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Clinical Article

Unilateral Posterior Atlantoaxial Transarticular Screw Fixation in Patients with Atlantoaxial Instability : Comparison with Bilateral Method

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Objective : Bilateral C1-2 transarticular screw fixation (TAF) with interspinous wiring has been the best treatment for atlantoaxial instability (AAI). However, several factors may disturb satisfactory placement of bilateral screws. This study evaluates the usefulness of unilateral TAF when bilateral TAF is not available.
Methods : Between January 2003 and December 2007, TAF was performed in 54 patients with AAI. Preoperative studies including cervical x-ray, three dimensional computed tomogram, CT angiogram, and magnetic resonance image were checked. The atlanto-dental interval (ADI) was measured in preoperative period, immediate postoperatively, and postoperative 1, 3 and 6 months.
Results : Unilateral TAF was performed in 27 patients (50%). The causes of unilateral TAF were anomalous course of vertebral artery in 20 patients (74%), severe degenerative arthritis in 3 (11%), fracture of C1 in 2, hemangioblastoma in one, and screw malposition in one. The mean ADI in unilateral group was measured as 2.63 mm in immediate postoperatively, 2.61 mm in 1 month, 2.64 mm in 3 months and 2.61 mm in 6 months postoperatively. The mean ADI of bilateral group was also measured as following; 2.76 mm in immediate postoperative, 2.71 mm in 1 month, 2.73 mm in 3 months, 2.73 mm in 6 months postoperatively. Comparison of ADI measurement showed no significant difference in both groups, and moreover fusion rate was 100% in bilateral and 96.3% in unilateral group (p=0.317).
Conclusion : Even though bilateral TAF is best option for AAI in biomechanical perspectives, unilateral screw fixation also can be a useful alternative in otherwise dangerous or infeasible cases through bilateral screw placement.

KEY WORDS : Atlatoaxial instability (AAI) · Atlantodental interval (ADI) · Transarticular screw fixation (TAF) · Unilateral · Vertebral artery.

INTRODUCTION

Simultaneous bilateral posterior transarticular screw fixation (TAF) and bone grafting with wire loop provides immediate, rigid internal fixation for atlantoaxial instability (AAI)[18]. It is the most effective biomechanical technique to attain C1-2 stability, and is superior to conventional wiring methods by virtue of more rigid fixation[18]. Solid atlantoaxial fusion has been reported in 80 to 100% of patients who were treated with this method[14,18].

However, bilateral TAF across the C1-2 may be contraindicated or impossible in up to 20% of patients because of its structural disfigurements such as anomalous course of the vertebral artery (VA), comminuted fractures of C-1 or C-2, or other pathological processes[14]. When encountering with these situations, unilateral TAF could be alternative method of C1-2 arthrodesis for managing AAI. The purpose of this study is, therefore, to assess the durability and safety of unilateral TAF with posterior wiring by means of comparison with bilateral TAF.

MATERIALS AND METHODS

Between January 2003 and December 2007, 54 consecutive patients underwent TAF for the AAI. The pathologic conditions responsible for the AAI included rheumatoid arthritis in 41 patients, os odontoideum in 6, non-union of a Type II odontoid fracture in 5, hemangioblastoma in one and atlantoaxial subluxation in one, respectively. These

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fifty-four patients were divided into two groups, according to the surgical methods, i.e. bilateral TAF vs. unilateral TAF.

All patients underwent extensive preoperative imaging (Fig. 1) studies to delineate the anatomy of the C1-2 complex and the pathological process causing its instability. Plain cervical radiographs with dynamic views were obtained to assess alignment of C1-2 and atlanto-dental interval (ADI). In addition, fine-slice (1 mm) C1-2 computerized tomography (CT) scans of coronal and sagittal views were used to visualize the potential path of transarticular screw in virtual planes of the reconstruction. A CT angiogram was also used to evaluate the pathway of vertebral artery, and magnetic resonance (MR) images were obtained to assess the degree of cervicomedullary compression as well.

Posterior atlantoaxial TAF combined with interspinous wiring was performed in all patients by using Margel's method. Autogenous iliac bone graft was harvested in 21 patients, and titanium mesh cage (Pyramesh®, Medtronic Sofamor Danek, Memphis, TN) with demineralized bone matrix (DBX®, Synthes, Paoli, PA) were used in 33 patients.

Plain cervical radiographs were serially examined at immediate, 1, 3 and 6 months postoperatively to define bone fusion from ADI (Fig. 1). The judgment of bone fusion was evaluated at 6 months postoperatively regardless of overall follow-up period.

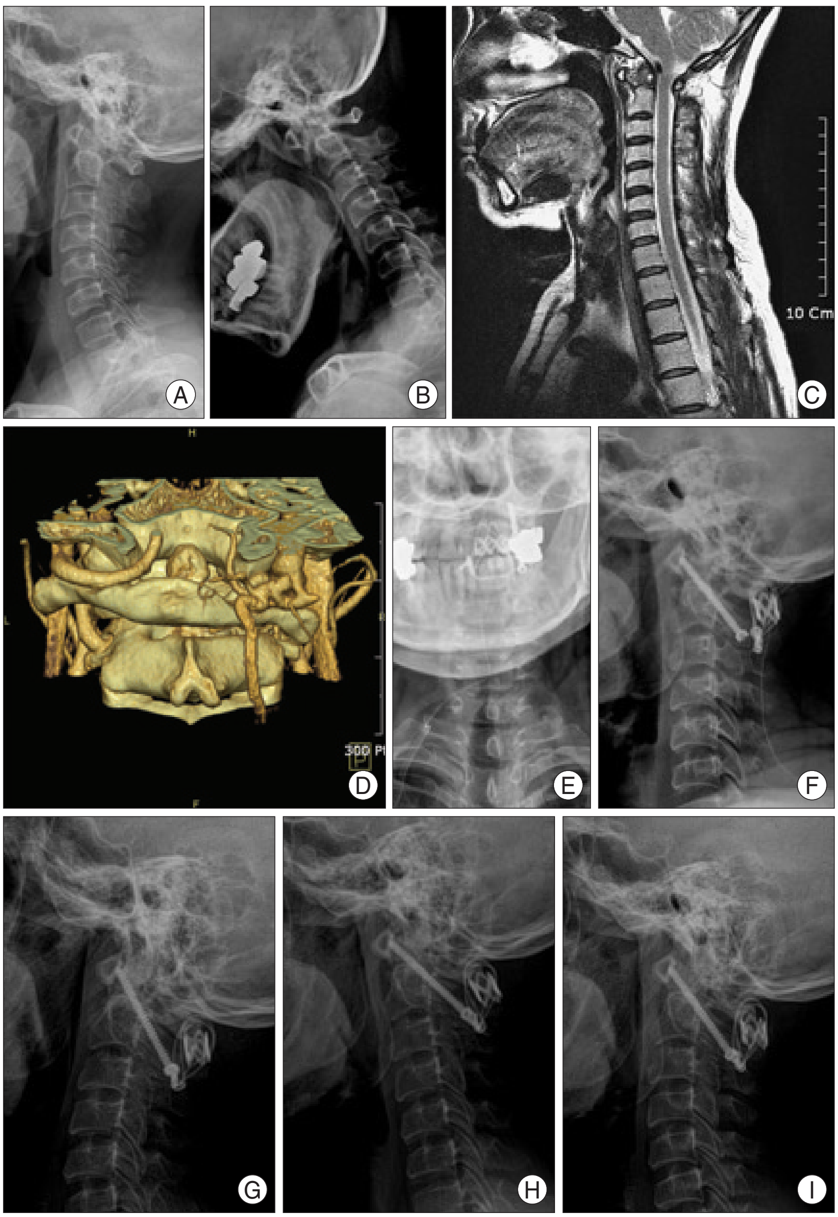

Fig. 1. A 56 years old woman underwent transarticular screw fixation (TAF) for atlantoaxial instability due to rheumatoid arthritis with 10 years history. Plain cervical radiographs with antero-posterior (AP), lateral (A), and flexion view (B) shows atlantoaxial instability with 7.88 mm atlanto-dental interval. Preoperative magnetic resonance image (C) reveals cord compression on the foramen magnum level and pannus formation on the C1 level. Preoperative 3-dimensional computed tomography with vertebral angiography (D) shows anomalous course of right side vertebral artery (VA), because of C1-2 anatomical variation from degenerative change. To prevent the VA injury, unilateral transarticular screw fixation is performed on the left side with interspinous wiring using mesh cage. On the immediate postoperative day, cervical AP (E) and lateral films are checked. Lateral view of plain cervical radiography shows decreased atlanto-dental interval in postoperative period as following; 3.25 mm in immediate (F), 3.20 mm in one month later (G), 3.25 mm in 3 months (H), and 3.23 in 6 months (I).

Statistical analysis of ADI

With regard to the ADI changes, radiographic data were obtained between one and 6 month postoperative days. Statistical analysis was performed using SPSS statistical software version 13.0 (SPSS INC., Chicago, IL). Non-parametric analysis was performed to both unilateral and bilateral TAF group. It was considered to achieve bone fusion, when p value was more than 0.05. The comparison of bone fusion rate between two groups was identified from Mann-Whitney test.

RESULTS

Among 54 patients, unilateral posterior TAF was performed in 27 (50%) patients. The mean age of unilateral group was 46.4 years (range, 13-75 years), and female gender was predominant (n=22). The causes of unilateral TAF were as following; anomalous course of vertebral artery in 20 patients (74%), severe degenerative arthritis in 3 (11%), fracture of C1 in 2 (7%), hemangioblastoma in one, and screw malposition in one, respectively. Whereas in bilateral TAF, the mean age was 48.0 years (range, 23-70 years) with the same sex distribution as unilateral group (Table 1). For all patients, major complications such as massive bleeding, neurologic deficits, apoplexy, or infection was not encountered, and preoperative symptoms were resolved as time went by except for one patient with failed unilateral TAF. Overall follow-up period was 36.7 months (range; 12-48 months) in unilateral TAF group and 34.2 months (range; 12-40 months) in bilateral TAF group.

In 26 patients of unilateral group excluding one failed case, mean ADI was 2.63 mm in immediate postoperative period. And, mean ADIs on 1, 3 and 6 months after operative procedure, were 2.61 mm, 2.64 mm and 2.61 mm, respectively (Table 1). On the other hands, mean immediate postoperative ADI of bilateral screw fixation in 27 patients was 2.76 mm. On 1, 3 and 6 months after operation, mean ADIs were 2.71 mm, 2.73 mm and 2.73, respectively. The postoperative ADI at immediate versus 3 months postoperatively was not significant statistically (unilateral group, p=0.940 and bilateral group, p=0.691). These results was not different in immediate versus 6 months postoperatively (unilateral group, p=0.842 and bilateral group, p=0.760), 1 month after versus 6 months postoperatively (unilateral group, p=0.992 and bilateral group, p=0.814) and 3 months after versus 6 months postoperatively (unilateral group, p=0.787 and bilateral group, p=0.993) (Table 2). These result means that the significant difference of ADI was not noticed during 6 months follow up period in each group. As a result, overall atlantoaxial fusion rate was 96.3% in unilateral group and 100% in bilateral group (Table 2). According to Mann-Whitney test, there was no statistically significant difference between two groups (p=0.317). This result demonstrates that the stability and fusion rate of unilateral TAF are not inferior to bilateral TAF.

Table 1. Demographic characteristics and atlanto-dental interval (ADI) of patients with atlantoaxial instability surgically treated with transarticular screw fixation either unilateral or bilateral method

Variable	Unilateral group	Bilateral group
No. of patients	27	27
Mean age (range)	46.4 years (13-75)	48.0 years (23-70)
Male : Female	5 : 22	5 : 22
	Mean atlanto-dental interval*	
Mean atlanto-dental interval (mm)		
Preoperative	8.15 (4.25-13.58)	8.73 (5.18-13.54)
Immediate postoperative	2.63	2.76
1 month after operation	2.61	2.71
3 month after operation	2.64	2.73
6 month after operation	2.61	2.73

Anomalous course of vertebral artery in 20 patients (74%), severe degenerative arthritis in 3 (11%), fracture of C1 in 2 (7%), hemangioblastoma in one, and screw malposition in one *the mean ADI of unilateral group was calculated in 26 patients, except one patient in whom bone fusion was not achieved

Table 2. Statistical analysis of bone fusion between two groups measuring atlantodental interval (ADI)

Evaluation period	Unilateral group	Bilateral group
Immediate vs 3 month	0.940	0.691
Immediate vs 6 month	0.842	0.760
1 month vs 6 month	0.992	0.814
3 month vs 6 month	0.787	0.993
Number of bone fusion	26 (96.3%)	27 (100%)
Mann-Whitney test*	0.317	

*Mann-Whitney test is used for comparison of bone fusion between both groups. The statistical significance is obtained when p value is less than 0.05. In other words, the bone fusion is considered when the p value is more than 0.05

DISCUSSION

Bilateral posterior TAF with interspinous wiring using either Brooks' or Gallie's technique is an excellent technique, in which rigid mechanical fixation and high fusion rates is achieved in patients with AAI[11]. However, bilateral screw fixation can be hampered due to the followings reasons; high riding or anomalous VA course, comminuted fracture, tumorous condition, and severe degenerative process[18]. Also, screw malposition is an underestimated mishap. Screw malposition is attributed either to inadequate evaluation of local anatomy, inadequate reduction, or inadequate monitoring during screw placement[1]. In the present series, one patient suffered removal of malpositioned screw due to inadequate reduction. Among the potential threats, the risk of VA injury with lethal complications is the most common cause of unilateral TAF. The rates of VA injury have been ranged from 2% to 5% from previous reports[1,11]. According to a survey of the American Association of Neurological Surgeons/Congress of Neurological Surgeons (AANS/CNS) Section on Disorders of the Spine and Peripheral Nerves, unilateral screws were placed in 144 of 1,318 patients (10.9%)[22]. The overall risk of VA injury was 4.1% per patient or 2.2% per screw inserted[22]. VA injury may occur not only because the screw path is very close to the VA, but also because the location of the VA is anatomically highly variable. There are several reports concerning anatomic variation of the VA groove of the axis[4,16]. According to Paramour et al., 18% to 23% of patients may not be suitable candidates for TAF on at least one side because of a high riding transverse foramen[16]. In our institute, unilateral TAF was performed in 50% of all cases, and this was quite higher rate than reported previously. It is because the authors did not place screw in side with any risk of VA injury. If both sides had risk of injury of VA, TAF was performed only in side with relatively low risk, and if both sides had very high risk, we did only posterior wiring. Some papers reported that unilateral TAF, if reinforced by supplemental posterior wiring with graft, might confer adequate stability even in cases where bilateral TAF was contraindicated[14,18].

To prevent VA injury or to insert screw safely in high riding VA patients, many methods for transarticular instrumentation have been introduced[1,8,11,12,19,20]. A previous reports demonstrated low risk of VA canal encroachment by using a frameless stereotactic image-guidance system or aiming device for safe screw trajectory[12,20]. Marcotte et al. defined the entry point for the TAF as 2 to 3 mm superior and 2 to 3 mm lateral from medial aspect of the C2-3 facet joint and target point as the midpoint of the anterior arch of C1. However, Lee et al. recommended to move the entry point more medially and superiorly and targeting inferior to the anterior arch of C1 to avoid high riding VA injury[8,9]. Positional control by the present system, however, is limited in to just one vertebra. Because the screw path penetrates through two vertebrae in TAF, the authors consider the current system being limited in effectiveness. Hence, many authors have accentuated careful preoperative evaluation of corresponding anatomy with three dimensional CT (3D CT) and vertebral angiography[1,8,11,19,23]. For more excellent images, thin-slice section and 3D reconstruction is prerequisite[7]. Nevertheless, careful evaluation of C1-C2 anatomy does not always offer suitable condition for TAF, and cannot locate optimal screw position in the operative field. Actually, there may be VA injury, such as dissection and fistula, despite careful consideration of anatomy in preoperative state or several devices[2,17]. There are, also, introduced different techniques for atlantoaxial stability without TAF to prevention of VA injury. First, there is not the risk of VA injury in only posterior wiring methods including Gallie and Brooks-Jenkins technique or interlaminar clamp technique[10]. But, these methods have limitations of stabilization at rotation force, and low bone fusion rate when compared with screw fixation technique[10]. Second, Harms and Melcher described a technique for the stabilization of the atlantoaxial complex via individual fixation of the C1 lateral mass and the C2 pedicle by using screw and rod system[5]. Because Harms technique avoids the need for passing posterior wiring, this method can be applied in cases, such as C1 posteior ring disruption or when removal of posterior elements is required for surgical decompression. If this method combined with posterior wiring technique, more bone fusion rate was achieved[6]. According to several reports, cervical pedicle screws are safe with respect to VA injury from clinical and anatomical study[3,13,22]. Third, Wright introduced the bilateral, crossing C2 laminar screws[21]. This involves the insertion of polyaxial screws into the laminae of C2 in a bilateral, crossing fashion, which are then connected to C1 lateral mass screws. Because the C2 screws are not placed near VA, this technique allows safer rigid fixation of C2 without VA injury.

Since 1987 when Magerl and Seemann[18] described the procedure, a concept of three-point fixation constituting bilateral posterior TAF and supplemental bone graft wiring technique has become mainstream in the management of patients with AAI. However, it is not always possible to use this three-point fixation due to previously addressed causes. Papagelopoulos et al.[15] demonstrated that three-point fixation has most powerful strength and fusion rate regardless of the method of posterior wiring technique. If solid fusion can be achieved by unilateral TAF assisted with posterior wiring technique, it is very useful when doing surgery to a patient in which VA injury is anticipated. In this point of view, our data successfully demonstrated that there was no significant difference of fusion rate, by comparing ADI at postoperative one month and 6 months 96.3% in unilateral TAF vs. 100% in bilateral TAF. The greatest advantage of TAF is the excellent fusion rate. The Brooks' technique was recommended if only a single screw was inserted, and these resultant 2 points of fixation was not inferior to 3 point fixation in fusion rate. So, in a highly risky case of VA injury, unilateral TAF can be alternative choice rather than instead of bilateral TAF. But, either a single screw or sole posterior wiring technique resulted in less solidity and fusion rate[15]. Even in the current study, one case of fusion failure in unilateral TAF was hemangioblastoma located in C1-C2 level which could not apply Brook's technique because of C1 laminectomy of the posterior arch. One month postoperative films revealed increased ADI and the patient underwent reoperation with C1 lateral mass and C2 pedicle screw fixation.

CONCLUSION

Unilateral C1-2 TAF with interspinous wiring provides an acceptable alternative treatment option of AAI when bilateral TAF is contraindicated. In the present study, the authors demonstrated that there was no difference of both postoperative ADI changes and fusion rate between unilateral and bilateral TAF. However, we should keep in mind the importance of careful anatomical evaluation in preoperative state. Also, by using 3D CT and angiogram in structures surrounding C1-C2, best anatomical situation for TAF can be provided.

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