Posterior atlantoaxial facet screw fixation

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Eighteen patients with atlantoaxial instability were treated with posterior atlantoaxial facet screws to obtain immediate rigid fixation of C1-2. Of these 18 patients, instability occurred due to trauma in nine, rheumatoid arthritis in six, neoplasms in two, and odontoid in one. Four patients presented with nonunion after failed C1-2 wiring and graft procedures. In all cases in this series the screw fixations were augmented with an interspinous C1-2 strut graft which was wired in place to provide three-point stabilization and to facilitate bone fusion. In every case fixation was satisfactory, and C1-2 alignment and stability were restored without complications due to instrumentation. One patient died 3 months postoperatively from metastatic tumor; the spinal fixation was intact. All 17 surviving patients have developed osseous unions (mean follow-up period 12 months, range 6 to 16 months). Posterior atlantoaxial facet screw fixation provides immediate multidirectional rigid fixation of C1-2 that is mechanically superior to wiring or clamp fixation. This technique maximizes success without the need for a supplemental rigid external orthosis, and is particularly useful for pseudoarthrosis.

KEY WORDS • atlantoaxial instability • atlas • axis • cervical spine trauma • spinal fusion

ATLANTOAXIAL instability has traditionally been treated surgically using C1-2 posterior wiring and bone grafts. Initially, C1-2 screw fixation was advocated as a salvage procedure or as an alternative for patients who failed conventional therapy. In 1987, Magerl and Seemann developed an original technique for posterior screw fixation of the C1-2 facets. Until recently, we have treated atlantoaxial instability with operative stabilization using an interspinous bone strut and posterior wiring. A supplemental halo orthosis was applied to augment the internal fixation and to increase the likelihood of fusion. We now prefer C1-2 facet screws for atlantoaxial stabilization. Transarticular atlantoaxial facet screws provide immediate rigid multidirectional stability, which is superior to wiring, or the use of Halifax clamps. The immediate rigid internal construct allows avoidance of a supplemental halo brace.

This report describes our operative techniques for posterior atlantoaxial facet screw fixation. The surgical indications, relevant anatomy, biomechanics, and the results in 18 patients are reviewed.

Summary of Cases

Preoperative Evaluation

Patients with atlantoaxial instability who required internal fixation were considered for screw fixation unless there was pathology of the C1-2 facets or the course of the vertebral artery was anomalous. Three patients were excluded based on these criteria. The C1-2 wiring was recommended for all patients, and the techniques and operative risks were fully described. Patients were given the options of internal C1-2 screw fixation or of wearing a halo vest for 3 months after surgery to supplement their posterior wiring. All patients chose screw fixation.

Full preoperative imaging was performed in all cases to delineate the pathological process causing the C1-2 instability. Plain radiographs were used to assess the C1-2 alignment and determine if subluxations could be reduced. Computerized tomography (CT) scans (axial, sagittal, and coronal reconstructions) were used to delineate fractures and assess whether the bone architecture and course of the vertebral artery would permit screw placement.

Patient Population

During a 12-month period at our facility, 18 patients were treated with posterior atlantoaxial facet screw fixation. Atlantoaxial instability was due to odontoid fractures in six, rheumatoid arthritis in six, atlas fractures in one, transverse ligament disruption in two, os odontoideum in one, and neoplasms in two. There were six men and 12 women, with a mean age of 56 years (range 19 to 75 years). Four patients had nonunion after failed posterior C1-2 wiring procedures. Eight patients presented with myelopathy and 10 with neck pain or occipital radicular pain.
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Fig. 1. Illustrations showing how flexion facilitates drilling and screw placement. A: If the neck cannot be flexed, then percutaneous drilling is performed. B: When the neck can be flexed, drilling is performed directly through the incision used to expose C-1 and C-2.

Operative Technique

Intraoperatively, controlled flexion of the patient’s neck was required to obtain the proper trajectory for insertion of drills and screws. The patient was placed on the operating table in a prone position with the head affixed with a Mayfield skull clamp. Lateral fluoroscopic monitoring with a C-arm was used to avoid increasing the atlantoaxial dislocation during positioning and screw placement. A posterior cervical incision was made to gain access to the atlas and axis. The incision extended from the inion to the C-7 spinous process. Skin preparation extended to the upper thoracic levels in the event that a longer incision or percutaneous access was required for drilling (Fig. 1).

Subperiosteal dissection was performed to expose the C-1 and C-2 vertebrae. The C-2 pedicle and the C1-2 articular surfaces were exposed and directly visualized. The ligamentum flavum was removed adjacent to the C-2 laminae and pedicles. A thin Kirschner wire (K-wire) or nerve hook was placed directly along the surface of the C-2 pedicle into the atlantoaxial facet joint. The K-wire or nerve hook was retracted upward to displace the C-2 nerve root and venous plexus superiorly. Ligament removal and retraction of the C-2 nerve root provided direct visualization of the C-2 pedicle and the C1-2 facet joint during drilling (Fig. 2).

The atlas and axis were realigned by manual reduction. With anterior atlantoaxial subluxations, C-2 was gently displaced anteriorly and C-1 was pulled posteriorly. Opposite forces were applied for posterior subluxations. A wire or braided cable was placed around the ring of C-1 for traction and for subsequent fixation of an interspinous bone graft. Traction of C-2 was applied with an Allis clamp attached to the C-2 spinous process. The C-2 spinous process was pulled up toward the base of the occiput to obtain an improved trajectory for drilling.

The drill entered the posterior C-2 cortex 2 to 3 mm lateral to and 2 to 3 mm above the medial edge of the C2-3 facet (Fig. 2). The entry point was occasionally adjusted by 1 to 2 mm to compensate for altered anatomy of the vertebrae. First, the posterior cortical bone of C-2 was penetrated with a bone awl or high-speed drill to precisely direct the drill insertion for the pilot hole. With lateral fluoroscopic monitoring, the drill trajectory was aimed toward the dorsal cortex of the anterior arch of C-1 (Fig. 3). In the anteroposterior direction, the drill was placed through the central axis of the C-2 pedicle. A trajectory between 0° and 10° medially was required (Fig. 4). The pilot hole was prepared using a drill bit 2.5 mm in diameter or a calibrated guide pin 9 in. long and 2.4 mm in diameter.
that was threaded along the distal 1 cm of the shaft* (Fig. 5). The pilot hole was drilled with a pneumatic drill. The guide pin was used if percutaneous access was needed to obtain the proper drill trajectory.

Fully threaded steel cortical bone screws 3.5 mm in diameter were used in all cases. The mean length of the screws was 39 mm (range 35 to 45 mm); screw length varied depending upon differences in vertebral size and the distance that the screw-head countersank into C-2. The screw was inserted into the pilot hole with the aid of a variable-angled Allen screwdriver. Screw insertion required 10 to 30 minutes of operating time. As the screws crossed the joint space into C-1, the atlas and axis became rigidly coupled. Satisfactory fixation was achieved with a minimum number of operative steps by inserting the screw directly into the hole without tapping the hole. Drilling the pilot holes and inserting the screws were both monitored with fluoroscopy to direct the trajectory accurately. After screw placement,

* Calibrated guide pin supplied by Zimmer, Inc., Warsaw, Indiana.

a bicortical interspinous strut graft was precisely fitted and wired in position so that the graft was compressed between C-1 and C-2 (Fig. 6).

Operative Results

Bilateral transarticular screws were placed in 17 patients. One patient had a unilateral screw placed because of neoplastic destruction of the contralateral C-2 facet and C-1 lateral mass. Postoperatively, 16 patients were stabilized in a Philadelphia collar and one patient wore a sternal occipital mandibular immobilizer (SOMI) brace. The patient with a metastatic tumor whose atlantoaxial instability was treated with placement of a single screw wore a halo brace postoperatively.

There were no screw failures or screw placement complications, and no neurological or vascular complications. Early in our experience, two screws were positioned suboptimally. In one patient, the screw was too inferior in C-1. In another, one screw was positioned near the left vertebral foramen. However, no sequelae or loss of fixation occurred in either case. Three patients had complications unrelated to the screw fixation. In one an infection of a graft donor site occurred that resolved with local care and oral antibiotic therapy. Two patients had small intraoperative dural tears that were repaired primarily without complication.

One patient died 3 months postoperatively from metastatic disease; this patient had an intact atlantoaxial fixation. Long-term follow-up review was achieved in 17 patients, ranging from 6 to 16 months after surgery (average 12 months). All 17 patients developed osseous unions and no instances of delayed screw breakage or instability occurred. Postoperatively, six of the eight patients with myelopathy improved neurologically. Nine of the 10 patients with isolated neck pain or radiculopathy improved. In no patient were symptoms worsened by surgery.

Discussion

Posterior transarticular screw fixation was first reported by Magerl and Seemann. They described 23 patients treated with this procedure. Screws were placed successfully in all 23 cases without vascular or neurological complications, and there were no screw fractures or pseudoarthrosis. One patient developed a wound

Fig. 6. Illustration of the final construct. A bicortical strut graft is wired so that it is compressed between C-1 and C-2. The graft facilitates fusion and provides three-point fixation.

Fig. 4. Illustration showing the screws positioned through the central axis of the C-2 pedicle. The angle varies between 0° and 10° medially and depends on the position of the screw entry site relative to the pedicle.

Fig. 5. Upper: Photograph of a calibrated guide pin, 3\(\frac{3}{8}\) in. (2.4 mm) in diameter. The 9-in. long pin was used for drilling the pilot hole percutaneously. Lower: A fully threaded cortical bone screw, 3.5 mm in diameter, and a 2.5-mm diameter drill bit. The diameter of the drill bit corresponds to the inner or core diameter of the screw (that is, the diameter of the shaft beneath the threads).
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infection that required screw removal. In another pa-
tient the screws were malpositioned; these were re-
moved and replaced.

Meticulous preoperative planning and precise op-
erative techniques are required for success with this
 technique. Plain radiography and CT are necessary
for preoperative evaluation. Plain radiographs are used
to assess the alignment of C1–2 and to verify that the
C1–2 complex can be reduced adequately. Axial CT
views display the architecture of the C-1 lateral mass
and C-2 facets. Minor displacements of the lateral
masses of C-1 must be identified so that the screw tra-
jectory can be altered accordingly. Comminuted fractures
or tumors destroying the C-1 lateral mass preclude
screw placement. The C1–2 alignment must be restored
to obtain the proper screw trajectory and to gain ade-
quate bone purchase in C-1.

Intraoperatively, the C-2 pedicle and the C1–2 facet
must be visualized directly in order to obtain the precise
screw trajectory. Identification of these structures pre-
vents inadvertent perforation through the C-2 pedicle
and allows medial-lateral adjustment of the drill tra-
jectory.

Depending upon the ability to flex the patient’s neck,
we developed several strategies to facilitate the proce-
dure. Flexion of the neck provides an unobstructed drill
trajectory through the incision. Manual reduction and
direct upward traction on C-2 with an Allis clamp can
also facilitate drilling. When the patient’s neck cannot
be flexed and direct drilling cannot be performed, per-
cutaneous drilling is performed. The end-threaded
guide pin provides an excellent tool to drill the pilot
hole percutaneously. The smooth shaft of the guide pin
does not become tangled in the paraspinal soft tissues;
therefore, a drill guide is not required. The calibrations
on the pin allow direct measurement of the screw
length. The diameter of the guide pin must match the
inner diameter of the bone screw.

Screw fixation techniques have been developed for
segmental vertebral fixation, for odontoid fracture fixa-
tion, and to secure plates that immobilize adjacent
motion segments.1,4,6,9,10 A thorough knowledge of the
principles of screw fixation and experience with the
proper operative techniques are prerequisites for satis-
factory screw placement.1 Lag screws, cannulated screw
systems, and self-tapping or non-self-tapping screws
can be used, depending on the surgeon’s preference. Lag
screws compress the facet joints together to help facil-
itate arthrodesis. Lag fixation can be achieved with a
proximal gliding hole drilled in the proximal bone of
C-2. A partially threaded screw can also be used as a
lag screw if the screw threads only gain a purchase on
the bone of C-1. Cannulated screws use a thin K-wire
to direct the screw trajectory into the bone. These have
the advantage of preserving the bone architecture if the
screw tract needs to be repositioned. Self-tapping screws
have wide threads that cut directly into the bone.
Non-self-tapping screws have narrower, duller threads,
and should have the thread profile cut into the bone
adjacent to the pilot hole with a tap.

Biomechanically, C1–2 facet screw fixation is signif-
ificantly more rigid than wiring techniques or Halifax
clamps for atlantoaxial fixation.3,5,8,11 Immediate mul-
tidirectional atlantoaxial stability is achieved after the
screws have been properly placed. The construct resists
translation and rotation.

Posterior atlantoaxial facet screws can be combined
with metal plates for fusion of the occiput or adjacent
cervical levels. Grob, et al.,4 used posterior transart-
icular screws to secure a Y-shaped plate for occipitocer-
vical fusion in 14 patients. One transarticular screw
pulled out when the patient’s head was forcibly ex-
tended during an emergency intubation; otherwise,
C1–2 facet screw fixation was satisfactory, uncompli-
cated, and without morbidity.

The C1–2 facet screw fixation procedure is supple-
mented with an interspinous wiring and fusion unless
the posterior arches of C-1 or C-2 are fractured or
incompetent.7 Adjunctive bone grafts promote fusion
and provide three-point fixation. This three-point fixa-
tion of C1–2 provides greater mechanical stability than
either technique used alone.3,5,11 The bone graft, which
is compressed between the posterior arches of C-1 and
C-2, facilitates the formation of a solid fusion. These
screw and wiring techniques are complementary.

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