Atlantoaxial transarticular screw fixation and posterior fusion using polyester cable: a 10-year experience

Werasak Sutipornpalangkul · Surin Thanapipatsiri

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Abstract

Purpose To retrospective review the clinical outcomes of the modified operative technique using a polyester suture material (Ethibond* Excel) for atlantoaxial transarticular screw fixation and posterior fusion.

Methods The retrospective reviews were conducted from 2002 to 2012. The patient's medical record reviews included demographic data, cause of atlantoaxial instability, orthopedic and surgical history, clinical presentation, radiographic finding including plain radiography, complications, operative detail, and outcome of treatment. Fusion of C1–C2 was defined as either graft consolidation or absence of C1–C2 movement on lateral flexion–extension radiograph.

Results Twenty-three patients demonstrated clinical and radiographic evidence of atlantoaxial instability (13 men and 10 women, with a mean age of 42 years). Majority of atlantoaxial instability was caused by trauma. Most common clinical symptom was neck pain with or without cervical myelopathy. Bilateral screws were placed in 18 of the 23 patients. Five patients underwent placement of unilateral screws. The 13 patients were inserted by screws with diameter 4.0 mm. The means screw length was 40.33 mm. The means of operative time and estimated blood loss were 3.6 h and 234 ml, respectively. The mean of follow-up duration was 18 months. All 41 screws were positioned satisfactorily in C1 lateral mass. All 23 patients achieved fusion (100 % fusion rate). After a period of

follow-up, 9 of the 10 neurological deficit patients had completely recovered.

Conclusions We concluded that the atlantoaxial transarticular screw fixation and posterior fusion using polyester cable can be used for C1–2 fusion with a high fusion rate and less complications in various cases.

Keywords Atlantoaxial instability · Polyester cable · Transarticular screw fixation

Introduction

Atlantoaxial instability can be caused by many etiologies such as trauma, inflammatory disease, infection, tumor, and congenital or acquired abnormalities. Various techniques of atlantoaxial fixation have been described and used in the treatment of patients with atlantoaxial instability, but each has its advantage and defects. The Gallie and Brooks technique, which are the two classic techniques for atlantoaxial fixation, carries a neurological risk when sublaminar wires are passed under the C1 arch [1, 2]. The laminar clamp, which uses laminar hooks to fix the C1–C2 posterior structure, has little mechanical stability, but it is still a simple atlantoaxial posterior structure fixation method [3]. The use of transarticular screw fixation offers biomechanical advantage and high fusion rate, but it requires both anatomic reduction of atlantoaxial dislocation and high technical expertise of the surgeon [4]. Nowadays, many studies demonstrate that transarticular screw fixation is safely done, achieving excellent clinical and neurological outcomes [5–8]. But posterior bone graft fixation with metal wiring can cause several complications, especially damage to dura or spinal cord during insertion the wires [9–12]. In response to these problems, our group modified

W. Sutipornpalangkul (✉) · S. Thanapipatsiri
Department of Orthopaedic Surgery, Faculty of Medicine,
Siriraj Hospital, Mahidol University, Prannok road,
Bangkoknoi, Bangkok 10700, Thailand
e-mail: werasak.sut@mahidol.ac.th

the operative technique using a braided non-absorbable polyester suture material (Ethibond* Excel) for posterior bone graft fixation, but there has been no outcome report for this modified technique. Therefore, this retrospective study was performed to evaluate the clinical outcomes of this modified technique in Siriraj hospital.

Materials and methods

The retrospective chart reviews and image reviews were conducted at the Department of Orthopaedics Siriraj Hospital, Thailand from 2002 to 2012. Twenty-eight patients who had atlantoaxial instability and were treated with C1–2 transarticular screw fixation at the Department of Orthopaedic Surgery, Faculty of medicine Siriraj hospital were included in this study. Three patients with incomplete medical record forms and who were lost follow-up were excluded. Furthermore, two patients who used wiring instead of Ethibond were also excluded. Therefore, 23 patients were enrolled in this study. All the patients were operated upon by the same senior orthopedic surgeon (ST). The study was reviewed and approved by the Siriraj Ethics Committee (Si 297/2012 [2012-06-01]).

After enrollment, each patient's medical history was reviewed. The patient's medical record reviews included demographic data, cause of atlantoaxial instability, orthopedic and surgical history, clinical presentation, radiographic finding including plain radiography, computerized tomography, magnetic resonance imaging, complications e.g., intra-operative and immediate postoperative period, operative detail such as operative time and estimated blood loss (EBL), and outcome of treatment. Operative time and EBL were determined from the anesthesia nursing records. All patients were assessed clinically for neurologic improvement by the American Spinal Injury Association scale (ASIA). Fusion of C1–C2 was defined by the operative surgeons as absence of C1–C2 movement on lateral flexion–extension radiograph, no evidence of hardware failure, and evidence of continuity of trabecular bone formation between C1 and C2 across the graft.

Surgical technique

Preoperative cervical traction with Gardner-Well traction tong (IntegraTM, Rietheim-Weilheim, Germany) was performed. After the subluxation was reduced, the operation proceeded. Under general anesthesia, the patient was positioned prone with the cranial tong on 965 Spinal SurgiBed (Stryker[®] Medical, Kalamazoo, MI). A midline incision was made from C1 to C4 to the tips of the spinous process. Subperiosteal dissection was carried out to expose the bony structures from the lower occipital region to the

upper C4. Before placement of transarticular screw, a small wire loop of appropriate size was applied subperiosteal under the arch of atlas and used as a guide wire for passing Ethibond* Excel polyester suture materials sized 2 (Ethicon, Inc., a Johnson-Johnson company, USA). Two Ethibond* Excel suture materials were passed under C1 arch. The first Ethibond suture was tightened to the C2 spinous process for augmentation of the reduction of C1–2 by Gallie technique (Fig. 1a). Then, C1–C2 transarticular screw was applied according to the technique described by Magerl et al. in 1979 [13, 14]. Lateral fluoroscopy was used to determine the planned entrance site and screw trajectory. Various screw systems were used, including the Stainless screw system (Synthes Co, Oberdorf, Switzerland), the Apfelbaum system (Aesculap Co, San Francisco, CA), the TiCP screw system (Synthes Co, Oberdorf, Switzerland), and the titanium screw system (Orthopeasia Co. Ltd., Samutprakarn, Thailand). One bone block of autologous bone graft was harvested from the posterior iliac crest. The graft was nibbled to H-shape (Fig. 1b). The lamina of the C2 vertebra and C1 arch were decorticated before application of the bone graft with a high speed burr. The H-shape iliac bone graft was placed between the posterior arch of C1 and the lamina of the C2 vertebra (Fig. 1b). The graft was pressed for fitting in the space by tightening the second Ethibond suture material by modified Gallie technique (Fig. 1c). The preoperative imaging (Fig. 2a), intra-operative photograph (Fig. 2b), and postoperative imaging (Fig. 2c, d) of one patient treated with this technique were shown. In one rheumatoid patient with spontaneous fusion of Occiput and C1, iliac bone grafts were placed from Occiput region and C2 lamina and Ethibond suture had to be modified for application from Occiput to spinous process of C2. The wound was closed in a standard fashion over a suction drain. Postoperatively, patients were immobilized in various types of orthosis, according to each operation, for 6–8 weeks.

Data analysis

All values were expressed as mean $\pm$ standard deviation (SD). Statistical analysis was performed using StatView for windows version 5 (SAS Institute Inc, Cary, NC, USA). Paired *t* test was used to compare the values. A *p* value <0.05 was considered to be statistically significant.

Results

Between 2002 and 2012, there were 23 patients who demonstrated clinical and radiographic evidence of atlantoaxial instability underwent C1–C2 transarticular screw and posterior fusion with Ethibond suture in our

Fig. 1 Drawing showing the step by step for application and tightening of two Ethibond* Excel suture materials with bone graft to atlantoaxial cervical spine. **a** The first suture was applied by Gallie technique without bone graft. **b** Transarticular screws were inserted with bone graft. **c** Tighten of bone graft by second Ethibond suture according to modified Gallie technique

department. Instability was defined by flexion–extension cervical spine plain radiography. The demographics and characteristic data are shown in Table 1. There were 13 men (56 %) and 10 women (44 %), with a mean age of 42 years (range 9–75 years). This group of patients had less BMI ($21.7 \pm 3.5 \text{ kg/m}^2$). The mean onset of atlantoaxial instability was 3.9 months (range 0.1–12 months). Majority of atlantoaxial instability was caused by trauma in

15 patients (66 %). Others were caused by rheumatoid arthritis in three patients (13 %), infection in one patient (4 %), congenital anomaly in one patient (4 %) and degeneration in three patients (13 %). Most common clinical symptoms were neck pain (39 %) and neck pain with cervical myelopathy (35 %). Neurological deficit was presented in 10 patients (43 %). Of these two patients were ASIA scale C and eight patients were ASIA scale D. Two patients had been previously operated using Gallie technique and had failure of fusion.

Bilateral screws were placed in 18 (78 %) of the 23 patients (Table 2). Five patients (22 %) underwent placement of unilateral screws due to the following reasons: vertebral artery injury in two patients, anatomic anomaly in one patient, entry point malposition in one patient, and injury to spinal cord in one patient. The thirteen patients (57 %) were inserted by screws with diameter 4.0 mm. Screws with diameter 3.5 and 4.5 mm were applied in three patients (13 %) and seven patients (30 %), respectively. The mean screw length was 40.33 mm (range 35–44 mm). Twenty-two patients (96 %) underwent C1 to C2 fusion using Ethibond sutures according to our modified technique for posterior atlantoaxial fusion. Only, in one rheumatoid patient fusion was performed from Occiput to C2 with Ethibond suture due to spontaneous fusion of C1 to Occiput. For postoperative immobilization, most of patients wore rigid cervical orthosis ($n = 11$, 48 %) and soft cervical orthosis ($n = 10$, 44 %). Halo vest and Minerva cast were applied to two poor compliance patients, one head injury patient and one Klippel-Feil syndrome patient, respectively. The means of operative time and estimated blood loss were 3.65 h and 234 ml, respectively.

The patients stayed in the hospital for an average of 21 days (range 7–68 days) (Table 2). There were three intra-operative complications during insertion of transarticular screw, but no complication was associated with posterior graft fixation using Ethibond suture materials. Two patients had vertebral artery injury and one patient had dura laceration during insertion of transarticular screw. These three intra-operative complications, however, did not cause any significant clinical consequences. Other postoperative complications included two patients who developed surgical wound infection at the posterior cervical incision. Both patients with surgical wound infections were managed effectively with debridement and intravenous antibiotic administration.

The mean of follow-up duration was 18 months (range 2–82 months) (Table 3). Postoperative radiographs showed adequate reduction of C1 over C2 in 23 patients. Of the 41 screws placed, all were positioned satisfactorily in C1 lateral mass. The mean of ADI was decreased in this group of patients after operation with statistical significance ($p < 0.01$). The mean and SD of ADI before operation and

Fig. 2 Imaging and intra-operative photograph before and after atlantoaxial transarticular screw fixation and posterior fusion using our modified technique. **a** Preoperative plain radiograph showed atlantoaxial subluxation. **b** Intra-operative photograph demonstrated the bone graft tightened by Ethibond suture material. **c** Nine months postoperatively, radiograph showed osseous fusion at C1–C2. **d** Two years 10 months postoperatively, T2 MRI showed no reaction such as fibrous tissue in area of Ethibond suture material

after operation were 4.86 ± 3.07 and 2.76 ± 1.38 mm, respectively. In addition, the mean of SAC was increased in this group of patients after operation with statistically significance ($p < 0.01$). The mean and SD of SAC before operation and after operation were 12.96 ± 4.22 and 18.14 ± 3.49 mm, respectively. All 23 patients achieved fusion (100 % fusion rate). Nine patients (39 %) had evidence of fusion from no hardware failure and consolidation of graft. Fourteen patients (61 %) also had above evidences plus no movement of C1–2 on postoperative lateral cervical flexion and extension radiographs. After a period of follow-up, 9 (90 %) of the 10 neurological deficit patients had completely recovered, with neurological deficit still persisting in only one patient. This patient belonged to ASIA scale C.

Discussion

Our retrospective study demonstrated that our modified technique for transarticular screw and posterior fusion using high molecular weight polyester cable (Ethibond* Excel) had a high fusion rate of C1–C2 (100 %),

less complications, either intra-operatively (12 %) or postoperatively (8 %), and excellent neurological recovery (90 %). Even though most of our patients had atlantoaxial instability due to trauma, all three rheumatoid patients also had 100 % of fusion rate of C1–C2.

Our finding corresponded to the study of Yonezawa et al. [15] that 100 % of C1–C2 osseous fusion occurred without any complications. These authors used the ultra-high-molecular-weight polyethylene (UHMW-PE) cable system and the technique described by Brooks and Jenkins [1] for posterior bone graft fixation. Even though we also used cable as material for posterior bone fixation, we used polyester suture materials instead of UHMW-PE. Furthermore, a modified technique for posterior fixation which combined Gallie technique and modified Gallie technique was performed [16]. The single loop technique of Gallie was applied first without bone graft between C1 and C2. Therefore, no loosening of suture material was encountered due to resorption of the bone graft. Then double loop technique (modified technique of Gallie) was redone for securing the iliac bone graft. Therefore, high fusion rate in this study might be derived from the enhancement of the stability of C1–C2 derived from the tightening of C1 arch

Table 1 Demographic and characteristic data of atlantoaxial instability patients

	Number of patients	Percentage (%)
Age (years) ^a	42.9 ± 20.8	
Gender		
Male	13	56
Female	10	44
BMI (kg/m ²) ^a	21.7 ± 3.5	
Onset (months) ^a	3.9 ± 3.6	
Causes of instability		
Trauma	15	66
Infection	1	4
Rheumatoid	3	13
Congenital anomaly	1	4
Degeneration	3	13
Clinical signs and symptoms		
Neck pain	9	39
Cervical myelopathy	5	22
Cervical radiculopathy	1	4
Both neck pain and myelopathy	8	35
ASIA scale		
C	2	8
D	8	35
E	13	57

BMI body mass index, ASIA American Spinal Injury Association classification

^a Data expressed mean ± standard deviation

with C2 spinous process using two suture materials instead of the traditional one suture material. In addition to special properties of UHMW-PE such as flexibility, soft material and flat shape described by Yonezawa et al. Ethibond* Excel furthermore has highly adherent coating materials (polybutylate or poly{oxy-1, 4 butanediyl oxy (1,6-dioxo-1, 6 hexanediyl)}) providing relatively nonreactive and high lubricant properties [17, 18]. Therefore, it is unlikely to cut through the lamina of C1 and bone grafts during tightening of the suture. The biocompatibility of this suture material is yet to be proven; however, there is a related report by Shuntaro et al. [19]. They found that there was macrophage response with fibroblast ingrowths but no hypertrophy of the Ethibond suture material within 12 weeks.

In our series, there were five cases (22 %) in which only unilateral transarticular screw fixation could be applied. But these patients still achieved biomechanics stability of C1–2 as a result of bilateral transarticular screw fixation. Normally, the superiority of the biomechanics of surgical stability of the C1–C2 articulation had been found in three point fixations (two transarticular screw plus posterior

Table 2 Operative details, length of hospital stay and complications

	Number of patients	Percentage (%)
Type of screw fixation		
Unilateral screw fixation	5	22
Bilateral screw fixation	18	78
Diameters of screw		
3.5-mm screw	3	13
4.0-mm screw	13	57
4.5-mm screw	7	30
Lengths of screw (mm) ^a	40.33 ± 2.82	
Type of Interlaminar fusion		
C1 to C2	22	96
Occiput to C2	1	4
Postoperative immobilization		
Halo vest	1	4
Minerva cast	1	4
Rigid cervical collar	11	48
Soft cervical collar	10	44
Operative time (h) ^a	3.65 ± 0.52	
Blood loss (ml) ^a	234.3 ± 167.3	
Length of stay (days) ^a	21.5 ± 17.8	
Intra-operative complication		
Vertebral artery injury	2	8
Dura laceration	1	4
Postoperative complications		
Surgical wound infection	2	8

^a Data expressed mean ± standard deviation

Table 3 The outcome of operations

	Number of patients	Percentage or <i>p</i> value
Follow-up time (months) ^a	18.0 ± 18.6	
Atlanto Dens Interval (ADI)(mm) ^a		
Before operation	4.86 ± 3.07 ^b	<0.01 ^b
After operation	2.76 ± 1.38 ^b	
Space available for the cord (SAC)(mm) ^a		
Before operation	12.96 ± 4.22 ^b	<0.01 ^b
After operation	18.14 ± 3.49 ^b	
Evidence of fusion	23	100 %
No hard ware failure plus consolidation	9	39 %
Above plus no movement on flexion–extension film	14	61 %

^a Data expressed mean ± standard deviation

^b Paired student's *t* test was used to compare ADI and SAC between before operation and after operation

fixation) [20, 21]. This may be explained by the enhancement stability of unilateral screw fixation derived from tighten C1 arch and C2 spinous process with

Ethibond* Excel by both Gallie technique and modified Gallie technique. Since 2002, in rheumatoid patients, our senior staff (ST) has also used polyester cable in place of wires. We did not encounter any posterior graft nonunion patients for whom previous study demonstrated several graft nonunion patients, especially in rheumatoid patients [22].

The limitation of this study was its design as a retrospective study. Hence, some patients were excluded from this study due to incomplete medical record forms and being lost to follow-up. Furthermore, there were a small number of respondents compared to other studies. This is the only study on the outcome in using this modified technique for treatment atlantoaxial instability in Thai patients.

Conclusions

We concluded that the atlantoaxial transarticular screw fixation and posterior fusion using polyester cable can be used for C1–2 fusion with a high fusion rate and less complications in various cases.

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Conflict of interest The authors confirm that there is no conflict of interest in the preparation of this article.

References

- Brooks AL, Jenkins EB (1978) Atlanto-axial arthrodesis by the wedge compression method. *J Bone Joint Surg Am* 60(3): 279–284
- Gallie WE (1939) Fractures and dislocations of the upper cervical spine. *Am J Surg* 46:495–499
- Holness RO, Huestis WS, Howes WJ, Langille RA (1984) Posterior stabilization with an interlaminar clamp in cervical injuries: technical note and review of the long term experience with the method. *Neurosurgery* 14(3):318–322
- Hanson PB, Montesano PX, Sharkey NA, Rauschnig W (1991) Anatomic and biomechanical assessment of transarticular screw fixation for atlantoaxial instability. *Spine (Phila Pa 1976)* 16(10): 1141–1145
- Dickman CA, Sonntag VK (1998) Posterior C1–C2 transarticular screw fixation for atlantoaxial arthrodesis. *Neurosurgery* 43(2):275–280 (discussion 280–271)
- Chih-Yun FC, Chi-Chien N, Meng-Ling L, Po-Liang L, Lih-Huei C, Wen-Jer C (2011) Treating C1–2 subluxation with transarticular screw and posterior atlantoaxial fusion-A 5-year experience. *Formos J Musculoskelet Disord* 2:125–130
- Haid RW Jr, Subach BR, McLaughlin MR, Rodts GE Jr, Wahlig JB Jr (2001) C1–C2 transarticular screw fixation for atlantoaxial instability: a 6-year experience. *Neurosurgery* 49(1):65–68 discussion 69–70
- Elliott RE, Tanweer O, Boah A, Morsi A, Ma T, Frempong-Boadu A, Smith ML (2012) Atlantoaxial fusion with transarticular screws: meta-analysis and review of literature. *World Neurosurg*. doi:10.1016/j.wneu.2012.03.012
- Smith MD, Phillips WA, Hensinger RN (1991) Complications of fusion to the upper cervical spine. *Spine (Phila Pa 1976)* 16(7):702–705
- Coyne TJ, Fehlings MG, Wallace MC, Bernstein M, Tator CH (1995) C1–C2 posterior cervical fusion: long-term evaluation of results and efficacy. *Neurosurgery* 37(4):688–692 discussion 692–683
- Fraser AB, Sen C, Casden AM, Catalano PJ, Post KD (1994) Cervical transdural intramedullary migration of a sublamina wire. A complication of cervical fixation. *Spine (Phila Pa 1976)* 19(4):456–459
- Blacklock JB (1994) Fracture of a sublamina stainless steel cable in the upper cervical spine with neurological injury. Case report. *J Neurosurg* 81(6):932–933
- Magerl F, Seemann P (1987) Stable posterior fusion of the atlas and axis by transarticular screw fixation. In: Kehr P, Weidner A (eds) *Cervical spine I*. Springer, New York, pp 322–327
- Easton R (1998) Atlantoaxial fixation with transarticular screws-Magerl technique. *Oper Techn Orthop* 8(1):13–15
- Yonezawa I, Arai Y, Tsuji T, Takahashi M, Kurosawa H (2005) Atlantoaxial transarticular screw fixation and posterior fusion using ultra-high-molecular-weight polyethylene cable. *J Spinal Disord Tech* 18(5):392–395
- Vender JR, Rekito AJ, Harrison SJ, McDonnell DE (2004) The evolution of posterior cervical and occipitocervical fusion and instrumentation. *Neurosurg Focus* 16(1):E9
- Najibi S, Banglmeier R, Matta J, Tannast M (2010) Material properties of common suture materials in orthopaedic surgery. *Iowa Orthop J* 30:84–88
- Alan Barber F, Boothby MH, Richards DP (2006) New sutures and suture anchors in sports medicine. *Sports Med Arthrosc* 14(3):177–184
- Shuntaro H, Sadaaki N, Yoshiyuki Y, Hiroaki I, Haruki Y (2005) Influence of the ultra high molecular weight polyethylene cable for the vertebral canal. *Central Jpn J Orthop Surg Traumatol* 48(6):1017–1018
- Melcher R, Puttlitz CM, Kleinstueck F, Lotz J, Harms J, Bradford D (2002) Biomechanical testing of posterior atlantoaxial fixation techniques. *Spine* 27(22):2435–2440
- Naderi S, Crawford NR, Song GS, Sonntag VK, Dickman CA (1998) Biomechanical comparison of C1–C2 posterior fixation. Cable, graft, and screw combinations. *Spine (Phila Pa 1976)* 15(23):1946–1955
- Ito H, Neo M, Fujibayashi S, Miyata M, Yoshitomi H, Nakamura T (2008) Atlantoaxial transarticular screw fixation with posterior wiring using polyethylene cable: facet fusion despite posterior graft resorption in rheumatoid patients. *Spine (Phila Pa 1976)* 33(15):1655–1661