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Anatomic Study of Individualized and Improved Pedicle Screw Implantation in the Lower Cervical Spine

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The objective of this study was to explore a safe, reliable, and effective method for pedicle screw implantation in the lower cervical spine. Recently, a number of studies have shown that cervical pedicle screw fixation is better than roadside steel plate after cervical screw internal fixation within the scope of its indications. However, the difficulty of the former surgery technology is relatively higher and it is much easier to cause many complications. Therefore, domestic and foreign scholars have been positively exploring safer, easier operations and cheaper methods of pedicle screw implantation in the lower cervical spine. The lower cervical spine areas (C3–C7) of 7 adult cadavers were carried out with computed tomography (CT) scans of 1-mm slices. The entry point, angle, and length of the screws were determined by the measurement of CT images in a picture archiving and communication system. The pedicle screws were implanted with the technique of improved Abumi pedicle screw placement in the lab. The accuracy of the screws was evaluated by the Andrew CT classification criteria of pedicle screw position and gross observation after the experiment. A total of 66 screws were implanted in the lower cervical spine, and 90.9% of the screws inserted were found to be in an optimal position. The method of individualized and improved pedicle screw implantation in the lower cervical spine is relatively safe and reliable, which can be considered to be used in the clinic.

Key words: Individualization – Improvement – Lower cervical spine – Pedicle screw – Anatomy

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Cervical pedicle screw fixation has been shown to be the most stable form of cervical instrumentation, which has 3-column biomechanical stability and is receiving increasing attention in the clinic.[1–4] Variation in cervical anatomy, tiny pedicle structure, and insufficient accuracy in current operations often lead to injury of the peripheral vascular, nerve, and vertebral arteries, and spinal cord.[5,6] Broad guidelines have been developed to locate the entry point successfully for cervical pedicles on the lateral mass in the clinic.[7–10] For instance, a computer-guided surgical navigation system has been reported to increase the probability of screws being inserted in an optimal position,[6,11,12] but in the meantime there are some limitations and serious complications. Therefore, cervical pedicle screw technique is still a challenging technology. To explore a safer and more reliable technique for lower cervical pedicle screw placement, the author improved the Abumi technique for cervical pedicle screw placement on the basis of individualization via a body anatomy study.

Materials and Methods

Computed tomography examination and measurement

The lower cervical spine areas (C3–C7) of 7 adult cadavers soaked in formaldehyde were carried out with computed tomography (CT) scans (1-mm slices) and 3-dimensional reconstruction, retained complete spine bony structure while removing paraspinal ligament and muscle. We measured and collected data on the widest oblique sagittal and axial radiographs of the cervical pedicle by using the toolbar of the picture archiving and communication system. We mainly determined the projection point or entry point of (C3–C7) each vertebral pedicle on the lamina and measured each distance from the entry point to the superior edge of the cervical lateral mass and the inferior edge of the

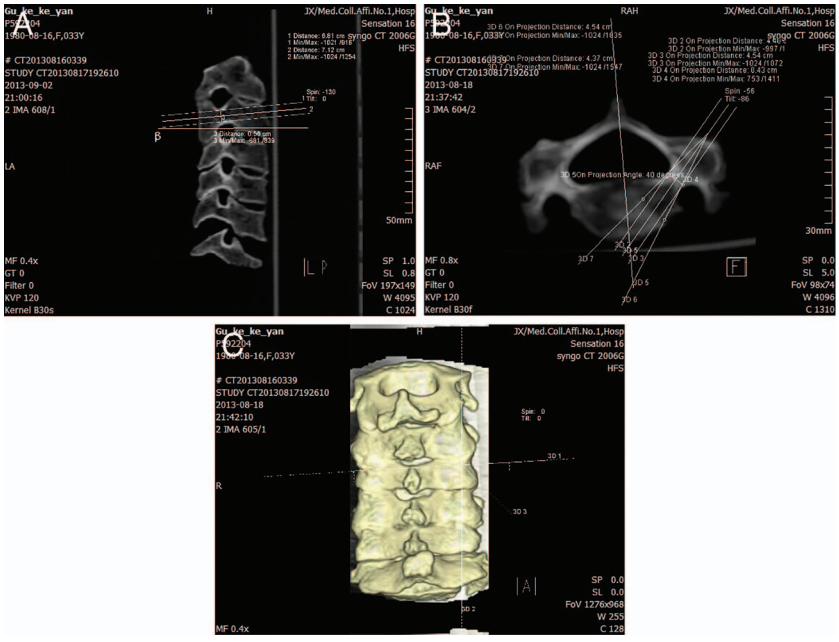

Fig. 1 Ideal entry point and angle of cervical pedicle screws. (A) In the widest pedicle sagittal axial plane, draw 2 parallel lines: line 1, which is drawn to the superior/inferior vertebral endplate along the pedicle cortex margin, and line 2, which is the median line of line 1. The crossing angle between line 2 and the horizontal line is the ideal sagittal angle of pedicle screws, whereas the screw diameter should be slightly smaller than the pedicle sagittal width (line 3 in length). (B) Choose the widest pedicle axial plane and draw a ligature (line 3D5) from the midpoint of line 3D4 (width in the axial pedicle plane) to the anterior midpoint in the axial pedicle view; the crossing angle between line 3D5 and line 3D6 (the sagittal middle axial line of the vertebral body) is the optimal transverse angle. Draw tangent line 3D7 and line 3D8 from the ideal entry point to the medial and lateral pedicle walls, respectively; the crossing angles between line 3D7 or line 3D8 and line 3D6 are the safety range of the transverse angle, whereas the screw diameter should be slightly smaller than the pedicle axial width (line 3D4 in length). (C) The intersection point between the plane of line 2 in panel A and the plane of line 3D5 in panel B; 3-dimensional reconstruction CT projections on the vertebral lamina are the ideal entry points of the cervical pedicle screw. We measured each distance from the entry point to the lateral edge of the cervical lateral mass and the inferior edge of the superior articular process.

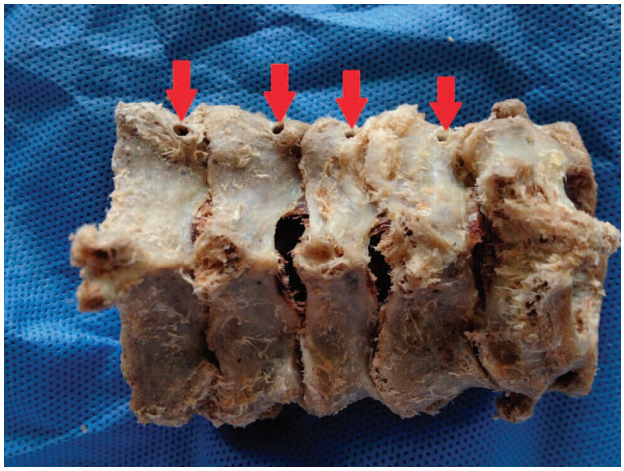

Fig. 2 Entry point for each cervical vertebral pedicle (C3–C7) was confirmed and marked on the lamina.

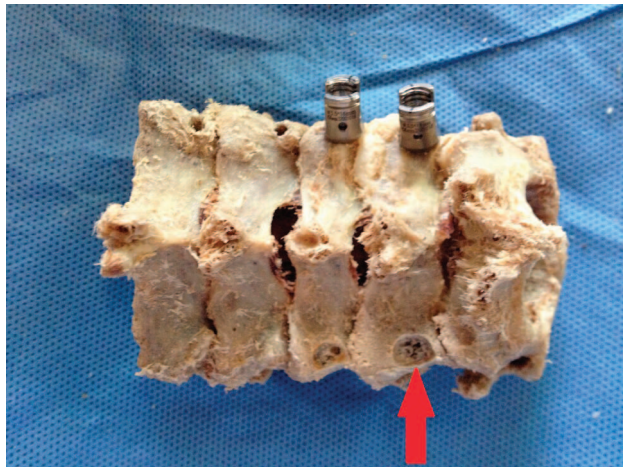

Fig. 3 A scope of about 5 mm in the bone cortex and cancellous bone was drilled as the center of the entry point in order to reveal the pedicle entrance, then the cervical pedicle screw was placed in it.

superior articular process; the width of the pedicle; and the angle and depth of the pedicle screws (Fig. 1). We recorded and saved the data.

Surgical procedure

Using data from the picture archiving and communication system, we determined and marked the projection point or entry point of each vertebral pedicle (C3–C7) on the lamina in the lab, including each distance from the entry point to the lateral edge of the cervical lateral mass and the inferior edge of superior articular process; the width of the pedicle; and the angle and depth of the pedicle screws.

We confirmed and opened the entry point of each vertebral pedicle (C3–C7) on the lamina (Fig. 2) with the improved Abumi technique, drilling a scope of about 5 mm in bone cortex and cancellous bone as the center of the entry point in order to reveal the pedicle entrance. We placed in pedicle entrances 3.5-mm cervical pedicle screws according to the measurement from CT images; the screws were from the medical company Kanghui (Changzhou, China; Fig. 3).

Postoperative assessment of screw placement

The accuracy of the placement of the pedicle screws into the medial/lateral pedicle walls and superior/inferior pedicle walls was assessed on axial and oblique CT scans (1-mm slices). The position of pedicle screws was evaluated by the Andrew CT classification criteria of pedicle screw position, whose specific standard of pedicle screw position can be divided into 3 levels: level 1, no pedicle cortex perforation; level 2, pedicle cortex perforation of 2 mm or less; and level 3, more than a 2-mm perforation. Then the data were calculated and recorded. The accuracy of the classification criteria was further confirmed through gross observation of specimen by eye.

Results

The results of Andrew pedicle screw CT position classification standard evaluation are basically identified through gross anatomic observation of the lower cervical spine specimen by eye. A total of 66 pedicle screws were used, all of which were 3.5 mm in diameter by 20 to 24 mm in length. A total of 90.90% of the screws were successful: 3 (4.55%) demonstrated level 2, and 3 (4.55%) exhibited level 3. Among those 6 screws, 1 (16.67%) breached the medial pedicle wall, and 5 (83.33%) the lateral wall (Fig. 4). The screw malposition was mostly seen at the C4 level (4 of 14 screws) and aimed lateral (Table 1).

Table 1 Results of screw placements at each level

Level	Screws	Andrew (II)	Andrew (III)	Lateral malposition	Medial malposition
C3	14	0	0	0	0
C4	14	2	2	4	0
C5	14	1	1	1	1
C6	14	0	0	0	0
C7	10	0	0	0	0
Total	66	3	3	5	1

Fig. 4 CT examination showed the lateral wall of the pedicle perforation.

Discussion

Front and back approaches, employing the anterior plate and posterior triple-wiring, and lateral mass fixation for the cervical spine demonstrated clear biomechanical advantages when the extent of instability increased to 3-column or multilevel.[6,13] Three-column fixation for the cervical spine using transpedicular screw fixation offers increased stability over that of conventional cervical fixation systems, and has led spine surgeons to use cervical pedicle screw fixation for reconstruction in numerous cervical spine disorders.[2,6,13,14] So, more and more spine surgeons prefer the placement of the cervical pedicle screw in recent years, which has been developing rapidly in the clinic.

However, compared with thoracic and lumbar pedicle screw internal fixation, the technology is far from universal. Because of the potential for serious injury to the spinal cord, nerve roots or vertebral arteries, pedicle screw fixation has generally been considered a risky surgery; therefore, it is key to position the entry point and angle of the lower cervical pedicle screws. Anatomically, the cervical pedicle diameter is smaller than that of the thoracolumbar pedicle, and the pedicle axis is largely inclined in the transverse plane.[15–18] Successful placement of pedicle screws requires an accurate identification of the pedicle axis, that is, variation in anatomic morphology of the cervical pedicle requires the sharp differences among different individuals or segments, which means in different conditions, the height, width, entry point, and angle of pedicle screws are entirely different. If an accurate entry point coinciding with the correct trajectory angle is determined during surgery, it would vastly improve the accuracy of screw placement.

A computer-guided surgical navigation system has been reported to improve the accuracy of screw placement, but these systems are cumbersome and time-consuming, and some, based on preoperative CT imaging, have no utility following the reduction of a fracture and/or a dislocation. Furthermore, because of their high cost and user unfriendliness, these systems are not installed in most hospitals.[6,11,12,19] It is hoped that in the near future, a more accurate, user-friendly, and real-time navigation system will be developed for clinical practice.

Therefore, preoperative CT examination (1-mm slices) and measurement can relatively position the entry point and the angle of the pedicle more accurately, but economic burden makes the hospital unable to popularize the computer-guided surgical navigation system. The deviation of entry point can certainly be corrected by modifying the technology of improved Abumi individualized pedicle screw placement to drill into the cortical bone surrounding the entry point and to probe cancellous bone to reveal the pedicle entrance. The angle of pedicle screw placement can also be further determined in the process of probing. In the meantime, the process can avoid force that leads to cervical vertebral

spondylolisthesis or dislocation, because of contacting pedicle cortex when an owl was inserted into the pedicle cavity through the entry hole.

Using this technique, our rate of pedicle perforation was far lower than that reported for the conventional technique in anatomic consideration (9.1% versus 25%∼47.3%).[20] But parts of screw malposition still exist; screw malposition was seen mostly at the C4 level. This study, together with previous studies, like that by Chanplakorn *et al*,[21] supported the anatomic finding that statistically significant differences existed between the pedicle dimensions at different levels of the cervical pedicle.[15,17] In the present study, the mean pedicle transverse angle was greatest at the C4 level, with small decreases for levels up and down. Correspondingly, Mohi Eldin[22] found similar results. These findings are supported by the fact that all minor pedicle wall violations in this study occurred laterally, mainly at the C4 level.

We could determine the entry point of screws through preoperative CT examination before transpedicular individual implantation. However, in our actual procedure a statistical analysis of cadaveric morphometric data obtained from the cervical spine could provide guidelines for transpedicular screw placement based on topographic landmarks, and sufficient variation exists to preclude safe instrumentation without additional anatomic data. Insufficient correlation between different surgeons' assessments of surface landmarks attests to the inadequacy of screw insertion techniques in the cervical spine based on such specific topographic guidance. Meanwhile, some experimental errors are concentrated at earlier stages; with the improvement of technology and the accumulation of experience, the pedicle screw failure rate will decrease rapidly.

Thus, the technique of individual-improved cervical pedicle screw placement is a relatively safe and reliable means in this operation. Nevertheless, the samples in our study are not numerous enough yet, and further research needs to be done in next clinical stage. Whether the implantation of cervical pedicle screw can succeed or not mainly depends on the following factors: (1) Operators must be familiar with the anatomy and adjacent structures of the cervical pedicle, equipped with rich experience in this area. (2) Sufficient preparations should be performed before the operation, including selection of a correct entry point, entry angle, and size of screws in case of vascular and cervical pedicle malformation. (3) Accuracy of positioning also plays a crucial role in the placement of screws. We ought to place the screw into the corresponding projection points with enough of an angle of cohesion, and we must avoid violence in the whole operation.

Conclusion

Current anatomic study indicated the method of individual-improved Abumi screw placement could be safe and reliable in the lower cervical spine, which is worthwhile for further confirmation in clinic.

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