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C2 Nerve Root Resection to Achieve Safe and Wide Exposure of Lateral Atlantoaxial Joints in Posterior C1-2 Instrumented Fixation: Technical Note

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Abstract

Posterior atlantoaxial (C1-2) fixation with individual screw placement in C1 and C2 has been one of the technical options to treat C1-2 subluxation or instability. In the present study, we demonstrate the surgical technique of C2 nerve root resection to avoid the troublesome bleeding from the perivertebral venous plexus and achieve full exposure of the lateral C1-2 joints. The present study includes a series of 16 consecutive patients who underwent posterior C1-2 instrumented fixation with individual screw placement in C1 and C2. All patients underwent unilateral or bilateral C2 nerve root resection at the sensory ganglion. Screw malposition resulting in vascular or neural injury was not encountered. Sensory pain scale analysis indicated that the mean score before surgery was 2.4, which significantly improved to 1.4 after surgery. No patients reported allodynia or C2 distribution neuropathic pain during the follow-up. C2 nerve root resection resulted in early postoperative dysesthesia in all 16 patients; however, neurological examination during the follow-up revealed that only 12.5% of all analyzed patients did not demonstrate satisfactory recovery of C2 sensory disturbance. Postoperative radiologic analysis revealed solid osseous or partial fusion at the lateral C1-2 joints in all cases during the follow-up. No case demonstrated non-union with pseudoarthrosis. Although C2 nerve root resection is still under debate and not fully justified, the present study suggests that C2 nerve root resection does not always result in significant morbidity and can be an option for surgical resolution to achieve safe and wide exposure of lateral C1-2 joints.

Key words: C2 nerve root, C2 sensory ganglion, lateral C1-2 joints, pain, posterior atlantoaxial fixation

Introduction

The goal of surgery for atlantoaxial (C1-2) joint instability is to reduce pathological subluxation, decompress neural elements, and maintain vertebral column alignment. Posterior C1-2 fixation with individual screw placement in C1 and C2 is called the "Goel-Harms method." This method has been one of the techniques available to achieve the surgical goals.[1,3,6–8,10,11,15,16,19,20,22,23] Routine bilateral C2 nerve root resection to provide wide exposure of the lateral C1-2 joints is essential for the Goel's technique.[6–8] However, C2 nerve root resection is still under debate and may not be fully justified. Surgeons may meet with the criticism that the C2 nerve root should not be sacrificed in any case. In the present series, we demonstrated the surgical technique of C2 nerve root resection to avoid the troublesome bleeding from the perivertebral venous plexus and achieve full exposure of the lateral C1-2 joints, and discussed its clinical impact with a careful review of the literature.

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Patients and Surgical Technique

I. Patients

The present study included a series of 16 consecutive patients who underwent posterior C1-2 instrumented fixation with individual screw placement in C1 and C2 over the past 7 years at our institute. All patients underwent unilateral or bilateral C2 nerve root resection at the sensory ganglion to achieve full exposure of the lateral C1-2 joints. There were 11 men and 5 women. The patients' ages ranged from 22 to 82 years with a mean of 58.2 years. Five patients presented with atlantoaxial instability as a result of degenerative disease, four presented with congenital disease, four presented with trauma, two presented with rheumatoid arthritis, and one presented with infection.

II. Surgical technique

Surgical technique has been described before.[23] Under general anesthesia, the patient was placed in the prone position with the head immobilized using a three-point head holder in case of reducible C1-2 subluxation or under the direct cervical traction using the Crutchfield skull tong in cases of irreducible C1-2 subluxation. The head was fixed in a neutral position. A midline incision was made extending from the inion to the C4 spinous process, and the C1 posterior arch, the C2 lateral mass, and the C2-3 facet joint were exposed subperiosteally. The medial aspect of the C2 dorsal element was carefully exposed to confirm the entry point and trajectory of the C2 pars interarticularis or pedicle screw. The C2 screws of the pars interarticularis, pedicle, or translaminar were first placed based on the images obtained before surgery. In case of a medially located vertebral artery (VA) at C2, so-called "high-riding VA," the pars interarticularis or translaminar screws were preferred.[24] Careful dissection over the C-1 posterior arch was performed to recognize the VA in the C1 vascular groove. The C1 posterior arch was resected, if necessary. The C2 nerve root was identified and mobilized (Fig. 1A). Bleeding from the perivertebral venous plexus was controlled with bipolar coagulation and application of a fibrin-soaked collagen sponge. The C2 nerve root was resected at the C2 sensory ganglion to expose the posterior surface of the lateral C1-2 joint (Fig. 1B, C). Both lateral C1-2 joints were manipulated and distracted under the microscope in case of irreducible C1-2 subluxation. The articular cartilage of the facet joint was removed using a high-speed drill, and autologous local cancellous bone with beta tricalcium phosphate (TCP) which was placed into the joints. The C1 lateral mass, inferior to the C-1 arch, was exposed. The medial and lateral aspects of the C1 lateral mass were palpated for safe placement of the C1 screw. The entry point of the C1 lateral mass screw was at the junction of the lateral mass and the inferior aspect of the C1 arch (Fig. 1D). The screw was advanced about ten degrees medial and superior toward the C1 anterior tubercle under fluoroscopic guidance. The C1 lateral mass and the C2 screws were connected tightly with a rod. The patient was immobilized on the first postoperative day and wore a cervical semi-rigid cervical collar for the first postoperative month and a soft cervical color for the subsequent 2 months.

III. Outcome measures

The neurosurgical cervical spine scale (NCSS) and sensory pain scale of C2 nerve distribution were used to assess the pre- and postoperative neurological condition (Table 1).[14] We defined occipital neuralgia as acute spasmodic pain of the suboccipital region. Postoperative C1-2 arthrodesis was determined based on plain radiograph or sagittal computed tomography (CT) images. Solid osseous fusion was defined as a clear osseous bridge, and partial fusion was defined as incomplete osseous or fibrous fusion without any instability on dynamic study.

IV. Statistics

Statistical analysis was performed using the paired *t*-test. Significance was set at $p < 0.05$.

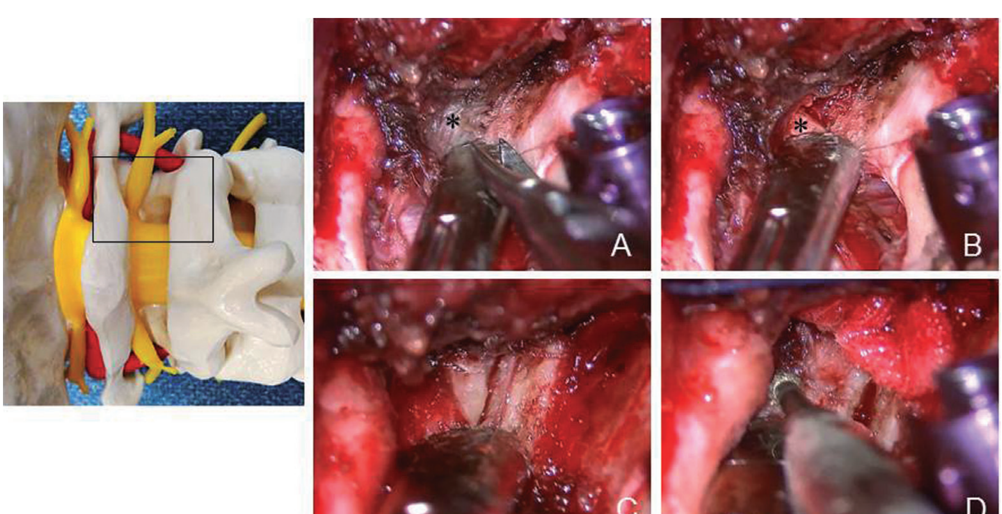

Fig. 1 **Intraoperative photographs showing that the right C-2 nerve root (*) with perivertebral venous plexus was identified (A) and resected at the sensory ganglion (B) to expose the posterior surface of the C1-2 facet joint (C). The entry point for the C1 lateral mass screw was marked at the junction of the lateral mass and the inferior aspect of the C1 arch (D). Intraoperative photographs correspond to the boxed area in the spine model.**

Table 1 Neurosurgical cervical spine scale (NCSS) and sensory pain scale

Score	Function
	Lower extremity motor function
1	Total disability: chair-bound or bedridden
2	Severe disability: needs support in walking on flat surfaces, and unable to ascend or descend stairways
3	Moderate disability: difficulty in walking on flat surfaces, and needs support in ascending or descending stairways
4	Mild disability: no difficulty in walking on flat surfaces, but mild difficulty in ascending or descending stairways
5	Normal: normal walking, with or without abnormal reflexes
	Upper extremity motor function
1	Total disability: unable to perform daily activities
2	Severe disability: severe difficulty in daily activities with motor weakness
3	Moderate disability: moderate difficulty in daily activities with hand and/or finger clumsiness
4	Mild disability: no difficulty in daily activities, but mild hand and/or finger clumsiness
5	Normal: normal daily activities, with or without abnormal reflexes
	Sensory function and/or pain
1	Severe disturbance: severe difficulty in daily activities with incapacitating sensory disturbance and/or pain
2	Moderate disturbance: moderate difficulty in daily activities with sensory disturbance and/or pain
3	Mild disturbance: normal daily activities, but mild sensory disturbance and/or pain
4	Normal: neither sensory disturbance nor pain
Scale	**Definition**
1	No symptoms
2	Mild pain or dysesthesia, slightly impairing QOL
3	Moderate pain or dysesthesia, fairly impairing QOL
4	Severe pain or dysesthesia, significantly impairing QOL

QOL: qulity of life.

Results

Clinical follow-up ranged from 6 to 82 months with a mean of 39.4 months. There was no surgery-related morbidity or mortality in the present case series. Screw malposition resulting in vascular or neural injury was not encountered.

The mean NCSS score before surgery was 10.1, which significantly improved to 11.9 after surgery ($p < 0.05$) (Fig. 2A). Sensory pain scale analysis indicated that the mean grade before surgery was 2.4, which also significantly improved to 1.4 after surgery ($p < 0.05$) (Fig. 2B). Eleven of 16 patients demonstrated both intense neck and occipital pain, consistent with greater occipital neuralgia before surgery, while 10 patients achieved satisfactory pain relief after surgery. Although C2 nerve root resection resulted in early postoperative dysesthesia in all 16 patients, pinprick sensory examination at the follow-up revealed that only 12.5% of all analyzed patients did not demonstrate satisfactory recovery of C2 sensory disturbance. At the recent follow-up, 7 of 16 patients (44%) reported symptomatic dysesthesia without any pain of C2 nerve distribution during the examination in the clinic. No patients reported allodynia or neuropathic pain in the C2 nerve distribution during the follow-up.

Postoperative radiologic analysis revealed satisfactory reduction of pathological C1-2 subluxation (Fig. 3) and solid osseous (13 cases) or partial fusion (3 cases) at the lateral C1-2 joints in all cases during the follow-up (Fig. 4). No case demonstrated non-union with pseudoarthrosis, and no patients needed revision surgery.

Discussion

Various surgical techniques may be used to achieve atlantoaxial fixation, including posterior interspinous fixation with sublaminar cables and iliac bone grafting, interlaminar clamp fixation, C1-2 transarticular screw fixation, and individual screw placement in C1 and C2.[1–3,5–8,10,11,13,15–17,19,20,22,23,25] Although all these methods have been successfully performed for atlantoaxial fixation, they may be limited by anatomical or other factors. Posterior C1-2 segmental fixation with individual screw placement in C1 and C2, the so-called "Goel-Harms method," is becoming a treatment of choice to achieve the goals of surgery.[1,3,6–8,10,11,15,16,19,20,22–23] Individual screw placement in C1 and C2 can achieve intraoperative reduction and fixation of the C1-2 complex. The C1 lateral mass screws can be connected via a rod or plate to the C2 pedicle, pars interarticularis, or translaminar screws. The biomechanical evaluations of various C1-2 posterior fixation techniques suggested that Goel-Harms technique can provide a satisfactory or acceptable rigidity to stabilize the C1-2 joints.[4,9,12,18,21]

Although routine bilateral C2 nerve root resection to provide wide exposure of the lateral C1-2 joints is essential to the Goel's technique,[6–8] C2

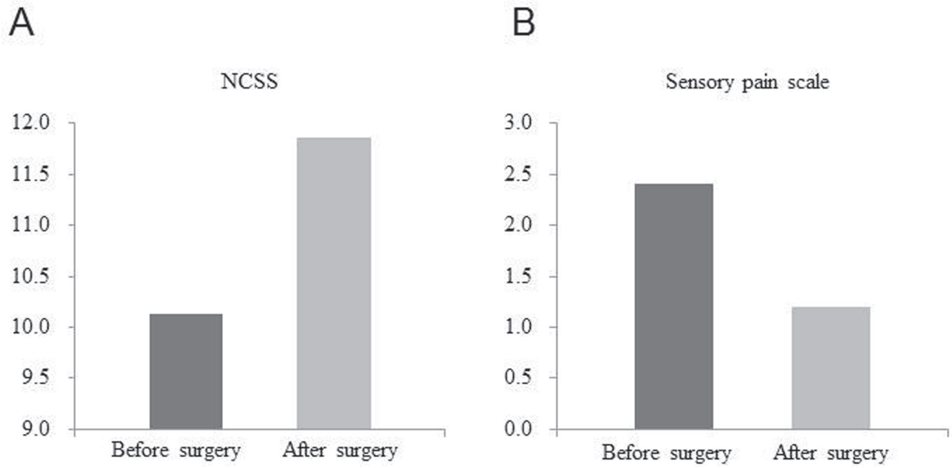

Fig. 2 Statistical analysis of neurosurgical cervical spine scale (NCSS) and sensory pain scale indicating significant improvement after surgery.

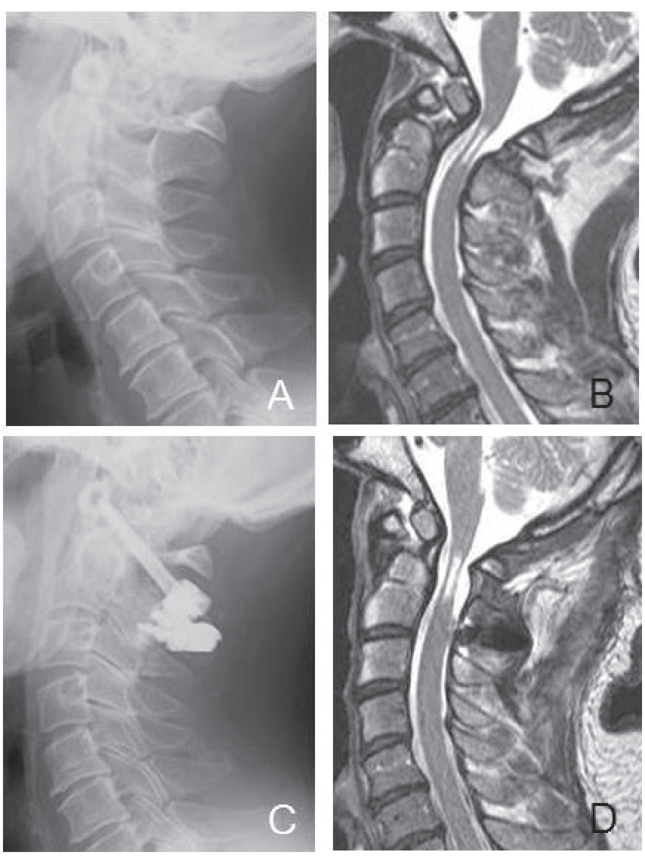

Fig. 3 Radiological analysis after surgery revealing satisfactory reduction of pathological C1-2 subluxation and decompression of neural elements. Case 14: before surgery (A, B), after surgery (C, D).

nerve root resection is still under debate and not fully justified. C2 nerve root resection may not always be necessary to treat C1-2 subluxation or instability. However, it may be useful to achieve safe and wide exposure of lateral C1-2 joints in cases of fixed C1-2 rotatory subluxation or retro-odontoid pseudo-tumor associated with chronic C1-2 subluxation where the posterior element of C1 needs to be resected.[8,23] There are possible advantages to C2 nerve root resection including facilitation of perivertebral venous plexus hemostasis as well as providing lateral C1-2 joint exposure. In addition, C2 nerve resection facilitates screw placement in C1 and enables adequate joint manipulation and arthrodesis. Several reports have documented the occurrence of new-onset occipital neuralgia following posterior C1-2 segmental fixation without C2 nerve root resection.[3,15,19,20,22] These occipital neuralgia symptoms are believed to arise from manipulation of the C2 nerve root and from direct irritation of the nerve root by the unthreaded portion of the C1 lateral mass screw protruding from the lateral mass. In addition, compression across the C1-2 joint space, in an effort to facilitate arthrodesis, may also contribute to C2 nerve root compromise. Recently, Hamilton et al. assessed the surgical and clinical impact of routine C2 neurectomy performed with posterior C1-2 segmental fixation in a consecutive series of elderly patients with atlantoaxial instability.[10] They concluded that postoperative side effects following C2 neurectomy are minimal with substantial benefit to patients with prior occipital neuralgia. A literature review on posterior C1-2 instrumented fixation with C2 nerve root resection is summarized in Table 2. There have been no published reports of cerebrospinal fluid leakage after C2 nerve root resection to date. Preoperative occipitalgia appeared to recover well following surgery. The argument against C2 nerve root resection is that it may cause neuropathic pain or C2 distribution sensory loss. Goel et al.[6] reported that the C2 dorsal root ganglion was cut sharply and that 18

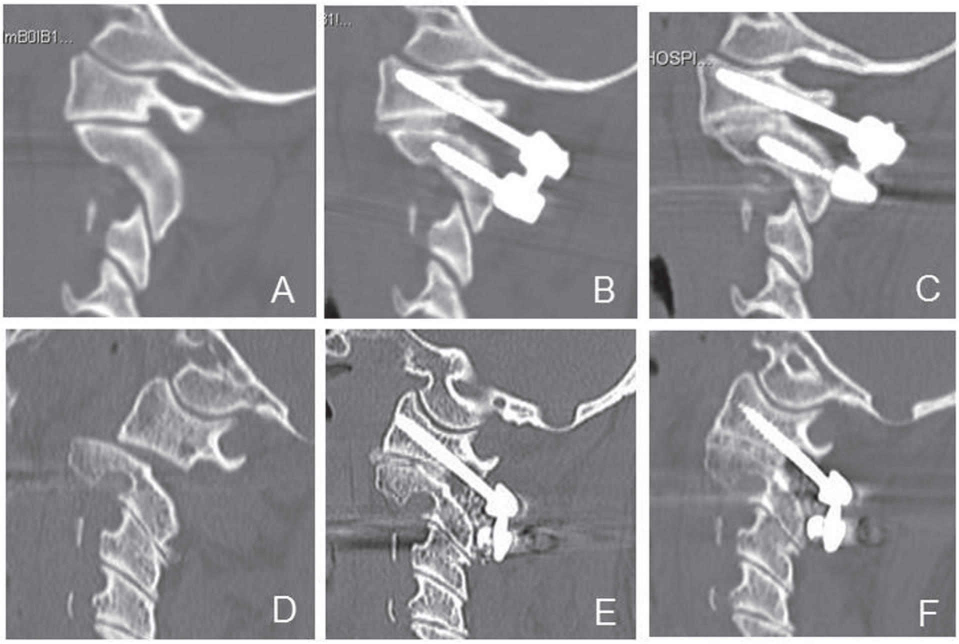

Fig. 4 Radiological analysis after surgery revealing chronological osseous fusion at the lateral C1-2 joints. Case 9: before surgery (A), early after surgery (B), 1 year after surgery (C); Case 14: before surgery (D), early after surgery (E), 6 months after surgery (F).

Table 2 Literature review of posterior C1-2 instrumented fixation with C2 nerve root resection

Author	Year	No. of patients	Mean age (yrs)	Mean follow-up (months)	Site of C2 nerve root resection	Occipital neuralgia		Postop sensory deficit of C2 distribution (%)	
						Preop	Postop pain relief	Allodynia or neuropathic pain	Sensory loss or hypalgesia
Goel A et al.[6]	2002	160	23	42	Ganglion	NR	NR	NR	11.5 (*1)
Aryan et al.[1]	2008	102	62	16.4	Proximal to Ganglion	NR	NR	0.98	NR
Hamilton et al.[10]	2011	30	71	36	Ganglionectomy	24	24	0	6.7 (*2)
Present cases		16	58	37.1	Ganglion	11	10	0	12.5

*1: Eighteen of 157 patients (11.5%) specifically reported an area of sensory loss of C2 distribution. *2: Seventeen of 30 patients noticed numbness of C2 distribution only during examination in the clinic, and 2 patients (6.7%) reported numbness, but it did not affect their daily function. NR: not recorded.

of 157 patients (11.5%) specifically reported an area of sensory loss of C2 dsitribution. Aryan et al.[1] reported that the C2 ganglion was cut sharply at the proximal side and that one patient (0.98%) had resultant postoperative neuropathic pain in the C2 distribution in their series of 102 patients. Hamilton et al.[10] also reported that 17 of 30 patients noticed numbness of C2 distribution only during examination in the clinic, and 2 patients (6.7%) reported numbness, but it did not affect their daily function. They also reported that none of the patients had neuropathic pain in the C2 distribution. These findings are not significantly different from the findings in the present study.

Posterior C1-2 fixation with individual screw placement in C1 and C2 has been one of the technical options to treat C1-2 subluxation or instability. However, C2 nerve root resection to avoid the troublesome bleeding from the perivertebral venous plexus and achieve full exposure of the lateral C1-2 joints is still under debate and not fully justified. Surgeons may meet with the criticism that the C2 nerve root should not be sacrificed in any case. The present study may suggest that C2 nerve root resection does not always result in significant morbidity and can be one of the surgical options to achieve safe and wide exposure of lateral C1-2 joints.

Conflicts of Interest Disclosure

No funds were received in support of this work. No benefits in any form have been or will be received

from a commercial party related directly or indirectly to the subject of this manuscript. Written informed consent was obtained from all patients.

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