Unstable atlas fracture treatment by anterior plate C1-ring osteosynthesis using a transoral approach

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Abstract

Study design A retrospective study was conducted to evaluate anterior plate fixation of unstable atlas fractures using a transoral approach.

Objective To further investigate the safety and efficacy of this surgical technique, as there is currently a paucity of available data.

Summary of background data While most atlas fractures can be managed by external immobilization with favorable results, surgery is usually preferable in highly unstable cases. Surgical stabilization is most commonly achieved using a posterior approach with fixation of C1–C2 or C0–C2, but these techniques usually result in loss of joint function and cannot fully stabilize anterior arch fractures of the atlas. Although a transoral approach circumvents these issues, only nine cases were described in the literature to our knowledge.

Methods Twenty patients with unstable atlas fractures were treated with this technique during a 6-year period. Screw and plate placement, bone fusion, and integrity of spinal cord and vertebral arteries were assessed via intraoperative and follow-up imaging. Neurologic function, range of motion, strength, pain levels, and signs of infection were assessed clinically upon follow-up.

Results There were no incidents of screw loosening or breakage, plate displacement, spinal cord injury, or vertebral artery injury. A total of 20 plates were placed and all 40 screws were inserted into the atlas lateral masses. CT scans demonstrated that two screws were placed too close to the vertebral artery canal, but without clinical consequences. Imaging demonstrated that bone fusion was achieved in all cases by 6 months postoperatively, without intervertebral instability. No plate-related complications were observed in any patients during the follow-up period.

Conclusions C1 anterior plate fixation using a transoral approach appears to be a safe, reliable, and function-preserving surgical method for the management of unstable atlas fractures. For this type of fracture, a transoral approach with anterior fixation should be considered as an alternative to posterior approaches or conservative treatments.

Keywords Unstable atlas fractures · C1 anterior plate fixation · Transoral approach

Introduction

Fractures of the atlas account for 2–13 % of all cervical spine fractures and approximately 1.3 % of all spine fractures [1, 2]. The question of whether to treat surgically or non-surgically is still discussed and remains controversial, as modern instrumentation techniques are sparking renewed interest in the treatment and outcome of upper cervical spine injuries. Unstable atlas fractures in particular lack consensus regarding ideal classification and treatment. The degree of stability in the case of an atlas fracture is determined by the integrity of the transverse atlantal ligament, the integrity of adjacent vertebrae, and the extent of anterior arch fracture [3, 4]. In cases of

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unstable atlas fractures, Magerl or Harms techniques are widely used to stabilize the atlantoaxial complex. Ideally, treatment of unstable Jefferson fractures should preserve rotation at the atlantoaxial joint and maintain alignment to allow healing of the atlas [5]. Although most of the surgical techniques used to address unstable Jefferson fractures achieve satisfactory stability and bone fusion, atlantoaxial rotation is rarely preserved. For instance, Kesterson recommends primary occipitocervical (C0–C1 or C0–C2) stabilization of Jefferson fractures, while others prefer transfacet screw fixation at C1–C2 to maintain motion between the occiput and C1 [6, 7]. In addition to loss of joint function, another disadvantage of posterior approaches is their inability to fully stabilize anterior arch atlas fractures. Conversely, Ruf demonstrated that an anterior transoral approach enables an anatomic reconstruction of the atlas, fully addresses anterior arch fractures, achieves bone fusion, and preserves C1–C2 rotation [8]. In Ruf's series of six patients, osteosynthesis of C1 was only complicated by one incident of partial redislocation of the lateral masses due to loosening of the screw–rod connection. Further data is needed to evaluate the safety and efficacy of this transoral anterior approach. We therefore present in this report a retrospective analysis of 20 cases of transoral reduction and C1-ring osteosynthesis in unstable atlas fractures. To our knowledge, this report currently represents the largest case series to evaluate the transoral technique of C1-ring osteosynthesis.

Materials and methods

Clinical data of 20 consecutive patients with unstable atlas fractures were collected (12 males and 8 females). C1 anterior plate fixation was performed in each case. The average patient age at the time of operation was 47.7 ± 13.9 years (ranging from 23 to 68 years). The mechanisms of injury were motor vehicle accident (10 cases), falling (8 cases), and other (2 cases). Combined morbidity included head injury (16 cases), soft tissue injury in the face (14 cases), and fracture of extremities (8 cases). Sixteen cases had failed to unite with primary conservative treatment for 3–6 months (hard collar in 10 cases, occiputocervicothoracic cast in 6 cases). Axial pain and restricted motion of the cervical spine was found in all cases. AP and lateral radiographs as well as computed tomography (CT) were collected in each case. All cases in this study were unstable based on multidetector CT, with anterior 1/2 Jefferson fractures (Fig. 1) in four cases and 1/2 ring Jefferson fractures (Fig. 2) in eight cases and anterior 3/4 ring Jefferson fracture (Fig. 3) in eight cases.

Preoperative care Traction was performed in each case, with a weight of 2 kg and appropriate angle according to

individual mechanism of injury. All patients received routine perioperative antibiotics (cefuroxime 1.5 g). The patients were placed in a supine position with a Mayfield head holder. The neck was situated to be slightly hyperextended.

Surgical Technique Transoral surgery was performed as described previously, with some modifications [9, 10]. A nasogastric feeding tube was placed and parenteral antibiotics were given prophylactically. The retraction of the soft palate was achieved with an S-pull hook. The anatomic landmarks in all transoral operations can be confirmed under fluoroscopic guidance. After splitting the soft palate, the mucosa of the posterior pharynx was incised to form a lateral-based door-like flap. The longitudinal muscles were split in the midline, after which the anterior arch of C1 and the anterior aspect of the lateral masses were exposed. Reduction was performed by traction at the head via a Crutchfield clamp with direct manipulation at the lateral masses. To define the entry point for the screws, the lower margin and the medial edge of the lateral mass of C1 was palpated. The entry point is ideally in the center of the lateral mass. Osteosynthesis of C1 was performed with reconstruction plates (Axis system Medtronic Sofamor Danek, Memphis, TN) and bone grafting of autologous ilium. The length and diameter of the screws used were 20 and 3.5 mm, respectively. The position of the plating was verified by C-arm fluoroscopy. Thorough irrigation of the operative site with povidone-iodine solution was performed. The surgical bed was then filled with gelfoam. The posterior pharynx was closed with a single layer of interrupted sutures.

Postoperative treatment

The patients were mobilized the first postoperative day. If there were no accompanying diseases or complications, no restrictions were ordered. Postoperative external immobilization via hard collar was used for 4–6 weeks. Antibiotics were continued for 5 days. Oral diet was usually started on the seventh postoperative day.

Follow-up

Neurologic function was assessed 180 days after surgery. AP and lateral radiographs were taken at 2, 60, and 180 days postoperatively. Dynamic flexion and extension radiographs were taken at 180 days postoperatively to detect any flaws in fracture consolidation.

Results

Postoperative radiographs demonstrated that all cases resulted in satisfactory surgical reduction. The average

Fig. 1 A 60-year-old men with anterior arch fracture treated by C1 anterior plate fixation using a transoral approach. **a** Axial CT image demonstrating two fractures through the anterior arch of C1. **b** The reconstructed images in the coronal planes from thin-section computed tomographic scan showing no displacement of the lateral masses. **c** Transverse T2-weighted MRI of the upper cervical spine shows bilateral break of the anterior arch with transverse ligament intact. **d** Transoral intraoperative view with anterior plate fixation. **e, f** Postoperative lateral and open-mouth roentgenogram after surgery, the relatively good alignment of C1–C2 is identified, all the screws are totally in the lateral masses. **g, h** The lateral and open-mouth X-ray at the 6 months after operation revealing adequate screw placement in the C1 lateral masses and the fixation system no loosening. **i** Axial reformatted CT images at the 6 months after operation revealing bone fusion and the fixation system no loosening

operative time was 101.4 ± 12.9 min (range 76–124 min). No patients required blood transfusion. All patients were followed up from 12 to 81 months, with an average of 48.5 ± 20.0 months. The preoperative VAS scores for these patients were 6.0 ± 1.3 (ranging from 4 to 8) and postoperative VAS scores were 1.3 ± 1.0 . The postoperative axial range of motion was 39.0 ± 12.0 ranging from 26.2° to 60.5° . There were no incidents of screw loosening or breakage, and no spinal cord or vertebral artery injury occurred intraoperatively. A total of 20 plates were placed, and all 40 screws were inserted into the atlas lateral

masses. CT scans demonstrated that two screws were placed too close to the vertebral artery canal, but without clinical consequences. CT scans 6 months after surgery confirmed that fusion was achieved in all cases. No plate-related complication was observed in any patient throughout the follow-up period. All patients had well-preserved range of motion. None had disabling neck pain, and follow-up radiographs demonstrated completely fused graft bone with no intervertebral instability. No complications related to this surgery occurred, and all patients had a good clinical outcome.

Fig. 2 A 39-year-old woman with a 1/2 ring Jefferson fracture treated by C1 anterior plate fixation using a transoral approach. **a** Axial CT image showing fractures of anterior and posterior arches of atlas on the *left side* with displacement of lateral masses. **b** The reconstructed images in the coronal planes from computed tomographic scan revealing one fracture through the anterior arch of C1. **c** Transverse T2-weighted MRI of the *upper* cervical spine showing fractures of anterior and posterior arches of atlas on the *left side* with displacement of lateral masses with transverse ligament intact. **d, e**. Postoperative lateral and open-mouth

roentgenogram after surgery, the relatively good alignment of C1–C2 is identified. **f–h** Postoperative computed tomography after surgery revealing adequate screw placement in the C1 lateral masses and the fixation system no loosening. **i** The open-mouth X-ray at the 6 months after operation revealing adequate screw placement in the C1 lateral masses and the fixation system no loosening. **j, k** The bending view radiographs at the 6 months after operation. No instability at flexion–extension. **l** Axial CT image at the 6 months after operation showing the bone fusion and the fixation system no loosening

Fig. 3 A 48-year-old male with anterior 3/4 ring Jefferson fracture. **a** Preoperative lateral X-ray films demonstrating the anterior arch fracture and posterior arch fracture combined with displacement. **b** Axial CT image of type III Jefferson fracture in Levine classification. **c** The reconstructed images in the coronal planes from computed tomographic scan revealing bilateral break of the anterior arch with displacement. **d** Transverse T2-weighted MRI of the upper cervical spine showing fractures of anterior and posterior arches of atlas with transverse ligament intact. **e** Transoral intraoperative view

with anterior plate fixation. **f** Postoperative lateral view radiographs after surgery, adequate screw placement in the C1 lateral masses and the fixation system no loosening. **g** Postoperative axial CT images revealing all the screws are totally in the lateral masses, and reduction is good. **h, i** The bending view radiographs at the 6 months after operation. No instability at flexion–extension. **j** Axial CT image at the 6 months after operation showing the bone fusion of anterior arch and the fixation system no loosening

Discussion

Atlas fractures are classified based on the fracture location and associated ligamentous injury [11]. The regions of the anterior and posterior arches that connect with the lateral masses are relatively thin and represent the weakest points of the atlas, therefore being highly probable locations for fracture [12]. The lateral masses of the atlas are relatively bulkier and bear the weight of the skull. These strong structures are therefore less likely sites for fracture. Due to its unique anatomy, the atlas most commonly fractures with two or more breaks in the ring structure—to our knowledge, only 14 cases of a single fracture of the atlas detected by CT have been reported in the English literature. In pediatric cases, most fractures occur through the synchondroses (the weakest components of the atlas); the inelasticity of intervertebral ligaments may also contribute in these instances [13, 14]. In adults, the junction of the posterior arch and the lateral mass in C1, where the vertebral artery crosses, is considered to be weaker than the anterior equivalent [11].

Fractures of C1 are assessed initially by radiographs; however, radiography is not always helpful in diagnosing atlas fractures since they can be two-part, three-part, or even four-part fractures. Prevertebral soft-tissue swelling in the lateral view or lateral mass displacement in the open-mouth view are often the only indicators of the diagnosis [15, 16]. Like all cervical fractures, atlas fractures are best assessed by multidetector CT [17]. Sagittal and coronal CT imaging may also be indicated when an odontoid fracture is suspected [18]. Rupture of the stabilizing transverse atlantal ligament, however, is most accurately assessed using magnetic resonance imaging (MRI) [5, 19].

Neurologic injury due to a Jefferson fracture is rare because fractures of the C1 ring increase the space that is available for the dural sac, thereby inhibiting compression [20]. Quadriplegia and hemiparesis may occur for a few minutes, but most often these episodes rapidly fade away (11.7–33 % of patients) [20, 21]. These neurologic deficits were reported most often when a concomitant fracture of the odontoid exists or with bilateral anterior arch fractures [20, 22, 23]. Cranial nerve palsies infrequently complicate Jefferson fractures; however, shifting of the lateral mass may contract the narrow space lateral to the transverse process of the atlas and medial to the styloid process of the skull, within which the 9th, 10th, 11th, and 12th cranial nerves pass [24, 25]. This space is only about 8–10 mm in diameter and may be nearly obliterated if the atlas is displaced laterally following fracture, giving rise to lower cranial nerve palsies [11]. Palsy of the lower four cranial nerves describes Collet–Sicard syndrome, which is a rare complication of Jefferson fractures [23]. Conversely, palsy of the greater occipital nerve with a Jefferson fracture is

somewhat common (23.5 % of patients) [24]. One case of unilateral high vagal palsy due to lateral mass fracture of the atlas has also been reported [26]. In addition to nerve palsies, a case of traumatic vertebral artery dissection caused by a Jefferson fracture was also reported [27]. The vertebral artery is prone to stenotic changes at the atlantoaxial level, leading to a potentially increased risk for bow hunter's stroke due to Jefferson fracture [28].

No definite guidelines exist regarding the decision to treat atlas fractures surgically or conservatively. Many authors argue that most unstable Jefferson fractures heal satisfactorily with immobilization in halo traction or halo vest without surgery [5, 20, 21]. The main intention of non-surgical strategies is to conserve the atlanto-dontoid joint, which is responsible for head rotation. Advocates of treatment with a halo vest argue that it provides traction to align the splayed lateral masses through ligamentotaxis and that it reduces any impaction below C1–C2, thereby preventing subluxation and promoting healing. Haus provides an example of a patient with an unstable Jefferson fracture that was successfully treated non-operatively with a cervical collar: at 12 months' follow-up painless healing of C1 with ankylosis of C1–C2 was achieved, and full pre-morbid activities had been resumed [5]. Critics of non-operative immobilization cite high rates of nonunion and persistent post-traumatic pain [29, 30]. Several authors recommend initial immobilization for 8 weeks in a halo vest followed by C1–C2 fusion to stabilize the joint if residual instability is documented through flexion–extension imaging [31, 32]. Most injuries are found to be relatively stable without associated neurologic deficits and can be treated by external immobilization with satisfactory outcomes. However, preservative treatment with a halo vest has a high risk of insufficient healing. Mechanical instability and incongruence of the atlanto-occipital and the atlanto-axial joints may lead to arthrosis, restricted neck motion, and persistent neck pain. It is a potential risk that old atlas fracture with joint incongruence treated with a halo vest may be harder to reduce by surgical intervention. Furthermore, immobilization of the cervical spine for several months may cause significant discomfort and other complications especially in elderly patients.

Severely unstable Jefferson fractures reflect a more serious injury of the atlas that occurs when the transverse atlantal ligament is also ruptured secondary to the extent of spread of the C1 arch [5]. Since stability at C1–C2 is primarily maintained by the transverse atlantal ligament, many surgeons recommend operative stabilization if there is proven ligamentous incompetency. Hein advocates immediate surgical stabilization, warning that repair of the dislocation after long-term immobilization can cause irreversible incongruence of the atlantoaxial joint followed by arthrosis and increasing neck pain [18]. Moreover, highly

unstable Jefferson fractures carry a risk of acute or chronic spinal cord injury.

Posterior atlantoaxial fusion techniques are widely used in order to stabilize the atlantoaxial complex. An unfortunate consequence shared by most posterior fixation techniques is arthrodesis of the spine, which results in deficits of rotational joint function and posterior head translation. Among these techniques, The Magerl technique uses a transarticular screw fixation method that limits C1–C2 articular rotation; biomechanical testing indicates that this fixation method yields robust biomechanical stability [33]. A modified posterior atlantoaxial fixation that uses bilateral atlas laminar hooks and transarticular screws has also been introduced to manage unstable bursting atlantal fractures [34]. This technique results in good biomechanical stability while preserving some degree of joint mobility. Recently, motion-preserving C1-ring osteosynthesis techniques using a C1 lateral mass screw construct with a transverse rod have been demonstrated [35, 36]. However, none of these posterior approach techniques can fully address anterior 1/2 Jefferson fractures.

In such cases of anterior arch fractures, fixation is best achieved by an anterior approach. Ruf describes a motion-sparing technique of C1-ring osteosynthesis using a transoral approach to implement a lateral mass screw-plate construct [8]. Clinical results were favorable, with 39° of axial rotation of C1–C2 as assessed by dynamic MRI. The technique was not without criticism, because CT and MRI data on the integrity of the transverse atlantal ligament were not reported in detail. Dickman hypothesizes that permanent anterior instability of C1–C2 results from transverse atlantal ligament rupture [19]. Transverse atlantal ligament integrity was believed to have been maintained in Ruf's cases as illustrated by CT imaging, but Dickman stresses that only MRI has the sensitivity to evaluate ligamentous stability. However, C1-ring osteosynthesis has been shown to provide adequate stabilization under physiologic loads even with concomitant transverse atlantal ligament rupture [37]. Notably, none of the documented cases of transoral C1-ring osteosynthesis for displaced Jefferson burst fractures have reported on late instability at C1–C2 [8, 38, 39].

Clinical data indicate that C1-ring osteosynthesis has the potential to become a valuable adjunct to the surgeon's armamentarium. By reconstructing C1–C2 congruency, important joint motion is preserved while late sequelae from malunion are prevented [40–42]. Whether an MRI-proven incompetency of the transverse atlantal ligament is a contraindication for C1-ring osteosynthesis (thereby indicating fusion of C1–C2 to prevent late translational instability) has not been thoroughly investigated, although studies indicate that C1-ring osteosynthesis restores sufficient stability at C1–C2 to prevent significant translation

under physiologic loads [37, 39]. C1-ring osteosynthesis may therefore be a valid alternative to C1–C2 fusion in the treatment of displaced Jefferson burst fractures.

In our study, 20 patients with an unstable atlas fracture were treated with C1 transoral reduction and osteosynthesis and were followed to assess the efficacy and safety of this technique. In this study, the primary reasons to choose the anterior approach were: direct repair of fractured arch and the cosmetic concern of the posterior approach. Wound infection can be a serious problem for the anterior transoral approach. But with proper preoperative preparation and postoperative care, the complication rate can be reduced. In this group, no patient suffered from postoperative infections. Such low complication rate was also reported in a recent study on minimally invasive transoral approach for atlas fracture [43]. None had disabling neck pain, range of motion was well preserved, and bone fusion was achieved without signs of instability or complications. The primary limitation of this study is its sample size, which is a byproduct of the small number of anterior C1 fixations conducted using a transoral approach. As more cases are performed using this technique, its safety and efficacy may be more thoroughly evaluated. An additional limitation of our study is its retrospective nature; future prospective studies may better control for follow-up timing intervals and may have the potential to include more standardized outcome measures (Table 1).

In conclusion, C1 anterior plate fixation using a transoral approach appears to be a safe and efficacious alternative method to manage unstable atlas fractures. This technique allows optimal stabilization and bone fusion of anterior 1/2 Jefferson fractures and preserves important

Table 1 Comparison of anterior and posterior approach for isolated atlas fractures with intact transverse ligament

Procedures	Anterior transoral approach	Posterior approach
Advantages	Direct repair of anterior arch Fixation closer to atlantoaxial joint Cosmetic Preservation of rotary motion	Lower risk of wound infection Preservation of rotary motion
Disadvantages	High risk of wound infection	Unable to stabilize fractured anterior arch Scars with cosmetic concerns Excessive bleeding Neural injury

The posterior approach consists of two pedicle screws and a cross link rod

cervical joint motion. Further investigation is warranted to establish the safety and efficacy of this technique.

Conflict of interest None.

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