Accurate and Minimally Invasive Cervical Pedicle Screw Insertion Procedure Using the Bone Biopsy Needle as Drill Guide

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Abstract:

Introduction: Cervical pedicle screw (CPS) fixation provides the strongest mechanical stability. It needs, however, wide soft tissue detachment to expose the entry point and carries the potential risk of iatrogenic damage to neurovascular structures. Malposition of the CPS cannot be completely avoided even using the navigation system.

Technical Note: Using the bone biopsy needle as drill guide, we developed a novel accurate CPS insertion technique. (1) The entry point of CPS was exposed using Southwick's technique for anterior fixation or Tokioka's technique for posterior fixation. (2) A 13G bone biopsy needle was inserted from the entry point established by the fluoroscopy-assisted pedicle axis view technique described by Yukawa et al. to within a few millimeters of the pedicle. (3) The external sleeve of the bone biopsy needle was left in place as a drill guide, and the 1.25 mm guidewire for a 4.0 mm cannulated screw was then inserted into the pedicle cavity. (4) The external sleeve of the bone biopsy needle was removed, and the screw trajectory was created by a 2.7 mm cannulated drill bit over the guidewire. (5) Tapping was conducted prior to CPS insertion.

Using this method, 29 CPSs in nine patients were inserted. Postoperative computed tomography scans revealed that all the CPSs were placed accurately.

Conclusions: Utilizing the bone biopsy needle as drill guide, our procedure enables accurate positioning of CPS without expensive instruments.

Keywords:

Cervical spine, Fluoroscope, Pedicle screw, Surgery, Trauma

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Introduction

Cervical pedicle screw (CPS) fixation provides the strongest mechanical stability. Favorable clinical results for CPS fixation have been reported for cervical trauma cases[1-3]. However, it needs wide soft tissue detachment to expose the entry point and carries the potential risk of vertebral artery (VA), nerve root, and spinal cord injury[1-16]. To avoid CPS mispositioning, several technical innovations such as the image-guided technique[2,3], surgical navigation system[5,8,13,14,16], computed tomography (CT) cutout technique[7], mechanical aiming device[6], and screw guide template system[10,12] have been introduced. However, the incidence of CPS mispositioning cannot be completely avoided. As with the percutaneous thoracolumbar pedicle screw or central vein catheter, the only option left to avoid CPS mispositioning is to accurately insert guidewire into the pedicle cavity.

Using the bone biopsy needle as drill guide and conventional C-arm fluoroscopy, we developed a novel technique for accurate CPS insertion. We describe in this paper the CPS placement procedure and report its accuracy as compared with that of the conventional method.

Technical Note

Conventional method

We have applied CPS fixation using the fluoroscopy-assisted pedicle axis view technique described by Yukawa et al.[2)] for reconstruction of cervical trauma cases since 2008.

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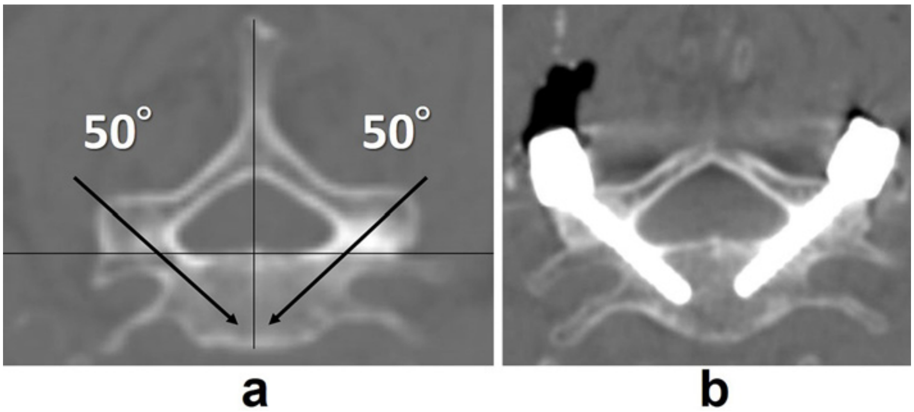

Figure 1. Pre- and postoperative CT images to assess screw placement in posterior fixation (case 1).
a. Preoperative CT. Pedicle transverse angle was 50 degrees.
b. Postoperative CT. CPSs were placed correctly via posterolateral approach according to the preoperative planning.

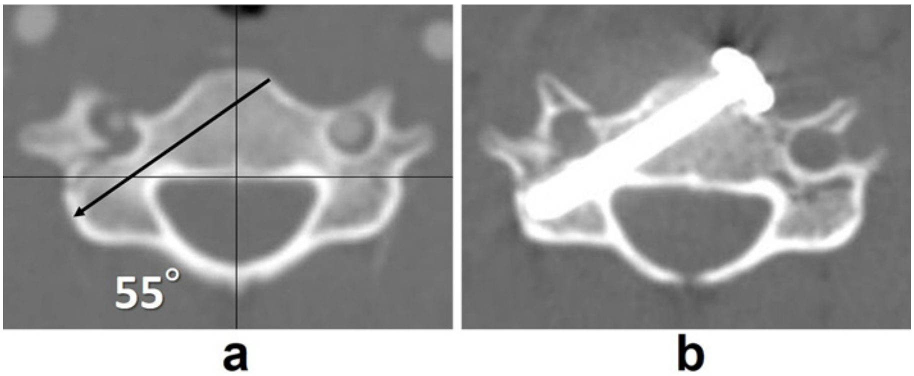

Figure 2. Pre- and postoperative CT images to assess screw placement in anterior fixation (case 2).
a. Preoperative CT. Pedicle transverse angle was 55 degrees.
b. Postoperative CT. ACPS was placed correctly according to the preoperative planning.

There were 39 cervical trauma patients (32 men and 7 women) with 115 CPSs in conjunction with 97 lateral mass screws (LMSs). Mean age at injury was 63 (range, 16 to 86). Contrast-enhanced multiplanar CT images for diagnosis of cervical spine and VA injury and for preoperative planning were obtained in all cases. Pedicle transverse angle (PTA) between a line perpendicular to the posterior cortex of the vertebral body and the screw trajectory in the transverse plane[6], the pedicle diameter, and the ideal length of CPS were measured (Fig. 1). The use of CPS fixation was contraindicated by narrow pedicle diameter (<3.5 mm) and VA anomaly at high risk of CPS insertion-associated injury. LMSs instead of CPSs were used in such cases.

New method

In 2013, we developed a novel accurate CPS insertion technique using the bone biopsy needle as drill guide for an anterior CPS (ACPS) fixation[17]. Because the pedicle cavity is distant from the screw entry point, placement of a bone biopsy needle as drill guide close to the entrance of the pedicle cavity should be useful for accurate placement of a guidewire and ACPS. It is also useful for protection of surrounding structures such as the esophagus during procedure. Subsequently, we applied this technique for posterior fixation. There were nine cervical trauma patients (nine men and no women) with 29 CPSs (CPS: 17, ACPS: 12). Mean age at injury was 66 (range, 16 to 91). Diagnoses of cervical trauma and preoperative planning were performed in the conventional manner (Fig. 1, 2).

1) After the patient was placed in the supine position for anterior fixation or in the prone position for posterior fixation on the operative table, the skin entry point of the surgical approach was determined by the pedicle axis view[2,3,17] and marked. The C-arm beam angle was adjusted to the PTA measured on preoperative CT scans (Fig. 3).

2) For anterior fixation, a skin incision of approximately 5 cm was made, and cervical vertebral bodies were exposed using Southwick's method. For posterior fixation, bilateral skin incisions of approximately 4 cm were made, and then the edge of the lateral mass was exposed using Tokioka's

method[13,14,16]. A separate midline posterior approach was implemented when posterior decompression was necessary.

3) The entry point was established by the pedicle axis view[2,3,17]. The C-arm fluoroscopy was rotated to the PTA so that an appropriate circular portion of the pedicle cortex walls was depicted (Fig. 3). The center of the cortical circular area indicated the entry point of the CPS. The pilot hole was created using a 3 mm high-speed drill burr. The pedicle axis view technique has a risk of radiation exposure for both the patients and the surgeons. Its use should be minimized to reduce radiation exposure despite its benefits.

4) A 13G bone biopsy needle was inserted from the pilot hole to within a few millimeters of the pedicle. The needle was visualized as a point at the center of the cortical circular area on pedicle axis view (Fig. 4). The placement of the needle was confirmed on anteroposterior, lateral, and pedicle axis views by fluoroscopy. On lateral imaging, the C7 pedicles are sometimes not well-visualized because of the overlying shoulders. Even in such cases, the placement of the needle can be confirmed on pedicle axis views[2,3] because the direction of the pedicle at C7 is almost parallel to the endplate of the vertebra[18].

5) The external sleeve of the bone biopsy needle was left in place as a drill guide, the 1.25 mm guidewire for a 4.0 mm cannulated screw (or 1.2 mm Kirschner wire) was then inserted into the pedicle cavity using a power drill driver (Fig. 5, 6). If increased drill resistance to guidewire advancement is felt by the surgeon, deviation of the path of advancement from soft cancellous bone to hard cortical bone should be suspected, and the placement of the needle should be reconfirmed to avoid perforation.

6) The external sleeve of the bone biopsy needle was removed, and the screw trajectory was created by a 2.7 mm cannulated drill bit for 4.0 mm cannulated screw insertion

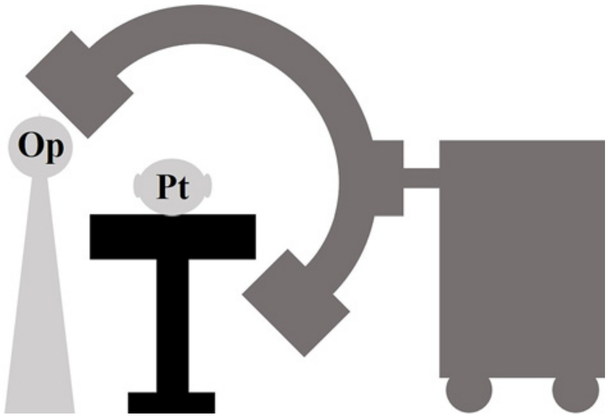

Figure 3. The location of the C-arm.
The C-arm was positioned on the lateral side of the operative table, opposite the operator. The C-arm beam angle was adjusted to the pedicle transverse angle measured on preoperative CT scans.
Op: operator; Pt: patient

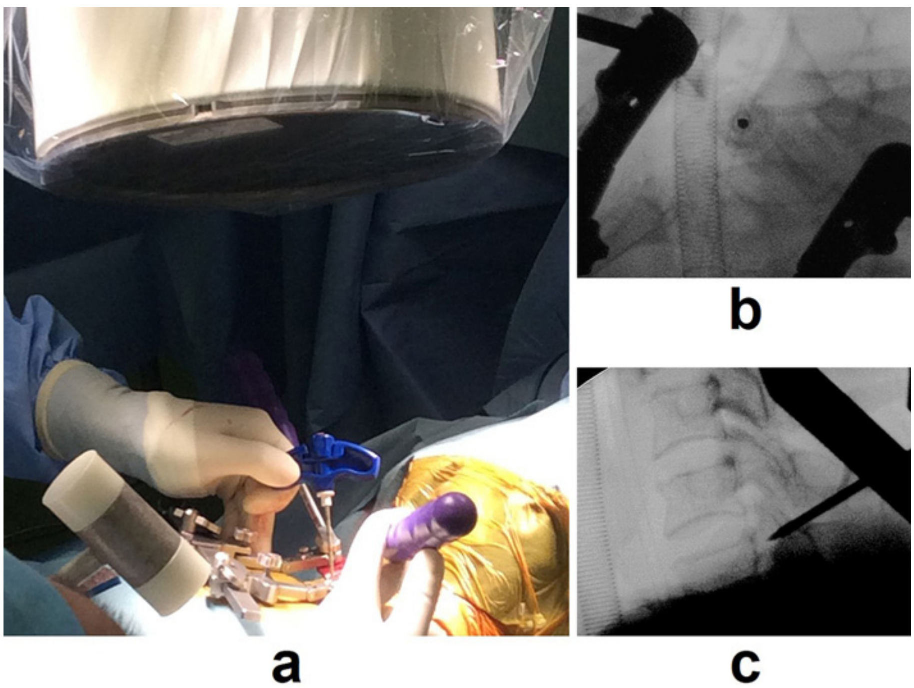

Figure 4. Bone biopsy needle insertion in posterior fixation (case 1).
a. The C-arm beam angle was adjusted to 50 degrees. A 13G bone biopsy needle was inserted obliquely from the entry point as determined by the fluoroscopy-assisted pedicle axis view technique.
b. The needle was visualized as a point at the center of the cortical circular area on the pedicle axis view.
c. The needle was inserted within a few millimeters of the pedicle.

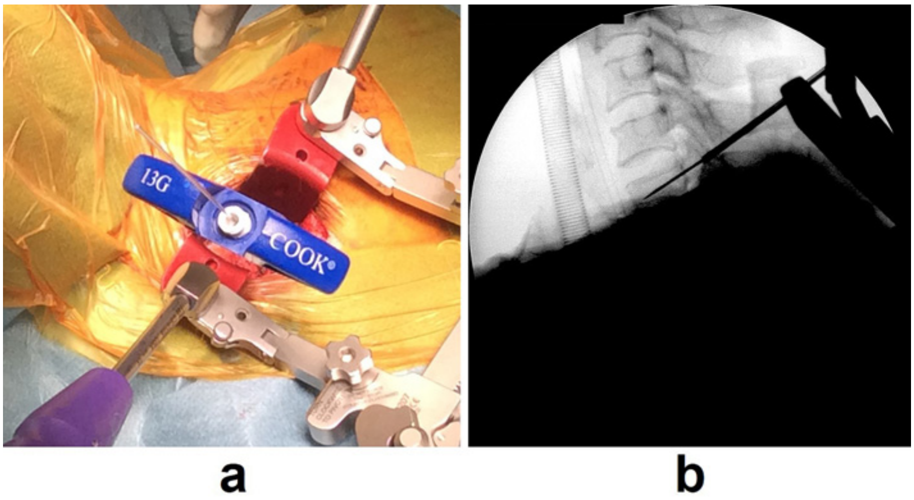

Figure 5. Guidewire placement in posterior fixation (case 1).
a. The external sleeve of the bone biopsy needle was left as a drill guide, the 1.25 mm guidewire for the 4.0 mm cannulated screw was then inserted into the pedicle cavity.
b. The placement of the guidewire was confirmed by fluoroscopy.

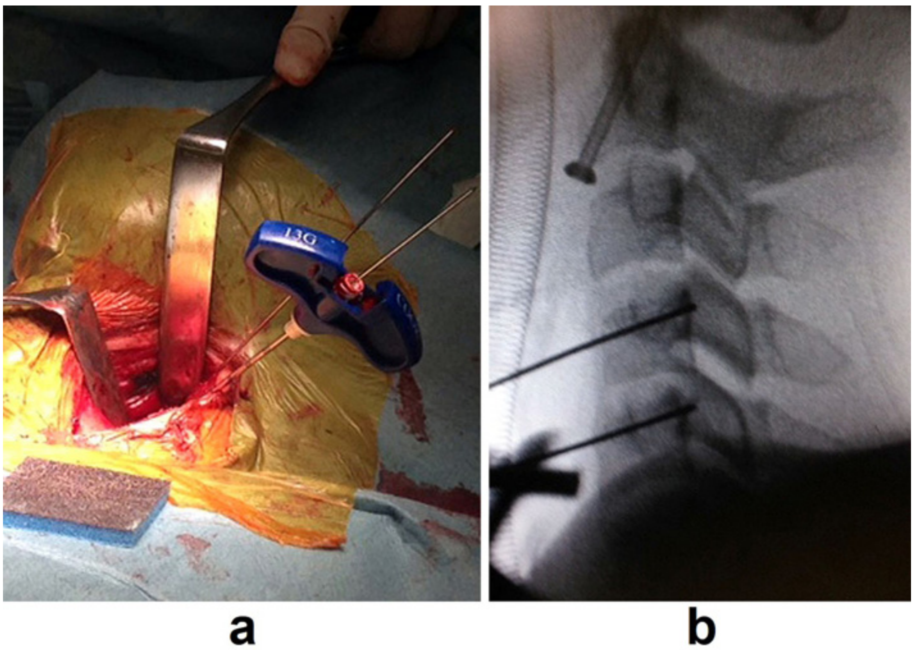

Figure 6. Bone biopsy needle and guidewire insertion in anterior fixation (case 2).
a. The external sleeve of the bone biopsy needle was placed as a drill guide using the fluoroscopy-assisted pedicle axis view technique, the 1.25 mm guidewire for the 4.0 mm cannulated screw was then inserted.
b. The placement of the guidewire was confirmed by fluoroscopy.

over the guidewire (Fig. 7).

7) The screw trajectory was confirmed using a pedicle sounder as well as fluoroscopy.

8) Tapping was performed before CPS insertion (Fig. 7). Cannulated taps and CPSs are not essential. The surgeon can place a CPS by a free-hand technique because ideal trajectory has already been established.

Results

The mean (±standard deviation) pedicle diameter was 4.1 ± 0.6 mm and 4.2 ± 0.4 mm in the conventional method group and the new method group, respectively. There was no statistical difference between the groups (p = 0.4433, t-test). For C3-6, anterior CPS diameter was 4.0 mm (11 screws) and posterior CPS diameter was 3.5 mm (87 screws). For C2 and C7, posterior CPS diameter was 3.5

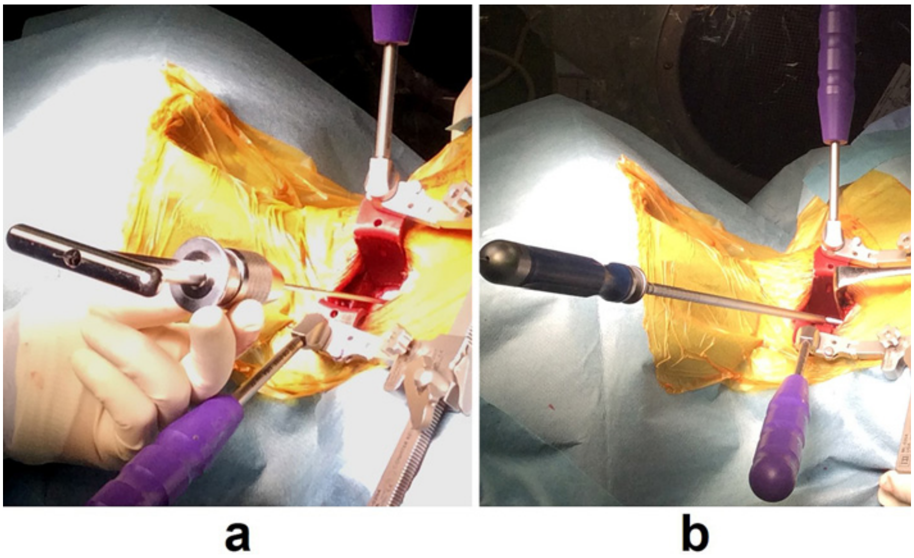

Figure 7. Screw trajectory placement in posterior fixation (case 1).
a. The external sleeve of the bone biopsy needle was removed, the screw trajectory was made by a 2.7 mm cannulated drill bit inserted over the guidewire.
b. After the screw trajectory was confirmed by use of a pedicle sounder as well as fluoroscopy, tapping was performed.

Table 1. Pedicle Screw Perforation in Both Groups.

		C2	C3	C4	C5	C6	C7	Total
Conventional method	No. of screws	11	8	12	27	29	28	115
	Grade 0 or 1	11	8	10	25	29	27	110 (95.7%)
	Grade 2 or 3	0	0	2	2	0	1	5 (4.3%)
New method	No. of screws	-	-	3 (ACPS 3)	11 (ACPS 4)	8 (ACPS 4)	7 (ACPS 1)	29 (ACPS 12)
	Grade 0 or 1	-	-	3	11	8	7	29 (100%)
	Grade 2 or 3	-	-	0	0	0	0	0 (0%)

ACPS: anterior cervical pedicle screw

mm (four screws) or 4.0 mm (45 screws), which was determined by preoperative measurement.

The accuracy of CPS placement was assessed postoperatively by reviewing multiplanar CT scans. Screw mispositioning was classified using the method described by Neo as follows: grade 0, no deviation; grade 1, deviation <2 mm; grade 2, deviation >2 mm but <4 mm; and grade 3, deviation >4 mm (i.e., complete deviation)[4]. In the conventional method group, 110 of 115 screws (95.7%) were classified as grade 0 or 1, and five of 115 screws (4.3%) were grade 2 or 3. Four of five screws were laterally deviated, and the remaining one was medially deviated. One patient developed VA injury because of lateral perforation of the pedicle by the pedicle probe. Fortunately, hemostasis was achieved by packing the screw cavity with bone wax, and there were no further complications. In the new method group, all the CPSs were classified as grade 0 or 1 (Table 1). No patient developed VA injury or neurological deterioration.

Discussion

The CPS fixation technique was first described by Abumi[1]. Despite its mechanical advantages, it was associated with potential risk of iatrogenic damage to neurovascular structures because of the small size and steep oblique axis of the cervical pedicles[1-20]. The mispositioning rate of CPSs inserted by a free-hand technique was reported in the range of 6.7% to 29%[1,4,11]. There are several cautions and strategies to avoid mispositioning. First, preoperative planning with multiplanar CT and accurate determination of the entry point and trajectory angle during surgery are indispensable[5,8,12]. The usefulness of image-guided techniques[2,3,17], navigation systems[5,8,13,14,16], and patient-specific screw guide templates[7,10,12], pedicle marker of the cervical spine[15] has been reported. Second, posterolateral approach would be a good choice because the ideal trajectories of CPSs are often disturbed by the pressure of the retracted paravertebral muscle[4,5,9,12-14,16]. Third, even using the navigation system, CPS mispositioning cannot be completely avoided because cervical alignment can easily rotate when force is applied on the cervical spine while probing and tapping the pedicle or inserting the CPS[4,5,8,12,20]. The surgeon should be aware of possible errors associated with the change of spinal alignment during surgery. To solve these issues, special devices including an aiming device[6] and patient-specific screw guide template system[7,10,12] were introduced.

In the beginning, we adopted the CPS fixation technique proposed by Yukawa et al.[2,3] They used a trajectory angle of 30-35 degrees from the sagittal plane to avoid excessive surgical exposure. In our study, the PTA of each vertebra, measured from preoperative CT scans, was used as the ideal trajectory angle and to determine its corresponding entry point. The average PTA of mid-cervical spine was reported to be 46 (range, 30 to 62) degrees[6], which was larger than the trajectory angle proposed by Yukawa et al.[2,3] It was sometimes difficult to maintain the ideal trajectory angle via the conventional approach because of the steep PTA, but the posterolateral approach described by Tokioka et al.[13,14,16] enabled us to maintain the ideal trajectory in the absence of pressure from retracted paravertebral muscles. Our procedure using the bone biopsy needle as drill guide has several advantages. First, once the entry point and drill direction are set by the installed bone biopsy needle, the proper insertion point and drill direction are maintained at the same time. It prevents drilling or screwing errors along with change in spinal alignment during surgery or unsteady hand movements. Second, it does not require expensive equipment such as navigation systems or special devices like patient-specific templates. There are several limitations in this study. First, the sample size was small, and the results are preliminary. Second, in patients with severe osteoporosis or severe deformity such as from rheumatoid arthritis and congenital palsy, CPS insertion by the pedicle axis view technique may be difficult. In conclusion, using the bone biopsy needle as drill guide, our procedure enables accurate placement of CPS without expensive instruments.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: None. (As this is a technical note without identifiers.)

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Author Contributions: TK performed the operations and wrote the manuscript; TA supported the operations and manuscript writing; EI is the scientific guarantor of this manuscript. All authors read and approved the final manuscript.

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