An Alternate Method for Placement of C-1 Screws

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ABSTRACT

OBJECT: Several techniques for the surgical stabilization of the atlas and the axis have been described. Placement of C-1 lateral mass screws is one of the latest technical advances, and has gained popularity due to its efficacy and biomechanical advantages. However, the technique for placement of C-1 lateral mass screws, as first described by Harms, can cause excessive bleeding or irritation of the C-2 nerve. An alternative technique is available for the placement of C-1 lateral mass screws that completely avoids the C-2 nerve/ganglion and its associated venous plexus. This new technique mitigates some of the risk associated with the Harms techniques and eliminates the need to use specialized screws (that is, smooth shanks).

METHODS: Twenty-six patients underwent atlantoaxial or occipitocervical fusions incorporating the alternative technique of C-1 screw placement. Three surgeons at 3 different institutions performed the surgeries. Standard lateral fluoroscopy and fully threaded polyaxial screws were used in each case.

RESULTS: Forty-nine screws were placed in C-1 lateral masses by using the new technique. Solid arthrodesis was achieved in all cases, with a mean follow-up period of 30 months. There were no cases of CSF leakage, new neurological deficit, injury to the C-2 ganglion, vertebral artery injury, or hardware failures.

CONCLUSIONS: The technique is a safe and effective way to fixate C-1 while avoiding the C-2 nerve/ganglion and venous plexus. The results indicate that excellent clinical and radiographic outcomes can be achieved with this new technique. (DOI: 10.3171/2009.10.SPINE08541)

KEY WORDS: C-1 screw, Lateral mass, Atlantoaxial subluxation, Pedicle screw

Several techniques have been described for instrumentation and stabilization of C1–2 in cases of atlantoaxial instability. Early posterior wiring methods, such as those described by Brooks and Gallie, are used less frequently today because of poor resistance to rotational forces and high rates of nonunion without the supplemental use of long-term rigid halo immobilization (6,14,16). Transarticular screws, first described by Magerl, offer superb biomechanical stability without the need for halo immobilization (3,12). Their placement, however, is technically challenging and is frequently prohibited by variations in the course of the VA, by the need for preoperative reduction of the C1–2 complex, and by severe kyphotic deformities and obesity in patients, which limit proper trajectory to the C1–2 facet complex (3,6). Indeed, almost 20% of patients will not be candidates for placement of transarticular screws because of aberrant VA anatomy (1,16,17).
Recently, the direct placement of screws into the C-1 lateral mass and the C-2 pars has provided a safe and facile method of atlantoaxial fixation (5,6,15). First described by Goel and Laheri, (5) who applied plate and screws after bilateral sacrifice of the C-2 ganglia, it was later modified and popularized by Harms and Melcher, (6) who used specialized polyaxial screws to preserve the C-2 ganglia. These techniques allow for greater ease of screw placement, the ability to reduce C1–2 intraoperatively, and they significantly reduce the risk of VA injury in comparison with transarticular screws.5,6 Also, several recent studies demonstrate that these C-1 lateral mass/C-2 pars fixation techniques are superior to transarticular screw fixation in their biomechanical stability during flexion and extension (8–10,13).

Several limitations of the Harms technique for C-1 lateral mass/C-2 pars fusion have been described. First, C-2 nerve root away from the rich venous plexus found on the underside of the posterior arch of the atlas (1,5). Also, irritation of the C-2 nerve root by screws in the C-1 lateral mass has been described.1 This irritation was mitigated in Harms and Melcher’s description with the use of special smooth-shanked screws in the C-1 lateral mass; the ganglion was sectioned to avoid irritation in other descriptions.

Several anatomical studies have raised the possibility of placing C-1 lateral mass screws through the “pedicle analog” of the posterior arch (1,11,15,17). Resnick and Benzel first demonstrated the clinical utility of this technique, albeit with the assistance of stereotactic guidance. This technique, as described in these reports, avoids the need for exposure of the C1–2 joint, thereby avoiding the vascular plexus on the underside of the posterior arch of C-1. Also, injury and irritation of the C-2 nerve root are avoided.

In this report, a series of 26 patients who underwent cervical or occipitocervical fusions with this new C-1 “pedicle” screw technique is presented. It is the largest series to date of patients undergoing this technique, and illustrates its safety and efficacy.

**METHODS**

Twenty-six patients underwent cervical or occipitocervical fusion, incorporating C-1 into the construct. Surgeries were performed at 3 different institutions by 3 primary surgeons (R.G.F., T.T., and F.A.S.) between July 2002 and September 2007. The mean age of the patients was 66.2 years (range 20–88 years), and there were 16 women and 10 men. The mean follow-up duration was 30.4 months (range 2–52 months). More of the patients’ demographic details are listed in Table 1.

After induction of general anesthesia, Mayfield head holders were applied and patients were placed prone with the neck slightly flexed. The position of the C1–2 complex was confirmed with fluoroscopy. A standard midline incision was made from just below the inion to approximately C-4. The cervical spine was exposed subperiosteally from the suboccipital region to approximately C-3, or lower if required. The lateral border of the C1–2 facet was exposed carefully to avoid disturbance of the C-2 ganglion and the associated venous plexus. Dissection proceeded caudally over the C-2 pars interarticularis. The medial and lateral borders of this landmark were clearly delineated.

After exposure of the posterior elements of the atlas and axis, the VA was dissected away from the superior surface of the arch of C-1 by using the subperiosteal technique. While protecting the VA with a No. 1 Penfield dissector, a starting point was marked on the C-1 arch with a high-speed bur at a point that is generally in line with the center of the C-2 lateral mass. A blunt nerve hook was used to palpate the medial border of the C-1 lateral mass to ensure a good starting point for the screw. The drill was directed vertically in line with the C-1 arch and medially 10°; power was used to ensure ease of penetration into the hard cortical bone in the C-1 lateral mass (Figure 1). The pilot hole was palpated, tapped, and a fully threaded 3.5-mm polyaxial screw was then inserted. Screws were placed with unicortical purchase, but length was maximized. The C-2 pars screws were placed in a manner similar to that described by Harms and Melcher.6 The trajectory of both C-1 and C-2 screws was confirmed with fluoroscopy. Contoured rods were then fixed to the screws bilaterally.

Bone grafts were obtained from the iliac crest or ribs except in cases of tumor, in which allograft and demineralized bone putty were used. In cases of C1–2 fusions done to treat atlantoaxial subluxation, bone grafts were placed between the arch of C-1 and the spinous process of C-2, and were secured by compressing the C1–2 rod construct (Table 1).
RESULTS

Forty-nine C-1 lateral mass screws were placed successfully via the posterior arch in 26 patients. The most common presenting diagnoses were atlantoaxial subluxation from rheumatoid arthritis and fracture (an equal number of each). The C-1 lateral mass screws were used in multilevel constructs in 10 patients; 6 of these patients had fusion constructs originating at the occiput. In 3 patients, only one C-1 lateral mass screw could be placed, for the following reasons. In one of these patients, an abnormally small pedicle analog prohibited placement. In the second patient, the contralateral C-1 lateral mass was involved by tumor. A single screw was placed in the third patient to treat a unilateral C-1 lateral mass fracture that failed to heal with bracing and caused severe neck pain. The average screw length inserted was 22 mm (range 18–28 mm); the diameter of all screws was 3.5 mm.

There were no dural lacerations, and there were no injuries to either the VA or the C-2 ganglion. There were no cases of neurological deterioration immediately after the procedure or at last follow-up evaluation. Finally, there were no hardware failures. At last follow-up, all patients demonstrated satisfactory evidence of radiographic fusion (see case example in Figure 2). Image guidance was not used in any case.

Table 1: Demographic data, presenting complaints, and surgeries performed in 26 patients who underwent fusions incorporating C-1 lateral mass screws*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Presenting Complaint</th>
<th>Op Performed</th>
<th>No. of C-1 Screws Placed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69, F</td>
<td>spondylosis, instability</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>71, M</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>64, M</td>
<td>spondylosis, deformity</td>
<td>C1–3 fusion</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>52, F</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>55, F</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>49, F</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>78, F</td>
<td>C-2 fracture</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>67, F</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>49, F</td>
<td>basilar impression</td>
<td>O–C2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>77, F</td>
<td>basilar impression</td>
<td>O–T1 fusion</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>80, F</td>
<td>C-2 fracture</td>
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<td>2</td>
</tr>
<tr>
<td>12</td>
<td>76, F</td>
<td>spondylosis, instability</td>
<td>C1–2 fusion</td>
<td>1†</td>
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<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>64, F</td>
<td>spondylosis, deformity</td>
<td>C1–3 fusion</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>51, M</td>
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<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>60, M</td>
<td>C-2 fracture</td>
<td>C1–2 fusion</td>
<td>2</td>
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<tr>
<td>17</td>
<td>20, F</td>
<td>C-2 fracture</td>
<td>C1–2 fusion</td>
<td>2</td>
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<tr>
<td>18</td>
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<tr>
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</tr>
<tr>
<td>21</td>
<td>52, F</td>
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<td>O–C6 fusion</td>
<td>2</td>
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<tr>
<td>22</td>
<td>81, M</td>
<td>C-1 lat mass fracture</td>
<td>C-1 ORIF</td>
<td>1‡</td>
</tr>
<tr>
<td>23</td>
<td>79, M</td>
<td>metastatic tumor, instability</td>
<td>O–C3 fusion</td>
<td>1§</td>
</tr>
<tr>
<td>24</td>
<td>58, M</td>
<td>AAS, RA</td>
<td>C1–2 fusion</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>72, F</td>
<td>C2–3 fracture, subluxation</td>
<td>C1–4 fusion</td>
<td>2</td>
</tr>
<tr>
<td>26</td>
<td>77, F</td>
<td>RA w/ large C-2 pannus</td>
<td>O–C3 fusion</td>
<td>2</td>
</tr>
</tbody>
</table>

* There were no complications. Abbreviations: AAS = atlantoaxial subluxation; ORIF = open reduction internal fixation; RA = rheumatoid arthritis.
† Anatomical abnormalities of one C-1 pedicle analog necessitated sublaminar wiring on one side of the fusion construct in this patient.
‡ A single lag screw was placed in this patient for direct reduction of a unilateral C-1 lateral mass fracture.
§ Only 1 screw could be placed in this patient because of tumor involvement of the contralateral C-1 and C-2 lateral mass.
DISCUSSION

The technique of C-1 lateral mass/C-2 pars fusion as described by Harms and Melcher6 has become a widely used technique for atlantoaxial fixation. Cervical fusion performed using this technique obviates the need for the postoperative immobilization that was required with previous posterior wiring techniques, and mitigates the technical challenges and risks of transarticular C1–2 screws without compromising stability or rate of fusion.

Several limitations of the Harms technique have been described that are primarily attributable to exposure of the C-1 lateral mass for screw placement. The technique of C-1 screw placement via the posterior arch, first described by Resnick and Benzel,15 avoids hazards of exposure of the C-1 lateral mass and therefore may be a more facile method of C1–2 fixation.

Placement of C-1 screws via the posterior arch necessitates only a superficial exposure of the posterior aspect of C-1, and therefore avoids more extensive exposure of the C1–2 facet joint and the overlying C-2 ganglion. This not only decreases the risk of injury to the nerve root, but also significantly reduces the risk of bleeding potentially encountered during mobilization of the C-2 ganglion and exposure of the posterior-inferior portion of the lateral mass of C-1. Much of this bleeding can be avoided by using meticulous subperiosteal technique during dissection of the ganglion. Proper subperiosteal dissection is important to both techniques; it minimizes bleeding from the rich venous plexus that surrounds the C-2 ganglia and allows for safe mobilization and protection of the VA. The risk of injury to the VA during exposure of the lateral aspect of the C1–2 facet is avoided as well in this technique.

In all patients, the VA was successfully mobilized and retracted away from the arch of C-1 with minimal difficulty or risk to the patient. This strategy of direct visualization and protection of the artery is the best way to prevent its injury. One can, however, imagine the potential for injury to the VA during screw placement, for the vessel courses medially in its groove on the rostral surface of the posterior arch. The maximum diameter of the C-1 screws used in this study was 3.5 mm. Ebraheim et al.4 found that the thickness of the posterior arch at the thinnest part of the VA groove in males was 4.1 ± 1.2 mm. Ma et al.11 found that the diameter of the posterior arch under the VA groove was < 4 mm in 12% of the C-1 specimens they analyzed. Although the majority of C-1 pedicles will allow for safe placement of 3.5-mm-diameter screws, the anatomy of some patients will not. We recommend checking a preoperative CT scan in all patients to ensure that the C-1 pedicle is of adequate diameter to accommodate screw insertion. This should help prevent iatrogenic fracture of the C-1 ring or delayed injuries to

Figure 2: Lateral pre- (A) and 1-year postoperative (B) cervical spine x-rays obtained in a patient who underwent C1–4 fusion for a traumatic C2–3 subluxation secondary to C-2 fracture. The C-1 screws were placed via the posterior arch and were used to help reduce the C2–3 subluxation intraoperatively.
the VA. In addition, the ideal screw entry point should be at the lateral aspect of the arch because it, based on Ma's analysis, is an average of 0.37 mm larger in a rostrocaudal direction. This entry point can be conveniently estimated using the midline of the C-2 lateral mass, which is on average 1.51 mm lateral to the midpoint of the C-1 pedicle, and therefore in line with the more robust lateral one-third portion of the pedicle (11). An approximately 10° medial angulation of the screw helps avoid injury to the VA in the C-1 transverse foramen laterally (11,15).

To avoid irritation of the C-2 ganglion and the greater occipital nerve, Harms and Melcher described leaving an 8-mm smooth-shank portion of the C-1 screw exposed so that the polyaxial head is flush with the posterior arch. In an elegant cadaver study of 120 C-1 vertebrae, Christensen et al.1 found the average lateral mass anteroposterior dimension inferior to the posterior ring insertion (that is, the screw trajectory length at the point of placement of the C-1 screw when using the Harms technique) to be 16.9 mm. In comparison, the longest trajectories measured in the analyses by Tan et al.17 and Ma et al.11 (that is, with screw placement via the posterior arch of C-1) were 30.7 and 28.55 mm, respectively. Placement of the C-1 screw via the posterior arch versus only the lateral mass increases the potential length of threaded screw in contact with bone by > 10 mm. Although this is a seemingly small amount, it is not insignificant in comparison with the 8-mm length of Harms-type screws that are not in contact with any bone at all. This increased screw-tobone interface probably increases the resistance to pullout of the C-1 screw and reduces screw toggle, thereby strengthening the entire fusion construct.

All C-1 screws placed in this study were placed unicortically. The additional purchase achieved by placing longer screws via the posterior arch argues against the need for bicortical placement. This also avoids potential complications associated with damage to structures anterior to the C-1 arch, such as injury to the internal carotid artery or hypoglossal nerve, which have been described in cases in which the Harms technique was used (2,7).

Finally, Resnick and Benzel,15 in their initial description of this technique, used stereotactic guidance to plan the trajectory and to execute the placement of the screws. This report illustrates that this technique can be safely used with conventional fluoroscopy, without the need for intraoperative stereotactic guidance.

CONCLUSIONS

This series of patients who underwent cervical or occipitocervical fusion by placement of C-1 screws directly through the posterior arch demonstrates that this technique is a safe and effective method for C-1 fixation. Placement of the C-1 screw via the posterior arch avoids exposure of the C-1 lateral mass and the overlying C-2 ganglion and venous plexus. In addition, the increased screw/bone interface gained by placing a longer screw through the arch may increase the strength of the fusion construct. This technique can be safely performed using conventional fluoroscopy without the need for stereotactic guidance. This technique is a facile alternative to other more technically demanding methods of atlantoaxial fusion.

DISCLOSURE

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

REFERENCES


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