Posterior C1-C2 Fusion Using C1 Lateral Mass and C2 Pars Screw with Rod Fixation: Techniques and Outcomes

Akkapong Nitising MD*, Chumpol Jetjumnong MD*,
Nanthasak Tisavipat MD*, Sarun Nantaaree MD*

** Department of Neurosurgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand*

Objective: *The atlantoaxial instability often requires posterior fixation surgery. Multiple techniques have been described for C1-C2 fixation. Transarticular atlantoaxial screw has been demonstrated to be effective for C1-C2 stabilization. However, up to 20% of patients are not candidates for the procedure. New technique concerning the placement of individual screws in C1 lateral mass and C2 pars screw with additional rods for their connection was described, either as a salvage method for unsuccessful C1-C2 stabilization or as an effective alternative technique. The authors presented their experience using C1 lateral mass and C2 pars screws with rod fixation for C1-C2 stabilization.*

Material and Method: *Between May 2007 and October 2008, 10 patients (7 male, 3 female) whose age ranged from 15 to 59 years-old underwent posterior fixation using C1 lateral mass and C2 pars screw with rod fixation. Six patients had atlantoaxial subluxation due to os odontoideum, two patients had chronic C1-C2 subluxation, and two patients had acute C1-C2 subluxation from a motor vehicle accident. All screws were placed under lateral fluoroscopic guidance.*

Results: *C1 lateral mass and C2 pars screw with rod fixation were used to achieve C1-C2 stabilization in all patients. All screws were positioned correctly in both C1 and C2. There were no permanent complications. In all cases, rigid fixation was confirmed on postoperative radiographs and maintained on follow-up radiographs.*

Conclusion: *The lateral mass and C2 pars screw with rod fixation is an effective method of stabilizing the atlantoaxial complex. This procedure provides rigid fixation with relative safety.*

Keywords: *C1 lateral mass screw, C2 pars screw, Posterior fixation, Craniocervical junction, Atlanto-axial fixation, Polyaxial screws and rods*

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Atlantoaxial instability may result from traumatic injuries, tumors, congenital malformations, and inflammatory conditions. Multiple techniques have been described for C1-C2 stabilization. C1-2 Transarticular screws fixation, posterior interspinous cable and graft constructs and interlaminar clamps have been used effectively to achieve atlantoaxial fixation. Although each of these methods has been successfully used to achieve atlantoaxial fusion, anatomical factors may exist in certain cases that preclude their use. Interspinous fusion at C1-2 with sublaminar cables or interlaminar clamps cannot be performed if the posterior elements of C-1 or C-2 are absent or disrupted. Rigid fixation with transarticular screws has been demonstrated to be a safe and effective method for C1-C2 stabilization in most patients. However, up to 20% of patients are not candidates for the procedure because of it cannot be placed successfully in the presence of a medially located VA or limited size of the C2 pars interarticularis, irreducible subluxation, severe cervicothoracic kyphosis, obesity, or destruction of the C-2 pars interarticularis[1-3].

A new technique concerning the placement of individual screws in C1 and C2 with additional rods for their connection was described by Harms and Melcher as an alternative method to achieve atlantoaxial fixation[4]. Biomechanically of this technique has also been shown to be equivalent to transarticular screws[5,6]. In this report, the authors describe their experience using C-1 lateral mass and C2 pars screw with rod fixation to achieve C1-C2 stabilization.

Correspondence to:
Nitising A, Division of Neurosurgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 0-2419-8003
E-mail: a_nitising@yahoo.com

Material and Method

Patient population

Ten patients with atlantoaxial instability were treated surgically between May 2007 and October

2008. Their age ranged from 15 to 59 years, there were seven males and three females.

Preoperative clinical data (Table 1)

Preoperative diagnosis included os odontoideum, Type II odontoid fracture and chronic atlantoaxial subluxation. Duration of symptoms varied from 1 day to 10 years. Six patients presented with symptoms and signs of cervical myelopathy (hemiparesis or quadriparesis), three patients presented with neck pain without neurological deficit after a motor vehicle trauma and one patient (case 1) was found incidentally from CT scan of head and neck during preoperative evaluation for his parotid gland tumors without a history of neck pain. Disability grades were defined using Di Lorenzo's grades[7] (Table 2). Four patients had disability grade I, three cases were grade II, two cases were grade III and one case was grade IV. The clinical data were summarized in Table 1. All procedures were performed using intraoperative lateral fluoroscopy.

Operative technique

Skull traction was applied to realign the C1-C2 complex as much as possible, usually before the operation for 24-48 hours. Under general anesthesia, the patient is placed in the prone position on the Stryker frame (Fig. 1). The cervical spine is exposed from the occiput to C2-C3. The C1-C2 complex is exposed to the lateral border of the C1-C2 articulation. Bleeding typically arises from dissection around the epidural venous plexus along the C1-C2 joint. This is effectively controlled with a combination of bipolar electrocautery, Surgicel, and fibrillar collagen. The C1-C2 joint is exposed and opened by dissection over the superior surface of the C2 pars interarticularis. This joint is a key anatomic landmark for accurate placement of the C1 lateral mass screw. The dorsal root ganglion of C2 is retracted in a caudal direction to expose the entry point for the C1 screw, which is in the middle of the junction of the C1 posterior arch and the midpoint of the posterior inferior part of the C1 lateral mass. This entry point is marked with a 1- to 2-mm high-speed burr to prevent slippage of the drill point. The pilot hole is then drilled in a straight or slightly convergent trajectory in an anterior-posterior direction and parallel to the plane of the C1 posterior arch in the sagittal direction, with the tip of the drill directed toward the anterior arch of C1 (Fig. 2a). The drilling is accomplished with guidance from intraoperative landmarks, and lateral fluoroscopic

Table 1. Summary of 10 cases with atlantoaxial instability

Case No.	Age (yrs), Sex	Presentation	Diagnosis	Duration of onset	Preoperative disability grades
1	59, M	Incidental findings from CT neck with C1-C2 subluxation	Os odontoideum	-	I
2	59, M	Hand weakness, progressive quadriparesis	Os odontoideum	2 yrs	III
3	51, F	Progressive quadriparesis	Os odontoideum	10 yrs	IV
4	50, M	Neck pain after trauma	Type II odontoid fracture	1 day	I
5	42, M	Numbness and Lt. hemiparesis	Os odontoideum	2 yrs	III
6	46, M	Numbness and Lt. hemiparesis	C1-C2 subluxation	1 mo	II
7	54, F	Neck pain, progressive quadriparesis	Os odontoideum	3 mo	II
8	57, F	Neck pain, progressive quadriparesis	C1-C2 subluxation	1 yrs	II
9	15, M	Neck pain after trauma	Type II odontoid fracture	7 mo	I
10	48, M	Neck pain after trauma	Type II odontoid fracture	3 mo	I

Table 2. Disability grade according to Di Lorenzo's grades[7]

Grade I	Independent, without deficits except hyperreflexia or neck pain (neurologically intact)
Grade II	Independent for daily activities but having minor deficits (minor disability)
Grade III	Partly dependent on others for their daily needs (moderate disability)
Grade IV	Totally dependent on others for daily needs (severe disability)

imaging._The hole is tapped and a 3.5-mm polyaxial screw of an appropriate length is inserted bicortically into the lateral mass of C1 (Fig. 2b). Subsequently, the C2-C3 facet joint is localized and its medial border in the spinal canal is palpated subperiosteally using a number 4 Penfield. The entry for placement of a C2 pars screw is marked with a high-speed burr. The entry point for the C2 pars screw is 3 to 4 mm rostral and 3 to 4 mm lateral to the inferomedial aspect of the inferior articular surface of C2 (Fig. 3a). The pilot hole is prepared with a 2-mm drill bit, just perforating the opposite cortex. The screw follows a steep trajectory, paralleling the C2 pars interarticularis. An appropriately steep trajectory (40° or more) is achieved by aligning the shaft of the drill or screwdriver with the tip of the T1 spinous process. This trajectory may be achieved by using percutaneous stab incisions about 2 cm lateral to the T1 spinous process. However, the authors are usually able to achieve the trajectory through an incision that extends down to C4 without using percutaneous stab incisions. The screws are passed with 10° of medial angulation. Screw length is typically 16 mm, which will stop short of the transverse foramen, avoiding injury to the vertebral artery. When possible, a larger (4.0 mm) diameter screw is used to achieve increased pullout resistance because the screw is unicortical (Fig. 3b). If necessary, reduction of the C1 ring is performed by repositioning the patient's head and/or directly manipulating C1 and C2 using the screws, followed by fixation to the rods to maintain the alignment. If a definitive fusion is required, C1 and C2 are decorticated posteriorly, and cancellous bone taken from a small incision in the posterior iliac crest are placed over the decorticated surfaces of C1 and C2. An intraarticular fusion can also be performed by decorticating the joint surfaces under direct vision. Patients are mobilized on the first postoperative day and wear a soft cervical collar for 2 to 3 weeks.

Fig. 1 Positioning of the patient

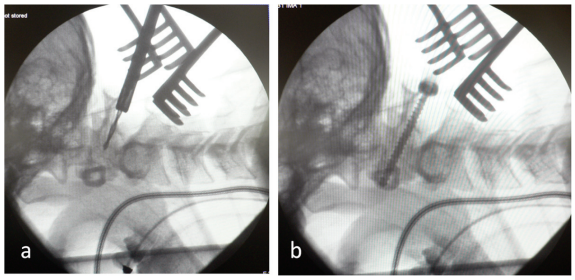

Fig. 2 Intraoperative photograph (a) show the tip of the drill directed toward the anterior arch of C1 and (b) a 3.5-mm polyaxial screw of an appropriate length is inserted bicortically into the lateral mass of C1

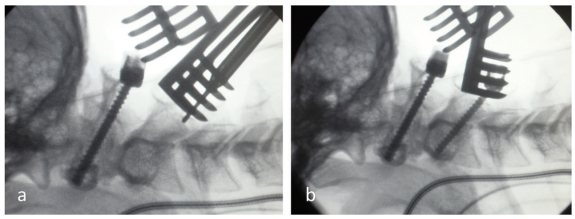

Fig. 3 (a) The entry point for the C2 pars screw is 3 to 4 mm rostral and 3 to 4 mm lateral to the inferomedial aspect of the inferior articular surface of C2. (b) The screw follows a steep trajectory, paralleling the C2 pars interarticularis

Results

Postoperative clinical data

Three cases had profuse bleeding (> 500 ml) from the vertebral venous plexus, which can be treated by bipolar coagulation and packed with surgicel and fibrillar collagen. No patient demonstrated neurological deterioration. Asymptomatic right vertebral artery injury (Case 1) was found in one case during C2 pars screw placement. One case (Case 4) had a superficial wound infection, which was successfully treated with orally administered antibiotics and local debridement. The follow-up period ranged from 1 month to 18 months (mean 7.4 months). The patients were evaluated at 1, 3, 6 month and then as necessary after the operation. Neurological examination and cervical spine AP and

lateral x-ray films were done at each patient follow-up. At 6-month follow-up, the lateral cervical flexion/extension film was performed to determine bony union of the C1-C2 fusion. The Di Lorenzo's grades improved in five cases in which grade 3 was improved to grade 2 and grade 2 was improved to grade 1. One patient (Case 3) was unchanged due to her severe preoperative status and long duration of symptoms (10 years) (Fig. 4).

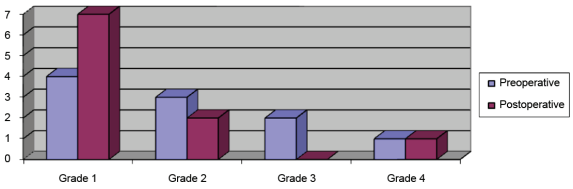

Fig. 4 Pre- and postoperative Di Lorenzo's grades

Postoperative image

By plain radiographs, all screws were positioned correctly in both C1 lateral mass and C2 pars interarticularis, and C1-C2 alignment was achieved. There were no cases of screw pullout. In one case (Case 9), the C1 lateral mass and C2 pars screws can be placed only on one side because of profuse bleeding from the vertebral venous plexus. No patient demonstrated loss of C1-C2 alignment or movement of C1 over C2 on lateral cervical flexion/extension film at 6-month follow-up or later. Consequently, the authors, so far, have no failure of fusion for the patients in this series.

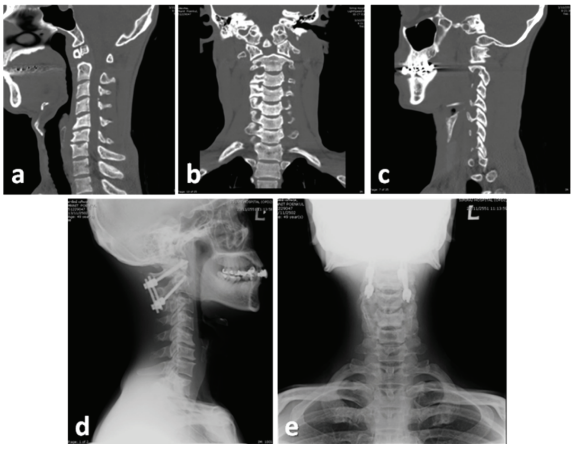

Fig. 5 Sagittal and Coronal reformatted computerized tomography demonstrated an os odontoideum (a, b). C1-2 transarticular screw was considered to be harmful due to high-lying of the vertebral artery (c). Postoperative lateral and AP radiograph of the cervical spine (d, e)

Case illustration

The 49-year-old male had a history of neck pain after a motorcycle accident for three months. There was no neurological deficit. Sagittal and Coronal reformatted computerized tomography demonstrated an os odontoideum (Fig. 5a, b). It was considered that C1-C2 transarticular screw could be harmful to the vertebral artery (Fig. 5c). He was operated on and posterior cervical fixation was achieved by C1 lateral mass and C2 pars screw with rod fixation. The postoperative course was uneventful with C1-C2 stabilization was achieved (Fig. 5d, e).

Discussion

A number of pathologies such as congenital malformations, trauma, neoplasms or inflammatory diseases can cause atlantoaxial instability and atlantoaxial fixation may be required to correct the deformity, provide stability and prevent neurological deficits. Several methods have been used to stabilize the atlantoaxial joint. However, certain anatomical factors may preclude their application in specific situations. Posterior wiring with sublaminar cables or interlaminar clamps requires the presence of intact posterior elements and they had a high incidence of nonunion[8]. C1-2 transarticular screw fixation provides a higher fusion rate but this technique is technically demanding and carries a potential risk of injury to the vertebral artery. The vertebral artery makes an acute lateral bend just under the superior articular facet of C2 in about 80% of individuals. Cadaveric and CT data have revealed that 18-23% of the population will preclude placement of C1-2 transarticular screw on ≥ 1 side of the spine because of aberrant vertebral artery anatomy or a large vertebral artery groove at the lateral mass of C2[2,9]. Other limitations of this technique are severe cervicothoracic kyphosis, obese patient and irreducible C1-C2 subluxation. The development of lateral mass screws in C-1 and pedicle screws in C-2 together with a polyaxial screw system, as described by Goel et al but later popularized by Harms and Melcher[4] in 2001, represented a safe and effective technique for C1-2 fusion. In many studies, the screw/rod system has provided superior stability in axial rotation compared with the wiring system and comparable stability to the transarticular screws fixation[5,6,10]. There has been considerable confusion

in the literature regarding screws placed into the C2 vertebral from a posterior approach. The pars interarticularis is defined as the portion of the C2 vertebra between the superior and inferior articular surfaces. The entry point for the C2 pars screw is 3 to 4 mm rostral and 3 to 4 mm lateral to the inferomedial aspect of the inferior articular surface of C2. The screw follows a steep trajectory paralleling the C2 pars interarticularis. The screws are passed with 10° of medial angulation. In contrast to the C1-C2 transarticular screw fixation, the C2-pars screw trajectory usually passes medial or superomedial to the vertebral artery and the risk of vertebral artery injury is lower. With the insertion of screws after Harms or Goel[11], neither of the two authors has recorded any case of a damage of the vertebral artery or the spinal cord. In the present series, the authors were able to place bilateral C1 lateral mass and C2 pars screw in most patients except one patient where C1 lateral mass screws could not be placed due to the presence of prominent vertebral venous plexus. Harms and Melcher recommend to leave the nerve intact, retract it caudally, and control bleeding by means of bipolar coagulation in combination with tamponade. Goel et al state that patients tolerate dissection of the nerve quite well and recommend making a sharp dissection of the nerve and control bleeding by means of bipolar coagulation. In early cases, the authors did not sacrifice the C2 nerve root but later the authors found that it sacrificed facilitates the placement of the C1 lateral mass and blood loss from the vertebral venous plexus was lower. We have not observed any cases of occipital neuralgia. One vertebral artery injury from C2 pars screw was thought to be too lateral and close to the vertebral artery. In later cases, we prefer placing a shorter pars screw that stops just posterior to the vertebral artery foramen. The hypoglossal nerve and internal carotid artery are at risk on the anterior surface of the lateral mass of the atlas. The hypoglossal nerve lies 2 to 3 mm lateral to the middle of the anterior aspect of the C1 lateral mass[12]. The internal carotid artery varies in location, but can lie within 1mm of the screw exit point[13]. Based on these data, during C1 lateral mass screws placement, the authors used the fluoroscope to confirm that the anterior cortex was not excessive by purchased. No patient demonstrated loss of alignment or fusion failure on the postoperative radiography. However, not all patients were followed long enough (at least 6 months) to truly determine the fusion rate of the patient series. Further study with longer follow-up is required.

Conclusion

The placement of C-1 lateral mass screws provides a useful alternative method to achieve atlantoaxial fixation when anatomical factors preclude the placement of C1-2 transarticular screws. This method achieves immediate rigid stabilization of the atlantoaxial joint and obviates the need for halo vest immobilization. This procedure may be used in certain cases as an alternative to occipitocervical fusion or to increase construct-related stability when occipitocervical fixation is performed. Evaluation of the course of the VA with preoperative CT scanning and the use of intraoperative fluoroscopy or image guidance are mandatory when performing this procedure. Placement of C-1 lateral mass screws is a technically demanding procedure that may result in grave VA injury-induced complications if improperly performed. Thus, the authors advocate that this procedure only be performed by surgeons who are highly experienced in the treatment of atlantoaxial instability and who have an intimate understanding of the regional anatomy. The uninitiated surgeon can minimize the possibility of complications during C-1 lateral mass screw placement by first performing this procedure in a cadaveric setting. Biomechanical analysis of this technique should be performed to quantify the strength of the constructs involving C-1 lateral mass screws compared with other fixation methods. Further clinical studies should be performed to determine the safety and efficacy of this technique.

Potential conflicts of interest

None.

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การผ่าตัดเชื่อมกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 จากทางด้านหลังโดยใช้วิธีใส่ C1 lateral mass และ C2 pars screw with rod fixation: เทฆนิฆและผลการรักษา

อัคคพงษ์ นิติสิงห์, ชุมพล เจตจำนงค์, หลักชัย พลวิจิตร, ศรัณย์ นันทอารี, นันทศักดิ์ ทิศาวิภาต

วัตถุประสงค์: *ภาวะ atlantoaxial instability มักจำเป็นที่จะต้องได้รับการรักษาโดยการทำการยึดตรึงกระดูกจากทางด้านหลัง ซึ่งได้มีการบรรยายเทคนิคการผ่าตัดไว้หลายวิธีในการยึดตรึงกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 การผ่าตัดทำ transarticular atlantoaxial screw ได้ถูกแสดงให้เห็นว่ามีประสิทธิภาพเพื่อสร้างความมั่นคงให้กับกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 อย่างไรก็ตาม มีผู้ป่วยถึง 20% ที่ไม่สามารถที่จะได้รับการผ่าตัดรักษาด้วยวิธีนี้ เทคนิคการผ่าตัดวิธีใหม่โดยการใส่ screw แยกกัน ที่ C1 lateral mass และ C2 pars แล้วเชื่อมกันด้วย rod จึงได้รับการบรรยาย โดยสามารถใช้ในการแก้ไข หรือ เป็นทางเลือกในการผ่าตัดเพื่อสร้างความมั่นคงให้กับกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 ได้อย่างมีประสิทธิภาพ ผู้นิพนธ์นำเสนอประสบการณ์การทำผ่าตัดโดยใช้เทคนิค C1 lateral mass และ C2 pars screw and rod fixation*

วัสดุและวิธีการ: *ระหว่างเดือนพฤษภาคม พ.ศ. 2550 ถึง ตุลาคม พ.ศ. 2551 ผู้ป่วย 10 ราย (ชาย 7, หญิง 3) อายุตั้งแต่ 15 ถึง 59 ปี ได้รับการผ่าตัดยึดกระดูกจากทางด้านหลังโดยใช้เทคนิค C1 lateral mass และ C2 pars screw and rod fixation ผู้ป่วย 6 ราย มีภาวะ atlantoaxial subluxation จาก os odontoideum 2 ราย มีภาวะ C1-C2 subluxation เรื้อรังส่วนอีก 2 ราย มีภาวะ C1-C2 subluxation เฉียบพลันจากอุบัติเหตุรถยนต์สำหรับ screw ทุกตัวได้รับการใส่ภายใต้การชี้นำของ lateral fluoroscope*

ผลการศึกษา: *C1 lateral mass และ C2 pars screw and rod fixation เป็นวิธีการผ่าตัดที่ใช้ในการสร้างความมั่นคงให้กับกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 ผู้ป่วยทุกราย โดย screw ทุกตัวอยู่ในตำแหน่งที่ถูกต้องทั้งในกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 ไม่พบว่ามีภาวะแทรกซ้อนถาวรเกิดขึ้น ในผู้ป่วยทุกรายการยึดตรึงกระดูกอย่างแน่นหนาถูกยืนยันบนภาพถ่ายรังสีหลังผ่าตัด และยังคงอยู่บนภาพถ่ายรังสีเมื่อผู้ป่วยมาตรวจตามนัดหลังผ่าตัด*

สรุป: *C1 lateral mass และ C2 pars screw and rod fixation เป็นวิธีการผ่าตัดที่มีประสิทธิภาพในการสร้างความมั่นคงให้กับกระดูกสันหลังส่วนคอปล้องที่ 1 และ 2 โดยทำให้เกิดการยึดตรึงกระดูกอย่างแน่นหนา และสามารถทำได้โดยปลอดภัย*