

Clinical Article



Freehand Placement of the C1 Pedicle Screw Using Direct Visualization of the Pedicle Anatomy and Serial Dilatation

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Conflict of Interest

The authors have no financial conflicts of interest.

ABSTRACT

Objective: We designed a method for inserting C1 pedicle screws using the direct visualization technique of the pedicle and serial dilatation technique to reduce complications and malposition of screw, and assessed the accuracy of this method.

Methods: Free-hand C1 pedicle screw insertion using the direct visualization technique of the pedicle and serial dilatation technique was performed on 5 consecutive patients with C1-2 instability at a single institute from March to December 2018. The method involved protecting the vertebral artery (VA) and C1 root using the Penfield No. 1, securing the entry point of the posterior arch screw and the pedicle was visible directly in Trendelenburg position. The hole at the entry point of the C1 posterior arch was serially dilated using a 2.5×3.0 mm drill bit, and the C1 pedicle screw was inserted with the free hand technique. We measured postoperative radiological parameters and recorded intraoperative complications, postoperative neurological deficits and the occurrence of occipital neuralgia. Postoperative computed tomography (CT) was performed to check screw malposition or construction failure.

Results: Of the 10 C1 pedicle screws on postoperative CT, 20% of screws (grade A) were in the ideal position while 80% of screws (grade B) occupied a safe position. Overall, 100% of screws were safe (grade A or B). There were no iatrogenic neurological deficits, VA injury.

Conclusion: Freehand placement of the C1 pedicle screw through the direct visualization technique of the pedicle and serial dilatation technique is safe and effective without intraoperative fluoroscopy guidance.

Keywords: Cervical atlas; Atlanto-Axial joint; Pedicle screws

INTRODUCTION

Posterior fixation of the cervical spine is commonly used to stabilize the atlantoaxial complex. Atlantoaxial problems can be caused by trauma, degenerative disorder, and malignancy.¹⁻⁵⁾ C1 lateral mass screw fixation is generally performed for C1-2 stabilization. The technique of insertion of the C1 lateral mass screw by Hams can damage structures anterior to C1, such as the hypoglossal nerve and internal carotid artery, because the screw must be bi-cortically

inserted.^{7,9)} The C1 pedicle screw fixation technique was introduced by Tan et al.²⁵⁾ in 2003 as an alternative to the C1 lateral mass screw.¹⁴⁾ This method involves placing the screw into the lateral mass via the posterior arch, without invading the anterior cortex.^{16,23,25)} In addition, in a biomechanical comparison study of the C1 pedicle and lateral mass screws, the C1 pedicle screw showed greater stiffness.^{2,17,27)} Although the technique is frequently used for C1–2 instability, it requires fluoroscopic guidance, which is time-consuming and has the risks of accumulative radiation.^{8,11,13,18,20,21)} It is occasionally difficult to interpret biplane X-ray scans acquired after C1–2 pedicle screw insertion. Therefore, we report a series of 5 patients who underwent freehand insertion of the C1 pedicle screw with the direct visualization technique of the pedicle and serial dilatation technique. The purpose of this study was to validate the safety and accuracy of freehand screw insertion of C1 pedicle screws.

MATERIALS AND METHODS

Patient population

This was a retrospective study of 5 consecutive patients who underwent free hand placement of the C1 pedicle screw with the direct visualization technique of the pedicle to treat C1–2 instability at a single institute from March to December 2018. All patients were treated by a single neurosurgeon specialized in spine surgery. The study included patients diagnosed with C1–2 instability because of degenerative, or congenital abnormalities. Patients who had an instability caused by an infection or rheumatoid arthritis or required occipital fixation were excluded from this study. The C1 vertebra with ponticulus posticus was not considered for pedicle screw use. The C2 vertebra with high-riding vertebral artery (VA) was also excluded for laminar or pars screw use. C1–2 instability can be determined using the atlantodental interval (ADI), which is the radiographic measurement of atlantoaxial joint articulation. In this article, we defined atlantoaxial dislocation as ADI greater than 3 mm in adults over the age of 18 years.

Surgical technique

The patient was placed in the prone position. The craniocervical junction was exposed in the usual fashion. Dissection was performed approximately 2 cm lateral to the midline using bipolar cautery. The VA and C1 roots were exposed. Bleeding from the epidural venous plexus when exposed to the C1 lateral mass was controlled using compression with gelfoam-coagulation. Since only the upper part of the lateral mass was exposed, the bleeding was mild. Medial and lateral margins of the C1 lateral mass were identified with palpation using a Penfield No. 4 dissector. The VA and C1 roots were exposed from the C1 posterior arch and dissected away cranially using the root retractor and suction tip (**FIGURE 1**). The C1 pedicle was then visualized directly (**FIGURE 2**). The entry point of the C1 pedicle screw was the midpoint between the lateral and medial margins of the C1 pedicle in the posterior arch (**FIGURE 3**). The pilot hole was estimated by directly visualizing the course of the C1 pedicle as follows. Protecting the VA and C1 root, a high-speed drill with a 1.8-mm match head bur was used to make a hole at the entry point of the C1 posterior arch, which was expanded deep and wide with a 2.5-mm-diameter drill bit and further widened with 3.0-mm-diameter drill bit at a depth of 26–30 mm, as measured on preoperative computed tomography (CT). The screw length was finally determined during surgery by measuring the depth of the ball tip probe after tapping. Subsequently, a 28–34-mm-long screw of 3.5-mm diameter was inserted (**FIGURE 4**). Identical to the C1 pedicle screw, freehand insertion of the C2 pedicle screw was performed (**FIGURE 5**).

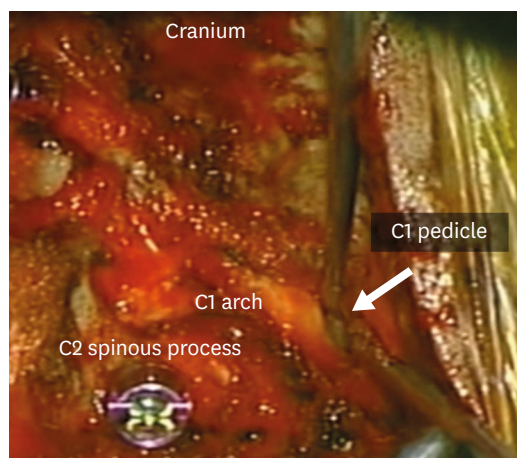


FIGURE 1. Exposure of the vertebral artery and C1 roots from the C1 posterior arch.

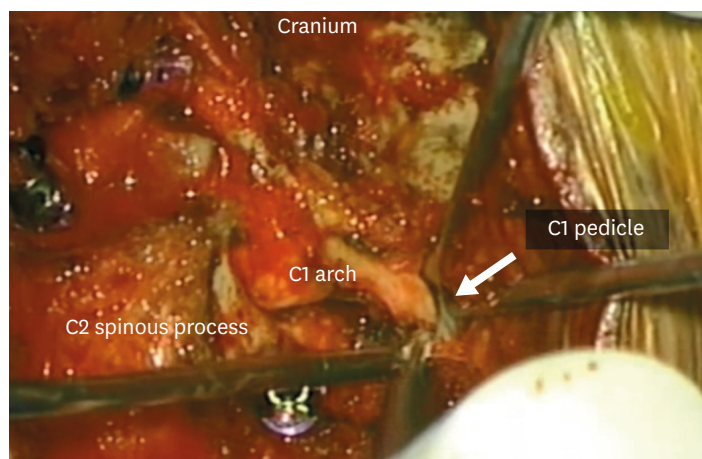


FIGURE 2. Direct visualization of the course in the C1 pedicle.

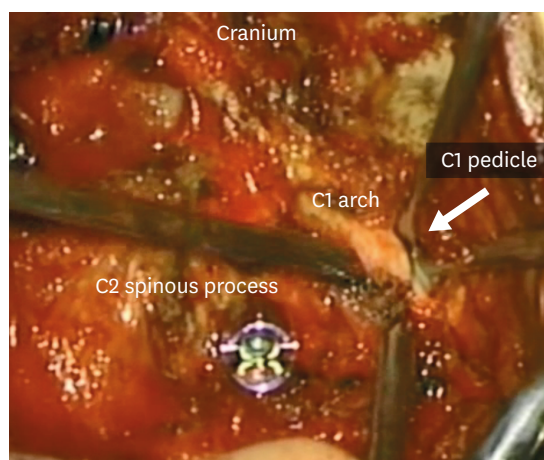


FIGURE 3. Entry point of the C1 pedicle screw.

This method of the serial dilatation technique allowed the insertion of the pedicle screw into the C1 pedicle with a diameter of less than 4 mm. If the pedicle was large enough, the pilot hole was tapped with a 3.0-mm tap without widening the hole using 2.5- and 3.0-mm-

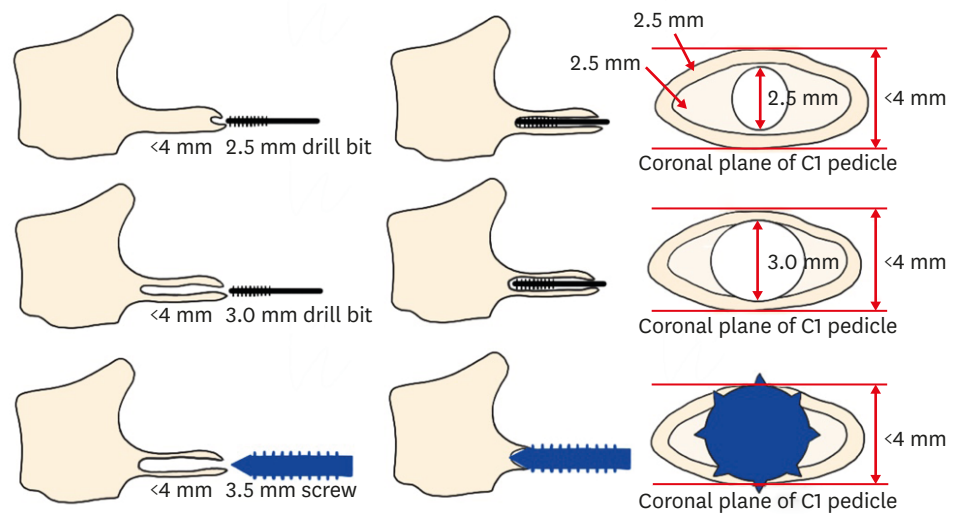


FIGURE 4. Serial dilatation technique.

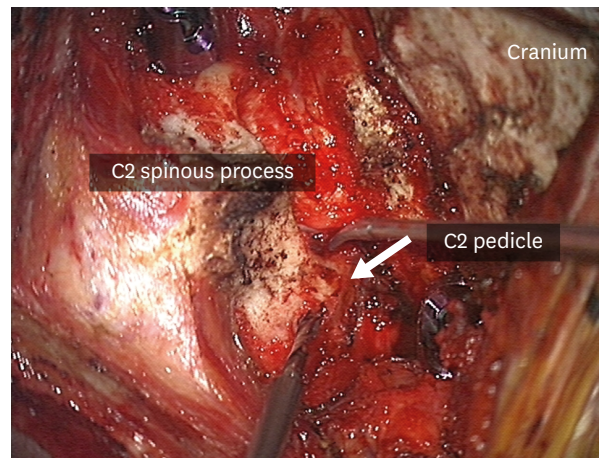


FIGURE 5. Entry point of the C2 pedicle screw.

diameter drill bits, and subsequently, a 28–34-mm long screw with a diameter of 4.0 mm was inserted. This method of the serial dilatation technique allowed the trajectory to be gradually and safely expanded through the cancellous channel of the pedicle without damaging the cortical bone on the C1 pedicle with a diameter of less than 4 mm. The Vertex Reconstruction System (Medtronic Sofamor-Danek, Memphis, TN, USA) was used in all 5 patients. After inserting the screws and atlantoaxial facet joint fusion (**FIGURE 6**), 3.0-mm rods were applied and fastened using cap nuts.

Radiographic and clinical evaluation

In all patients, preoperative CT and magnetic resonance imaging were performed to determine the ideal screw lengths and diameters of the C1 and, C2 pedicle screws. The patients also underwent CT angiography for evaluation of possible occult VA injury. Thin-cut CT was performed for the evaluation of screw malposition 1–3 days after surgery. The accuracies of the screws were rated as grades A, B, C, D, and E for perfectly insertion to the pedicle, 0–2 mm, 2–4 mm, 4–6 mm, and more than 6 mm of cortical breach, respectively. Grade A and B screws were considered well positioned.³⁾ The 5 patients were examined clinically after 1 postoperative month. The electronic medical record review included patient

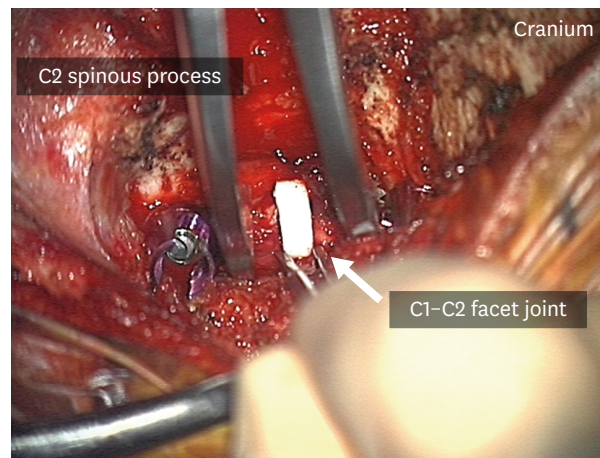


FIGURE 6. Atlantoaxial facet joint fusion.

demographics, diagnosis, and estimated blood loss as identified by anesthesiologists. Intraoperative injury of the nerve structure or VA and postoperative symptom of occipital neuralgia were also included. The Nurick grade was used to assess neurological outcomes before and after surgery.

RESULTS

Demographic data

A total of 10–C1 pedicle screws were implanted in 5 consecutive patients: one man and four women, aged 49–76 years (mean, 59 years) at the time of surgery. The mean follow-up period was 2.2 months (range, 1–3 months). Three patients had myelopathy due to os odontoideum while 2 had C1–2 subluxation. The preoperative Nurick grade was 1, 2, and 5 in one, three, and one patient, respectively. The mean operation time was 212.2 minutes (range, 180–249 minutes), and the mean intraoperative blood loss volume was 120 mL (range, 100–200 mL) (**TABLE 1**).

Radiological and clinical outcomes

On preoperative CT, the right and left mean diameters of the C1 posterior arch at the VA groove were 3.1 mm (range, 2.5–4.1 mm) and 3.0 mm (range, 2.7–3.9 mm), respectively. All screws inserted using a serial dilatation in the pedicle with a diameter of less than 4 mm were acceptable on postoperative CT (**FIGURE 7**). Of the 10 C1 pedicle screws imaged with postoperative CT, 20% of screws were grade A while 80% were grade B. Overall, 100% of screws were rated as safe (grade A or B). There were no known neurological or VA injuries.

TABLE 1. Demographic characteristics of 5 patients who underwent free hand placement of a C1 pedicle screw with direct visualization of the pedicle and serial dilatation technique

Case	Sex	Age (years)	Diagnosis	Operative level	Operative time (min)	Blood loss (mL)
1	F	49	Os odontoideum	C1–2	249	100
2	M	54	C1–2 subluxation	C1–2	200	100
3	F	54	Os odontoideum	C1–2	180	200
4	F	76	C1–2 subluxation	C1–2	241	100
5	F	62	Os odontoideum	C1–2	191	100

F: female, M: male.

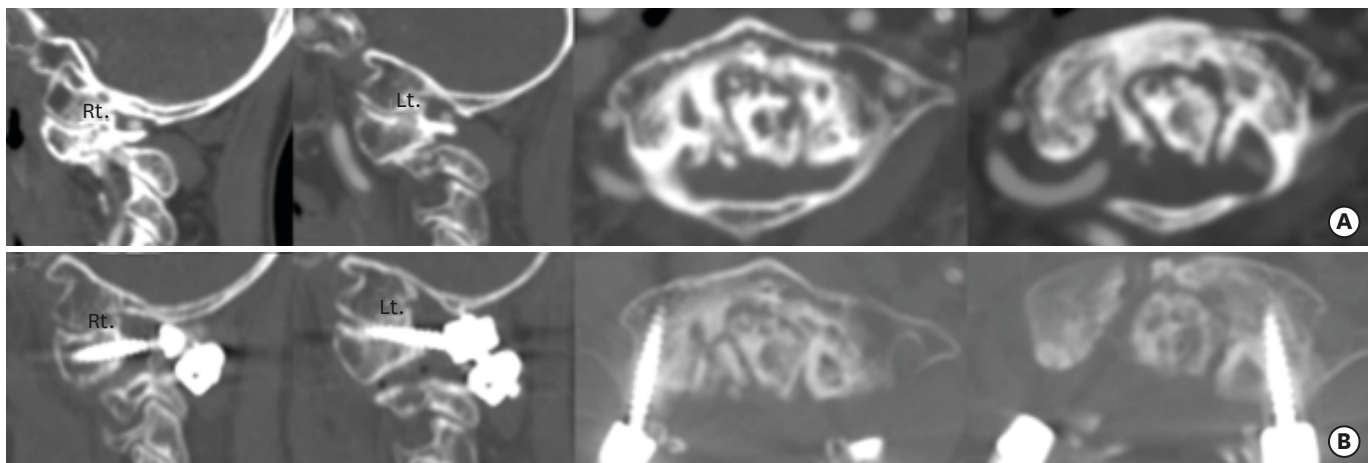


FIGURE 7. Sagittal and axial CT images. (A) Preoperative CT image, (B) Postoperative CT image. CT: computed tomography, Rt.: right, Lt.: left.

TABLE 2. Radiologic and clinical outcomes of 5 patients who underwent free hand placement of a C1 pedicle screw with direct visualization of the pedicle and serial dilatation technique

Case	Diameter of the C1 posterior arch		C1 pedicle wall violation grade		Nurick grade		Occipital neuralgia	
	Rt.	Lt.	Rt.	Lt.	Pre-op	Post-op (1 month)	Rt.	Lt.
1	3.1	3.0	B	B	1	0	x	x
2	2.9	2.7	B	B	2	1	x	x
3	3.0	2.7	B	B	2	1	x	x
4	2.5	2.7	B	B	5	4	x	x
5	4.1	3.9	A	A	2	1	x	x

Rt.: right, Lt.: left, Pre-op: pre-operative, Post-op: post-operative.

The 5 patients were free of neck pain after surgery, and all patients with preoperative myelopathy improved by more than one Nurick grade at the postoperative 1-month status (TABLE 2). After C1 pedicle screw insertion, none of the patients had iatrogenic neurological deficits, wound infections, VA injuries, cerebrospinal fluid leakage, or occipital neuralgia. There was no radiographic evidence of construct failure, and all screws were in excellent sagittal alignment.

DISCUSSION

The C1 level is a common anchor point for posterior approach to treat occipitocervical and atlantoaxial spinal pathology. The C1 lateral mass and C2 pedicle screws for atlantoaxial stabilization are generally used in patients with atlantoaxial instability owing to the safety of screw insertion.^{1,4,7)} However, since the C1 lateral mass screw entry point is covered with the C1–2 venous plexus, C1–2 venous plexus injury can cause profuse bleeding, extending the operation time, when exposed to the C1 lateral mass. Pan et al.¹⁹⁾ demonstrated blood loss of up to 1,000 mL. Furthermore, occipital neuralgia is a possible complication of C2 nerve root traction or irritation during C1 lateral mass fixation. Several studies showed that occipital neuralgia occurred in many cases after C1 lateral mass screw insertion.^{5,24)} Although some studies suggested that C2 root sacrifice was not related with occipital neuralgia, further studies are required to identify the occurrence of occipital neuralgia after the sacrifice of the C2 nerve root.^{6,22)}

As an alternative to the C1 lateral mass screw, Lee et al.¹⁰⁾ introduced the notching technique of C1 screw insertion. In this method, the entry point is made on the notching of the inferior arch, where the inserted screw is placed partially out of the inferior wall of the posterior arch.¹⁰⁾ The notching technique provides a higher entry point than the C1 lateral mass screw to reduce the injury of the C1–2 venous plexus and C2 nerve root. Several studies have provided a method to protect the surrounding tissue of the C1 posterior arch by placing the bone wax and gelatin sponge under the C1 posterior arch.^{14,19)} However, the notching technique still carries a risk of the C1–2 venous plexus and C2 nerve root injury since the entry point of notching technique is close to the entry point of the lateral mass screw. The screw pull-out strength can be weakened from placing the screw out of the inferior wall of the posterior arch.

In the early 2000s, the use of the C1 posterior arch screw was reported independently in two studies.^{23,25)} In the subaxial vertebra, the pedicle is anatomically located at the connection between the vertebral body and the posterior arch. The connection of the C1 posterior arch and the lateral mass in the atlas is anatomically and biomechanically similar to the pedicle of the subaxial vertebra. Therefore, previous studies considered this connection of C1 as a pedicle of C1.^{14,15)} C1 pedicle screw insertion involves placing the screw into the lateral mass via the posterior arch without violating the anterior cortex. There are several advantages to C1 pedicle screw fixation compared to the C1 lateral mass screw and notching technique. First, C1 pedicle screw fixation provides a greater pull-out strength and minimizes the focus of the stress at the screw–bone junction. Second, this method results in less irritation to the C2 nerve root and venous plexus since there is no need to coagulate the C1–2 venous plexus or to retract the nerve caudally when placing the screw via the C1 posterior arch. Third, the C1 pedicle screw entry point is visible better directly. Therefore, C1 pedicle screw fixation is becoming a popular alternative for C1–2 stabilization. However, according to an anatomical study by Tan et al.,²⁵⁾ C1 pedicle screw fixation is not suitable for patients with a thickness of less than 4 mm in the thinnest part of the posterior arch groove.

In a later published study by Tan et al.,²⁶⁾ C1 pedicle screw fixation is feasible for a C1 posterior arch <4 mm or even 2.5 mm using the pedicle exposure technique. However, in the pedicle exposure technique, the outer bone at the posterior arch, inferior to the VA groove along the direction of the trajectory, is removed by Rongeur for exposing the feasible screw entry point in the C1 posterior arch <4 mm. The process of removing part of the cortex of the C1 posterior arch may influence the screw pull-out strength. In addition, the direction of the trajectory was confirmed with fluoroscopic guidance, which is time-consuming and has the risks of accumulative radiation. It is difficult to interpret biplane X-rays taken after C1 pedicle screw insertion. In our study, the C1 pedicle screw can safely inserted in patients with a posterior arch thickness less than 4 mm using direct visualization of the pedicle and serial dilatation technique without fluoroscopy guidance. With minimal exposure of the upper part of the lateral mass and Trendelenburg position change, the C1 pedicle is fully exposed and the C1 pedicle screw was inserted while looking directly at the C1 pedicle so that the screw could be inserted into the desired trajectory without fluoroscopy guidance. A screw of 3.5-mm size can be inserted in patients with less than 4 mm of posterior arch thickness because the pedicle is dilated with serial 2.5- or 3.0-mm drill bits. The pull-out strength does not also decrease from holding the cortical bone above or below or cancellous bone beside the coronal section of the pedicle. In the present study, although patients were only few, the accuracy of the screw was acceptable for grade A and B on postoperative CT in all inserted screws. All screws of grade B were inserted into the pedicle with a diameter

less than 3.5 mm. There was no venous plexus bleeding and occipital neuralgia using direct visualization or the serial dilatation technique in our study. However, in pedicles with a diameters of less than 3.5 mm, a long-term follow-up is needed to evaluate the delayed VA injury because the thread of the screw is located beyond the cortical bone above or below the coronal section of pedicle. In addition, more studies should be performed to identify a reduced rate of bleeding of the venous plexus and occipital neuralgia as demonstrated in this study by using direct visualization and serial dilatation technique. Although this study provides only preliminary results and is subject to selection bias, we believe that the described technique is a useful addition to the surgical techniques available for the treatment of C1–C2 instability.

CONCLUSION

According to previous studies, pedicle with a diameter of 4 mm or less pose difficult in pedicle screw insertion. However, our study suggests that C1 pedicle screw insertion using direct visualization and serial dilatation technique is feasible for a C1 posterior arch <4 mm or even 2.5 mm. Freehand placement of the C1 pedicle screw technique is safe and effective even without fluoroscopy guidelines during surgery.

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