Minimally invasive anterior transarticular screw fixation and microendoscopic bone graft for atlantoaxial instability

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Abstract

Purpose Even though transarticular screw (TAS) fixation has been commonly used for posterior C1–C2 arthrodesis in both traumatic and non-traumatic lesions, anterior TAS fixation C1–2 is a less invasive technique as compared with posterior TAS which produces significant soft tissue injury, and there were few reports on percutaneous anterior TAS fixation and microendoscopic bone graft for atlantoaxial instability. The goals of our study were to describe and evaluate a new technique for anterior TAS fixation of the atlantoaxial joints for traumatic atlantoaxial instability by analyzing radiographic and clinical outcomes.

Methods This was a retrospective study of seven consecutive patients with C1–C2 instability due to upper cervical injury treated by a minimally invasive procedure from May 2007 to August 2009. Bilateral anterior TAS were inserted by the percutaneous approach under Iso-C3D fluoroscopic control. The atlantoaxial joint space was prepared for morselized autogenous bone graft under microendoscopy. The data for analysis included time after the injuries, operating time, intraoperative blood loss, X-ray exposure time, clinical results, and complications. Radiographic evaluation included the assessment of atlantoaxial fusion rate and placement of TAS. Bone fusion of the atlantoaxial joints was assessed by flexion extension lateral radiographs and 1-mm thin-slice computed tomography images as radiographic results. Clinical assessment

was done by analyzing the recovery state of clinical presentation from the preoperative period to the last follow-up and by evaluating complications.

Results A total of 14 screws were placed correctly. The atlantoaxial solid fusion without screw failure was confirmed by CT scan in seven cases after a mean follow-up of 27.5 months (range 18–45 months). All patients with associated clinical presentation made a recovery without neurologic sequelae. Postoperative dysphagia occurred and disappeared in two cases within 5 days after surgery. There were no other complications during the follow-up period.

Conclusions Percutaneous anterior TAS fixation and microendoscopic bone graft could be an option for achieving C1–C2 stabilization with several potential advantages such as less tissue trauma and better accuracy. Bilateral TAS fixation and morselized autograft affords effective fixation and solid fusion by a minimally invasive approach.

Keywords Cervical instability · Atlantoaxial fixation · Transarticular screw · Fusion · Minimally invasive spine surgery

Introduction

In 1939, Gallie [1] reported his technique of posterior C1–C2 wiring and fusion. Several modifications such as the Brooks technique and the Halifax clamps were introduced to improve the stability of the construct [2, 3]. In 1979, Magerl and Seemann [4] first described the placement of transarticular screws (TAS) in conjunction with traditional posterior wiring and bone grafting, which showed higher biomechanical stability [5] and fusion rates up to 100% [6]. Complications such as misplacement of the screws, injury

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to the vertebral arteries, injury to the hypoglossal nerve or even the spinal cord, and screw breakages were widely reported in posterior fixation [7]. A less discussed problem of posterior transarticular screw (PTS) fixation concerns its extensive soft tissue damage due to stripping of posterior neck muscles, particularly in elderly patients [8, 9]. Lesoin et al. [10] described the direct osteosynthesis for odontoid fractures and atlantoaxial fixation using a screw fixation of the articular processes in 1987. Apostolides et al. [11] reported the successful treatment of an acute combination atlas–axis fracture in an 85-year-old man using anterior odontoid and C1–2 transarticular facet screw fixation and a Philadelphia collar. Schaeren et al. [12] introduced anterior transarticular screw (ATS) fixation of the atlantoaxial joint in 2007. Sen et al. [8] found similar stiffness of PTS and ATS. ATS is a useful technique for achieving C1–C2 stabilization with less trauma in comparison to PTS [13–15]. We introduce a new minimally invasive technique for anterior atlantoaxial fixation and fusion with the aid of intraoperative fluoroscopic guidance and microendoscopy.

Materials and methods

Clinical data

From May 2007 to August 2009, seven consecutive patients (mean age 40.9 years) with C1–C2 instability received minimally invasive ATS and autogenous iliac bone graft under microendoscopic and fluoroscopic guidance. All patients suffered from atlantoaxial instability due to upper cervical injury and underwent radiologic evaluation via plain cervical spine radiographs, 1-mm thin-slice computerized tomography (CT), and magnetic resonance imaging (MRI) examination. The cases included four Jefferson fractures combined with transverse ligament disruption verified by cervical MRI, two type II odontoid fractures with small and distracted distal parts of the dens, and one comminuted type II odontoid fracture. Reduction

or near reduction of atlantoaxial joint structure was accomplished by skull traction. Seven patients underwent minimally invasive ATS fixation and microendoscopic atlantoaxial joint morselized autograft by one experienced surgeon. The demographic characteristics of the patients, clinical diagnosis, and presentation are listed in Table 1.

Surgical techniques

Minimally invasive anterior transarticular screw fixation

After induction of general endotracheal anesthesia, patients were positioned supine on a radiolucent frame. A radiolucent bite block was placed in the patient's mouth to improve radiographic transoral visualization of the atlantoaxial structure. Reduction or near reduction of the atlantoaxial facet joint was achieved under fluoroscopic control using skull traction and postural adjustment. At this point, the bilateral facet joints and lateral masses of C1–C2, the vertebral body of C2, and the odontoid process should be visualized under anteroposterior and lateral fluoroscopy.

A 1.6-cm unilateral horizontal incision was made along the medial border of the right sternocleidomastoid muscle at approximately the C3–4 level. The platysma and the fascia of the sternocleidomastoid were divided by mosquito forceps. A blunt dissection was performed using a guide tube with a blunt tip to arrive at the anterior surface of the vertebral body at the midcervical level by opening the natural tissue planes medial to the carotid artery sheath and lateral to the trachea and esophagus. The guide tube continued upward along the anterior margin of the vertebral body and was placed straight to below the C2 vertebral body. Under fluoroscopic control, the blunt tip of the guide tube was at the left anteroinferior edge of the C2 pointing directly to the medial of the C1–C2 articulation. While an assistant held the guide tube, the operator used a power drill to insert a 1.2-mm guide wire into the body of C2 across the atlantoaxial joint in a posterior and superior direction, with an angle of 25° in the coronal plane and 30°

Table 1 Patient demographic data and clinical characteristics

No.	Sex/age (years)	Mechanism of injury	Diagnosis	Clinical presentation
1	Male/35	Falling	Jefferson fracture with transverse ligament disruption	Numbness and weakness in bilateral upper extremity, neck pain
2	Male/52	Falling	Jefferson fracture with transverse ligament disruption	Neck pain
3	Female/46	Traffic accident	Type II odontoid fracture	Weakness in grasping
4	Male/39	Falling	Old type II odontoid fracture with dislocation of C1–C2	Neck pain
5	Male/61	Falling	Jefferson fracture with transverse ligament disruption	Numbness in left arm, neck pain
6	Male/36	Falling	Jefferson fracture with transverse ligament disruption	Numbness in right shoulder, neck pain
7	Male/17	Traffic accident	Type II odontoid fracture	Neck pain

in the sagittal plane. The entry point of the guide wire was less than 10 mm lateral to the mid-sagittal line of the C2 vertebra. The wire was advanced until it reached the subchondral bone of the superior joint surface of the C1 mass articularis. The accuracy of placement of the guide wire was verified by acquiring transverse and sagittal reconstructed images using the Iso-C3D C-arm fluoroscopic system (Siemens Medical Solutions, Erlangen, Germany). The working channel was advanced along the guide tube and held by the assistant. The length of the screw was measured and a 4.0-mm cannulated screw (Medtronic Sofamor Danek, USA) was inserted. A 1.0-cm skin incision was made at the opposite site. The second screw was placed into the right atlantoaxial joint in the same aforementioned manner. Both screws should be placed close to the mid-sagittal line of C2 and underneath the pinna of C2 to prevent anterior or lateral cut-out of the screws at that point where they transect the pinna of C2.

A 1.6-cm tubular retractor (Metrx system, Medtronic Sofamor Danek, Memphis, TN, USA) was placed at the C1–C2 level under fluoroscopic guidance and a rigid microendoscope was then inserted into the tubular retractor. Partial longus colli muscles, the anterior longitudinal ligament, the anterior part of atlantoaxial articular capsules, and cartilaginous surfaces were removed. Decortication

and space preparation of the anterior half of the C1–C2 facet joint were performed by using a high-speed burr and other tools. Cancellous morselized bone harvested from the patient's iliac site was packed into the atlantoaxial joint space. After satisfactory completion of the procedure, the patient underwent a passive cervical flexion and extension maneuver under real-time fluoroscopic visualization. The patient is immobilized in a soft cervical collar for 4–6 weeks. A representative case is shown in Figs. 1, 2, 3.

Clinical and radiological evaluation

The data collected retrospectively for analysis were time after the injuries, operating time between open and closure of the skin incision, intraoperative blood loss, X-ray exposure time, clinical and radiographic results, and complications. On postoperatively day 1, plain X-ray and CT scan were performed. Lateral, open mouth, and flexion extension lateral radiographs of the C1–C2 vertebrae were obtained at 3, 6, and 12 months postoperatively to assess union and atlantoaxial alignment. The 1-mm thin-slice CT scans were necessary to assess bone healing and placement of screws. Definitive fusion was identified by formation of trabecular and cortical bony bridges through the atlantoaxial joint.

Fig. 1 A 17-year-old male with type II odontoid fracture. Preoperative plain radiographs (a, b), CT scans (c, d), and T2-weighted sagittal MRI (e) showed a type II odontoid fracture with small and

distracted distal parts of the dens, and anterior subluxation of C1. There was no compression and injury of the spinal cord

Fig. 2 Percutaneous transarticular screws were inserted under fluoroscopic (a) and Iso-C3D fluoroscopic (b) guidance. Decortication of the C1–C2 facet joint (c) and morselized bone graft (d) was performed by using the Metrx tubular retractor and microendoscope

Fig. 3 On postoperatively day 1, CT scans showed morselized bone in the right atlantoaxial facet joint (a) and a good position of the bilateral transarticular screws (b, c). At 6 months after surgery, the

cervical spine flexion (d) and extension (e) plain radiographs, and CT scans (f, g) showed atlantoaxial stability and solid bony union of the right atlantoaxial joint

Results

The mean follow-up was 27.5 months with a range of 18–45 months. Conversion to open surgery was not needed

in any of the patients. Six patients obtained reduction or near reduction of the atlantoaxial joints by skull traction before surgery and underwent the minimally invasive procedure within 3 weeks after trauma. One patient with an

Table 2 Operative data and clinical results in seven patients

No.	Time after injury (days)	Operative time (min)	Blood loss (ml)	X-ray exposure time (s)	Neurological function	Atlantoaxial joint fusion	Complication
1	20	148	60	67	Normal	Yes	Dysphagia
2	19	139	65	70	Normal	Yes	None
3	12	105	55	35	Normal	Yes	None
4	187	155	80	74	Normal	Yes	Dysphagia
5	10	133	65	42	Normal	Yes	None
6	13	127	65	36	Normal	Yes	None
7	8	100	50	33	Normal	Yes	None

old dislocation of the C1–C2 vertebrae underwent intraoperative anterior release and reduction of the atlantoaxial structure under microendoscopy. Bilateral percutaneous ATS fixations were accomplished in seven patients. A total of 14 screws were placed correctly. Two side atlantoaxial fusions were performed in four cases with a Jefferson fracture and one side atlantoaxial fusion in three cases with an unstable odontoid fracture. The average operating time was 130 min with a range of 100–155 min. The mean intraoperative blood loss was 63 ml with a range of 50–80 ml. The mean X-ray exposure time was 51 s (range 33–74 s). Although all patients with associated clinical presentation made a recovery without neurologic sequelae, they complained of different limitations of cervical rotation. Bone fusion and good placement of screws were confirmed by CT scans and dynamic cervical radiographs in seven cases, although single side atlantoaxial autograft was performed in three patients with odontoid fracture. All details of clinical data are listed in Table 2.

No serious morbidities, such as esophageal perforation, carotid artery laceration, vertebral artery injury, neurological deterioration, or airway obstruction, occurred in the seven patients. There were no implant-related complications such as screw cut-out anteriorly through the C2 facet joint or screw back-out. Transient dysphagia occurred in two cases. This complication resolved gradually and spontaneously without special therapy within 5 days after surgery.

Discussion

Fusion between the C1 and C2 vertebrae due to instability and dislocation has traditionally been performed with the Gallie or the Brooks methods using wire or cable fixation. In order to increase the stability, Magerl and Seeman added transarticular C1–C2 screws, which gained wide acceptance with or without posterior laminar wiring and bone grafting. This procedure showed high fusion rates up to 100% [6, 7, 16–20]. Although the high primary stability provided by PTS fixation meant that it was favored over

sublaminar wire-based techniques, complications such as misplacement of the screws with injury to the vertebral artery and spinal cord highlight its potential risks. PTS fixations require a posterior exposure which has been associated with a complication rate as high as 10% involving superficial infections and occipital nerve injury [21–23]. PTS with computer-assisted surgery (CAS) has its own shortcomings, e.g., in highly unstable traumatic injuries of the atlas only C2 can be referenced, even though CAS and intraoperative CT imaging are supposed to increase the accuracy of screw placement within the atlantoaxial joint [24–26]. Meanwhile, up to 22% of patients are not suitable for bilateral PTS because of the thin diameter of the pars interarticularis C2 and neurocentral junction of C2, respectively [27, 28]. Posterior lateral mass C1/isthmus C2 (or ‘pedicle’ C1/isthmus C2) fixations prevent articular damage and enable anatomic reduction under visible control of the atlantoaxial joints; however, this is a technically demanding approach [29].

ATS fixation of the atlantoaxial joint was first described by Lesoin et al. [10] in 1987. In light of the aforementioned shortcomings of PTS and posterior screw and rod fixation for atlantoaxial instability, certain centers have attempted ATS fixation of the C1–C2 vertebrae [8, 9, 13, 14]. Sen et al. [8] reported a biomechanical study on atlantoaxial fusion using ATS fixation of the C1–C2 vertebrae, which supported previous clinical case experience introduced by Reindl et al. [9]. The strength of the construct, ease of the surgical approach, and the decreased risk associated with screw insertion make ATS fixation comparable, and in certain situations superior, to the Magerl screw technique. Apostolides et al. [11] reported a triple anterior screw fixation technique for stabilization of an unstable atlas and odontoid fracture. After anterior odontoid screw placement, the atlantoaxial joints were decorticated and the grooves between the junction of the C2 articular facets and the body represented the drill entry point for insertion of TAS. Clinical course depicted solid union C1–2. Vaccaro et al. performed ATS fixation in a chronically displaced non-united type II odontoid fracture. The screws were placed at the midpoint of the C2 body in the superior and

inferior plane and at the medial third of the C1–2 articulation [14]. Koller et al. [13] reported a morphometric study on the anatomical feasibility of ATS and outlined a suitable technique for the stabilization of atlantoaxial instabilities. Their modifications of previous ATS with a transcorporeal pathway of the screws inside the vertebral body of the C2 vertebra increased the screw purchase inside the C2 vertebra and enhanced the stability of the ATS.

Fong et al. [30] reported an anatomic study on a minimally invasive anterior approach to the upper cervical spine using the Metrx tubular retractor system. The authors concluded that the new surgical approach could replace transoral surgery, allowing direct anterior access to the C1 and C2 vertebrae. Wolinsky et al. [31] developed a novel surgical approach, an endoscopic transcervical odontoidectomy, which allows access for resection of the odontoid and for brainstem and spinal cord decompression without traversing the oral cavity. To our knowledge, few clinical reports of using a minimally invasive technique to perform ATS fixation are available in the literature. In our series, seven consecutive patients with traumatic atlantoaxial instability were successfully treated by ATS fixation and microendoscopic bone graft. Displacement of the atlantoaxial joints should be less than 3 mm in our cases at the time of surgery if an anatomic reduction of the C1–C2 vertebrae is not obtained during operation. All screws were placed without incurring any major complications. The entry site and trajectory of the screw are very important to the success of ATS fixation. The skin entry point of the working channel and tubular retractor was chosen at approximately the C3–4 level in order to avoid injury to the superior thyroid artery, hypoglossal and superior laryngeal nerves. Although the modified technique described by Koller et al. [13] increased the screw purchase inside the bone of the promontory of C2, it is difficult to use the technique in our cases because of limitations of the minimally invasive approach. The entry point for the TAS was determined at the grooves between the junction of the C2 articular facets and the body. No implant-related complications such as screw breakage or failure of the stabilization were observed in our series.

ATS fixation is not a new technique. However, minimally invasive screw placement can be technically challenging, particularly to the novice surgeon without minimally invasive spinal surgery experience. As compared with the technique described by Wu et al. [15], using Iso-C3D fluoroscopic guidance may reduce the risk of injury to the spinal cord and vertebral artery. The intraoperative CT imaging will ease and increase the accuracy of screw placement in ATS. In the case series reported by Wu et al. [15], six patients had a slightly sore throat while swallowing. Those symptoms disappeared 7 days

postoperatively. A large number of autografts in the retropharyngeal space was a potential factor. Two cases of transient dysphagia were observed and disappeared within 5 days after surgery in our series. Longer operative time may be a reason for this complication. Concerning the small joints C1–2, Sen et al. [8] did not rely on the use of bone grafts. Preliminary results in seven patients undergoing ATS showed stable ATS fixation without bone grafts [13]. After osseous fusion of the C1–2 fractures takes place, fibrous and partly osseous ankylosis of the atlantoaxial joints occurs, which may stabilize sufficiently the atlantoaxial complex. There is no doubt that bone graft and decortication of the C1–C2 joints in ATS will improve bony fusion and long-term stability of the atlantoaxial joint. One side atlantoaxial bone graft was performed in three cases with unstable odontoid fracture by reason of intact atlas arch, which achieved enough long-term stability and decreased operating time.

There is increasing concern about the exposure of operating room personnel to radiation during extensive use of intraoperative fluoroscopy. Rajasekaran et al. [32] reported a case of displaced hangman's fracture treated successfully using direct pedicle screw osteosynthesis assisted by Iso-C3D fluoroscopic navigation. This navigation technique may reduce radiological exposure during the process of ATS fixation. But, ATS with the aid of navigation has its own shortcomings, e.g., in highly unstable traumatic injuries of the C1–C2 vertebrae no upper cervical spine can be referenced, particularly in a minimally invasive approach. Iso-C3D fluoroscopic guidance provides ideal intraoperative guidance for the percutaneous transpedicular screw instrumentation of atlantoaxial instability while avoiding registration-related errors and shortening operating time with near real-time intraoperative image acquisition. Rheumatoid arthritis (RA) patients are more likely than non-RA patients to develop subaxial subluxations after posterior atlantoaxial TAS fixation [33]. Care should be taken in performing ATS fixation in RA patients because of the osteoporotic factor.

Minimally invasive ATS fixation and microendoscopic bone graft for atlantoaxial joint is a useful technique for achieving C1–C2 stabilization with less invasiveness and blood loss. The indications are the same as for PTS in the case of traumatic atlantoaxial instabilities, and particularly in anatomic circumstances which preclude posterior screw placement. If decompression is required, it will not be possible through this approach to the cervical spine. All patients are relatively young in our case series. Care must be taken to avoid failure if the C1 and C2 vertebrae are osteoporotic, e.g., in the elderly. Although there are several potential benefits to the minimally invasive procedure, the technique does have its drawbacks and limitations. A challenging learning curve and potential risk must be

stressed to any surgeon without experience on cervical minimally invasive surgery. Because the study is retrospective, data collection and treatment methods are not standardized and controlled as in a prospective study. Further studies with a larger sample size and long-term follow-up results should be performed in a randomized controlled clinical trial. In any event, the described advantages and the absence of evident disadvantages advocate the clinical use of the minimally invasive technique.

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Conflict of interest None of the authors has any potential conflict of interest.

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