Posterior Atlantal Lateral Mass Fixation Technique With Polyaxial Screw And Rod Fixation System

Poliaksiyal Vida ve Rod Sistemi ile Posterior Atlantal Lateral Mass Fiksasyon Tekniği

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ABSTRACT

OBJECTIVE: Atlantoaxial instability may result from various pathologic conditions and operative treatment may be required to correct the deformity, provide stability and prevent neurological deficits. We presented our clinic's experience using C1-C2 fusion with polyaxial screw and rod fixation for C1 and C2 instability for various reasons.

METHODS and MATERIAL: Four patients with atlantoaxial instability were operated using polyaxial C1 lateral mass and C2 lateral mass or pedicle screws. The mean age of the patients was 44±14,07 years.

RESULTS: Satisfactory screw placement was achieved in all patients. There were no vertebral artery injuries, C2 nerve root injuries or spinal cord injuries. No per-operative or early postoperative instrumentation failure was observed.

CONCLUSIONS: C1 lateral mass/C2 pedicle polyaxial screw fixation is a safe technique and can be used to achieve rigid and immediate atlantoaxial stabilization.

KEY WORDS: Atlantoaxial instability, C1 lateral mass, C2 pedicle, Polyaxial screw

ÖZ

AMAÇ: Atlantoaksiyal instabilite çeşitli hastalıklar sonucu ortaya çıkabilir ve deformiteyi düzeltmek, stabiliteyi sağlamak ve nörolojik defisitleri engellemek için cerrahi tedavi gerekebilir. Bu makalede çeşitli patolojiler neticesinde C1-C2 instabilite gelişmiş hastalarda uyguladığımız poliaksiyal C1 lateral mass/C2 pedikül vidalama tekniği ile ilgili kliniğimizin deneyimini sunduk.

YÖNTEM ve GEREÇ: Atlantoaksiyal instabilitesi olan dört hasta C1 lateral mass ve C2 lateral mass ya da pedikül vidalama tekniği ile opere edildi. Hastaların ortalama yaşı 44±14,07 idi.

BULGULAR: Bütün hastalarda poliaksiyal vidalar başarılı olarak uygulandı. Hiçbir hastada vertebral arter yaralanması, C2 kök yaralanması ya da spinal kord yaralanmasına rastlanmadı. İntraoperatif ya da erken dönem enstrumentasyon problemi tespit edilmedi.

SONUÇ: Poliaksiyal C1 lateral mass/C2 pedikül vidalama tekniği erken ve rijid stabilizasyonun sağlanmasında güvenle uygulanabilir.

ANAHTAR SÖZCÜKLER: Atlantoaksiyal instabilite, C1 lateral mass, C-2 pedikül, Poliaksiyal vida

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INTRODUCTION

Atlantoaxial instability may result from various pathologic conditions including congenital malformations, trauma, neoplasm and inflammatory diseases. In such conditions, atlantoaxial fixation may be required to correct the deformity, provide stability and prevent neurological deficits.

A variety of fixation techniques have been used to provide the stability of C1-C2 vertebra including posterior interspinous fusion with sublaminar wires and iliac bone grafts, including Brooks fusion and Gallie fusion, interlaminar clamps and C1-C2 transarticular screw fixation described by Magerl. Although previous wiring techniques are easy to do, they cannot provide immediate stabilization and fusion rates are not satisfactory and need intact lamina of C1 and C2. The Magerl transarticular fixation technique therefore became more popular though it has its own technical difficulties such as risk of vertebral artery injury in case of high riding and it is impossible to use it in case of fixed subluxation of C1 on C2. Three-point fixation (combination with Brooks or Gallie techniques) is another good option for good stabilization and high fixation rate but it is not always possible. The Harm technique of stabilizing C1-C2 by fixation with polyaxial screws is another attractive option since the risk of vertebral artery injury is lower and

posterior reduction and fixation of C1 and C2 can be achieved. In this report, we describe our clinic's experience using C1-C2 fusion with polyaxial screw and rod fixation for C1 and C2 instability for various reasons.

MATERIALS and METHODS

Four patients with atlantoaxial instability were operated at our clinic using polyaxial C1 lateral mass and C2 lateral mass or pedicle screws (Blackstone, U.S.A.) between the year 2006 and 2007. The mean age of the patients was 44±14,07 years (range 24-57 years) and female to male ratio was 3/1. The demographic data of the patients are summarized in Table I.

Operative technique:

Under general anesthesia, the patient was placed in either the prone or sitting position according to the surgeon's preference. The neck was fixed in neutral position and held in alignment by skull tongs under fluoroscopic control. A Philadelphia-type cervical collar was used while turning the patient to reduce the risk of malalignment of C1-C2. Suboccipital and posterior cervical region was prepared in the usual fashion and a midline incision was made from the inion to the fifth cervical vertebra. After bilateral subperiostal dissection of the paraspinal muscles to expose the lateral margins of

Table I: Summary of preoperative, operative and postoperative data of the patients.

Case No	Age/Sex	Presentation	Diagnosis	Treatment	Outcome
1	47/Female	Neck pain	Traumatic Type III odontoid fracture	C1-C2-C3-C4-lateral mass polyaxial screw-rod fixation	Rigid fixation, neurologically intact
2	48/Female	Neck pain, ataxia, difficulty in manual skills	Os odontoideum	C1-lateral mass/C3-pedicle/C4-lateral mass polyaxial screw-rod fixation	Rigid fixation, neurologically intact
3	57/Female	Neck pain, quadriparesis	Atlantoaxial subluxation due to romatoid artritis	C1-laminectomy, C1-lateral mass/C2-pedicle polyaxial screw-rod fixation	Rigid fixation, clinically stable
4	24/Male	Neck pain	Traumatic C1-C2 subluxation	C1-lateral mass/C2-pedicle polyaxial screw-rod fixation	Rigid fixation, neurologically intact

the facet joints from C2 to C4, the dissection was continued over the posterior arc of C1 to expose the vertebral artery and its grove on C1 arch. The dissection should be extended up to lateral border of the C1-C2 articulation in order to expose the C1-C2 joint. Dissection was then continued over the superior surface of the C2 pars interarticularis. Typical bleeding from the perivertebral venous plexus was seen and controlled with bipolar coagulation and using gelfoam and/or surgicell. The vertebral arteries were protected under cotton-paddies and the C2 nerve roots were exposed and mobilized inferiorly bilaterally. A surgical microscope was used during this part of surgery. The dissection provided exposure of the C1 lateral masses inferior to the C1 arch. The medial wall of the lateral mass was identified using a Penfield dissector for the identification of the medial limit of screw placement and the medial border of the transverse foremen was identified as the lateral limit for screw placement. The entry point for C1 screws was 3 to 5 millimeters lateral to the medial border of lateral mass and inferior to the C1 arch. A high-speed drill was used to remove a small portion of the C1 arch inferiorly to create a recess for the screw as needed. While the C2 nerve root was retracted inferiorly, a 10 to 15° medially directed hole was drilled using a high-speed drill aiming for the anterior tubercle of C1. Bicortical or unicortical screws can be placed according to the surgeon's decision. The width of the lateral mass and height of the posterior arch of C1 just below the vertebral artery were measured on thin section C1 tomography preoperatively. This information helped find out the different trajectories in the C1 lateral mass and calculate the drilling required to placement the head of the screw. Anatomical localization of the internal carotid artery in front of C1 is an important anatomical key point for making the decision of uni- or bicortical screw placement. Harms et al recommended using an 8-mm unthreaded portion of the C1 screw that stays above the bony surface of the lateral mass to minimize any chance of irritation to the greater occipital nerve and allow the poly-axial portion of the screw to lie above the posterior arch of C1. Since partially unthreaded screws are custom made and difficult to obtain, we used 3.5x26-28 mm unicortical screws in our cases. A starting point using a 3 mm burr was made on the posterior arch while the assistant protected the vertebral artery with a

Penfield dissector. The lateral mass was then perforated using a hand-held drill with a 2.5 mm K-wire, under fluoroscopy, stopping just short to the anterior arch cortex, with the drill angled 10-15 degrees medially. After drilling the pilot hole and feeling the trajectory with a blunt 1.0 mm probe, the hole was tapped and a 3.5 mm screw inserted. Usually the screw measures 18-30 mm in length, depending on the size of the lateral mass and whether the starting point is on or below the posterior arch.

The other possible entry point is directly on the posterior arch of the atlas, midpoint between the medial edge of the transverse foramen and the medial surface of the lateral mass (Figure 1A). This entry point is easier than the previously described entry point, since the C2 ganglion and venous plexus dissection is not needed. However, the C1 posterior arch cannot be chosen in some cases because of a too thin posterior arch (Figure 1B). The entry point on the posterior arch of C1 can be used if the C1 lateral mass is not cleaned adequately because of a large amount of bleeding. In this case, the vertebral artery in the groove should be elevated and the trajectory of screw should be inspected. Since the entry point is higher than the C1 lateral mass, shorter screws should be selected to allow easy rod connection to the C2 screw head.

The C2 entry point was in the medial and superior third of the facet joint. A pilot hole was drilled and tapped to a 14 to 18 mm depth for pedicle screws (Figure 1C). The direction of the screw was sharply medial and superior and toward the superior aspect of the body of the axis vertebra towards the midline. The screw was directed at an angle approximately 25° medial to the sagittal plane and 15° superior to the axial plane. Since one of the pedicles were involved with the traumatic odontoid fracture, C2 lateral mass screws instead of pedicle screws were applied in one patient. In this case, the site of screw implantation in the lateral mass of the axis was the inferior mid-portion and the trajectory was directed rostrally and laterally to the transverse foramen (Figure 1D). Next, the rods were placed and secured in position. A cross-link between the C1 and C2 connectors can be used to increase rigidity in the rotational and axial planes. The posterior arch of C1 and the lamina of C2 were decorticated and a bone allograft used to provide bony fusion. The ideal position of the C1 lateral mass/C2 pedicle screws in
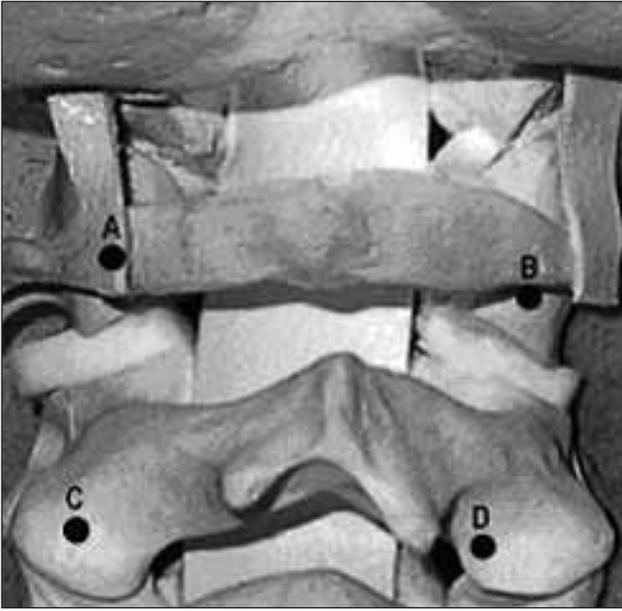
RESULTS

Satisfactory screw placement was achieved in all patients. There were no vertebral artery injuries, C2 nerve root injuries or spinal cord injuries. No per-operative or early postoperative instrumentation failure was observed. None of the patients had neurological compromise due to surgery. However, one patient, a 57-year-old female who presented with quadriparesis preoperatively (case-3), did not improve after surgery and was transferred to our university's rehabilitation unit.

Case Illustration-1:

This 47-year-old female presented to the emergency department with severe neck pain after a motor vehicle accident (case no: I in Table I). There was no neurological deficit. Coronal and sagittal reformatted computerized tomography demonstrated a Type III odontoid fracture involving the left pedicle and transverse foramen (Figure 3A,B). Magnetic resonance imaging revealed no neural compression. She was operated on the next day and bilateral C1-C2-C3 and C4 lateral mass screws were inserted (Figure 3C). A bone allograft was applied for C1-C4 osseous fusion. There were no per-operative or postoperative complications. The patient was released from the hospital on the sixth postoperative day.

Case Illustration-2:

This 48-year-old female was admitted to our clinic complaining of neck pain, ataxia and difficulty in manual fine motor skills for 12 years (case no: II in Table I). She had a history of previous physical treatment for the neck pain and she had no history of trauma. Neurologically, she had minimal motor loss (motor power 4+/5) in her hand intrinsic muscles bilaterally. Preoperative cervical MRI and CT revealed os odontoideum (Figure 4A). She had congenital fusion of C2 and C3 cervical laminas on lateral cervical X-ray film. She was operated on and posterior cervical fixation was achieved by C1 lateral mass, C3 pedicle and C4 lateral mass screws (Figure 4B). Bone allograft was used to supply C1-C4 fusion. The rest of the clinical course was eventless and she was released from the hospital on the fourth postoperative day.

DISCUSSION

The stability of atlantoaxial joint is mainly provided by the dens and the ligamentous structures including transverse ligament, apical ligament and
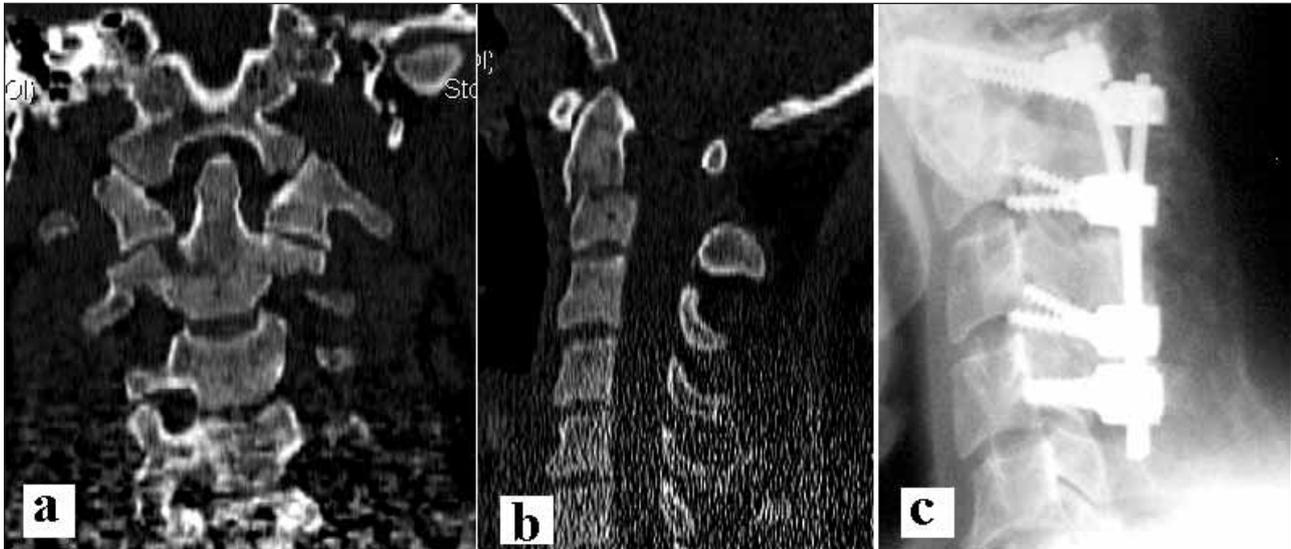

Figure 1: Schematic picture indicating screw insertion points for C1 vertebra (A,B) and C2 vertebra (C,D).

one of our patients (case no: II in Table I) is presented in Figure 2. A hemovac drain was placed prior to wound closure. All patients were instructed to use a Philadelphia-type cervical collar for eight weeks postoperatively.

Figure 2: Ideal positions of C1 lateral mass and C2 pedicle screws in lateral cervical X-ray of Case-IV in Table I.

Figure 3: *Preoperative coronal (**A**) and sagittal (**B**) reformatted CT images showing a Type III odontoid fracture involving left C2 pedicle and transverse foremen. Postoperative lateral cervical x-ray (**C**) shows the position of the lateral mass screws.*

Figure 4: *Preoperative coronal (**A**) reformatted CT images showing os odontoideum. Postoperative lateral cervical x-ray (**B**) shows the final position of C1 lateral mass, C3-pedicle and C4 lateral mass screws.*

alar ligaments. 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.

Various surgical methods have been described in the literature to treat atlantoaxial instability. These techniques included posterior interspinous fusion with sublaminar wires and iliac bone grafts, interlaminar clamps, C1-C2 transarticular screw fixation and posterior atlantoaxial fixation with polyaxial screws and rods. Posterior interspinous fusion with sublaminar wires and iliac bone grafts

was first described by Gallie in 1939 (6). This technique has been modified by Brooks and Jenkins by applying sublaminar wires bilaterally with bilaterally interposed iliac crest grafts (1). Sonntag, in 1991, modified Gallie's technique by placing the wire under the posterior arch of C1 and around the spinous process of C2 to avoid the potential risk of spinal cord injury at the C2 level (3). Posterior wiring techniques provide a fusion rage between 60 and 100% (2,3,5). However, these techniques has several drawbacks such as the need of long term postoperative Halo immobilization, risk of intra-operative vertebral artery or spinal cord injury and requirement of intact posterior vertebral elements. Posterior interlaminar clamps can be used if the C1-C2 laminas are intact. Biomechanically, laminar clamps provide a reliable stability with flexion and extension maneuvers. However, in rotational motion the clamps are not as effective as other techniques involving posterior screws or wires (4). Consequently, poor clinical results for interlaminar clamp constructs have been reported in the literature (13,16). In order to prevent undesired rotational and translational motion in wiring techniques, Magerl and Seemann introduced atlantoaxial transarticular screw technique (12). Biomechanically, this technique provided greater stability in rotatory motion but the results were similar to the wiring techniques in anteroposterior translational motion (8,9). A further advantage of the transarticular screw technique is that there is no requirement of intact

posterior vertebral elements. This is particularly important when laminectomy is required for spinal cord decompression or, when C1 or C2 lamina has been disrupted by trauma, neoplasm or other pathologies. The limitations of this technique are anatomical variations such as medially located vertebral artery, severe cervicothoracic kyphosis or irreducible C1-C2 subluxation. The risk of vertebral artery injury has been reported as 2.2% per screw and the risk of neurological deficit as 0.1% per screw (18). Additionally, the placement of a transarticular screw was precluded by anatomical variations in 18 to 23% of the patients (23).

The idea of building a construct that uses a three-point fixation comes from the principles of biomechanics that the more points of fixation one uses, the more rigid and stable the construct is (17,20). Several techniques using a three-point construct for stabilizing the C1-C2 complex have been described and also tested biomechanically. They include the C1-C2 transarticular screws combined with posterior wiring; the C1-C2 transarticular screws combined with a C1 claw and the C2 pedicle screws combined with a C1 claw. These techniques have also been studied biomechanically with the C1-C2 transarticular screws combined with posterior wiring and the C1-C2 transarticular screws combined with a C1 claw showing the smallest overall range of motion and neutral zone (20). The C2 screws plus a C1 claw construct had larger values of range of motion and neutral zone for axial rotation, flexion-extension and lateral bending (20). Although the transarticular screws combined with a wiring technique is considered to provide an excellent three-point fixation technique (14,15,17,20), there is a potential hazard when passing the sublaminar wires under the lamina. This risk is higher in patients who have non-reducible C1-C2 subluxation and/or compressed spinal cord. There are several reports that describe worsening of a preexisting myelopathy as a complication of passing sublaminar wires (2,19). Additionally, this technique has other limitations such as non-reducable subluxation of C1-C2 cases.

Goel et al. described a new fixation technique, later popularized by Harms et al., involving C1 lateral mass and C2 pedicle screws for atlantoaxial instability (7,10). The main advantages of this technique are reported as; a) the risk of vertebral artery and spinal cord injury is minimized, b) integrity of C1 or C2 posterior elements is not necessary for a stable fixation and, c) there is no need for postoperative Halo vest immobilization owing to immediate rigid stabilization. In addition, polyaxial screw-rod system enables the fixation extends cranially to occipital bone and caudally to subaxial cervical vertebra when additional fixation is required. The suitability of the lateral mass to accept screws has been demonstrated either via posterior arch or lateral mass alone. Moreover, the pullout strength of the C1 lateral mass screws has been shown to be equivalent to the C2 pedicle screws (11). In our series, we preferred placing C1 lateral mass screws with a starting point right on the posterior arch of the atlas in one case, as suggested by Tan et al (22). We did not observe any spinal cord, vertebral artery or C2 nerve root injuries. Bleeding from the vertebral venous plexus can be massive and prolong the surgery; this point will therefore be our preferred entry point for future cases (22).

Since the anatomy of C1 and C2 is completely different than the rest of vertebral bodies; the anatomy and their variations should be known prior to the surgery. The width and length of C1 and C2 lateral masses should especially be calculated and the appropriate screw should be prepared prior to surgery. Screwing of C1 requires a comprehensive knowledge of bone, vascular and neural anatomy. The suboccipital portion of the vertebral artery lies beneath the superior suboccipital triangle that consists of obliquus capitis superior, obliquus capitis inferior and rectus capitis muscles. The posterior arch of C1 vertebra and the posterior occipitoatlantal membrane form the floor of this triangle. The venous plexus covers the C1 lateral mass, vertebral artery and C2 root. In their human cadaveric studies, Rocha et al reported the width of C1 lateral mass as 7.7 to 12.8 mm while the height ranged between 4.3 and 6.1 mm (21). They reported that the entry point of C1 screw is generally in the middle of the lateral mass, however this site should be individualized for each patient. Additionally they specified the screw angles as $16.7\pm1.3°$ medially and $21.7\pm4.7°$ superiorly for the best position. Careful preoperative evaluation of venous anatomy, vertebral artery anatomy and bone structure of C1 vertebra via computerized tomography and magnetic resonance images is necessary to minimize operative injury to these structures.

Goel et al. advocated bilateral sacrifice of C2 ganglia where the space for C1 lateral mass screw is large enough and irritation of C2 nerve root has not been reported previously. The risk of injury or irritation of C2 nerve root can be avoided by traction of the root inferiorly during screw insertion. One other advantage of C1 lateral mass/C2 pedicle screw fixation is that the C1-C2 facet joint is not damaged during the procedure so that it can be used in patients needing temporary fixation such as rotatory subluxation. None of our patients required reduction of C1-C2 vertebra; this maneuver can however be achieved by directly manipulating the C1 and C2 screws with simultaneous repositioning of the patient's head as needed.

CONCLUSION

We conclude that, although our cases are small in number, C1 lateral mass polyaxial screw fixation is a relatively safe method when performed according to the given instructions by surgeons familiar with spinal surgery. This method can be used as an alternative method to achieve rigid and immediate atlantoaxial stabilization. The decision for using this technique should be tailored on case-by-case basis considering the main pathology causing atlantoaxial instability, bone quality of the patient and anatomical variations.

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