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Clinical Article

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Posterior Atlantoaxial Transarticular Screw Fixation

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Objective : Posterior arthrodesis in atlantoaxial instability has been performed using various posterior C1-2 wiring techniques. Recently, transarticular screw fixation (TASF) technique was introduced to achieve significant immediate stability of the C1-2 joint complex. The purpose of this study is to assess the clinical outcomes associated with posterior C1-2 TASF for the patient of atlantoaxial instability.

Methods : We retrospectively reviewed data obtained from 17 patients who underwent C1-2 TASF and supplemented Posterior wiring technique (PWT) with graft between 1994 and 2005. There were 8 men and 9 women with a mean age of 43.5 years (range, 12-65 years). An average follow-up was 26 months (range, 15-108 months).

Results : Successful fusions were achieved in 16 of 17 (94%). The pain was improved markedly (3 patients) or resolved completely (14 patients). There was no case of neurological deterioration, hypoglossal nerve injury, or vertebral artery injury. Progression of spinal deformity, screw pullout or breakage, and neurological or vascular complications did not occur.

Conclusion : The C1-2 TASF with supplemental wiring provided a high fusion rate. Our result demonstrates that C1-2 TASF supplemented by PWT is a safe and effective procedure for atlantoaxial instability. Preoperative evaluation and planning is mandatory for optimal safety.

KEY WORDS : Atlantoaxial · Instability · Posterior fusion · Transarticular screw.

INTRODUCTION

The atlantoaxial motion segment allows the significant mobility. When the C1-2 motion segment is destabilized, its range of motion increases significantly, leading to serious translational and rotational instability[7,14]. Atlantoaxial instability (AAI) can be caused by various pathologic conditions such as trauma (odontoid fracture, Jefferson fracture, Hangman fracture, ligamentous injury), congenital anomalies, skeletal dysplasia, Down syndrome, rheumatoid arthritis, osteoarthritis, infections, or tumors[4,6,10,14,17,26,27].

Three basic techniques have been used to incorporate C2 into posterior internal fixation such as sublaminar wiring, interlaminar clamps, and transarticular screw fixation (TASF). While the C1-2 posterior wiring technique (PWT) is a simple procedure, significant mobility of atlantoaxial motion segment contributes to a high fusion failure as high as 30%[13]. The posterior C1-2 TASF provides immediate stability of the C1-2 joint and higher fusion rate, compared with traditional PWT, even when the latter is immobilized with a halo orthosis[14,15,17]. Furthermore, this may be achieved without the use of rigid external immobilization, avoiding halovest-related complications, and result in a significantly decreased reoperation rate. The purpose of this study is to assess the outcomes associated with posterior C1-2 TASF for the patient with atlantoaxial instability.

MATERIALS AND METHODS

The medical and radiographic records of patients who underwent atlantoaxial fusion for AAI at our hospital between February 1994 and May 2005 were retrospectively reviewed. Only subjects who underwent attempted surgical fusion isolated to atlantoaxial segment were included. Reduction of atlantoaxial complex was achieved in all patients preoperatively. Patients who underwent occipitocervical fusion for AAI were excluded. Patients who underwent unilateral TASF were also excluded. Seventeen patients who underwent a posterior C1-2 TASF and supplemented by PWT with autograft had sufficient follow-up documentation. As an outcome-based study, the primary end-point of evaluation was radiographic fusion.

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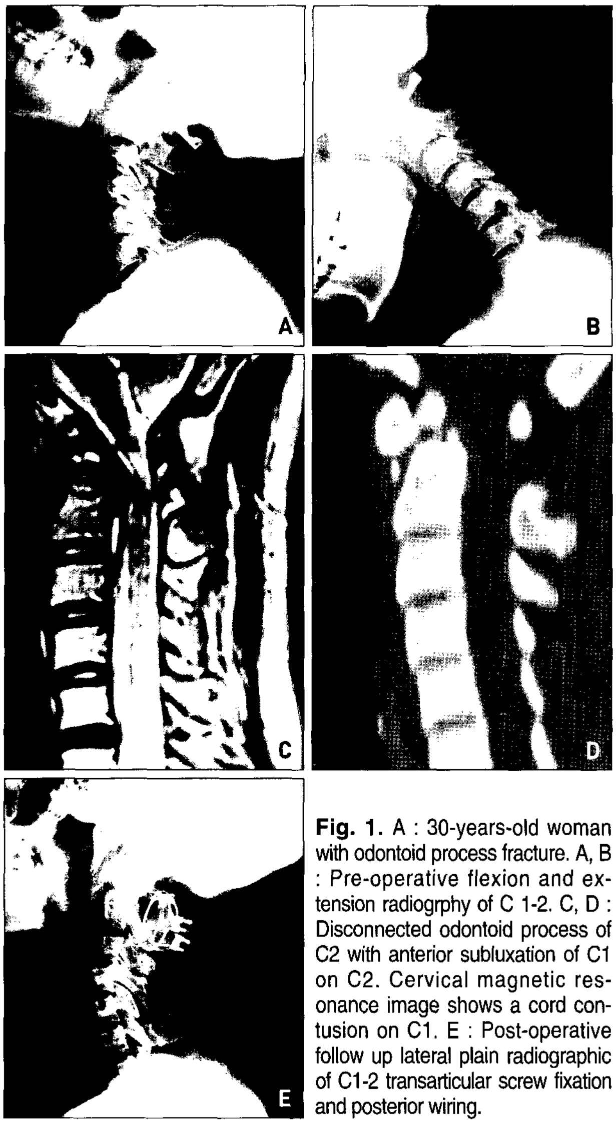

Fig. 1. A : 30-years-old woman with odontoid process fracture. A, B : Pre-operative flexion and extension radiogrphy of C 1-2. C, D : Disconnected odontoid process of C2 with anterior subluxation of C1 on C2. Cervical magnetic resonance image shows a cord contusion on C1. E : Post-operative follow up lateral plain radiographic of C1-2 transarticular screw fixation and posterior wiring.

Serial clinical assessments were conducted throughout the last follow-up. The minimum acceptable interval of radiographic follow-up was 12 months, and the radiologic outcome was determined through independent interpretation by a radiologist. Radiographic evaluation included lateral cervical plain films to assess for maintenance of alignment during healing and flexion-extension radiographs to assist in determination of fusion status. Patients were considered to have displacement if the atlantodental interval or odontoid process-C2 body alignment was more than 2 mm after healing. Solid fusion was defined as the presence of bridging trabecular bone between C1, the autograft, and C2. Furthermore, there was no motion on lateral flexion-extension radiographs (Fig. 1). Fusion status was considered as a stable fibrous union if there was lack of apparent consolidation of the autograft at the C1 or C2 posterior arch interfaces but had less than 2 mm of motion on the lateral flexion-extension films. Finally, patients who had obvious failure of posterior bony consolidation, with or without resorption of the autograft, and demonstrated more than 2 mm on the lateral flexion-extension films were determined to have radiographic evidence of pseudoarthrosis.

Surgical technique

Under general anesthesia, the patient is positioned prone. The neck remains neutral and the head is flexed in a 'military tuck' position. The atlantoaxial subluxation is reduced with the aid of fluoroscopic guidance. A midline incision is made to expose the posterior elements of C1-C3, with careful attention to the C2-C3 facet joints. The lamina and isthmus of C2 are exposed so that screw-hole preparation and screw placement can be performed under direct visualization. The medial aspects of the C2 pars is exposed and palpated with a No. 4 Penfield dissector. The dissector is then passed medially to palpated the medial border of the C2 pedicle and to determine the pedicle angle and screw direction. A epidural venous plexus is routinely encountered, and bleeding form venous plexus can be controled with bipolar coagulation. The medial and lateral aspects of the isthmus are exposed before screw-hole preparation. This will minimize the potential for slippage of drilling laterally into the vertebral artery or medically into the spinal canal. Landmarks used for the screw entry site are 2 mm above the center of the C 2-3 facet joint and 2 mm medial to the middle of the joint. This keeps the screw as far away from the vertebral artery as possible and, at the same time, allows the preparation of a second screw hole, starting further laterally and angled more medially if the initial screw is unsatisfactory. A high-speed drill is used to decorticate the entry site. With fluoroscopic imaging and direct visualization of the dorsal isthmus of C2, a 2.4 mm drill bit is used to begin the screw-hole preparation. The drill is inserted with the trajectory 10 degrees medially and aimed at the anterior tubercle of C1, and the drilling is stopped at the posterior cortical surface of the anterior arch of C1 in the fluoroscopic guidance. The majority of adult patients underwent screw fixation with a permanent cortical screw measuring 3.5 mm in major diameter. At the completion of the drilling, a short cortical screw is placed on top of the C2 isthmus to help determine the diameter of the permanent screw. The limiting factor is the transverse width of the isthmus directly below the C1-2 joint. Additional information is obtained from preoperative CT isthmus survey. A 3.5 mm tap is used to continue the hole preparation before placement of the 3.5 mm diameter cortical screws, which are not self-tapping. A depth gauge is then inserted into the screw hole determine permanent screw lengths. The

Table 1. Summary of surgical indications in 17 patients

Operation indication	No.of cases	Total (%)
Dens fracture	3	17.6%
Ligamentous instability	7	41.2%
Os odontoideum	6	35.3%
Rheumatoid arthritis	1	5.9%

Table 2. Radiologic outcome

Fusion status	No. of cases
Solid fusion	16 (94%)
Stable fibrous	1 (6%)
Non union	0

* Solid fusion : apparent consolidation of the autograft bone with posterior arch of C1, C2<2 mm of motion on flexion-extension radiographs. Stable fibrous : lack of consolidation in the autograft bone,<2 mm of motion on flexion-extension view. * Non union : No posterior bony consolidation, with or without resorption of the autograft block, >2mm on the flexion-extension view

Table 3. Clinical outcome

Outcome	No. of cases
Excellent	14 (82%)
Good	3 (18%)
Fair	0
Poor	0

*Excellent : no pain, Good : pain decrease. Fair : no change, Poor : pain increase

Table 4. Surgery-related complications

Complication	No. of cases (n=6)
Malposition	1
Screw fracture	2
Infection (Operation)	2
(No Operation)	1

average screw length in the series is 40 mm. A bone graft is harvest from the iliac crest, placed between the posterior arches of C-1 and C-2, and secured by titanium wire. Additional onlay grafts are placed on the lateral parts of the posterior arches of C1 and C2. Immobilization is provided by a Philadelphia cervical collar for 12 weeks after surgery for all patients, and early ambulation was encouraged.

RESULTS

Demographics

There were 8 men and 9 women with a mean age of 43.5 years (range, 12-65 years). An average follow-up was 26 months (range, 15-108 months). Of the entire group, 7 patients had ligamentous instability, 3 had dens fracture, 6 had os odontoideum, and one had rheumatoid arthritis. Indications for atlantoaxial arthrodesis are outlined in Table 1.

Clinical and radiographic outcomes

Sixteen of 17 (94%) developed a solid fusion and one patient (6%) developed an apparently stable fibrous union. There was no obvious nonunion by our criteria (Table 2). The pain was improved markedly (3 patients) or resolved completely (14 patients) (Table 3).

Complications

The postoperative complications were summarized in Table 4. There was no operative mortality and no permanent sequelae from any perioperative complications. There were 6 complications. These include three wound infections (one iliac crest harvest site and two posterior cervical incision site) that did not require instrumentation removal. However, revision and wound irrigation were required in two cases. One patient showed screw malposition, and reposition of screw was performed without sequalae. There were two cases of screw fracture One patient had a trauma history six months after operation. Both of them had solid fusion on the follow-up radiographs. Because the stability was already confirmed in spite of screw fracture, they did not require instrumental removal and reoperation. There were no cases of neurological deterioration, hypoglossal nerve injury, or vascular injury associated with screw placement.

DISCUSSION

The axis has a unique anatomy and form a pivot on which the atlas rotates. The atlantoaxial motion segment allows the greatest mobility of any spinal segment, accounting for 50% of cervical rotation and 12% of cervical flexion-extension[20,30]. The transverse ligament is the principal stabilizing structure for atlantoaxial motion. Because the cervicomedullary junction lies at the C1-2 level, instability has the potential for serious neurological sequelae.

PWT, such as the Gallie or Brooks and Jenkins technique have been used as a traditional surgical stabilization for AAI[2,8]. Although these approaches are reasonably safe and effective, sublaminar passage of wires can produce irreversible and devastating neurological injury, especially in the setting of ventral canalicular lesions (e.g. retrodisplaced dens fracture). Additionally, the potential for further canal compromise after C1-2 wiring exists[10]. Dickman et al.[8] introduced interspinous wiring technique in which the passage of sublaminar wiring under C1 was required but not under C2. PWT with a graft acts biomechanically as tension bands to limit primarily flexion and extension. However, it provides comparatively less stability in axial rotation and translation. The rates of nonunion have been reported as more than 30% because all posterior C1-2 wiring constructs loosen after cyclical loading and allow significant increases in C1-2 rotational and translational motion[8,11,26,29]. Supplemental halo-vest immobilization has been recommended to augment the fusion rate by lowering the risk of movement at the surgical site[4,5,16]. However, it has been associated with significant complications such as pin-site infection, scar formation, osteomyelitis, nerve injury, dural penetration and cerebrospinal fluid leakage, intracranial abscesses, dysphagia, restriction of respiratory function, and loss of reduction[12,21].

Laminar clamp contructs (Halifax clamps) eliminate the potential hazard of sublaminar wire passage and do not have the risks of wire breakage or pull-out, but loosening of clamps and loss of fixation have been reported. Fusion failure rates of 20% for C1-2 arthrodesis have been reported[1,24,25]. Furthermore, posterior C1-2 wiring techniques or Halifax clamps can be used only if the posterior C1 arch is intact.

In 1979, Magerl and Seemann described the posterior C1-2 TASF as an alternative surgical management for patients with AAI[23]. TASF is biomechanically more rigid than wire or cable for prohibiting atlantoaxial rotation and translation. One might expect this to be clinically advantageous, as approximately 50% of cervical spine axial rotation occurs at C1-2[5]. TASF provides immediate multidirectional stability and an optimal environment for bone graft incorporation, with fusion rates of 95 to 100 % being reported[3,6,22]. Combining a PWT and bone graft with TASF achieves a very rigid three-point fixation and is biomechanically superior to PWT with a graft or TASF alone[5,9,11,14]. Although it does not require intact C1 posterior arch, TASF requires an intact pars interarticularis of C2 and C1 lateral masses.

Our study demonstrated a high fusion success rate with the posterior C1-2 TASF technique. There were no instances of pseudoarthrosis and 1 case (6%) of stable fibrous union. None of the patients with TASF demonstrated more than 2 mm displacement on follow-up radiographs.

Despite the high fusion rate, many spine surgeons are hesitant to perform this procedure. The placement of transarticular screws is technically challenging and incurs significant risk of neural and vascular injury. A precise screw trajectory is mandatory to avoid complications of vertebral artery injury, neurological injury, or inadequate bone purchase. Safe and accurate screw placement requires a careful preoperative evaluation to exclude anomalous anatomy that would increase the risk of vertebral artery injury and preoperative planning of screw trajectory[30]. Incomplete reduction of C1-2 is a risk factor for improper screw placement and vertebral artery injury[18,20,22]. Previous clinical studies of C1-2 TASF have reported screw misplacement in up to 15% of patients, with an 8% rate of vertebral artery injury[15,19,22]. According to the survey of Wright and Lauryssen[31], the confirmed vertebral artery injury rate was 4.1% per patient or 2.2% per screw placed. Injury to surrounding vascular and neural structures can be avoided by delicate surgical techniques, clear visualization of the operative anatomy and sequential radiographic imaging during the procedure. Lateral intraoperative fluoroscopy or frameless stereotactic guidance is helpful. In our series, there was one malpositioned screw placement (5.9%). However, there were no documented episodes of vascular or neurological injury. In this series, all patients had undergone preoperative CT evaluation to determine anatomic suitability for TASF. Furthermore, TASF was not attempted unless anatomic reduction was possible intraoperatively. Both criteria have been found to be critical for the prevention of procedure-related complications with TASF, especially malpositioning of screws.

TASF of the atlantoaxial joint is becoming a routine procedure for the C1-2 instability. The development of better imaging modalities has made it easier to recognize a subset of patients in whom this procedure may be inappropriate. Careful scrutiny of the vertebral artery course will enable the surgeon to avoid inflicting a potentially catastrophic injury during this procedure. The transarticular screws were safely and successfully placed in all of the C1-2 joint spaces that had been considered anatomically feasible preoperatively. The drawbacks of TASF are the inability of intraoperative reduction and the potential risk of vertebral artery injury.

C1 lateral mass screw and C2 pedicle screw connected by a rod can be used when TASF cannot be placed[18,19,28]. The approximately 20% of patients diagnosed with atlantoaxial instability who have anatomic variations in vertebral artery. Biomechanically, the overall rigidity of C1 lateral mass and C2 pedicle screws is similar to that achieved with transarticular screws. The former acheives statistically a greater axial rotation than the latter. The C2 pedicle screws are actually placed through the pars interarticularis into the pedicle of axis. The trajectory for the insertion of the C2 pedicle screw is guided by anatomic landmarks (medial margin of pedicle), ensuring accurate screw placement. Comparing with the transarticular screw placement, the more medial trajectory of these screws decreases the risk of vertebral artery injury. C1 lateral mass screw and C2 pedicle screw fixation can be a treatment option for atlantoaxial instability with bilateral high-riding vertebral arteries.

CONCLUSION

C1-2 posterior TASF is a biomechanically superior fixation technique that provides immediate rigid stability without the use of rigid external orthosis. Ultimately, TASF provides significantly higher fusion rate, compared with traditional posterior C1-2 wiring methods. The significant fusion rate of TASF compared with conventional posterior graft/wiring constructs and unnecessariness for postsurgical rigid immobilization make this technique superior for AAI. Careful preoperative evaluation and planning are mandatory for accuracy and safety. With the knowledge of regional anatomy and meticulous surgical technique, C1-2 posterior TASF can be a safe and effective procedure of achieving atlantoaxial fusion.

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COMMENTARY

It's been 20 years since transarticular screw fixation for C1-2 instability was introduced. And it became a popular standard procedure as a strong construct due to its high fusion rate. It is unfortunate that this article could not exceed more than a basic text book level. It seems it's just a reconfirmation of already known facts.

I'd like to recommend using mesh cage for rheumatoid arthritis patients as an interlaminar spacer in terms of gaining an experience and like to emphasize that the fusion result of unilateral screw fixation and bilateral screw fixation is reported as having similar fusion result.

I'd also like to point out that performing a reduction by fluoroscopic guidance before the incision, which was one of the comments made by authors, is a very dangerous and unnecessary task. Rather it is safer and essential to perform a reduction right before screw fixation. Further more, transpedicular screw fixation of C2 cannot avoid the vertebral artery injury at all.

However, I believe that this would have been a very productive experience for the authors and it'd be helpful to technical development which C1 lateral mass screw and C2 pedicle screw procedures can be applied.

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