed also that PTW was smaller-sized compared to the result of Jay U et al. [16], Tomasino et al. [18] and Sakamoto et al. [19] with an average range of range 6.4–9 mm, 5.6 ± 1.2 mm and 5.5 – 7.7 mm respectively. This study concludes that pedicle diameter was smaller in females compared to male patients. This difference is statistically significant in the Moroccan population, than exists in the European/American and Asian populations [6,7].

It is well known that bony measurement differs across gender and human races [20]. The cervical pedicles of Asian populations are smaller in most dimensions than Europeans and Americans but similar to Moroccan subjects. And in both races, female display smaller pedicles than their male counterparts [3,6].

When comparing sides, statistically significant differences were also found between right and left pedicle axis especially in width than in length. The mean PTW is slightly greater on the left side as compared to the right side [2]. However, many CT study concluded in a that there was no significant difference in transverse diameter between the right and left pedicles in both male and female patients [3,12,19].

Therefore, it is important to keep the gender and race of patients in mind when evaluating and planning for transpedicular screw fixation. Thus, a study of pedicles in a regional population is essential for the assessment of the pedicle condition and determination of the pedicle size that also allows surgeons to decide appropriate pedicle screw size and insertion technique. The results of this study can be used to answer numerous research questions about C2 pedicle size in Moroccan and African populations, identifying significant differences concerning age, gender and geographical race in order to choose the adequate screw size. Pedicle fracture and/or damage of the neurovascular structures may occur if the size of the screw is not less than 2 or 3 mm as that of the pedicle. For this reason, the minimal pedicle dimensions as well as the outer and inner pedicle diameter must be determined [12,21].

Conclusion

Significant knowing and understanding of the pedicle size and morphology, its relation with adjacent structures, namely, the vertebra artery, the spinal cord and nerve roots, may enhance the safety of transpedicular screw fixation. Because of these concerns, preoperative computed tomography (CT) scans data, are essential for successful intraoperative screw placement. We believe that the data from this study will substantially increase the spinal surgeon's understanding of the C2 pedicle of the Moroccan people.

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