Combined C1-C2 Transarticular with C1 Lateral Mass Screw Fixation for the Treatment of Atlantoaxial Instability: A Single Center Experience

Murtuza Sikander, Sean Martin, Bassam Dabbous, Stewart Griffiths, Sumit Karia, Erlick Pereira, Thomas Cadoux-Hudson

ABSTRACT

Aim: To study the outcome of a cohort of patients with atlantoaxial instability (AAI) treated with a combination of C1-C2 transarticular screws and C1 lateral mass fixation.

Background: Several surgical techniques have been described for stabilization of the atlantoaxial complex. Each technique differs in its biomechanical properties, advantages, and disadvantages. In this series, we describe our experience with a combined four-point fixation technique that combines C1-C2 transarticular screws with C1 lateral mass fixation for AAI.

Materials and methods: We present a single-center retrospective case series of 30 patients who were surgically treated for AAI over one decade. All patients presented with symptoms and signs of AAI and consequently underwent extensive clinical and radiological evaluation prior to surgery.

The median follow-up of our cohort was 8.3 months (3–143) with three patients lost to follow-up. Pre and postoperative symptoms were compared, including the visual analog scale (VAS) scores for neck and C2 radicular pain. All patients’ pre- and postoperative lateral dynamic cervical radiographs were evaluated and the posterior atlantodental interval (PADI) was measured. Ranawat functional disability score was used for pre and postoperative evaluation.

Results: Of the 30 patients, 8 were male and 22 female. The mean age was 60.4 years (18-78 years). The median hospital stay following surgery was 5 days (2–25 days). The mean preoperative VAS score for neck pain was 6.3 vs 4.3 at the first postoperative review (p≤0.001) on paired comparison. Ranawat scores were available for 26 out of 30 patients. The scores improved following surgery in 8/26 (30.7%) patients, did not change in 17 (65.4%) patients, and deteriorated in only one patient (3.8%). Like the VAS score, improvement in Ranawat scores were available for 26 out of 30 patients. The median hospital stay following surgery was 5 days (2–25 days).

Conclusion: The addition of C1 lateral mass screws to C1-C2 transarticular screw fixation for the treatment of AAI is an effective and safe procedure worthy of note. Our results and experience prove that this method is extremely beneficial where decompression of the posterior elements of C1 is required and may obviate the need of additional posterior wiring traditionally described. Further studies are necessary to look at the long-term fusion rates and compare them with other procedures.

Keywords: Atlantoaxial fixation, Atlantoaxial instability, Atlantoaxial joint, Neck pain.

INTRODUCTION

The surgical management of atlantoaxial instability (AAI) is challenging because of its anatomical complexity and potentially serious complications.1-10 The pathological cause of the AAI, the course of the vertebral artery, the internal height of the C2 vertebra, and the degree of C1 and C2 subluxation are all factors that need to be taken into consideration when planning stabilization of the C1-C2 complex.3,7,11-15

Several techniques have been developed for the surgical management of AAI, each with its own advantages and disadvantages. Over the years, it has become apparent that variations exist among surgeons in the definition of various anatomical structures and screw trajectories.5,6,11,13,14,16 Regardless of the nomenclature and definition, it is of paramount importance that the operating surgeon is aware of different options and screw trajectories to minimize the incidence of complications. Of the well described procedures of surgical management.
of AAI are Magerl’s C1-C2 transarticular\textsuperscript{1,8} screw fixation
technique and the Goel–Harms\textsuperscript{7} procedure. In our center,
we use a combined surgical technique for the treatment
of AAI that combines the mechanical advantage of both
the aforementioned procedures. The addition of C1 lateral
mass fixation via a vertical posterior connecting rod
combines the superior stabilization in axial neck rotation
provided by the transarticular screw with stabilization
in flexion and extension provided by the posterior rod
connecting the C1 lateral mass. This technique provides
a tension band in flexion, obviating the need for the
traditionally described C1-C2 wiring procedure with
posterior C1-C2 transarticular fixation. This proves even
more beneficial when decompression of the posterior
elements of C1 or C2 is indicated. In this case series, we
share our experience utilizing this fixation technique in
30 patients.

**MATERIALS AND METHODS**

All patients treated for AAI between 2004 and 2014
who have undergone this combined surgery were
identified. The patients’ records were reviewed and the
documented clinical and radiological data was evaluated
retrospectively in a comparative pre- \textit{vs} postoperative
manner. Clinical outcomes were graded using pre- and
postoperative pain visual analog scale (VAS scores for
neck and C2 distribution pain. In addition, Ranawat
classification of functional disability was recorded and
compared in the same manner.\textsuperscript{17} Radiologically, all
patients had pre- and postoperative cervical dynamic
radiographs (CDR) as well as computed tomography (CT)
and magnetic resonance imaging (MRI). The posterior
atlantodental interval (PADI) distances in neck flexion
and extension were recorded. Other key imaging features
assessed included the degree and reducibility of AAI,
C2 pedicle and pars dimensions to rule out high-riding
vertebral arteries and neural compression.

**Surgical Procedure**

Patients were positioned on the operating table (OT) in the
prone position with the head in a Mayfield head clamp.
The head is positioned flexed on the neck (military tuck
position) without traction to allow for translation and
reduction of the C1-C2 complex. After skin preparation
and draping, a midline incision is made from just below
the inion to C4. Exposure the occiput, C1 arch and the
C2-C3 facet joints bilaterally follow in the traditional
manner. The transarticular screw entry point was placed
3 mm superior and 3 mm lateral to the inferomedial
angle of the C2-C3 facet joint. The trajectory is aimed
toward the anterior arch of C1 aided with intraoperative
fluoroscopy (Figs 1A and B). In all our cases, 4 mm
diameter screws were used that were between 44 and
46 mm in length. For the C1 lateral mass screws, the entry
points were at the posterior aspect of the lateral mass just
below the posterior arch. The trajectory was directed
10 to 15° medially utilizing 3.5 mm diameter screws
(Figs 1C and D). Short titanium rods were placed between
the polyaxial screws posteriorly (Figs 2A to C). The C1
and C2 cortical surfaces in the vicinity of the screws were
decorticated bilaterally and bone graft was laid.

**Data Analysis**

Data were analyzed using a statistical analysis software
platform “R” (R-project.org). Results were expressed as
percentages (%), mean values with confidence intervals
(CI) at 0.95, or medians, as appropriate. Fisher’s exact test
or Wilcoxon’s signed rank test and paired t tests were
used to compare categorical and numerical variables.
All p-values <0.05 were considered to be statistically
significant.

**RESULTS**

Our cohort included a total of 30 patients who have
undergone this combined procedure between September
2004 and October 2014. There were 8 males and 22 female
patients with a mean age of 60.4 years (18–78 years).
The median hospital stay following surgery was 5 days (2–25 days). Within the cohort 28 patients (93.3%)
underwent surgery for instability causing neck pain. Ten
patients (33%) had paresthesiae of variable distribution;
6 patients (20%) had occipital neuralgia; 3 patients (10%)
had objective upper limb weakness preoperatively. Out
of the cohort of 30 patients with instability, there were
25 patients (83.3%) patients had rheumatoid arthritis (RA)
(one was associated with trauma); two patients had os
odontoidem; one patient had septic arthritis resulting in
instability; one patient had a nonunited type II odontoid
teg fracture; and one patient had severe spondylotic
myelopathy and AAI.

Postoperatively median clinical follow-up was
8.3 months (3–143 months). Three patients were lost to
follow-up. The VAS scores for neck pain were available for
20 out of 30 patients. The mean preoperative VAS score for
neck pain was 6.3 \textit{vs} 4.3 at the first postoperative review
which was statistically significant (p ≤ 0.001) on paired
comparison. The pre- and postoperative Ranawat scores
were available for 26 out of 30 patients. Ranawat scores
improved following surgery in 8/26 (30.7%) patients, did
not change in 17 (65.4%) patients, and worsened in only
one patient (3.8%). Like the VAS score, improvement in
Ranawat score following surgery was significant (p = 0.02)
in paired analysis. All patients’ postoperative imaging
confirming stability of the construct.
Complications in this series included two unilateral intraoperative vertebral artery injuries associated with placement of C1-C2 transarticular screws, another patient had worsening C2 pain following surgery, and three patients had numbness in the C2 distribution following the procedure. Radiologically, two patients had suboptimal unilateral C2 screw placement despite satisfactory intraoperative fluoroscopic imaging. In both

Figs 1A to D: Intraoperative fluoroscopy for placement of the C2 transarticular screws followed by the C1 lateral mass screw (A and B), trajectory of the drill from the entry point on C2 to the anterior arch of C1 (C and D); and this is followed by C1 lateral mass screw placement with an entry point under the posterior arch of C1

Figs 2A to C: A postoperative CT image showing the pre and postoperative lateral X-rays along with a CT image of screw trajectories
patients, the construct was stable in dynamic views as the proximal portion of the transarticular screw functioned as a C2 pars interarticularis screw. There were no postoperative infections found (Table 1).

**DISCUSSION**

The anatomy of the C1-C2 region is complex due to the surrounding neurovascular structures. Surgical intervention aimed at obtaining atlantoaxial stabilization can be challenging and thus created the need for the development of a wide variety of stabilization procedures over the years. The earlier posterior wiring/cabling techniques of Gallie, Brooks-Jenkins, and Sonntag, have given way to the introduction of more complex instrumentation techniques utilizing a variety of screws, plates, rods, and hooks for atlantoaxial fixation. The posterior approaches that eventually evolved include: Magerl and Jeanneret, modified Magerl and Jeanneret; Goel and Laheri, the Harms/Goel technique, C1-C2 transarticular screws, combined with C1 laminar hooks, and the Wright technique (C1 lateral mass to crossing C2 laminar screws). Anterior retropharyngeal transarticular screw fixation for C1-C2 stabilization has also been described in the literature.

Posterior atlantoaxial fusion with transarticular screw fixation has been considered the surgical “gold standard”. Though this technique offers maximal rotational stability, it has been shown to be less efficient in resisting flexion and extension forces unless combined with a posterior wire/graft technique. However, wiring techniques cannot be used if C1 arch decompression is needed or if the post elements of C1 and C2 are osteoporotic. On the contrary, the C1 lateral mass to C2 pars construct has been shown in cadaveric studies to have greater stability in flexion and extension compared to transarticular C1-C2 screws or C1 lateral mass to C2 pedicle construct. However, studies have also shown that it has the least rotational stability compared to the other two procedures.

In this series, we describe our experience with a procedure combining a C1-C2 transarticular screw fixation with a C1 lateral mass screw linked by connecting rods (Figs 2A to C and Figs 3A and B). This construct provides a four-point fixation. The transarticular screw effectively limits axial rotational movements, and the rest of the construct acts as a tension band offering additional stability to the joint in flexion, extension, and lateral bending movements. Our results and experience prove that this method is extremely beneficial where decompression of the posterior elements of C1 is required and may obviate the need of posterior wiring completely when performing a transarticular screw fixation. We have performed a C1 decompression in three patients in our series using this technique. Our institution has previously published a case of Maladie de Grisel successfully treated with this technique, which highlights the benefit of this procedure for C1 decompression.

We adopted this method as a modification of the “double insurance antlantoaxial fixation” first described by Goel et al. While Goel’s technique used a transarticular screw with a C1 lateral mass screw in conjunction with an intraarticular spacer and a compression plate, our modification utilizes polyaxial C1-2 transarticular and C1 lateral mass screws with a posterior rod construct only.

In our experience, addition of a C1 lateral mass screw does not compromise the biomechanics of the C1-C2 transarticular screw within the C1 lateral mass. It can be argued that the lateral mass of C1 may not be able to accommodate both the C1 lateral mass screw together with the transarticular screw, or that the trajectories may collide within the C1 lateral mass. Review of our postoperative imaging did not demonstrate any evidence of conflicting screw trajectories within the bony cortex (Figs 4A to D).

Our results in this series indicate definite reduction in the mean preoperative VAS score of neck pain from 6.3 to 4.3 at the first postoperative review which was statistically significant (p ≤ 0.001) on paired comparison.
Figs 3A and B: Three-dimensional CT reconstruction of the combined surgical construct postoperative CT 3D reconstruction of the construct combining C1-C2 transarticular screw with a C1 lateral mass screw

Figs 4A to D: A postoperative CT image showing optimal placement of the transarticular screw and the C1 lateral mass screw. The image shows bony purchase within the C1 lateral mass without conflicting screw trajectories
Ranawat scores improved following surgery in 8/26 (30.7%) patients, remained stable in 17 (65.4%) patients, and deteriorated in only one patient (3.8%).

All 30 patients in the series showed postoperative stability on the dynamic X-rays. There were no recorded implant failures. There was a subgroup of four patients that had unilateral C1-C2 transarticular fixation to C1-C2 lateral mass screw, or a standalone C1-C2 transarticular screw. This variation was resorted to intraoperatively in two patients who had vertebral artery injury and patients who did breach of the cortex during screw placement (two patients).

In this series two patients had vertebral artery injury making the rate of injury per cervical screw 2/120 (1.2%) and 2/56 (3.5%) for transarticular screws which is within the range of reported in the literature (0–10%) for transarticular fixation without computer assisted navigation.1,5,10

While this case series is a relatively small single center retrospective study, it nevertheless provides a surgical technique worthy of note. Long-term fusion rates are yet to be determined and we plan to study this as well as biomechanical attributes of this construct. In addition, we plan to use image-guidance technology for optimization of screw placement, reduction in the rate of vascular injury, operative time and radiation exposure.

CONCLUSION

The addition of C1 lateral mass screws to C1-C2 transarticular screw fixation for the treatment of AAI is an effective and safe procedure. Our results and experience prove that this method is extremely beneficial where decompression of the posterior elements of C1 is required, and may obviate the need for additional posterior wiring traditionally described with posterior transarticular screw fixation. Further studies are necessary to look at the long-term fusion rates, and compare them with other procedures.

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REFERENCES


