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ORIGINAL ARTICLE

QUANTITATIVE ANATOMICAL EVALUATION OF C7 VERTEBRA IN TURKISH POPULATION IN ORDER TO IMPLANTATION OF LATERAL MASS AND PEDICULE SCREWS

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ABSTRACT

Objective: The purpose of this study is to evaluate the anatomical features of C7 vertebra using some specific measurements in order to select the most appropriate screw for implantation of lateral mass and the pedicle.

Material and Method: We retrospectively enrolled 100 consecutive patients who were admitted to our hospital's emergency Computed Tomography (CT) department suffering from general body trauma in order to evaluate a potential cervical injury with cervical CT. All subjects are Turkish and 18-60 years old. Patients with cervical fractures or malignancies, anatomical variations, cervical deformity, previous cervical surgery were not included in the study. Pedicle width, pedicle screw length and lateral mass screw length were measured in multiplanar reconstructed CT images at workstation. The mean values in Turkish society were determined and these measurements were compared with the previous studies including other societies.

Results: The mean pedicle length, mean pedicle with and mean lateral mass screw length were 29.1 ±1.1, 6.3 ±0.3, 13.5 ±0.6 respectively. Pedicle screw length was higher in men than women and this difference was statistically significant. Additionally, when compared to other studies in the literature, the length of lateral mass screw was higher in Turkish population and this difference was also statistically significant.

Discussion: C7 vertebra is a transitional vertebra with difficulties in fixation due to its close relation with important anatomical structures. This level is also known as the transition between the lordotic cervical vertebral column which is quite mobile and kyphotic thoracic vertebral column which is fixed biomechanically. When planning the fixation of the cervicothoracic region with instrumentation, it has some difficulties for the spine surgeons due to its anatomical features. Compared to other studies in the literature with Magerl technique usage in measurements, the lateral mass screw length in Turkish society is statistically different than other races. Our study is the first study about the anatomy of C7 vertebra in Turkish society.

Key Words: Morphometric analysis, transitional vertebra, lateral mass fixation, pedicule screws

Level of Evidence: Retrospective clinical study, Level III

INTRODUCTION

Although C7 vertebra is a cervical vertebra, it has similar features to the thoracic vertebrae since it is at cervicothoracic transition level. Compared to other cervical vertebrae, it's transverse process is more prominent, and the spinous process is longer and not bifid [12]. In addition to these anatomical differences, this is the level of transition between the biomechanically mobile lordotic cervical spine and fixed kyphotic thoracic spine [4]. Considering that this region is a complex area associated with increased biomechanical stress, difficulty in radiographic imaging and closeness to neurovascular structures, C7 vertebrae instrumentation can be associated with significant morbidity and mortality rates [29].

Sub-axial cervical instability can be caused by the etiologic factors such as trauma, tumor, infection and degenerative diseases [16, 22, 29]. Some spinal instruments are used in order to make the fixation of unstable cervical spine in these clinical conditions [21, 29]. In the last half-century, spinal reconstruction and fixation has been a major advance in both spinal instrumentation and surgical techniques [29]. Because of the aforementioned biomechanical and anatomic features of C7 vertebra, it is very important to determine the most appropriate instrumentation at this level which creates difficulties for spine surgeons [14]. The lateral mass and pedicle screws are often preferred instruments for posterior stabilization of this region [11, 18]. The C7 lateral mass is smaller and thinner than the other sub axial cervical vertebrae. It has a lesser width in the sagittal plane and a steeper angle than the lateral mass of the other cervical vertebrae. The length of the C7 lateral mass screw is therefore restricted [26]. Also, spinal nerve roots and vertebral arteries are close to the lateral mass and there is a risk of injury during screw insertion [21]. Improper screw placement may result in violation of facet joint (C7-T1) and potentially penetration of C7-T1 neural foramen [1]. However, the short screw reduces the pull-out force [26]. On the other hand, It is difficult to place the pedicle screw through C7 vertebra due to the small size of the C7 pedicles and the variability in the pedicle morphometry, the steep converging angle, the lack of a significant entry point for the screw placement, the difficulty of radiological imaging and the critical structures near the pedicle [11].

Morphology of the cervical spine pedicles and lateral mass structures has been evaluated extensively with both cadaveric and computed tomography studies. The studies in the literature have been conducted in different populations and mean values may vary across societies [1,8,18,23,26].

Since the cervical spine pedicles and lateral mass structure in our population may be different from other populations, preoperative evaluation and understanding of their morphology in a quantitative manner will minimize the risk and improve the successful surgical outcome. According to our knowledge, there is no study in Turkish society in the literature. Our aim in this present study was to evaluate the quantitative anatomical features of C7 vertebra in Turkish population in order to understand and to decide the appropriate lateral mass and pedicle screws for using in cervical vertebral stabilization.

MATERIAL AND METHOD

We retrospectively enrolled 50 consecutive patients who were admitted to our hospital's emergency Computed Tomography (CT) department suffering from general body trauma in order to evaluate a potential cervical injury with cervical CT. All subjects are Turkish and 18-60 years old. Patients with cervical fractures or malignancies, anatomical variations, cervical deformity, previous cervical surgery were not included in the study. Pedicle width, pedicle screw length and lateral mass screw length were measured in multiplanar reconstructed CT images at workstation. Lateral mass and pedicle measurements were done using Margerl's technique [13]. The starting point was 1 mm medial and superior to the center of the posterior lateral mass in the 3D reconstructed image (Fig. 1A). We then obtained a reformatted image superiorly elevated 45 degrees based on the start point, which was tilted 45 degrees with respect to the vertical plane along the posterior border of the C7 lateral mass (Fig. 1B). The screw length was then measured at a trajectory of 25 degrees angulated laterally on the axial plane (Fig. 1C). Pedicle width was measured on a reformatted image. The width was the outer cortical width of the isthmus that was parallel to the pedicle axis and at the mid-point of the pedicle height (Fig. 2). The mean values in Turkish society were determined.

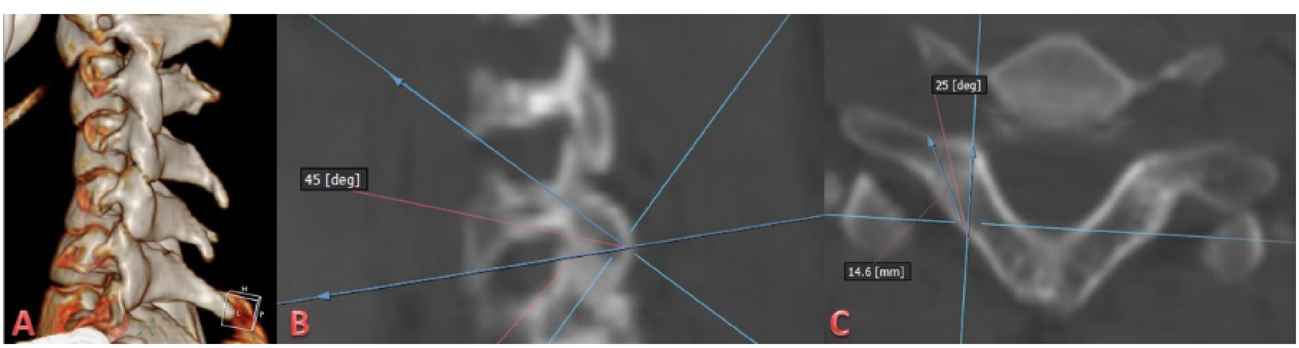

Figure-1.A-C. Measurement of lateral mass screw length in 3D volume-rendering and multiplanar reconstructed CT images.

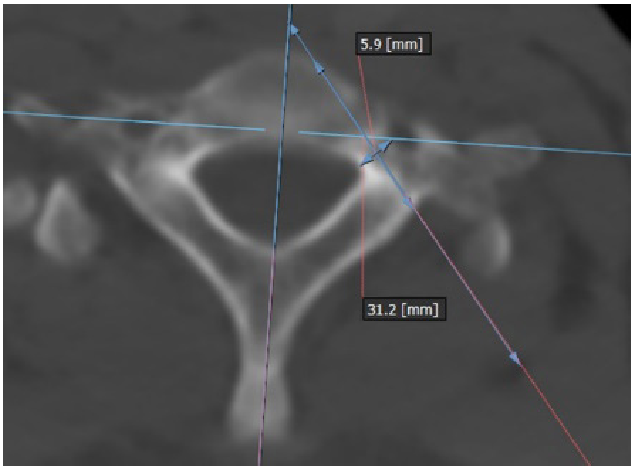

Figure-2. Measurement of pedicle width and pedicle trajectory in axial CT image.

Statistical Analysis

The analyses were performed by using the SPSS software (Statistical Package for the Social Sciences, version 20.0, SPSS Inc, Chicago Illinois, USA). Descriptive statistics; mean, the standard deviation was given for numerical variables. The independent simple t-test was used for the comparisons between the two independent groups when the numerical variables provided the normal distribution condition. Statistical significance was accepted as $p < 0.05$.

RESULTS

Mean age was 39.7 ± 14.6 (18-60) in 50 consecutive patients (25 male and 25 female). Mean pedicle length (PL) was 28.8 ± 1.2 in females and 29.4 ± 0.9 in males. Among these two groups, male's PL was longer and there was a statistically significant difference ($p < 0.05$). Mean pedicle width (PW) was 6.3 ± 0.3 and the lateral mass length (LML) was 13.5 ± 0.6 in all patients (Table-1).

The mean PW and LML values were similar in males and females and there was no statistically significant difference.

Table-1. PWO: pedicle outer cortical width, PL: pedicle length, LMSL: Lateral mass screws length results of patients.

	PWO	PL	LMSL
All patients	6.3±0.3	29.1±1.1	13.5±0.6
Male	6.3±0.3	29.4±0.9	13.6±0.5
Female	6.2±0.2	28.8±1.2	13.5±0.8
P value	*0.091*	*0.048*	*0.984*

DISCUSSION

Since C7 vertebra is a transition level in cervicothoracic spine and the lateral mass is thinner than the others, it is hard to perform the classical bone fixation method. Hereby, the angle of lateral mass screw placement should be changed [27-28]. There are many methods related to mass screw placement technique have been defined in the literature. First, Roy-Camille et al. described lateral mass screw insertion technique [24]. Louis et al. [20], Magerl et al. [13] and Anderson et al. [5] described other alternative techniques to reduce the risks associated with screw misplacement, such as adjacent nerve root lesions, vertebral artery injuries, and adjacent lateral mass damage. However, there are contradictory results in the literature regarding each technique. Because of the lateral mass of C7 vertebra was smaller than that of the other cervical vertebrae, it was stated in some studies that the lateral mass screws for the C7 vertebra were not strong and robust [11,18] and that the pedicle screw should be the first choice for posterior stabilization in C7 [11,17-18]. C7 cervical spine pedicle screw was first proposed as an alternative fixation method of this region by Abumi et al. [2]. However, the different morphological features of C7 also cause difficulty in the placement of pedicle screws [29]. Therefore it is not clear which technique is safer. It is important to quantify the anatomical structure of the C7 vertebra to avoid complications and to select the best surgical technique. The use of preoperative CT imaging in C7 vertebrae implantation is useful for visualizing and understanding the size of the pedicle as it visualizes the relevant bone anatomy. It is also important to know the relationship of pedicle to the vertebral artery in the lateral aspect and the spinal canal in the medial aspect in order to plan a secure and effective fixation. These valuable informations can be evaluated with CT in the preoperative period [4].

Studies comparing the fixation strength between lateral mass screws and pedicle screws have shown that the cervical pedicle screws have significantly higher pull out strength than the lateral mass screws [14-15]. However, the cervical pedicle screw has a risk of breaking the pedicle wall by % 6.7-13 and it is stated that we should consider the decrease in the pull out force when the screw comes out of the pedicle wall [3, 26]. It is reported a 21 % reduction in the average pull-out force when the lateral pedicle wall was broken in a biomechanical study examining the effect on the pull-out force in the thoracic pedicle screws in cases where the pedicle wall was broken [6]. It is therefore important to evaluate the width of the preoperative pedicle and choose the correct screw thickness. As stated in the latest anatomical studies of the cervical spine, pedicle widths increase from C3 to C7 vertebrae. The mean pedicle width in C3 and C7 vertebrae were reported in the literature as 4.76 ± 1.1 mm and 6.56 ± 1.2 mm respectively.

Jang et al reported in their study of Korean population that the width of the pedicle was 6.8 ± 1.2 mm and the length of the transpedicular screw was 33.9 ± 3.1 mm [12]. In this present study; we demonstrated that the mean outer cortical width of pedicle was 6.3 mm (range 5.7-6.9) in Turkish population. Additionally, mean transpedicular screw length was 28.8 ± 1.2 in females and 29.4 ± 0.9 in males and it was significantly longer in males ($p<0.05$). We found that pedicle width and screw length are shorter when compared to the study in Korean population. Assuming we use a 3.5 mm pedicle screw, a minimum pedicle diameter of 4.5 mm is required to allow at least 0.5 mm bone wall, both medially and laterally. Considering the fact that pedicle structure can show differences between different societies, it is clear that this should be taken into consideration when selecting the thickness of the appropriate screw.

It is also reported the length of lateral mass screws in some studies in the literature. These articles pointed out that the screw length in the Magerl technique was a few millimeters longer than the Roy-Camille technique [9,21,25]. However, in a study on cadaver, the biggest difference between these values was found to be only 1 mm. Therefore, there was no significant difference in clinical practice [21]. It is compared the bicortical screws with longer unicortical screws in lateral mass fixation in a biomechanical study of 11 human cadavers for construct stiffness. It was stated in mentioned study that there was no significant difference in construct stiffness between long unicortical screws and bicortical screws if the patient did not undergo laminectomy. Muffoletto et al. reported that the unicortical lateral mass screws had an equal pull-out force compared to bicortical placement and recommended the use of unicortical screws to reduce the risk of neural or arterial injury [19].

Bicortical screws can potentially cause injury to the nerve root and vertebral artery and may damage the facet joints. It is important to understand the anatomical features of the ventral lateral mass which is the exit of the lateral mass screws in order to avoid these complications [21]. The risk of vertebral artery injury by lateral mass screwing is considered to be relatively low compared to the use of pedicle screws. On the other hand, nerve root injury is a more important concern in lateral mass screwing since it is more common than vertebral artery injury [21].

The vertebral artery enters the transverse foramen at the level of C6 vertebra during its normal anatomical course. But the entry point is known to be the C7 vertebral level in 0.8 % of the population [7]. Graham et al. stated in their study that there was a risk of radiculopathy at 1.8 % without any spinal cord or vertebral artery injury in lateral mass screw placement and especially the risk of C8 nerve root injury during bicortical screw insertion [10]. Abumi et al. reported the cases of vertebral artery injury in one patient and radiculopathy in two patients without an incidence of spinal cord injuries in their study with 180 patients who underwent cervical pedicle screw fixation. They also mentioned 6.7 % of the screws breaking the pedicle wall in their series [3]. Preoperative evaluation of the appropriate lateral mass screw length is important to prevent complications. Stemper et al. reported a mean C7 lateral mass length of 9.6 mm in women and 9.8 mm in men with Magerl technique [25]. Jang et al. reported a mean lateral mass length of 10.6 mm [12]. In a recent study in Chinese population, the average lateral mass length was reported as 13.2 mm [26]. A reasonable length of unicortical screw for C7 lateral mass was determined as 13.5 ± 0.6 mm for Turkish population with the Magerl technique in our study. While the average value in Turkish population has higher values than the first two aforementioned studies, we see that it has close characteristics with Chinese population.

The most important limitation of our study is the small number of cases. The other limitation of our study is that we did not make statistical comparisons with studies in other societies.

CONCLUSION

C7 vertebra is an anatomically and biomechanically complex area that complicates the decision of vertebral instrumentations. Since the selection based solely on anatomy of lateral mass or pedicle screw insertion for C-7 vertebrae is not a clear, other factors also should be considered. According to studies conducted in other societies, choosing standard pedicle screw thickness in Turkish society may cause fracture in the medial or lateral pedicle wall and decrease in pullout strength or damage of neurovascular structures. We think that anatomical evaluation with preoperative CT should be taken into account and social differences should be considered in the selection of screws in order to minimize the complications

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