



## Mini-open percutaneous transarticular screw fixation for acute and late atlantoaxial instability

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The treatment of atlantoaxial instability by means of posterior transarticular screw fixation combined with a Gallie fusion is an established method when direct anterior odontoid screw fixation is not indicated or has failed. In this retrospective study, the results of a modified percutaneous mini-open transarticular C1-C2 screw fixation are presented. Between February 1998 and March 2006, 47 patients with acute or late (after failed conservative treatment) atlantoaxial instability were treated with the modified technique. Their average age was 74.9 years. There were no intraoperative injuries to neural structures or blood vessels; 96.8% of the screws were placed correctly. A revision operation was necessary in one patient because of infection at the graft donor site. No patient experienced a neurological complication. Three patients died during hospitalisation, 6 others later on; 6 could not be traced, leaving thirty-two patients or 68% available for follow-up. The average clinical follow-up was 42 months (range: 12 to 91). The results with respect to the pain and activity status were good or excellent in more than 90% of cases. The radiographic follow-up averaged 25 months (range: 12 to 75). Bony fusion was documented in all cases. The modified technique of transarticular screw fixation presented here is a safe and functionally satisfactory method of achieving stabilisation of the atlantoaxial complex. Special cannulated instruments are not required. This mini-open transcutaneous technique is an alternative to the conventional open procedure, and reduces operation time as well as blood loss.

**Keywords:** cervical spine; atlantoaxial instability; transarticular screw fixation; mini-open approach; transcutaneous.

### INTRODUCTION

The treatment of atlantoaxial instability by means of posterior transarticular screw fixation of C1-C2 as described by Magerl and Seemann (19) is well known. Combined with a Gallie fusion (11), this procedure provides superior stability of the atlantoaxial complex as compared to other methods (4,12,21). Particularly in elderly patients with

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osteoporosis, transarticular screw fixation appears to be superior to direct anterior screw fixation of the fractured odontoid (2). McGuire and Harkey (21) modified the procedure by developing special cannulated instruments to achieve percutaneous screw insertion with minimal soft tissue dissection. Furthermore, screws could be directed more vertically with this technique and thus over a longer distance and more centrally in the articular masses of C1 and C2 (21). El Saghier *et al* (8) also described percutaneous screw insertion, using a special sleeve and screwdriver ; they presented their results in patients with rheumatoid arthritis.

The authors present their experience with the mini-open percutaneous technique for post traumatic atlantoaxial instability, without a special instrumentation.

## PATIENTS AND METHODS

Transarticular screw fixation was performed between February 1998 and March 2006 in 47 consecutive patients with traumatic atlantoaxial instability. This retrospective study was based on hospital records, consecutive outpatient visits, radiographs and post-mortem reports. For further information the authors contacted the patients, their general practitioners and other orthopaedic surgeons treating them. The last available radiographs were used to assess the radiographic outcome.

### Patient population

There were 28 women (59.6%) and 19 men (40.4%) with an average age of 74.9 years (range : 18 to 93). In 34 patients (72.3%) the cause of the instability was an acute fracture of the odontoid process ; 13 other patients (27.6%) had nonunion after nonoperative treatment. All patients complained of posterior cervical pain. The 34 acute injuries of the odontoid process were classified according to Anderson and D'Alonzo (1) : there were 28 type II injuries and 6 type III injuries. Eleven of the 34 acute fractures were combined with a fracture of the C1 arch. Preoperative neurological deficits were documented in three patients (6.4%). The neurological lesions were classified according to the American Spinal Injury Association (ASIA) (20). One patient with late nonunion of the odontoid and cervical myelopathy had ASIA impairment grade B. Two other patients with

acute odontoid injury were classified as ASIA impairment grade C and D respectively. The other 44 patients (93.6%) had no neurological symptoms. In 46 patients (97.9%) the cause of the atlantoaxial instability was traumatic : 37 cases (78.7%) were due to a fall and 9 cases (19.2%) were due to a road traffic accident.

### Radiologic evaluation

The atlantoaxial instability was determined radiographically using the criteria defined by Apuzzo *et al* (3) and Hadley *et al* (14) : more than 2 mm motion on flexion/extension views and/or more than 5 mm displacement or more than 11° angulation of the odontoid. Each patient had conventional radiographs of the cervical spine in two planes, pre- and postoperatively and during follow-up. The angle between the inferior end plate of C2 and the screws was determined postoperatively and at follow-up, according to Blauth *et al* (4) (fig 1). The closer the angle was to 90°, the steeper the orientation of the screws and the more central their position in the pedicle. Computed tomography of the cervical spine was performed pre- and postoperatively ; coronal and sagittal reconstructions, focused on the foramina, were used to plan the screw trajectory and to measure the pedicle size. According to Madawi *et al* (18), the screw



**Fig. 1.** — Plain radiograph, lateral view : Determination of the angle between the inferior end plate of C2 and the inserted screws.

Table I. — Classification of pain and activity status

Result	Pain status	Activity status
excellent	No pain	Unlimited return to previous activities of daily living
good	Occasional or mild pain, no need for analgesics	Return to previous activities of daily living with restrictions
fair	Moderate pain, occasional pain medication	No return to previous activities of daily living. Modified activities
poor	Severe or constant pain, requiring continuous pain medication	Totally disabled

position was classified as correct if the screw passed through both lateral masses of C1 and C2, crossed the C1-C2 joint and protruded less than 5 mm through the anterior cortex of C1, totalising 4 cortices. Bony fusion of the laminae was assessed at follow-up using conventional radiographs ; when in doubt, a CT-scan was performed. Fusion was defined as bridging trabecular bone along the surfaces of the graft and the laminae of C1 and C2, without lucency or resorption of the graft, and without C1-C2 instability on flexion-extension views.

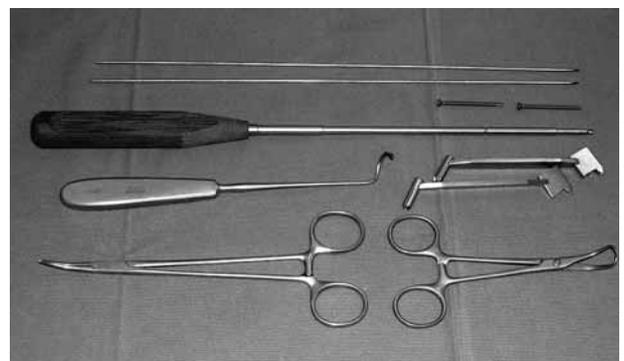
### Clinical outcome

The pain and activity status of the patients were assessed according to the classification previously presented by the authors (16) : poor, fair, good, or excellent (table I). Moreover, the patients were questioned about their subjective satisfaction.

### Operative technique

The operative procedure was the same in all patients. The mini-open percutaneous technique according to El Saghier *et al* (8) was used, but special instruments were not used (fig 2). All procedures were performed by or under the supervision of the senior author.

The patient's head was held in a Mayfield holder. The fracture was reduced under fluoroscopic control. The incision extended from the external occipital protuberance to the spinous process of C3. The neck muscles were dissected off the atlas and axis. Dissection continued until the entry site for the transarticular screws at the junction of the laminae, and the articular mass of C2 was exposed. The C1-C2 facets were not decorticated. It was not necessary to expose the laminae distally to C2. After exposure, a non-absorbable suture or a wire was passed around the posterior arch of the atlas with a Deschamps ligature carrier, to stabilise the final bone graft.



**Fig. 2.** — Instruments required for the mini-open transcuteaneous transarticular technique : two 2-mm K-wires, two 2.7-mm or 3.5-mm self-tapping fully threaded screws, one long screwdriver, one Deschamps ligature carrier, two drill guides 2.0 mm, one clamp and a reduction forceps.

Definitive reduction of C1-C2 was accomplished before drilling the 2-mm Kirschner wires percutaneously on both sides from level T2-T3 through the C1-C2 joint, totalising four cortices (fig 3). The large diameter of the wires and the use of a drill guide allowed optimal guidance of the wires and prevented them from deviating while crossing the C1-C2 joint line. Positioning of the wires was performed under biplanar fluoroscopy. When the position was correct, the wires were replaced by 2.7 mm or 3.5 mm self-tapping fully threaded titanium screws. The screws were brought into position with a clamp through the operative field whereas the screw driver was inserted percutaneously (fig 3). The screw length varied from 36 to 46 mm. A modified Gallie fusion with an H-shaped bone graft from the iliac crest was added in all cases.

Postoperatively a hard collar (Miami-J Collar) was applied for 6 to 10 weeks depending on the radiographic evolution.



**Fig. 3.** — The operative field after insertion of the K-wires. Soft tissue dissection is minimised by percutaneous placement of the 2-mm K-wires.

## RESULTS

The average duration of the operation was 98 min (range : 73 to 122). In one case a screw cut out of the axis lamina during insertion and the fusion had to be extended to C3 using a hook plate. There were no other intraoperative complications. None of the patients received blood transfusions postoperatively. Three patients (6.4%) died postoperatively during the same hospitalisation : one patient with multiple associated injuries (ISS = 41) died from Multiple Organ Failure ; two other patients died as a result of pneumonia or cardiac arrest. The postoperative CT-scan demonstrated malposition of a single screw in two patients ; in both cases the screw was inserted too horizontally and was not anchored sufficiently in the articular mass of C1. However, the contralateral screw was in a correct position, stability was not diminished and no further measures were necessary. Thus, 91 of 94 inserted screws (96.8%) were placed correctly. One patient developed infection at the graft donor site, necessitating revision. One patient complained of intermittent problems with swallowing one year after the operation despite correct screw position. A causal association between the operative method and the complaints described by the patient could not be confirmed ; there was no

hypoglossal nerve paresis. No patient experienced a neurological complication.

Three patients died during hospitalisation, as mentioned. Six other patients (12.8%) died later on : 5 due to unrelated causes, and one, with incomplete tetraplegia ASIA grade B, because of respiratory failure. Six patients (12.8%) were lost to follow-up. So thirty-two patients or 68% were available for follow-up and were checked radiographically for an average of 25 months (range : 12 to 75). Clinical follow-up was longer with an average of 42 months (range : 12 to 91).

At the time of follow-up, the Pain and Activity Status was predominantly excellent or good (table II). Moreover, 27 out of 32 patients (84.4%) were subjectively satisfied with the outcome of treatment. Two patients (6.3%) complained of occasional pain at the bone graft donor site. Two of the three patients with a preoperative neurological deficit experienced improvement by at least one ASIA impairment grade ; the third patient recovered completely. C1-C2 fusion was confirmed radiographically in every patient. The angle between the inferior end plate of C2 and the screws was 63° on average (range : 40 to 75) and was identical with the postoperative measurement. No screw migration was observed. The position of the odontoid was maintained in all patients. Screw breakage was observed in 5 patients at follow-up, always at the level of the C1-C2 joint line (fig 4), but fusion was achieved in all cases.

Table II. — Pain and activity at the time of follow-up (32 patients)

Result	Pain status	Activity status
excellent	n = 26 (81.2%)	n = 21 (65.6%)
good	n = 3 (9.4%)	n = 8 (25.0%)
fair	n = 2 (6.3%)	n = 2 (6.3%)
poor	n = 1 (3.1%)	n = 1 (3.1%)



**Fig. 4.** — Reformatted CT-scan, lateral view. Screw breakage at the typical location.

## DISCUSSION

In the literature, fusion rates between 81.0% and 100% have been reported in non-homogeneous groups treated with transarticular screw fixation (4,7-10,13,15,18,21,23). The influence of the underlying disease on bone healing has not yet been adequately investigated. Madawi *et al* (18) reported much lower rates of fusion (81%) in patients with rheumatoid arthritis compared to patients with traumatic instability (100%). The cause of the lower fusion rate was resorption of the bone graft, often observed in patients with rheumatoid arthritis (18). However El Saghier *et al* (8) did not observe this problem in 57 patients with rheumatoid disease. In our patient population, bony fusion was obtained in all cases. However, after transarticular screw fixation even absence of bony fusion does not necessarily result in a secondary procedure since a fibrous nonunion develops in many cases, which is stable and not painful (5,6,15).

A serious intraoperative complication is injury to the vertebral artery: an incidence of 0 to 5% has been reported (4,7,10,13,15,17,18,23,24). With unilateral injury of the vertebral artery, neurological

lesions are rare (4,5,18), but considerable blood loss can occur (18). This complication did not occur in this series. Indeed, in each patient the position of the foramina and the width and shape of the C2 pedicle were analysed preoperatively using CT-reconstruction to plan the screw trajectory in order to ensure safe passage across the C2 pedicle. The importance of preoperative imaging planning was emphasised by Haid *et al* (15). The authors anticipate that image-guidance technology, like frameless stereotaxy and virtual fluoroscopy, will be an integral part of C1-C2 transarticular screw fixation in the future (15).

In the classical Magerl and Seemann open procedure (19), the main difficulty consists of directing the screws sufficiently vertically in the cephalad direction to place them as centrally as possible and thus over a long distance in the articular mass of the atlas. The “percutaneous” technique of screw insertion reduces this problem because drilling can take place from a more caudal level (21). Blauth *et al* (4) compared Magerl and Seemann’s open procedure (19) to McGuire and Harkey’s percutaneous method (21), with respect to the angle between the inferior end plate of C2 and the screws. With the percutaneous technique, the screw direction was 10° more vertical on average and remained constant (4). The average angle of 63° achieved in our study was less steep than the 73.9° in Blauth’s series (4), but it remained constant. A possible explanation for the more horizontal screw trajectory in our patients was that the average age of our patients (74.9 years) was significantly greater than the average age (43 years) of Blauth’s patients (4). Thoracic kyphosis is more marked in older patients and makes vertical screw placement difficult. However, Schmidt *et al* (22) also investigated this question retrospectively and found no significant difference in screw angulation between the “open” and “percutaneous” group. In two of our cases the screws were placed too horizontally, but they represented the start of our learning curve, respectively in 1998 and in 1999.

The expected advantages of reduced soft tissue dissection in the technique presented here, as compared to the classical open procedure according to Magerl and Seemann (19), are a shorter operating

time and a smaller intraoperative blood loss. However, the retrospective character of this study and the lack of a control group (evidence level IV) do not furnish proof. We know of only two studies (evidence level III) which deal with this question (4,22). Blauth *et al* (4) described significantly shorter operation times (+/-93 minutes) with the percutaneous technique of McGuire and Harkey (21), compared to +/- 128 minutes with the classical Magerl and Seemann open procedure (19). The first value is in the same range as our operation time : +/- 98 minutes. Schmidt *et al* (22) noted an average operation time of 110.6 min for the percutaneous method, but this was still significantly shorter than the +/- 175.3 minutes necessary for a classical open procedure. The latter authors also reported a significantly lower intra- and postoperative blood loss in their “percutaneous” series.

### CONCLUSIONS

The results with the “mini-open” percutaneous technique of transarticular screw fixation in patients with traumatic atlantoaxial instability demonstrate a high fusion rate (100%) and a low complication rate. Percutaneous screw insertion is possible with a reduced operative field, without special instruments. Exact preoperative planning using appropriate imaging appears to be very important to achieve a low complication rate. Limited operation time and blood loss are advantages of the modified technique. The technique is safe and provides high initial stability, especially in elderly patients with acute or late C1-C2 instability.

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