Ann Med Res

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Annals of Medical Research

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Accuracy and reliability of free hand C7 pedicle screws in posterior cervical fixation

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ARTICLE INFO

Keywords:
Cervical vertebra
C7 vertebra
Pedicle screw
Free hand

Received: Jun 21, 2023
Accepted: Aug 14, 2023
Available Online: 25.08.2023

DOI:
10.5455/annalsmedres.2023.06.142

Abstract

Aim: Lateral mass screws are widely used for cervical vertebra fixation. The lateral mass of the C7 vertebra is small in volume. Therefore, the potential risks of biomechanical failure of screws applied to lateral masses make the pedicle screw a better option for the C7 level. Although cervical pedicle screw application is thought to be a difficult and risky procedure in terms of neurovascular injury, it is actually a very safe method since a.vertebralis does not pass through the C7 vertebra. In this study, we aimed to evaluate the technical details and screw accuracy of free hand pedicle screw placement in C7 vertebra fixation.

Materials and Methods: Forty-six patients (92 screws) who underwent free hand pedicle screw placement in the C7 vertebra due to various cervical pathologies were included in this study. Measurements were made on routinely obtained preoperative and postoperative CT images. Screw malpositions and screw application angles, such as the pedicle screw causing a cortical violation in the bone structure or its progression towards the spinal canal and vertebral foramen, were carefully examined.

Results: Postoperative CT imaging revealed grade 2a cortical violation in 6 screws, grade 2b cortical violation in 1 screw, and grade 3 malposition in one screw. Radiculopathy was seen postoperatively in one patient. No vascular injury was observed postoperatively in any patients.

Conclusion: Placing a free hand pedicle screw in the C7 vertebra is a successful and safe method. At this point, we see the C7 pedicle screw application as a starting point in the learning curve for the entire cervical region pedicle screwing.

Introduction

In cases where posterior screws are required to be placed in the cervical spine, lateral mass screws, laminar screws or pedicle screws are often used. In all cervical spines except C1 and C7, the selected screws are chosen according to the surgeon's preference or the surgical situation. Since the lateral mass of the C7 vertebra is smaller than that of the other vertebrae, the pedicle screw is generally used as the first choice for posterior stabilization in the C7 vertebra [1].

Lateral mass screws are widely and effectively used in subaxial cervical spine fixation. In this region, pedicle screws are avoided because of the small pedicle structure and possible vascular-neural injury risk. Facet screws and intralaminar screws are used as the first choice or rescue method under appropriate conditions. C7, one of the subaxial vertebrae, differs from other subaxial vertebrae in terms of the risk of vascular injury, mostly because the vertebral artery does not pass through its transverse foramen. At the same time, unlike other levels, it is very difficult to get perop fluoroscopy help compared to other levels.

In 1994, Abumi et al. first described the method of inserting pedicle screws into the cervical spine, after which many researchers suggested various methods for this operation [2-4].

Screw placement in the cervical vertebral pedicle provides biomechanically stronger fixation than other cervical vertebra internal fixation methods. In screw application to the subaxial cervical vertebra pedicle, there is a notch at the pedicle level at the lateral edge of the lateral mass of the cervical vertebrae. The entry point for C3-C7 cervical vertebral pedicles is 3-4 mm medial to this notch and lateral to the center of the cervical vertebral lateral mass and just below the lower border of the inferior articular process of the upper cervical vertebra. In most patients,

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the anatomical direction of the pedicles of the C3-C6 cervical vertebrae is 40-50 degrees medially in the horizontal plane, and 30-40 degrees medially in the C7 cervical vertebra. While the screws are angled slightly towards the head for the C3 and C4 cervical vertebra pedicle in the sagittal plane, they are in the neutral position for the C5, C6, C7 cervical vertebral pedicles [5].

Pedicular screw fixation is a frequently used method in the treatment of spinal pathologies in recent years. However, since pedicular screw fixation is in close proximity, there is a risk of damaging neurological and vascular structures [6].

In this study, we aimed to evaluate the technical details and screw accuracy of free hand pedicle screw placement in the C7 vertebra.

Materials and Methods

This study was approved by the Health Sciences University Bağcılar Training and Research Hospital Non-Interventional Clinical Research Ethics Committee with the date 22.02.2022 and number 2022/01. The clinical and radiological records of 46 patients who were applied C7 free hand pedicle screws for C7 fixation, out of a total of 225 patients who underwent posterior cervical stabilization by our senior author between 2011 and 2022 in the Department of Neurosurgery at the University of Health Sciences, Bağcılar Training and Research Hospital, were retrospectively analyzed for the accuracy and reliability of instrumentation.

Of the 46 patients included in this study, 22 were male and 24 were female. The mean patient age was 57 ± 9.85 (age range 23-76). The mean age of women was 57.45, and the mean age of men was 56.5. 2-6 levels of instrumentation were applied, with the median value of the instrumentation level being 4 ± 2. Instrumentation was applied to 46 patients with a total of 92 C7 free hand pedicle screws.

Inclusion criteria for the study: being over 18 years old and having used a pedicle screw for C7 fixation in posterior cervical instrumentation due to degeneration or trauma. Exclusion criteria: being under the age of 18, having been operated for malignancy and having advanced osteoporosis.

MRI and CT scans were performed preoperatively in all patients who were scheduled for surgery. Postoperative measurements were made on CTs obtained routinely in cases where instrument was applied. In the preoperative MRI, the course of the vertebral artery and whether it passed through the foramen transversarum of the C7 vertebra were checked. The thickness and angle of the C7 vertebral pedicle and the ideal entry point of the pedicle screw were determined on the sagittal and axial sections of the preoperative CT. A free hand pedicle screw was applied to the C7 vertebra in all patients and postoperative neurological, vascular complications and screw malposition were recorded.

Surgical techniques

In the technique we call C7 freehand pedicle screwing, peroperative fluoroscopic imaging is used only for level detection in most cases. Although it is used from time to time in the first cases for screw entry point detection, its use for this purpose has been abandoned as it has no practical use. The operations were performed in the prone position with a spiked head. After level determination after midline incision and paravertebral muscle retraction, lateral mass screws are applied first. Then C7 pedicle screws are applied. The determination of the ideal entry point and screw delivery angles of the C7 pedicle screw is based on the calculation made on preop 2D CT. The ideal entry point is calculated by measuring the distance from the lower edge of the C7 superior facet to the line passing through the midpoint of the pedicle in sagittal slices and by measuring the distance from the midpoint of the C6-7 facet in axial slices (Figure 1). The craniocaudal entry angle is the angle that the line passing through the midpoint of the pedicle makes with the C7 lateral mass. The medial entry angle is the angle between the pedicle entry point and the midpoint of the anterior corpus wall with the coronal plane (Figure 1). We think that screw application should be done before laminectomy for many reasons. Performing a laminectomy first carries risks such as possible injury to the exposed cord during instrumentation, more epidural bleeding, and deterioration of anatomical signs. After the ideal screw entry point is found, the cortical bone is passed with a fast speed motor and advanced approximately 6-7 mm. The flat pedicle probe is advanced with the help of a hammer, and the corpus is entered by controlling it with a ball-tipped probe. Controlled advancement through the pedicle with the flat and ball-tipped pedicle probe is the critical stage of the surgery. Where this stage is due to the resistance against the surgeon, it can be advanced up to 32 mm according to the resistance encountered at this stage. Exit of the bony tissue after 10-12 mm probably indicates weaker lateral wall penetration. Screws longer than 16 mm remaining in the bone will have greater biomechanical durability compared to side mass screws. In lateral pen-

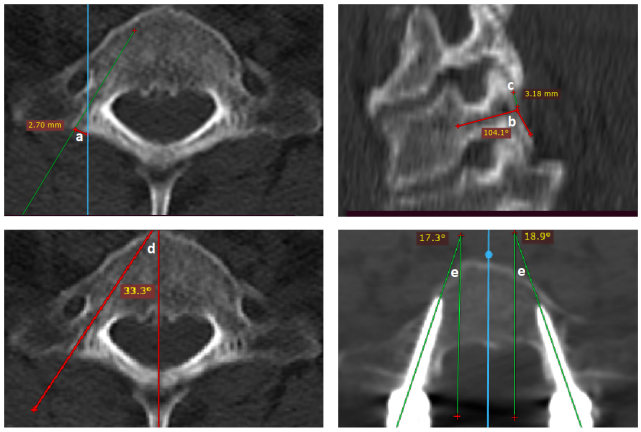

Figure 1. C7 vertebra pedicle ideal entry point and ideal entry angle. a: Distance between the midpoint of the C6/C7 facet joint and the ideal pedicle entry point (mm), b: Angle between the midpoint of the pedicle axis and the lateral body, c: Distance between the inferior edge of the C7 superior facet and the ideal pedicle entry point (mm), d: C7 pedicle angle.

etrations below this length, a new application is tried by increasing the coronal angle. If it is not possible to be sure that the pedicle screw is still in the pedicle, a C7 laminotomy is performed and a retry is made after the pedicle is detected. Decortication is performed after laminectomy. If necessary, the spiked cap is loosened, the neck is brought to the neutral position and the rods are put in place. An important technical problem during surgery is the difficulty of placing rods due to the misalignment of the C6 lateral body and C7 pedicle screws. To overcome this difficulty, the entry point of the C6 screw can be displaced 1-2 mm cranially and the entry point of the C7 screw 1-2 mm medially. However, since it is necessary to reduce the angle of the pedicle screw applied more medially in the coronal plane, the risk of lateral wall penetration arises. In addition to these methods, in cases with C4-5 lateral mass and C7 pedicle screw, bypassing the C6 vertebra is a practical solution that also shortens the surgical time. We think that the C7 pedicle screw will provide sufficient biomechanical strength in the distal of the system in these cases (Figure 1 and Table 1).

Results

Thirty nine (84.78 %) patients were operated with the diagnosis of cervical spondylotic myelopathy, and 7 (15.21 %) patients were operated for traumatic reasons. C7 pedicle screws were located in the distal part of the fixation plot in 35 (76.1 %) cases, proximal in 2 (4.34 %) cases, and in the middle in 9 (19.56 %) cases. A total of 92 free hand C7 pedicle screws were applied to 46 (100 %) patients. 86 pedicle screws were applied only according to the preoperative CT measurements. Additional mini laminotomy technique was used while applying 6 pedicle screws. All patients were controlled with postoperative CT. Unilateral grade IIa and unilateral grade 2b cortical violations were detected in 6 patients. Unilateral grade III malposition was seen in only 1 patient and revision surgery was performed (Table 1). In this study, the C7 pedicle screw was successfully and safely applied with a rate of % 91.3 on the right side, % 91.3 on the left side, and % 91.3 in general (Table 1).

Table 1. Parameters measured on Preoperative CT and Postoperative CT.

	Right	Left
	Mean± SD	Mean± SD
Pedicle thickness	7.48 ± 1.41	7.36 ± 1.4
Pedicle angle	33.97 ± 2.76	33.34 ± 2.52
Sagittal angle	96.67 ± 3.09	96.69 ± 3.01
Distance of screw entry point to facet midpoint	1.63 ± 0.79	1.58 ± 0.77
Distance of screw entry point to lower edge of proximal facet	2.78 ± 1.07	2.82 ± 0.9
Screw entry angle	25.32 ± 4.87	23.21 ± 4.46
Screw length	25.52 ± 3.32	25.39 ± 3.47
Incorrect number of screws	4 (8.69 %)	4 (8.69 %)
Grade 2a	4 (8.69 %)	2 (4.34 %)
Grade 2b	-	1 (2.17 %)
Grade 3	-	1 (2.17 %) (screw has been revised)
Number of screws applied with additional laminotomy	2 (4.34 %)	4 (8.69 %)
Number of screws applied with CT measurement only	44 (95.65 %)	44 (95.65 %)
Screw accuracy using both techniques (freehand)	% 91.3	% 91.3
Screw revision rate	-	% 2.17

Table 2. Complications.

Neurogenic Complication	1 (2.2 %) (radiculopathy)
Vascular Complication	-
Malposition	1 (2.2 %) (screw has been revised)

Complications

No vascular injury occurred in any of the patients, including a patient who was found to have passed through the foramen transversarum on the unilateral left side in the preoperative evaluation. No neurological complications developed in 6 patients with grade 2a malposition and 1 patient with grade 2b malposition. In one patient with grade 3 malposition, radicular pain and non-preoperative weakness developed. This patient's symptoms improved after screw revision surgery (Table 1 and Table 2).

Discussion

Laminar, translaminar, transfacet, and pedicle screws are posterior fixing options for subaxial cervical vertebrae [7]. Although it is well known that pedicle screws have a significant biomechanical resistance, there have been several research on lateral body screws, which are extremely simple to use for C7 fixation. In long-level posterior cervical spine fixation, lateral mass screws are equally secure and efficient as C7 pedicle screws, according to research by Zhang et al. Compared to pedicle screws, it is technically simpler to put and has a lower risk of postoperative complications [8]. According to research by Viswanathan et al., C7 Lateral Mass Screw, it is the most secure fixation technique for the majority of patients. Intralaminar screws and the C7 pedicle screw also provide biomechanical stability. The C7 has substantial anatomical variances, nevertheless, and only (40–60 %) of patients may benefit from these different screws. Therefore, before C7 fixation, a required, meticulous, and complete preoperative preparation should be carried out [9].

The pedicle screw is typically utilized as the primary choice for posterior stabilization in the C7 vertebra since its lateral mass is smaller than that of the other vertebrae [1]. According to research by Jang et al., the architecture of the C7 lamina is acceptable for laminar screw placement even though pedicle screw fixation is the most ideal instrumentation approach for C7 fixation in terms of length and cortical diameter. In situations when fixing the C7 pedicle screw is not acceptable, the C7 intralaminar screw may be an alternate fixation option [10]. Pedicle screws and laminar screws offer an equally robust fixation for salvage applications at the cervicothoracic junction, according to research by Hong et al [11]. The strongest structure

to maintain the cervicothoracic connection, according to Rhee et al., is provided by the C7 pedicle screw fixation [12]. These investigations demonstrate that pedicle screw implantation in the C7 vertebra results in a secure, reliable fixation.

Due to the misalignment of the C6 mass and C7 pedicle screws, the C6 mass screw is slightly displaced cranially and laterally similar to the technique described in a study by Clifton et al. We think that C6 mass screws may not be used in case of problems in rod placement [13]. In a study by Nagashima et al., it was reported that not applying a C6 mass screw may fail the C7 pedicle screw, which is in the most distal part of the system in long fixations [14].

In the C7 vertebra, the vertebral artery enters at a small rate (10-15%) through the transverse foramen, and thus placing the pedicle screw in the C7 vertebra poses a very low risk of arterial injury [15].

The pedicle screwing method in the cervical spine can be easily applied in these regions since there is no risk of vertebral artery in the C7 vertebra and upper thoracic region. However, there may be difficulties in imaging in this region with scopy. For this reason, the free hand technique is often used when placing a pedicle screw on the C7 vertebra [16].

In the literature, it has been reported by some authors that the use of fluoroscopic methods prolongs the operation time and increases the risk of infection. For this reason, they reported that this procedure can be performed without using fluoroscopic methods, together with a very good preoperative determination of the pedicle entry point and a good command of the surgical anatomy of the patient [17].

The diversity of cervical pedicles, according to research by Reinhold et al., makes preoperative CT examination with multi-plane reconstructions of pedicle anatomy crucial for transpedicular screw insertion in the cervical spine. Cadaveric investigations are still necessary to create safer, less complicated techniques [18].

In a similar study on C7 pedicle screwing, pedicle entry points were made on preop 3D CT. In this study, the midpoint of the C6 articular process was used in the vertical plane, while the superior lateral notch was used in the horizontal plane. The thickness of the pedicle angle, sagittal and transverse angles are similar to our study. However, in our study, only the midpoint of the C6 articular protrusion was used as a guide point in both the horizontal and vertical axis. The use of a single guide point facilitated the calculation and enabled calculation on 2D CT [19]. In another cadaver study, the point where the midpoint of the transverse body in the horizontal plane cuts the posterolateral isthmus in the vertical plane was found to be the ideal C7 entry point. This method requires more muscle retraction laterally [20]. Another anatomical study of the C7 pedicle entry point relied on a rather complicated calculation between the superior edge of the lamina C7 and the superior articular process. However, the ideal entry point shows similarities to our study [21].

When we examine the literature, the placement of pedicle screws is divided into four degrees from ideal to unacceptable. These are grades as follows :

I = pedicle centered screw

IIa = perforation of the pedicle wall less than a quarter of the screw diameter

IIb = perforation of more than a quarter of the screw diameter without contact with neurovascular structures

III = screwing more than one-quarter outside of the pedicle in contact with neurovascular structures [18].

Due to the mismatch between the diameter of the screws and the limited spongy bone space of the pedicle, a correct trajectory of the pedicle screw might result in first degree perforation. The vertebral artery is seen to be reasonably safe with a grade 1 perforation. The danger of vertebral artery damage or thrombus formation brought on by irregular blood flow may be significantly higher than those of grade 1 perforations, however, because grade 2 perforations reflect a large departure from the trajectory angle of the hand drill that directly enters the transverse foramen [22]. According to this grading, in our investigation, grade 2a cortical infringement developed in 6 screws, grade 2b violation in 1, and grade 3 malposition in 1.

There are many techniques in the literature for C7 vertebral pedicle screw placement, including freehand, CT-guided navigation, and fluoroscopic guidance [23].

A fresh free-hand method for inserting pedicle screws into the C7 vertebra was disclosed by Lee et al. This procedure is only carried out without fluoroscopic supervision and only with a surgical microscope. This method is simple to learn, has no neurological side effects, and has a low risk of cortical damage. This novel procedure results in a low percentage of cortical infringement and successfully places the C7 pedicle screw [1]. In our investigation, the cervical vertebrae's pedicle entry locations were identified using preoperative CT measurements without the use of fluoroscopy, and a free-hand pedicle screw was inserted into the C7 vertebra. According to us, this method is quite dependable and requires little training.

Desai et al.'s study used solely fluoroscopic imaging in the anteroposterior (A/P) plane to do an anatomical and clinical investigation to assess a method for pedicle screw implantation in the C7 vertebra. In order to determine the pedicle width, slope, and ideal entry site for pedicle screws, ten adult cadaver C7 vertebrae were utilized. On 28 patients who had posterior instrumentation to the cervical spine by inserting a C7 pedicle screw, prospective research was also carried out. The findings of this study suggest that this method is secure and appropriate for inserting pedicle screws in the C7 vertebra [25]. According to a study by Liu et al., the "slide technique" appears to be a safe, effective, and cost-effective technique for pedicle screw placement in the cervical spine [25]. In the study conducted by Schiffer et al., transpedicular screw placement in the cervical spine appeared to be successfully accomplished using intraoperative 3D C-arm guidance [26]. The fixing of posterior cervical structures at the cervicothoracic junction is a safe and viable alternative, according to the findings of a research by Clifton et al. and may be accomplished by inserting a free hand pedicle screw into the C7 vertebra. This study suggests that direct pedicle palpation with a minor laminotomy and free hand pedicle screw insertion on the C7 vertebra is a secure and reliable

technique [27]. As seen in these studies, many techniques have been reported in addition to the free hand technique to insert pedicle screws into the cervical vertebrae. In a study by Abumi et al., the rate of clinically important complications caused by cervical pedicle screw placement was found to be low. It was concluded that complications associated with cervical pedicle screw fixation can be minimized with adequate preoperative imaging studies of the pedicles and tight control of screw placement. In addition, they reported that pedicle screw fixation is safe [28].

According to a study by Yoshihara et al. based on the available literature, the rates of perioperative neurological and late biomechanical complications, including pseudarthrosis, appear to be similarly low for both lateral mass screw and pedicle screw techniques. In contrast, vertebral artery injuries are extremely rare with either technique, although statistically significantly more common when pedicle screws are used. Surgeons using both techniques should have a deep knowledge of cervical anatomy and have an adequate preoperative assessment for each patient [29]. As seen in these studies, cervical pedicle placement is a reliable method with a very low complication rate.

Although the accuracy rate of freehand applied C7 pedicle screws is high despite visualization difficulties, the error rate can be further reduced with peroperative neuromonitoring [30]. In our study, neuromonitoring was not used in most cases. The results of a study reporting the results of percutaneous cervical pedicle screwing performed with navigation methods seem similar to our study [31].

The C7 vertebra is located at the most distal part of the fiction in most fixation surgeries, as in our series. Considering that the distal part of the fixation setup is exposed to more biomechanical loads, short screws to be applied to small volume lateral bodies, especially in patients with poor bone quality, have the potential to be inadequate.

The facet screw to be applied to C7, on the other hand, will lead to an unnecessary increase in the number of fusion levels, since T1 superior facet will be used, as well as weak attachment strength. In addition, as in our series, most fixation cases require partial or total C7 laminectomy due to cervical spondylotic myelopathy. Laminar screw application is not possible in these cases requiring laminectomy. For these reasons, it is understood that lateral body, laminar and facet screws are not a realistic alternative to C7 pedicle screws, and C7 pedicle screw fixation is often not an option but a necessity.

Conclusion

Pedicle screws are surgeons' greatest weapon in spine fixation. This weapon is used by almost every surgeon in the thoracic and lumbar region. In the cervical region, many surgeons stay away from cervical pedicle screwing since many problems can be solved with simpler methods. But surgeons who frequently deal with spinal surgery in their daily practice will eventually need this weapon at all levels. At this point, we see the C7 pedicle screw application as a starting point in the learning curve for the entire cervical region pedicle screwing.

Ethical approval

This study was approved by the Health Sciences University Bağcılar Training and Research Hospital Non-Interventional Clinical Research Ethics Committee with the date 22.02.2022 and number 2022/01.

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