The "slide technique" - a novel free-hand method of subaxial cervical pedicle screw placement

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Research article

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Abstract

Background : Cervical Pedicle Screw(CPS) placement is a challenging work due to high risk of neurovascular complications. Although there have been a number of different free-hand or navigation assisted techniques for CPS placement, perforations always occur during screw insertion, especially lateral perforation. The objective of this research is to describe a novel free-hand technique for subaxial CPS placement (C3–C7) for improving security and decreasing the chances of perforation.

Methods : Thirty-two patients undergoing surgery with CPS instrumentation (C3–C7) at our institute between June 2017 and December 2018 were included in the study. All the patients had cervical trauma, and pedicle screw insertion was made according to the free-hand “slide technique”. Lamina, lateral mass and facet joint of the target area were clearly exposed and the optimal entry point was found on the lateral mass posterior surface. A pedicular probe was then inserted and gently advanced. During the pedicle probe insertion, the cortex of the medial margin of the pedicle acted as a “slide” to permit safe insertion of the screw. If the pedicle screw pathway was intact, screw of appropriate size was carefully placed. Three-dimensional (3D) CT imaging reconstruction was performed in all the patients after surgery, and screw perforations were graded with the Gertzbein-Robbins classification.

Results : A total of 257 CPSs (C3-7) were inserted, of which 41 CPSs in C3, 61 CPSs in C4, 55 CPSs in C5, 53 CPSs in C6, and 47 CPSs in C7. The diameter and length of CPSs were 3.5 mm and 22-26 mm respectively. According to the Gertzbein-Robbins classification, grade 0, 231 screws; grade 1, 19 screws; and grade 2, 7 screws. No neurovascular complications occurred stemming from malpositioning of pedicle screws. In perforated screws (26 screws), lateral perforations were 16, medical perforations were 5, and inferior perforations were 4.

Conclusions : The initial usage result show the “slide technique” is a safe, effective and cost-effective technique for pedicle screw placement in the cervical spine. This is the first report of such technique, we recommend it to wide practical application though further studies are needed.

Background

Due to the excellent three-column stability, pedicle screws have been widely used in spinal surgeries, including spinal fracture, deformity, tumors and so on. Although pedicle screws have been routinely used for lumbar and thoracic fixation, many surgeons doubt whether they could be safely used in the cervical spine, and they tend to use spinous process wire, lateral mass screws or facet screws rather than cervical pedicle screws(CPSs) for cervical posterior fixation.

It is a fact that anatomical structure and adjacent relationship of cervical spine is complex and dangerous, cervical spinal cord is close to the medial pedicle cortex, and vertebral artery is close to the lateral pedicle cortex. CPS placement is a very challenging work due to high risk of neurovascular complications, including critical bleeding, cerebral infarction, paralysis, and even death. Since Abumi et al. [1]first described the CPS placement method in 1994, many researcher have proposed various improved methods for this technique. However, there is no ideal solution to make it routinely using for cervical posterior fixation up to now.

With the advancement of technology in the field of digital navigation, the security as well as the accuracy of CPS placement has been improved greatly. However, we should realize that the navigation system has its limitations, for instance, the high cost, tedious procedures, and relatively limited indications. Therefore, it is difficult to be popularized in primary hospitals or developing countries.

Inspired by the “slide technique” in the thoracic spine[2], we devised a novel method for free-hand CPSs insertion also called “slide technique”, to increase the accuracy of CPS placement via direct slide on the cortex of the medial margin of the pedicle. The purpose of this study is to describe the specific procedures of “slide technique” in CPS placement and evaluate the security and accuracy of CPS placement with this new technique.

Methods

- Patient Population

Inclusive criteria: patients with cervical trauma underwent posterior cervical surgeries, and the CPS instrumentation aimed at reconstructing cervical stability.

Exclusion criterion: patients with cervical pedicle stenosis, dysplasia or severe destruction that cannot insert CPS.

A total of 32 patients who fulfilled inclusion criteria between June 2017 and December 2018 were included in this study. All patients came from department of spinal surgery, Hunan Provincial People’s Hospital. Their mean age was 52.8 years (range, 28–74 years). There were 23 male and 9 female patients.

- Surgical Technique

All patients underwent three-dimensional CT scan of cervical spine to measure pedicle diameter and appropriate screw length before operation.

All patients were placed in the prone position with the head fixed using craniocephalic traction. After successful general anesthesia, we made a standard midline skin incision on posterior neck. Subperiosteal dissection was performed along the spinous process and lamina. Lateral mass and facet joint of the target area were clearly exposed. The target vertebral lateral mass was divided into three equal parts by longitudinal lines and the optimal entry point was chosen at a point on the lateral longitudinal line and slightly below the inferior margin of facet joint. The distance between the inferior margin of facet joint and entry point needed to be measured on X-ray or CT images before operation (Fig. 1). First, the cortex at the entry point was penetrated with a high-speed burr or awl. The pedicle probe was blunt and its head was bent (Fig. 2). After entered from the entry point with head bend inside, the pedicle probe rotated while gently advancing at an maximum angle on more than 45°medially. Probe stopped when meeting resistance. At this time, the probe head had reached the cortex of the medial margin of the pedicle (Fig. 3a). Thereafter, by rotating the probe by 180 ° (its head became to bend outward) (Fig. 3b) and reducing medial angle, the pedicle probe avoided the medial cortex easily and it could continue to advance to the vertebrae body. During this procedure, the cortex of the medial margin of the pedicle acted as a "slide" to permit safe insertion of the probe (Fig. 3c). Once the probe reached a depth of 15 mm (head of probe had reached the body), it was rotated by 180 ° again to make its head bend inside (Fig. 3d). After increasing the medial angle, pedicle probe was then continue to insert and gently advanced to a depth of 20 mm (Fig. 3e). We rotated the probe by 360°for two times so as to expand the pathway (Fig. 3f). A ball-tip probe was used to evaluate the integrity of the pedicle screw pathway. If the pathway was intact, screw of appropriate size was carefully placed (Fig. 3g). The blue line in Fig. 3h represented the changes of the pathway during the probing, and the red line represented the final screw pathway. C-arm fluoroscopy was used to preliminarily evaluate the screw position during operation.

The key point of the "slide technique" was to use the cortex of the medial margin of the pedicle as a "slide" to permit correct probe positioning. The theoretical supports of this novel method includes: 1. the cortex of the medial margin of cervical pedicle was 1.4–3.6 times thicker than that of the lateral margin[3], so it was not easy to break through when negotiating, tapping and placing screw. In comparison, the cortex of the lateral margin was thin and easy to be perforate. Previous studies had confirmed that the incidence rate of lateral perforation was significantly higher than that of the medial perforation during CPS insertion [4,5]. 2. There were buffer tissues such as dural sac and epidural fat between the medial pedicle cortex and cervical spinal cord. Cases of medical perforation without spinal cord injury often could be seen in clinical work. In contrast, vertebral artery closed to the lateral pedicle cortex was easily to be damaged due to the limitation of the vertebroarterial foramen. Therefore, we believed that it was safe and reliable to select the cortex of the medial margin of the pedicle for sliding.

- Evaluation of security and accuracy

Three-dimensional (3D) CT imaging reconstruction was performed in all the patients after cervical surgeries, so as to assess pedicle screw instrumentation. We observed whether CPSs penetrate the pedicle cortex or not, and if so, measured the distance between screws and pedicle cortex. According to Gertzbein-Robbins classification[6], the degree of perforation was classified into four grades on postoperative CT scans. If the CPS located within the pedicle and did not perforated, that was defined as grade 0. Grade 1 perforation was defined if perforation was less than 2 mm. If perforation was 2–4 mm, it was classified as grade 2. Perforation more than 4 mm was defined as grade 3. We also recorded the direction of perforation, including lateral perforation, medical perforation, superior perforation, and inferior perforation.

Besides, we reviewed the clinical information of all patients. Complications directly related to CPSs placement were recorded in all patients, such as spinal cord injury, nerve root injury, vertebral artery injury/rupture, aortic injury, etc.

Results

A total of 257 CPSs (C3–7) were inserted, of which 41 CPSs in C3, 61 CPSs in C4, 55 CPSs in C5, 53 CPSs in C6, and 47 CPSs in C7. The diameter and length of CPSs were 3.5 mm and 22–26 mm respectively. According to the Gertzbein-Robbins classification, grade 0, 231 screws (89.9%); grade 1, 19 screws (7.4%); and grade 2, 7 screws (2.7%). In perforated screws (26 screws), lateral perforations were 16(61.5%), medical perforations were 5(19.2%), and inferior perforations were 4(15.4%).

No neurovascular complications occurred stemming from malpositioning of pedicle screw during operation. None of the patients showed neurological deterioration after the surgery. Symptom related to vertebral artery injury/rupture was not appeared. There was also no condition related to nerve root injury after CPSs placement. Typical case is showed in Figure 4.

Discussion

Cervical fixation using pedicle screws are becoming increasingly popular for various cervical diseases due to their advantages, such as three column fixation, sagittal correction and excellent biomechanical stability when compared with spinous process wire, lateral mass screws or facet screws[7,8]. However, the CPS has not become the routine for posterior cervical fixation due to the high risk and high technique required.

The most challenging obstacle of placing CPSs safely into cervical vertebrae is the difficulty in making the exact cancellous pathway between vertebral artery and cervical spinal cord for the pedicle screw. We can imagine that lateral pedicle perforation when placing CPSs may injury the vertebral artery, while medial pedicle perforations can injury the cervical spinal cord.

The cortex of the medial margin of cervical pedicle is much thicker and stronger than that of the lateral margin, so it is predisposed to lateral perforation while pathway preparation, tapping, or insertion of the screw. Previous literature has confirmed this view，for instance, Japanese scholars conducted a multicenter study on the complications of CPS placing when the conventional free-hand technique is used, and the results showed that 75% (57/76) of all misplaced screws were lateral pedicle perforation, while only 25% (19/76) were medial pedicle perforation[5]. Therefore, we must pay more attention to how to reduce lateral pedicle perforation when designing a new CPS placing technology duo to it is more likely to occur and more dangerous.

The most representative conventional free-hand technique for subaxial CPS placing is the method proposed by Abumi et al. [1]in 1994. The contents include: the entry point at the posterior cortex of the articular mass was determined slightly lateral to the center of the articular mass and close to the posterior margin of the superior articular surface. The intended angle of the screws based on measurements of preoperative CT images was 30–40° medial to the midline in the transverse plane, and parallel to the upper end-plate in the sagittal plane. Insertion of the screw was greater than two thirds of the AP vertebral body depth. Subsequently, Jeanneret[9], Miller[10], Liu[11] and other researchers proposed various improved free-hand methods for CPS placement. There were also studies reported the CPS placement using medial funnel technique[12] and medial cortical pedicle screw technique[13]. Burcev et al.[14]introduced a standardized and fast method for subaxial CPS: screw insertion based on the simple angles to the bony landmarks. However, the accuracy of conventional CPS placement methods need to be improved though there are many methods to choose.

With technology developing, digital navigation technology, 3D printing technology and robotic technology are also beginning to be used in CPS placement in recent years. For example, Ishikawa et al.[15]placed 108 cervical CPSs using an intraoperative, full-rotation, 3D image (O-arm)-based navigation system. The results showed that 96 of them (88.9%) were grade 0, 9 were grade 1 and 3 were grade 2. There were no complications such as vascular and nervous complications, indicating that a combination of intraoperative 3D image-based navigation with other techniques may result in more accurate CPS placement. But not all the results about using navigation in CPSs placement were so optimistic. Uehara et al. [4]inserted the CPSs by using a CT-based navigation system during operations. The results showed that the combined rate of grades 2 and 3 perforations was 20.0 % (116/579). Therefore, the authors concluded careful insertion of pedicle screws is necessary, especially at C3 to C5, even when using a CT-based navigation system. There were a few studies even showing more perforations with navigated screws than with the free-hand technique[16,17]. Although most of the studies support navigation technology can improve the accuracy of pedicle screw placement[18], none of the high-tech can completely avoid the occurrence of screw perforations. The navigation system and other computer aided technology always associated with complex operation procedures and expensive equipment costs[19]. Moreover, due to the highly mobility of cervical spine, cervical spine alignment can easily change during operation[20], which leads inaccurate synchronization to preoperative images. All the shortcomings limit the popularization and application of digital navigation technology, especially in primary hospitals or developing countries.

Based on the above background, it is of great clinical significance to develop an economical, safe and accurate method for free-hand CPS placement. Raphael Vialle et al.[2]developed the “sliding technique” for safe pedicle screw placement in the thoracic spine in 2004. The key point of this novel technique was to use the cortex of the anterior aspect of transverse process and the lateral margin of the pedicle as a "slide" to permit correct probe positioning during pedicle probe insertion. Inspired by it, we devised a novel method for free-hand CPSs insertion also called “slide technique”, to increase the accuracy of CPS placement via direct slide on the cortex of the medial margin of the pedicle.

Preliminary clinical results of this novel technique showed a relatively high rate of correct screw position, which was comparable to CPS placement with navigation system. Meanwhile, no neurovascular complications occurred stemming from malpositioning of pedicle screws. In the process of this free-hand technique, screw perforations inevitably occurred, and lateral pedicle perforation accounted for the majority, which was consistent with previous studies.

Several points should be paid attention to in the clinical application of the “sliding technique”: 1. It is necessary to carefully read and analyze the imaging data before operation, especially to accurately measure the diameter of pedicle and pay attention to the variation of anatomical structure (such as pedicle sclerosis, pedicle slenderness, vertebral foramen malformation, local bone destruction, etc.). 2. The pedicle probe should rotate while gently advancing, and stop in case of resistance. No violence can be used during the whole operation. In order to ensure the accuracy of the pathway, Intraoperative fluoroscopy is necessary when uncertain. 3. When CPS placement is difficult, lateral mass screw or other fixation should be flexibly selected. It must be admitted that subjects selected in this study were patients with cervical trauma, whose pedicle variation rate was small, so the accuracy of screw placement was relatively high. The accuracy of the screw may decrease when applied to difficult situations such as cervical deformity.

Conclusion

To our knowlege, This is the first report of slide technique used in CPS placement. We think that this novel free-hand “slide technique” could be considered as a safe, effective and cost-effective method for CPS placement.

However, this study is also limited due to the relatively small number of screws and uniform criterion for pedicle perforation. In addition, all the CPSs placements were evaluated by the researcher involved in the surgery, which could have led to bias in evaluation. The multicentre large sample study is desired to establish in future.

List Of Abbreviations

CPS: cervical pedicle screw

3D: Three-dimensional

CT:Computed tomography

Declarations

Ethics approval and consent to participate

All patients receive written information among their participation in the study. They sign a written consent to participate in the study. The Ethics Committee of Hunan Provincial People’s Hospital approved current study. All clinical investigations were performed in accordance with the guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed in the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

LB conceived and designed this study, performed the literature searches, extracted the data, interpreted the data and drafted the manuscript. LXY, SXJ, and WGP participated in performing the literature searches and drafting the manuscript. CYX revised the manuscript and acted as guarantor for the paper. The guarantors accept full responsibility for the conduct of the study, had access to the data, and enrolled the decision to publish. All authors have read and approved the final manuscript.

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Figures

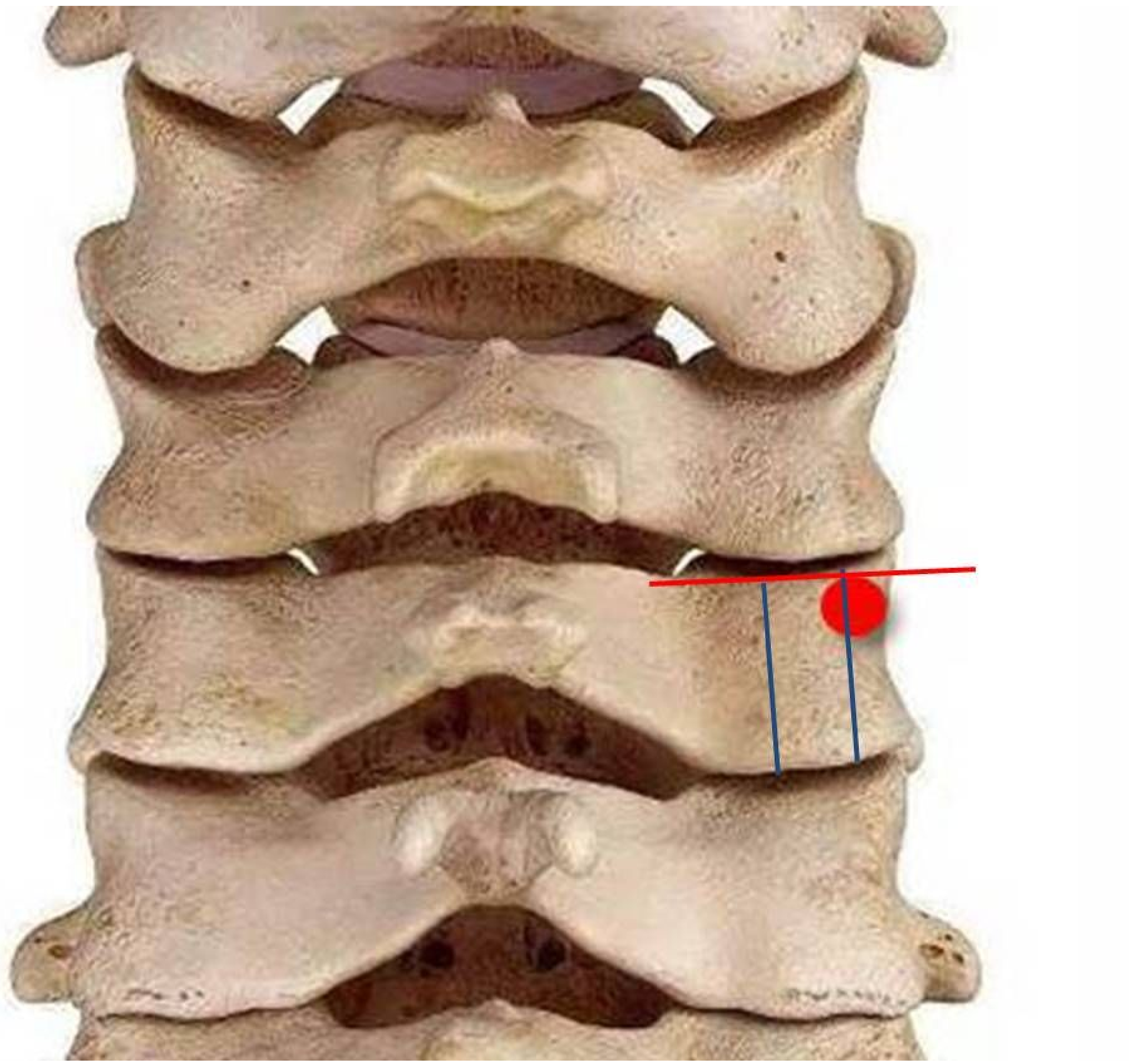

Figure 1

Optimal entry point (frontal view)

Figure 2

Diagram of the pedicle probe

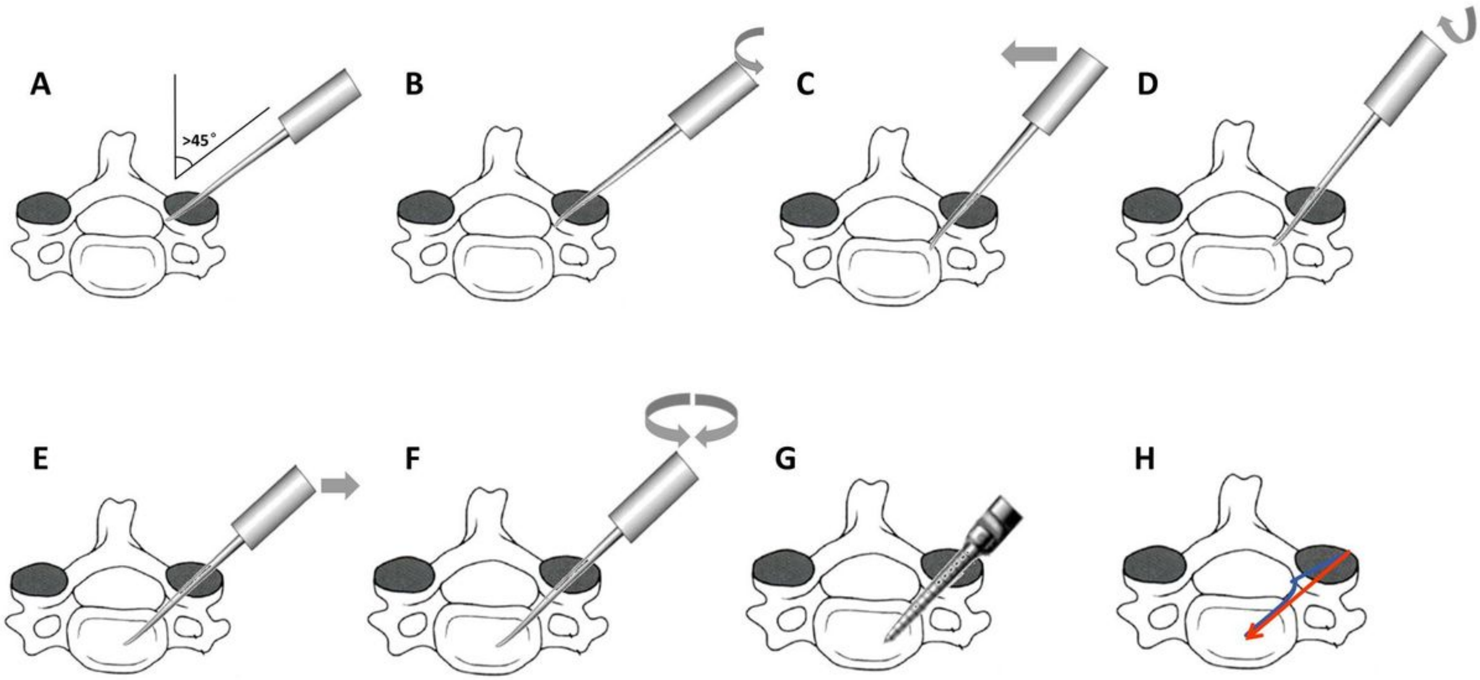

Figure 3

Operative technique(axial view)

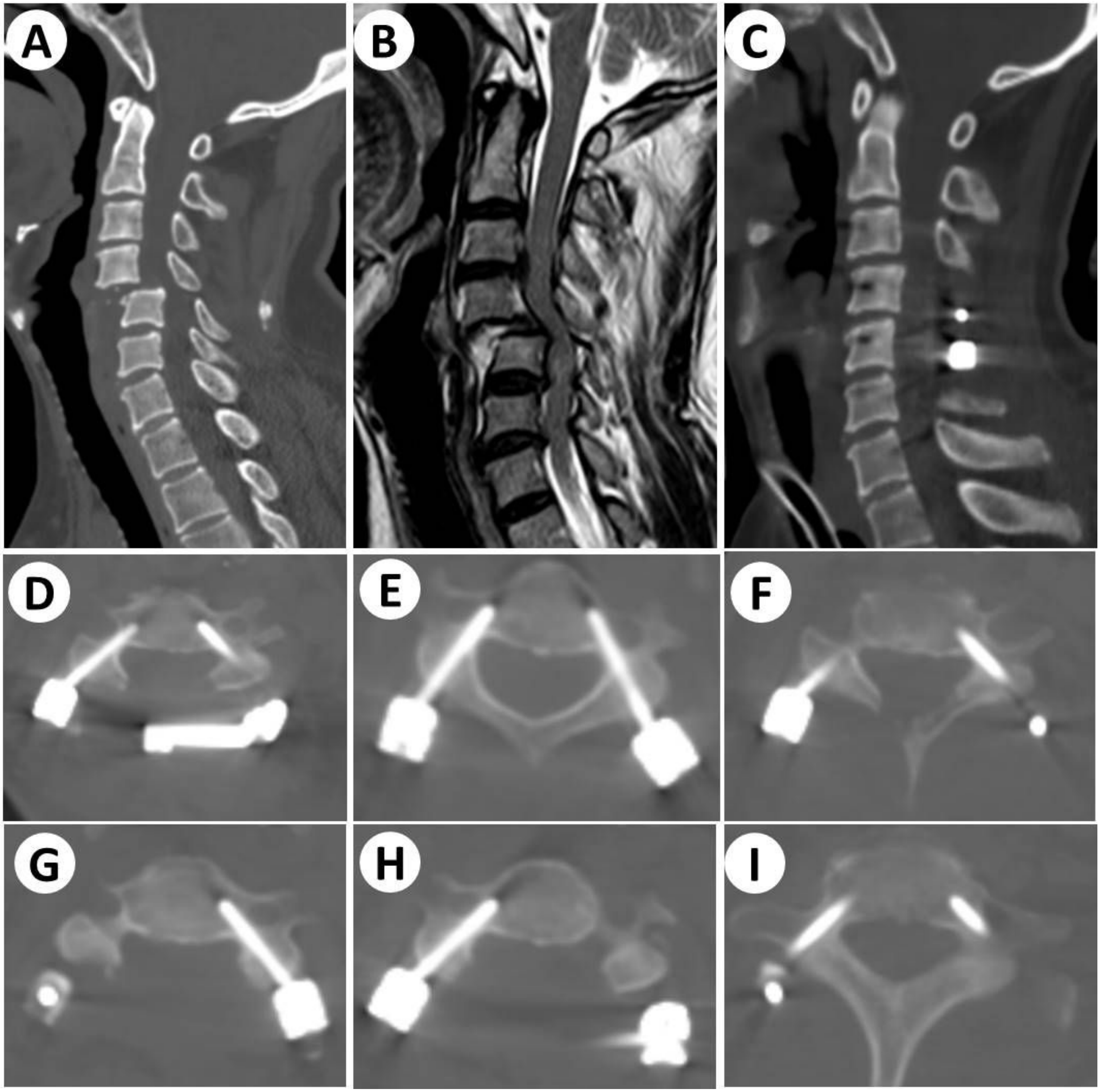

Figure 4

Example of a patient with cervical trauma. a Preoperative cervical CT scan, b Preoperative cervical MR imaging, c Sagittal CT image after cervical operation, d-I transverse CT images after cervical operation.