Easy method to simplify “freehand” subaxial cervical pedicle screw insertion

ABSTRACT

Study Design: Technical note.

Objectives: The objective of this study is to check out safety and rationality of standardized and fast tricks to select trajectory of subaxial cervical pedicle screw (SCPS) insertion, based on simple angles to bony landmarks.

Materials and Methods: Stage 1 – Computed tomography (CT)-morphometric analysis of C3–C7 vertebrae of ten patients with cervical degenerative diseases. Stage 2 – SCPS insertion in 6 cadavers, according to the developed technique (59 pedicle screws). Stage 3 – SCPS insertion in 6 patients, according to the developed technique (32 pedicle screws).

Results: CT-morphometric analysis showed that the average length of C3–C7 pedicle channels was 32 mm, the average angle between a pedicle axis and an axis of contralateral lamina - 180 , the average angle between a pedicle axis and plane of a posterior surface of a lateral mass amounted to 90 and the coordinates of an optimal entry point – 2 mm from a lateral edge and 2 mm from an upper edge of the lateral mass posterior surface. During the cadaveric study, 39 screws had a satisfactory position (66.1%), 7 screws permissible (11.9%), and 13 screws unacceptable (22%). During the clinical study, 26 screws (81.25%) had satisfactory position, 4 (12.5%) had permissible position, and 2 (6.25%) unacceptable position.

Conclusion: Developed and clinically approved a method for simplicity SCPS insertion is relatively safe and cheap. No doubt, it requires further investigation, but the results of primary analysis allow us to recommend it to wide practical application.

Keywords: “Freehand” pedicle screw, subaxial pedicle screw fixation, screw insertion technique

INTRODUCTION

Unstable cervical spine requires spondylodesis using fixation tools. A great amount of publications about subaxial cervical pedicle screw (SCPS) fixation shows the high popularity of this method. However, almost each clinical study indicates a high risk of the neurovascular injury that explains the high number of tricks, proposed for SCPS insertion. Most of these methods are individualized. We would like to introduce a standardized and fast method for SCPS: Screw insertion based on the simple angles to the bony landmarks. The protocol was approved by Ethics Committee of the Hospital and informed consent of patients who were surgically treated was received.

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MATERIALS AND METHODS

This study consists of three stages, measurements at all three stages were performed by the same radiologist with the assistance of the same spinal surgeon, who performed screw insertion on the second and third stages.

Alexander V Burcev, Olga M Pavlova, Konstantin A Diachkov, Galina V Diachkova, Sergey O Ryabykh[1], Alexander V Gubin

Russian Ilizarov Scientific Center, [1]Division Spine Pathology and Rare Diseases, Russian Ilizarov Scientific Center, Kurgan, Russian

Address for correspondence: Dr. Olga M Pavlova, Russian Ilizarov Scientific Center, Kurgan, Russian.
E-mail: pavlova.neuro@mail.ru

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Stage 1 – CT-morphometric analysis of C3–C7 vertebrae of 10 patients 38–64-year-old with cervical degenerative diseases (50 vertebrae and 100 pedicles).

A 64-slice multidetector CT scanner (Aquilion, Toshiba, GE Light Speed, Neck Standard program, Helical) with a gantry rotation speed of 0.5 s per rotation was used. Slice thickness of 3 mm, reconstruction interval of 3 mm, tube voltage of 120 kV, and tube current of 175 mA were used for scanning. CT was carried out on supine position: In the neutral position of a head, and after that in maximum right- and left-side head tilts. Coronal and sagittal multiplanar images were reconstructed. The morphometric parameters of the pedicles were measured on images of multiplanar reformations. Measurements of each subaxial vertebra included four marks: angle between the pedicle axis and the axis of contralateral lamina [Figure 1]; angle between the pedicle axis and plane of the lateral mass posterior surface [Figure 2]; the coordinates of optimal entry point for SCPS-the distance from the lateral edge and from the upper edge of the lateral mass posterior surface; and the length of the pedicle channel (for bicortical screw insertion).

Stage 2 – Cadaveric study (6 cadavers and 59 pedicle screws): SCPS insertion through the mean optimal entry point (2 mm from the lateral edge and from the upper edge of the lateral mass posterior surface) according to two found standard angles (parallel to the lamina axis and perpendicular to the posterior surface of the lateral mass) in C3-C7 vertebrae of 6 cadavers. The cadaveric operations were carried out from the posterior approach by one surgeon, without preoperative CT. We used 3.5 mm × 25 mm and 3.5 mm × 30 mm screws. After insertion of screws, all operated vertebrae were carefully extracted from cadavers, and CT scan was done to perform the analysis of screw courses. Evaluation of the position of the screw was assessed as satisfactory when the screw was completely in a pedicle, permissible when a screw malposition was 1 mm and less in a radicular or spinal canal and if a vertebral artery canal overlapping was <25%, unacceptable when the screw malposition was more than 1 mm in a radicular or spinal canal and if a vertebral artery canal overlapping was more than 25%.[1,2]

Stage 3 – Clinical study (6 patients and 32 pedicle screw): SCPS insertion based on the simple angles to the bony landmarks by the same surgeon as in the cadaveric study. Three patients had traumatic injuries, one patient had rheumatoid lesions, and two patients had degenerative spinal stenosis.

RESULTS

Stage 1 – CT measurement results are shown in Table 1. The average length of a pedicle channel of the C3–C7 vertebrae in ten patients was 32 mm. The average angle between a pedicle axis and an axis of contralateral lamina of a vertebra was 180°. The average angle between a pedicle axis and plane of a posterior surface of a lateral mass amounted to 90°. The coordinate of an optimal entry point – 2 mm from a lateral edge and 2 mm from an upper edge of the lateral mass posterior surface.

Based on these data, we suggest the following simple method of SCPS insertion: optimal entry point is located 2 mm from the lateral edge and 2 mm from the upper edge (or joint plane) of the lateral mass posterior surface [Figure 3]; the horizontal plane trajectory is parallel to a contralateral lamina axis of the same vertebra [Figure 4]; and the sagittal plane trajectory is perpendicular to a lateral mass posterior surface.

Stage 2 – During the cadaveric study, 59 screws were inserted in C3 to C7 pedicles: Thirty-nine screws had satisfactory

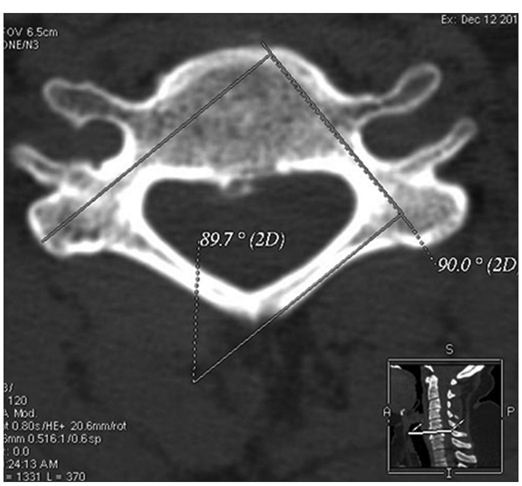

Figure 1: Angle between the pedicle axis and the axis of contralateral lamina

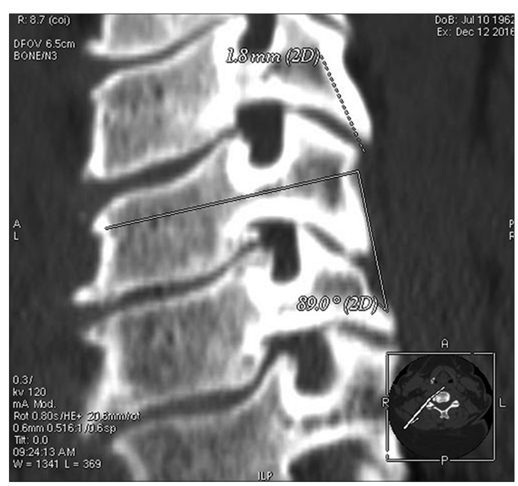

Figure 2: Angle between the pedicle axis and plane of the lateral mass posterior surface

Table 1: Computed tomography-morphometric analysis of the C3-C7 vertebrae of 10 patients 38-64-year-old with cervical degenerative diseases (50 vertebrae, 100 pedicles)

Vertebra	C3	C4	C5	C6	C7	Total average value
Screw length (mm)	30.9±1.7	31.6±1.3	32.5±1.6	33.2±1.7	33.4±2.2	32.4±1.9
Angle between the pedicle axis and the axis of contralateral lamina (°)	176.5±1.7	178.1±1.9	176.8±1.8	176.4±1.3	174.9±2.9	176.3±2.2
Distance from the lateral edge of the lateral mass posterior surface (mm)	1.3±0.6	1.7±0.6	1.9±0.8	2.1±0.6	2.7±0.9	1.9±0.8
Distance from the upper edge of the lateral mass posterior surface (mm)	2.1±0.8	1.8±1.0	2.0±0.9	2.0±1.3	2.6±1.2	2.1±1.1
Angle between the pedicle axis and plane of the lateral mass posterior surface (°)	91.1±2.7	92.8±2.3	91.6±2.7	91.1±3.2	93.9±2.3	92.1±2.8

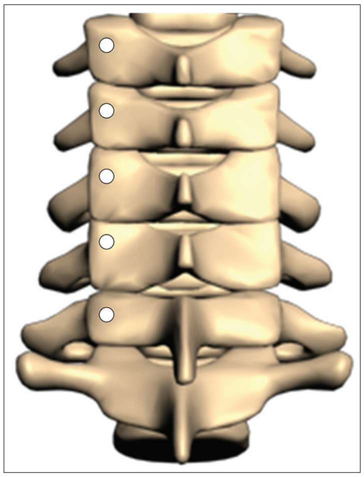

Figure 3: Screw entry point for SPSF

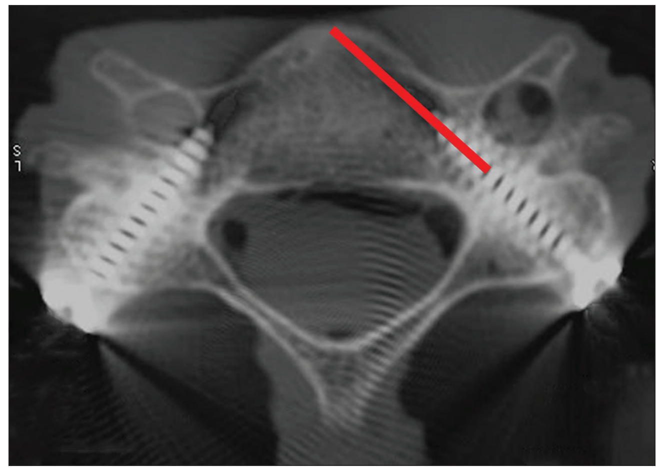

Figure 4: Screw trajectory parallel to the axis of contralateral lamina

position (66.1%), 7 screws permissible (11.9%), and 13 screws unacceptable (22%) [Figure 5]. Intraoperative fluoroscopy was not used.

Stage 3 – The new method of SCPS insertion was applied to 6 patients, 32 screws were introduced using this method (preoperative CT and intraoperative fluoroscopy were used). Postoperative CT showed that 26 screws (81.25%) had a satisfactory position, 4 (12.5%) had permissible position, and 2 (6.25%) unacceptable position [Figure 6]. In all cases, screw malpositions were asymptomatic. CT angiography in 2 cases with unacceptable screw position determined vertebral arteries stenosis with a stored blood flow, these screws were removed. There were no other intraoperative and early postoperative complications. The average volume of bleeding during operations was 316.6 ± 211.34 ml. The average duration of the operation was 175 ± 65.7 min.

DISCUSSION

The concept of SCPS insertion was proposed by Abumi *et al*.[3] Pedicle screw fixation in the cervical spine due to three column stabilization provides significantly greater rigidity compared with lateral mass screw fixation,[4-7] this is most important in cases of poor bone quality.[4] Numerous biomechanical studies show the reliability of the SCPS fixation,[4,6,8,9] nevertheless many authors note high risk of neurovascular injury.[1,10-15] The wide variability of pedicle size in cervical region complicates the choice of standard bony landmarks, necessary to determine the optimal screw entry point.[16-18] According to the anthropometric data the "safest" vertebrae for SCPS are C6 and C7, due to the larger diameter of pedicles,[1,3,11,16-19] besides, more than 95% of C7 vertebrae do not contain a vertebral artery.[20] "Most dangerous" vertebrae for SCPS are C3–C5, the risk of neurovascular injury is much higher due to smaller diameter and steep slope of axis of the pedicle.[1,3,11,16-19] In general, the method of SCPS insertion is recommended for application by experienced surgeons.[12,13,21]

The usage of navigational systems and laminoforaminotomy reduces the risk of malposition.[2,5,7,12,14,22-33] Comparison of three insertion techniques (anatomical landmarks, laminoforaminotomy, and computer-assisted navigation) showed that the critical malposition accounted for 65.6%, 39.6%, and 10.6%, respectively.[34] However, other authors determined that the risk of screw malposition in the computer-assisted navigation is higher than without it,[1,4] perhaps due to the fact that CT-based navigation cannot provide real-time navigation and intraoperative changes of spinal alignment can appear during the patient positioning, flexion or extension, rotation, and torsion of the neck. Besides, the high cost of navigation equipment, as well as the duration of its setting, limits its usage. The conception of navigation template systems has been reported by several authors and reduced screw malposition risk up to zero.[35,36]

Large number of articles devoted to SCPS show us different variants of the "freehand" method,[12,13,21] the screw insertion angle varies from 35° to 50°.[2,3,14,37-41] However, intraoperative selection of the screw insertion angle is difficult, and slightest deviation can cause screw malposition.[15,38-43] Therefore, in this study, we tried to develop a method of SCPS insertion, based on usage of simple angles (90° and 180°) to bony landmarks, which should reduce the number of screw malposition, the duration and cost of the operation.

Another important aspect of SCPS insertion is the choice of the entry point, which varies on different levels. Anthropometric measurements obtained in this study indicate the possibility of standardizing methods of SCPS insertion: Entry point coordinates can be identified using the so-called "rule of two" (2 mm from the lateral edge and 2 mm from the upper edge of the lateral mass posterior surface). The trajectory of the insertion in the horizontal plane parallel to the contralateral lamina axis of the same vertebra, the sagittal plane trajectory perpendicular to the lateral mass posterior surface, the screw length 30–32 mm. It should be noted that the bony landmarks for SCPS insertion can be used only if the preoperative CT showed the normal vertebral anatomy.[15,21,44,45] In all other cases, additional methods of SCPS positioning should be used (three-dimensional guide,[46,47] laminoforaminotomy) or other fixation techniques (lateral mass screw, interlaminar screw, and transarticular screw).

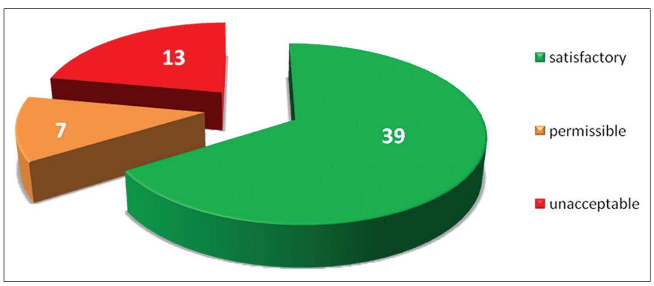

Figure 5: Position of the subaxial cervical pedicle screw on the postoperative computed tomography in the cadaveric study (59 screws)

Fatal or invalidating neurovascular injuries during the SCPS insertion are described only in a few papers.[10,48] The present study has limitations: First, the proposed method does not eliminate the risk of screw malposition and secondly, a small cohort of people in the study. However, we revealed patterns that can have practical value. Further research work should study possible difficulties in this method usage.

CONCLUSION

Developed and clinically approved method of SCPS insertion is relatively safe and cheap. No doubt, it requires further investigation, but the primary analysis allows us to recommend it to wide practical application.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients

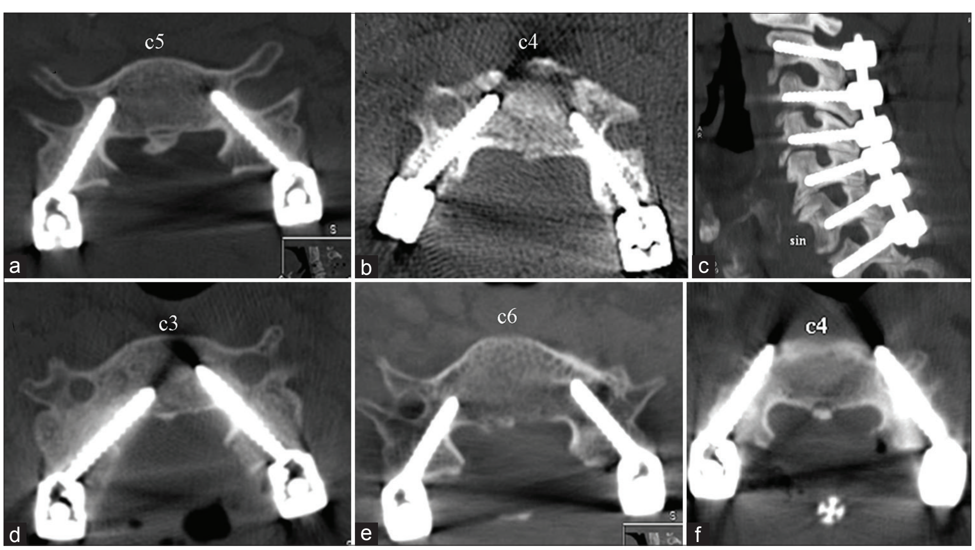

Figure 6: Position of the subaxial cervical pedicle screw on the postoperative computed tomography in the clinical application on six patients: (a-c) Satisfactory position, (d and e) permissible position, (f) unacceptable position

understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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