Surgical Treatment of Traumatic Type II Odontoid Fracture Using Polyaxial C1 Lateral Mass and C2 Pedicle Screws Fixation

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ABSTRACT

Background Data: Posterior atlantoaxial fixation is indicated for C1-C2 instability or painful osteoarthritis. Different techniques were designed for atlantoaxial fixation as sublaminar wiring, transarticular screw fixation, and, recently, C1 lateral mass and C2 pedicle polyaxial screws and rod system.

Purpose: To investigate the safety, advantages, and complications of posterior atlantoaxial fixation with polyaxial C1 lateral mass and C2 pedicle screws in C1-C2 instability.

Study Design: A retrospective clinical case series.

Patients and Methods: Fourteen consecutive patients, ten males and four females, with a mean age of 40.8±9.6 years were reported. All had traumatic C1-2 instability due to type II odontoid fractures and underwent posterior fixation with polyaxial C1 lateral mass and C2 pedicle screws. Nine patients suffered from motor vehicle accident (MVA) and 5 suffered from falls. All patients were neurologically intact except four patients who had neurological deficits. We used Japanese Orthopedic Association Score (JOA) for their functional evaluation. The average follow-up was 17±1.96 (range, 12–20 months). Operative time, operative blood loss, screw trajectory, screw length, and injury of neurovascular structures were reported. Fusion and construct stability were evaluated by plain radiography and/or CT. Visual Analogue Scale (VAS) of neck pain and JOA were used to evaluate the functional outcome.

Results: The mean duration of surgery was 175.3±12.3 min. The mean blood loss was 553.6±106.5 ml and two patients required transfusion of one unit of blood. The mean length of C1 lateral mass and C2 pedicle screws were 30±1.6 mm and 16.4±1.8 mm, respectively. Correct screw placement and good stability were reported in all patients (100%) at the last follow-up. Mean neck pain on VAS was 2.8±0.8 and 2.3±0.5 at 6 and 12 months, respectively. The complications included moderate pain at iliac graft site for 3 months in 2 patients, pain and dysesthesia in C2 dermatome for 4 months in 3 patients, and superficial wound infection in 2 patients.

Conclusion: Posterior atlantoaxial fixation with polyaxial C1 lateral mass and C2 pedicle screws is a safe and effective method in the treatment of traumatic atlantoaxial subluxation due to type II odontoid fractures. (2019ESJ176)

Keywords: Atlantoaxial, spinal trauma, spinal fusion, instability, dens fracture.
INTRODUCTION

The atlantoaxial joint is a complex articulation between the C1 and C2 vertebrae. The anatomical features of this joint allow for high levels of movement under normal physiological conditions, especially in rotation which makes this joint very unstable. So, external or nonrigid surgical immobilization is complicated by a failure rate more than that in subaxial cervical spine.\textsuperscript{7,24,22,25} Different pathological conditions can cause atlantoaxial instability and are classified into either traumatic or nontraumatic causes. The traumatic causes include odontoid fracture and ligamentous injury. The nontraumatic causes include rheumatoid arthritis, congenital anomalies, infection, and malignancy.\textsuperscript{6,13,22,30}

Clinical manifestations of atlantoaxial instability include pain, progressive myelopathy, neurological motor or sensory deficit, and even death. Many traumatic injuries of C1-2 that are relatively stable can be treated with a rigid cervical neck collar or a halo-vest; however, the transverse ligament, which is the main support to C1–2 articulation, does not heal once injured. Furthermore, type II odontoid fractures that are common have a high nonfusion rate and can be complicated by atlantoaxial instability. These types of injury require surgical stabilization.\textsuperscript{3}

The development of surgical techniques by using rigid screw fixation systems improves the fusion rates without using rigid external immobilization in the treatment of atlantoaxial instability. The surgical approaches for atlantoaxial stabilization can be classified into posterior and anterior procedures.\textsuperscript{10,13} The posterior transarticular screw technique for C1-C2 fixation and fusion, described by Magerl in 1986, achieved high fusion rates and became popular. In this technique, the straight screw trajectory in the sagittal plane increases the risk of vertebral artery injury and up to 20\% of patients cannot have safe insertion of bilateral transarticular screws in the event of medially located vertebral artery.\textsuperscript{1,27,28} Harms and Melcher\textsuperscript{13} introduced a modification of Goel and Laheri’s technique\textsuperscript{9,10} for atlantoaxial fusion using C1 lateral mass screws and C2 pedicle screws and rods system. This method was to decrease the risk of vertebral artery injury and may be performed in the situation of a medially located vertebral artery.\textsuperscript{14}

We reported that our results in surgical management of 14 consecutive patients had traumatic atlantoaxial instability due to type II odontoid fractures with atlantoaxial subluxation using polyaxial C1 lateral mass screws and C2 pedicle screws to do posterior atlantoaxial fixation.

MATERIAL AND METHODS

This study included fourteen consecutive patients, ten males and four females. Patients’ data were retrospectively collected from patients’ files, while patients with missing data were excluded from the study. Patients’ data, diagnosis, and treatment outcomes are confidentially kept private and patients are presented by specific codes. Patients’ ages ranged between 25 and 55 years with a mean age of 40.8±9.6 years. All patients had traumatic atlantoaxial subluxation due to type II odontoid fracture. Nine patients suffered from high speed motor vehicle accident (MVA) and 5 patients suffered from falls. All patients were admitted to and operated upon at the Department of Neurosurgery, Tanta University Hospitals, from October 2014 to October 2017. (Table 1)

All patients were evaluated and subjected to clinical history, general and neurological examination, and routine laboratory investigations. Severe mechanical upper cervical neck pain was the presenting symptom in all patients, where Visual Analogue Score (VAS) was used to quantify degree of pain in every patient preoperatively. We used Japanese Orthopedic Association Score (JOA) for their functional evaluation. All patients were neurologically intact except four patients who had neurological deficits.

All patients were preoperatively radiologically evaluated with plain X-ray cervical spine in lateral, anteroposterior, open mouth view and lateral views in flexion and extension, multislice cervical spine computed tomography (CT) with
sagittal and coronal reconstruction, and Magnetic Resonance Imaging (MRI). Written consent was obtained from all patients before surgery.

We evaluated intraoperative bleeding. Intraoperatively we monitored injury of the neural tissue and the vertebral artery. Operative time was recorded (retrieved from operative records). Purchase and length of screws were evaluated by postoperative CT done in the third day after surgery. Monitoring of postoperative complications was focused on delayed healing of the wound, breaking or loosening of screws, and development of malunion. Clinical outcome of neck pain and functional recovery was evaluated by postoperative CT done in the third day after surgery. Monitoring of postoperative complications was focused on delayed healing of the wound, breaking or loosening of screws, and development of malunion. Clinical outcome of neck pain and functional recovery was evaluated by means of radiographs taken at 3, 6, and 12 months postoperatively. Fusion of C1–C2 segment was evaluated by VAS and JOA score at 3, 6, and 12 months postoperatively. Fusion of C1–C2 segment was followed up to a period ranging from 12 to 20 months by VAS and JOA score at 3, 6, and 12 months postoperatively.

RESULTS

The estimated blood loss was 553.6±106.5ml (range, 450–800), and two patients required one unit of blood transfusion. The duration of surgery was 175.3±12.3 min (range, 150–195). The mean length of C1 lateral mass and C2 pedicle screws was 30±1.6 mm (range, 28–32) and 16.4±1.8 mm (range, 14–18), respectively. The length of stay from admission to hospital discharge was 9.4±3.2 days (range, 5–17) and means postoperative length of hospital stay was 6.1±2.4 days (range, 4–12). Neck pain was the main presenting symptom in all patients and was 8.1±0.8 (range, 7–9). Postoperatively, the mean neck pain on the VAS...
was 5.6±0.7, 2.8±0.8, and 2.3±0.5 at 3, 6, and 12 months, respectively. Four of 14 patients required irregular courses of analgesics. Quadriparesis was reported in 4 patients; two patients were grade 1, one patient was grade 2, and one patient was grade 3 according to JOA score. The remaining 10 patients were neurologically intact and remained the same after surgery. The four patients with quadriparesis showed neurological improvement according to JOA score. One patient became normal, and three patients became grade 1 at the 12-month follow-up (Tables 1 and 2).

There were no vascular or neurological injuries. Two patients had pain at the site of bone graft (posterior iliac crest) for about 3 months, which was classified as moderate according to Numerical Rating Pain Scale that is a segmented numeric version of the visual analogue scale; its pain scale is like VAS but more rapid and easy for our patients. Two patients had superficial wound infection. Three patients had postoperative occipital pain and dysesthesias from caudal retraction on C2 ganglion, but all patients showed marked improvement with medical treatment after 4 months (Table 1).

On the postoperative CT scan, correct screws position of the C1 lateral mass was reported in all 28 screws. 25 screws were bicortical and 3 screws were monocortical, and no screw perforated the anterior cortex more than 3 mm. Adequate C2 pedicle screws insertion was observed in all 28 screws, but two screws perforated the vertebral artery canal (< 1mm) without any complication. Plain X-rays done after 12 months of follow-up showed good stability and alignment without any change in screw position or loss of reduction in all patients. Generally, no system failures were reported in any patient. As fusion evaluation is difficult due to the metallic artifacts of titanium implants, construct stability was defined by absence of hardware breakage or displacement. According to these criteria, construct stability was achieved in all 14 patients (100%) at the 6-month follow-up and maintained at subsequent follow-ups.

Table 1. Summary of patient demography and outcome.

<table>
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<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Neck pain (VAS)</th>
<th>JOA score</th>
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Table 2. Summary of perioperative data of study patients (N=14).

<table>
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<th>Parameters</th>
<th>Mean±SD (range)</th>
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<tr>
<td>Duration of surgery (min)</td>
<td>175.3±12.3 (150–195)</td>
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<tr>
<td>Blood loss (ml)</td>
<td>553.6±106.5 (150–800)</td>
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<tr>
<td>C1 screw length (mm)</td>
<td>30±1.6 (28–32)</td>
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<tr>
<td>C2 screw length (mm)</td>
<td>16.4±1.8 (14–18)</td>
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<tr>
<td>Hospital stay (day)</td>
<td>9.4±3.2 (5–17)</td>
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<tr>
<td>Postoperative stay (day)</td>
<td>6.1±2.4 (4–12)</td>
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Figure 1. Intraoperative fluoroscopy showing operative steps of screw insertion.

Figure 2. (A) Preoperative X-ray cervical spine open mouth view showing odontoid fracture type II and (B) X-ray flexion and extension films showing atlantoaxial instability. (C) Coronal preoperative CT showing type II odontoid fracture. (D) Preoperative MRI cervical spine sagittal T2 showing odontoid fracture and atlantoaxial dislocation. (E) Postoperative X-ray cervical spine lateral and A-P views showing reduction and fixation by C1 lateral mass screws and C2 pedicle screw. (F) Postoperative CT scan axial views showing good screws position.
DISCUSSION

Type II odontoid fractures are known by their high nonfusion rate. Management of these fracture types is still questionable. Nondisplaced type II odontoid fractures may be treated by halo-vest immobilization. However, it is important that the patient knows the risk of nonfusion, which is up to 50%, and up to half of the patients may need surgical fixation. Also, halo-vest immobilization in elderly patients has been reported to increase morbidity and mortality and is poorly tolerated and provide low outcomes when compared to C1-2 fusion. Acute trauma which leads to transverse ligament injury, with an atlantodens distance more than 5 mm, in an adult patient is considered to be unstable and should be surgically fused.

Although anterior fixation with the odontoid screw technique is considered a simple procedure and advantageous because it does not affect atlantoaxial movement, however, its indications are limited and it is contraindicated in multiple situations. The posterior approach is the most common approach for C1-C2 fixation and dorsal wiring techniques have increasingly been replaced by screw fixation techniques. Posterior wiring for atlantoaxial fixation was first described by Gallie in 1939. Multiple modifications of the technique were subsequently introduced. However, these systems do not control rotation and need postoperative halo-vest immobilization. Also, these techniques need intact posterior elements of atlas and axis.

Because of the limitations observed with all dorsal wiring techniques, newer techniques of dorsal atlantoaxial fixation have used rigid screw fixation of the atlas and axis. These rigid screw techniques provide significantly higher rates of fusion, do not require postoperative halo immobilization, and can be done in absence of intact posterior elements, but are technically more demanding, requiring intraoperative fluoroscopy and/or surgical navigation tools.
Magerl and Seeman\textsuperscript{20} published the technique of direct transarticular C1-C2 screw fixation in 1986, usually associated with one of the dorsal wiring techniques for bony fusion. This technique provides strong biomechanical stabilization for flexion/extension and rotation.\textsuperscript{12,28} The success rate of bony fusion of the Magerl technique ranges within around 86.9–100\%.\textsuperscript{4,12,15} Because the trajectory of the transarticular screw is straight in the sagittal plane, up to 20\% of cases cannot have safe insertion of bilateral screws.\textsuperscript{1,19} In a large survey of about 2,500 transarticular screws, injury to the vertebral artery has been reported in 2.2\%, causing neurological deficit in 3.7\% of injured vertebral arteries.\textsuperscript{52} Transarticular screw fixation is often combined with sublaminar wiring to improve the fusion and increase the stability, which also increases the risk of complications.\textsuperscript{20} A cadaveric study by Abou-Madawi et al.\textsuperscript{1} and Madawi et al.\textsuperscript{19} demonstrated that bilateral screws could not be placed in up to 20\% of specimens because of anatomic variations in the location of the foramen transversarium that placed the vertebral artery at risk during screw placement.

Goel and Laheri in 1994\textsuperscript{10} described a new technique for atlantoaxial fixation by using C1 lateral mass screws and C2 pedicle screws connected with plates. Harms and Melcher, in 2001\textsuperscript{13}, described a technique for posterior atlantoaxial fixation with polyaxial C1 lateral mass and C2 pars screws, connected with rods. The trajectory of C2 pedicle screw is directed 20–25° medially and thus passes medial to an enlarged or medially located vertebral artery.\textsuperscript{6,10,13,22,29,30} Moreover, direct visual control during drilling and insertion of C2 pedicle screw increases the safety over transarticular screw insertion.\textsuperscript{10,13}

Many authors\textsuperscript{6,9,10,13,29,30} concluded that no clinically significant vertebral artery injury from C2 pars screw placement has been observed. In Stulik et al.\textsuperscript{30} three out of 56 C2 pedicle screws (5.4\%) perforated the vertebral artery canal without any clinical significance. In the current series, we had two out of 28 (7.1\%) C2 pedicle screws which had perforated the vertebral artery canal (<1mm), without any clinical consequence. The main drawback of C2 pedicle screw insertion over C1-2 transarticular screw insertion is the caudal retraction or cutting of the C2 ganglion for C1 screw placement. In three out of 14 patients, we reported pain and/or annoying temporary paresthesia along with the distribution of C2 dermatome that improved after 6 months with medical treatment. We did caudal retraction in all patients to spare the greater occipital nerve. Payer M. et al.\textsuperscript{24} and Harms and Melcher\textsuperscript{13} also recommended leaving the nerve intact and retracting it caudally. Stulik et al.\textsuperscript{30} reported the same results in 28 patients and they saved the greater occipital nerve in all patients.

In 2002, Goel et al.\textsuperscript{9} published the results of 160 patients with atlantoaxial instability treated by C1 and C2 screw fixation; in order to gain wide exposure of C1 lateral mass, they sectioned the C2 ganglion sharply and reported no significant clinical symptoms. They stated that patients can tolerate dissection of the nerve quite well and explained this by the fact that patients were so satisfied with total pain relief and functional improvement and they simply ignored the C2 anesthesia.

The internal carotid artery and the hypoglossal nerve pass a few millimeters along the anterior aspect of C1 lateral mass and may be injured from excessive anterior perforation during bicortical C1 lateral mass screw insertion. You can avoid this injury by directing the drill toward the anterior tubercle of C1 on the lateral fluoroscopic image and advancing the drill under fluoroscopic guidance. Caution should be taken in order to not advance the drill beyond the anterior border of the odontoid and not go all the length to the anterior border of C1 on the fluoroscopic images as the vertebral body is curved anteriorly.\textsuperscript{24} Correct C1 screw insertion is reported in the series by Harms and Melcher.\textsuperscript{13} Stulik et al.\textsuperscript{30} and Goel et al.\textsuperscript{9} adequate C1 screw insertion within the lateral masses was reported in all screws in the current study, with 25 screws being bicortical and three being monocortical.

Fusion has been reported in the majority of patients managed by posterior atlantoaxial fixation using polyaxial C1 lateral mass screws and C2 pedicle screws.\textsuperscript{6,13,29,30,33} We reported the
same results in our study as we achieved a good fusion and constructed stability in all 14 patients 6 months after surgery. The same results were encountered by AlQzaz and AbouMadawi who reported fusion in all their patients.2

Many studies17,21,19 have compared the biomechanical characteristics of both transarticular technique and C1 lateral mass C2 pedicle screw technique and concluded that biomechanical stability of both techniques was the same. Both methods have high clinical fusion rates.

The most important issue in all types of C1–C2 fixation with screws is the possible injury of the vertebral artery and the nerve structures. Some authors reported damage of the vertebral artery when using the Magerl technique in 3.7–8.2% of patients.4,19,31,32 Madawi et al.19 reported misdirected screws in 14%, vertebral artery injuries in 8%, hardware failure in 4%, temporary hypoglossal nerve paresis in 2%, and iliac crest donor site infection in 2%. The risk of vertebral artery injury with this technique has been well documented in the literature. With the insertion of screws after Harms13 or Goel9,10 neither of the two authors has reported any case of vertebral artery or spinal cord injuries. They explained this fact to a better direct visual control of screws insertion as compared to the Magerl technique.30 It is the same in our study as there were no vertebral artery or spinal cord injuries.

The study limitations are the small number of patients and the short follow-up period. But the clinical and radiological improvements are significant. On the other hand, we used one atlantoaxial fixation technique with all patients. Increasing the patient numbers will improve the accuracy of the results especially in regard to the safety of the described procedure, particularly regarding vertebral artery injuries.

**CONCLUSION**

Posterior atlantoaxial fixation with individual polyaxial C1 lateral mass screws and C2 pedicle screws is a safe and effective method in the treatment of traumatic C1-2 instability due to type II odontoid fractures.

**REFERENCES**


The analysis

The analysis of the results showed that the use of screw fixation in the atlas via the posterior arch and lateral mass resulted in a significant improvement in the stability of the cervical spine. The morphometric evaluation of the screw fixation showed a decrease in the screw loosening rate compared to the traditional methods. The study also demonstrated the effectiveness of the screw fixation in the treatment of atlas fracture dislocations. The patients who underwent the screw fixation procedure showed a significant reduction in pain and improvement in neurological function.

The conclusion

The study concluded that the use of screw fixation in the atlas via the posterior arch and lateral mass is an effective and safe method for the treatment of atlas fracture dislocations. The results of the study support the use of this method in clinical practice. Further studies are needed to evaluate the long-term outcomes of this procedure.