Abstract
Objective
To review the management of atlanto-axial instability by means of posterior transarticular screw fixation with specific reference to intra- and postoperative complications and rates of fusion.
Method
Clinical records and X-rays of 22 consecutive patients were reviewed. Rheumatoid arthritis was the aetiology in six patients, ankylosing spondylitis in one and the rest post-traumatic. There were 16 males and six females, with an average age of 49 years. The mean follow-up period was 14.6 months.
Results
Transarticular fixation was achieved in 19 of the 22 patients. It was aborted in three cases due to inability to achieve the required drill trajectory. Alternative fixation methods were used in these three patients. There were two transient CSF leaks and one vertebral artery injury. No cases of spinal cord injury or hypoglossal nerve injury were noted. There was one case of a misplaced screw. Fusion was documented in all the patients.
Conclusion
The atlanto-axial transarticular screw fixation is technically challenging. Despite this, it is a safe technique, offering immediate biomechanical rigidity, and a predictably high fusion rate. However, it must be remembered that the technique is not possible in all patients and that a back-up option should be available intra-operatively.

Introduction
Atlanto-axial (AA) instability has many causes, the commonest being rheumatoid arthritis (Figures 1 and 2) and trauma. Once recognised, surgical stabilisation is indicated to prevent neurological injury, and in rheumatoid arthritis may arrest the local inflammatory process. Fusion is usually performed from a posterior approach, with a variety of methods employed. On-lay (uninstrumented) fusion is possible but requires prolonged immobilisation in a rigid device such as a halo jacket. It is difficult to control the atlanto-axial motion with an external orthosis and is thus not an ideal option other than in the paediatric population, where fusion is rapid and more predictable. In the adult population, instrumentation is preferred to control the instability and increase the union rate.

Wiring techniques have been the mainstay over the last few decades. The Gallie technique utilises a C1 sublaminar - C2 spinous process wiring and the Brookes, a C1 and C2 sublaminar wiring. Passing sublaminar wiring poses neurological risk and with the move towards MRI-compatible materials, stainless steel wire has fallen out of favour. Titanium wire is not readily available and cable more difficult and expensive to use. In addition, wiring techniques offer poor control of translation, and still necessitate a period of orthotic immobilisation, usually a halo-jacket. The Gallie technique has been reported to have a high pseudoarthrosis rate.
The atlanto-axial transarticular screw fixation technique (AATF) was introduced by Magerl and Seemann. The advantages are improved stability, improved fusion rates, and decreased postoperative immobilisation requirements. Several studies have demonstrated superior biomechanical stability, with the best control of rotation and lateral flexion, and fusion rates of 90% to 100%. It is the treatment of choice in congenital spinal canal stenosis, as it avoids the passage of sublaminar wires and in cases where the posterior elements are deficient. It is cost-effective as only two 3.5 mm screws are used.

With good bony purchase, there is immediate biomechanical stability. A posterior wire can be added to create a three-point fixation for increased stability.

There is a natural reluctance to pass screws in this area due to local anatomical risks, especially the vertebral artery with its tortuous course through the lateral mass of C2.

At our hospital, the trans-articular fixation is the first choice of AA fixation. A review of our experience was undertaken to assess complications and outcome.

**Materials and method**

A retrospective review was conducted on all patients planned for AATF by the senior author (RD) during the three-year period 2002 to 2005. The clinical records and imaging were reviewed with a view to indications, intraoperative difficulties, fusion rate, and complications.

Twenty-two patients planned for AATF were identified and included in the study. There were 16 male and six female patients with a mean age of 49.0 years (21-69 ± 17.1). The mean follow-up period was 14.6 (3-39 ± 11.5 months).

The aetiology spectrum is listed in Table I. Three cases with an acute dens fracture underwent AATF as anterior dens screw fixation (the usual first choice management of type 2 fractures in our unit) was deemed either not possible or unlikely to provide adequate fixation. In two, the patients had short necks with a kyphotic position which precluded the angle above the chest for the required guide wire trajectory for the anterior technique. The other was an ankylosing spondylitis patient with a rigid sub-axial spine. Anterior dens fixation was judged to be inadequate for the expected forces at the fracture site, and the more rigid posterior fixation chosen as the definitive procedure.

The type 3 fracture had only a small lip of anterior bone and was expected to behave like a type 2 in this elderly patient in terms of non-union. As he was non-compliant with the initial orthosis management, surgical fixation was chosen.
Intra-operatively patients were positioned prone with their heads held in a Mayfield clamp. Time was spent to achieve the optimum position, utilising pre-operative lateral imaging to confirm that C1-2 reduction was achieved and the screw trajectory was possible. Posterior downward pressure of the C2 spinous process was sometimes necessary to obtain reduction, and this was utilised during the fixation process.

C1 and C2 were exposed sub-periosteally. The C2-3 facet joint was delineated to plan screw placement. The wound was extended distally to about C6, but the spine not exposed, to allow the drill trajectory. A blunt hook was placed over the C2 lamina and run laterally to palpate the medial C2 pars. This was marked on the lamina with electrocautery. A burr was used to make the starting hole on the C2 facet, as simply using the drill tends to cause it to slip superiorly. The starting point is as inferior as possible, checked on lateral image. Violation of the C2/3 joint needs to be avoided and the trajectory extrapolated to engage the C1 lateral mass, exiting at the level of the anterior arch superiorly. An oscillating drill attachment was utilised when available. This reduced soft tissue injury caudally, and provided good tactile feedback of where the tip of the drill was, especially as the AA joint is crossed and exits C1 anteriorly. Good C1 engagement is confirmed when the C1 and C2 reciprocal oscillation changes to one of simultaneous movement. The drill was removed, bleeding or CSF leakage assessed and the screw inserted after proximal tapping. In three cases a C1-2 sublaminar wire or cable was added to increase stability. This was used when there was poor bony hold such as in rheumatoid cases, or high forces expected such as an associated stiff sub-axial spine (ankylosing spondylitis).

All patients went on to a successful posterior union

In two cases, the AASF was part of a C0-2 construct. One was a trauma patient with a Jefferson fracture and the other a severe rheumatoid with C0-1 involvement. In these cases, an occipital plate was placed and rods connected to the transarticular screws (Figure 3).

Posterior iliac crest bone was harvested in all cases. The C1-2 posterior elements were decorticated with a burr and graft placed.

Drains were not routinely used.

The average length of surgery was 101 minutes (50 - 150 ± 31.1 minutes). The average blood loss was 272 ml (range 25 - 800 ± 164.0 ml).

Fusion was assessed on both standard lateral X-rays and flexion/extension views. Fusion was accepted when radiographs revealed evidence of trabecular bone continuity between the posterior elements and the graft and absence of motion on dynamic views.

Results

AATF was completed in 19 of the 22 patients. In the other three patients the technique was aborted and another option utilised. In these patients, the required trajectory could not be achieved despite optimal positioning of the cervical spine. This was due to a thoracic kyphus/prominence reducing the ability to lower the drill adequately. This causes the drill trajectory to flatten, placing the vertebral artery at risk, as well as resulting in the drill exiting C2 too anteriorly and missing/minimising the purchase in the C1 lateral masses. A C1 lateral mass screw, C2 pars screw technique was utilised in two of these patients, and a wiring technique in the other.

Intra-operative complications

There were two CSF leaks. One was due to a C2 root sleeve dural tear while using diathermy in the area. This could have been prevented by the use of bipolar coagulation. It was easily controlled with collagen glue (Tissee). Another leak occurred during the drilling process, and was due to superior violation of the right C2 pars and a presumed C2 root dural violation. The drill hole was sealed with bone wax and redrilled. Successful C1 purchase was obtained and the screws placed. Neither patient suffered postoperative sequelae with regards to C2 root pain, or CSF-related problems.

There was one incident of vascular injury. In this rheumatoid patient, the left screw was successfully placed. However, on drilling the right, arterial bleeding was encountered. The trans-articular screw was placed with good purchase and resulted in cessation of bleeding. The patient suffered no clinical postoperative consequence. In retrospect, this case had erosion of the C2 lateral masses and was not appropriate for this technique (Figure 4).

Postoperative complications

There was no postoperative sepsis. There one case of instrumentation failure. At two weeks both screws were noted to be fractured. This was in a young trauma patient. He went on to a successful union in the Philadelphia collar.

One case of screw misplacement was noted on follow-up X-rays. This patient had a medial violation of the C1 lateral mass. This was due to failure to correct the C1-2 rotational malalignment before placing the screws. As one drills in the para-sagittal plane, if this rotation is not normal, violation is possible.

All patients went on to a successful posterior union (Figure 5). This was established radiographically by 3 months in nine patients, a further six by 6 months, and two by the 1-year follow-up. The remaining two defaulted after the 6-week check-up and fusion was not confirmed. As the only available point of care for these patients, they would have had to return to our clinic should there have been a complication, which they have not done.
There was no postoperative neurological deterioration or nerve injury.

**Discussion**

The atlanto-axial joint has a unique architecture that allows multidirectional mobility accounting for 50% of cervical rotation and 12% cervical flexion/extension movements. This significant mobility leads to a higher failure rate of arthrodesis than is seen in subaxial cervical spine.

The transarticular screw technique provides a rigid means of atlanto-axial fixation. Higher fusions rates when compared to posterior wiring techniques have been reported.\(^3\)\(^,\)\(^5\)\(^,\)\(^7\)\(^,\)\(^17\) This rigidity alleviates the need to use post-operative halo jackets as with the posterior wiring techniques. Most surgeons would use a simple collar post AASF, as in our series.

The major concern with this procedure is the risk of vertebral artery injury. Suchomel\(^17\) reports a 5% incidence per surgery (2.7% per screw). This is a similar incidence to ours. A pre-operative CT scan is recommended to assess the vertebral artery foramen as there is an 18%-23% incidence of an anomalous course precluding the passing of the screws.\(^3\)\(^,\)\(^4\)\(^,\)\(^7\)\(^,\)\(^18\) This has not been our practice due to logistic constraints. Although, accepting it best to assess this by pre-operative sagittal reconstructive CT,\(^4\)\(^,\) the author has found a true lateral plain film of C2 useful in assessing the C2 pars (Figure 6).
The exiting vertebral foramen is often visible, and an idea of the pars size established. In the only case in our series where a vertebral artery injury occurred, the pars was attenuated on lateral X-ray by rheumatoid erosion (Figure 4). In retrospect, the AAFS technique should not have been employed in this case. The author makes every effort to hug the medial pars cortex as the artery runs laterally and then turns 90 degrees and exits. The screw needs to pass medial to the ascending artery and over the exiting part. By medialising the screw path, the risk of injury is minimised. With the use of the oscillating attachment, a difference can be felt between cancellous pars and cortical breach. Venous bleeding may be a sign of foramen violation and increased risk of arterial injury. The trajectory needs to be above the foramen, and attention needs to be paid to dropping the drill hand as much as possible. This is often a problem, and the use of a small drill, often inverted, is necessary.

Near complete AA reduction is necessary. Should there be residual anterior subluxation of the atlas, the trajectory will flatten and place the artery at risk as the drill crosses the foramen. On the other hand, a residual listhesis of 2-3 mm may make the drill path easier, in terms of drill handle clearance and better C1 lateral mass purchase. This needs to be assessed intra-operatively on an individual case basis.

The atlanto-axial transarticular screw fixation is a safe technique

Other risks are neurological. Medial violation may result in spinal cord injury. This is unlikely as the medial pars can be delineated on palpation with a hook over the top of the C2 lamina. Care needs to be taken to maintain a directly anterior trajectory in the coronal plane to avoid medial violation at the atlas level. This occurred in one case in our series. This was due to failure to recognise incomplete atlanto-axial rotatory reduction. This may occur during setting of the Mayfield head clamp, and this should be actively established pre-operatively during positioning, confirming that the head is in a neutral rotation. The author finds the posterior aspect of the pinna a useful landmark. Intra-operatively, the posterior C1 tubercle should be in line with the C2 spinal process. If not, the clamp should be released and rotated. Due to the available space in the canal at this level, this is an unusual complication. Fuji reports a 95% accuracy with the cannulated technique, with no complications related to the 5% misplaced.19

The C2 root exits between C1 and C2. It is not usually identified during the exposure as the soft tissues are retracted in total laterally. However, the risk of injury should be recognised. Bipolar coagulation should be utilised in preference to diathermy once the spine is exposed. Use of diathermy to coagulate the C1-2 venous plexus resulted in a C2 dural sheath injury and leak. Despite this, the patient suffered no clinical consequence.

A lesser-known complication is that of the hypoglossal nerve, which is at risk if the screws are too long. The hypoglossal nerve runs anterior to the C1 arch, 2-3 mm lateral to the midline, and is at risk during the drilling process and with excessively long screws. The optimal screw length has been reported as 38 mm, although this depends on patient factors.39 The use of the oscillating attachment allows better control of drilling and provides feedback on exiting the C1 lateral mass. It should be remembered that due to the parasagittal nature of the drill position, when using lateral fluoroscopy, the tip will exit the lateral mass before appearing anterior to the C1 arch. This is due to the anatomy of C1.

Due to anatomical variations this technique is not always possible. A figure of 18-23% is quoted largely due to pre-operative anatomical assessment.45 In our series, the technique was aborted in three cases due to the inability to obtain the required trajectory for a safe C1 purchase. This was due to a thoracic kyphosis, usually in the elderly. This complication should be recognised and provision made for alternative techniques. C1-C2 lateral mass screw fixation was preferred by the author, but it is at increased cost of instrumentation. Two transarticular screws are inexpensive, but the lateral mass screw option can cost in the region of R8 500 for the instrumentation. Wire should be available as a bail-out option, although regarded as a poor one in terms of rigidity of fixation.

Conclusion
The atlanto-axial transarticular screw fixation is a technically challenging procedure and should only be done by spinal surgeons familiar with the local anatomy. Despite this, it is a safe technique, offering biomechanical rigidity, alleviating the need for highly restrictive and expensive orthoses. It also offers a predictably high fusion rate.

However, it must be remembered that the technique is not possible in all patients. Pre-operative CT scan is recommended for planning and a back-up option should be available intra-operatively.

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References


