Original Article

Posterior Cervical Lateral Mass Screw Fixation
Analysis of 1026 Consecutive Screws in 143 Patients

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Objective: This study evaluates the results and complications of 1026 consecutive lateral mass screws inserted in 143 patients by a single surgeon.

Methods: Over a 50-month period, a total of 1026 lateral mass screws were placed in 143 patients ages 12–96 years (56 females and 87 males), with these records retrospectively reviewed. Screw position was evaluated by computed tomography (CT) scanning postoperatively, with screw positions assessed for facet, foraminal, or foramen transversarium violation.

Results: All screws were placed by a modification of the Anderson technique, but 20 screws were converted to Roy-Camille trajectories because of screw pullout. No patients experienced neural injury or vertebral artery injury as a result of screw placement. Three patients had screw pullouts using the Axis system, which did not require reoperation. Most patients had 14-mm screws placed. Postoperative CT scanning showed no compromise of the foramen transversarium or neural foramen. A total of 94 C7 lateral mass screws were placed without the need for pedicle screws at this level. Forty-four cases were performed with a screw/plate construct with the remainder performed using a polyaxial screw/rod construct. One patient had a symptomatic adjacent-level disc herniation that required surgical intervention. One patient required extension of laminectomy for residual compression.

Conclusions: Lateral mass screw fixation is a safe and effective stabilization technique. This study demonstrates the safety and efficacy of lateral mass cannulation for a range of cervical pathologies with the largest reported series of consecutive lateral mass screws in the literature. In most cases of subaxial disease, nonconstrained plate/screw systems provide a reasonable alternative to polyaxial screw/rod constructs. Most patients can be fixed with 14-mm length × 3.5-mm diameter screws. The C7 lateral mass can be drilled with an adjusted trajectory.

Key Words: cervical, lateral mass, surgery, vertebral artery, screw

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METHODS AND MATERIALS

Over a 50-month period, a total of 1026 lateral mass screws were placed in a subaxial position (C3–C7) in 143 consecutive patients by a single surgeon. The demographics of these patients were analyzed through retrospective chart review.

Surgical Technique

The surgery was performed in a consistent fashion. Intubation was performed for cases with severe stenosis or gross instability in an awake fiberoptic fashion. The patient was positioned prone using three-pin skull fixation on a radiolucent spinal operating table. Almost all cases were performed...
with digital fluoroscopic guidance. Exposure of the lateral masses was effected in a subperiosteal fashion to the lateral margins of the facet joints. The motion segments to be fused had their facet joints decorticated. Great care was taken to protect the facet joints above and below the instrumented levels. The lateral masses were drilled and tapped prior to any decompression, if required. Screw length was decided predominantly through assessment of preoperative imaging; however, if bicortical fixation was specifically desired, the floor of the hole was palpated with the drill advanced at 2-mm intervals until anterior cortical breach occurred. Placement of instrumentation was performed after any decompression. A modified trajectory was taken for screw placement from standard trajectories. The entry point was 1 mm medial to the midpoint of the facet joint. The screws were angulated 20–25° laterally and superiorly to try to attain the best purchase of the lateral mass with minimal risk of neural or vascular injury (Fig. 1), which is a modification of the Anderson technique. At C7, lateral mass cannulation was effected through the use of a steeper trajectory to allow for the shallowness of the lateral mass, as shown in Fig. 1B (arrow). In most cases, morcellized local autograft bone from the posterior elements was placed over the decorticated lateral masses and into the appropriate facet joints prior to screw placement. The patients were monitored overnight in a high dependency unit and postoperatively were placed into an Aspen collar (Aspen Medical Products, Long Beach, CA).

**Screw Position Assessment**

For assessment of screw position, a thin-slice reconstructed CT scan was performed 24 hours postoperatively to confirm adequate screw placement. All lateral mass screws were evaluated for encroachment into the foramen transversarium (graded as either 0, 0–1, or >1 mm) or into the neural foramen. Any intraoperative or postoperative clinical evidence of nerve root or vertebral artery injury was also evaluated by further imaging to elucidate precise etiology. Evaluation was performed by the author, but any radiologic reports that suggested foramen transversarium or neural foramen violation were not ignored and were consistent with the author’s scoring.

Postoperatively patients were evaluated clinically and radiologically at 6 weeks, 3 months, 6 months, 12 months, and yearly thereafter. All myelopathic patients underwent postoperative MR scanning. No living patients were lost to follow-up. Follow-ups ranged from 3 months to 4 years. Emphasis for our study remained on the initial postoperative imaging as the objective of this study rather than fusion status over time.

Results are expressed as means ± SD.

**RESULTS**

The demographics of the 1026 screws per 143 patients are shown in Table 1. The majority of patients were male, with an average age of 50–60 years, although patients up to 95 years were operated upon. Co-morbidities were relatively infrequently present. Only 6% of patients were workers compensation patients and only 15% smokers. Preoperative bone density studies were not found to be overly useful in planning surgical intervention and not routinely employed.

The 143 cases studied covered a wide range of pathologies. The indications included trauma (35 cases), degenerative disease (92 cases), iatrogenic instability (4 cases), rheumatoid arthritis (3 cases), malignant spinal tumor (6 cases), and benign spinal tumor (2 cases) (Fig. 2). Instrumentation was performed in cases where instability was present or where wide decompression would lead to instability. A variety of different implants were used including Axis (Medtronic Sofamor-Danek, Memphis, TN) and Cervifix plates and screws (Synthes Spine, Paoli, PA) and Vertex (Medtronic Sofamor-Danek), Summit (Depuy Spine, Raynham, MA),

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**FIGURE 1.** Anteroposterior (A) and lateral (B) postoperative C-spine radiographs of a typical patient who underwent C3–C6 lateral mass fixation, the most common construct used for spondyloptic myelopathy. The position of the screws is well demonstrated; in the lateral radiograph, the steeper trajectory required to cannulate the relatively shallow C7 lateral mass is arrowed.
Oasys (Stryker Spine, Cestas, France), and Starlock (Synthes Spine) polyaxial screw/rod constructs. This spread of implants is shown in Figure 3. The majority of initial experience was with plate/screw constructs prior to the introduction of polyaxial screw/rod constructs (30.8% of all cases). The polyaxial screw/rod constructs all performed equally well in the subaxial region. The majority of constructs were stand-alone subaxial constructs, although lateral mass fixation was also incorporated as part of an occipitocervical or cervicothoracic construct or as additional supplemental fixation for an anterior construct (Figure 4).

All lateral masses between C3 and C7 were fixated. As is reflected by the proportion of cases associated with degenerative disease, 502 screws were placed into either C5 or C6 (see Figure 6). A mean of 205.2 ± 64.9 screws were placed at each level with, on average, 7 screws placed per level. Intraoperatively, of the 1026 lateral mass screws placed, there was no observation of vertebral artery injury. C7 was able to be adequately drilled with a steeper trajectory (see Figure 1) in 94 instances with only four C7 pedicle screws placed. If poor screw purchase was achieved with breakout from the lateral mass initially, conversion to a modified Roy-Camille16 technique was effected. This was performed in 1.9% of all screws. Only eight 4-mm rescue screws were required. As a result, stripping of the screw thread was not as big an issue as lateral breakout of the lateral mass cortex.

There was no clinical evidence of vertebral artery injury. One patient experienced a persistent C5 nerve root lesion with a satisfactory postoperative CT scan showing no violation by screws of the C4–C5 neural foramen. The cause of this deficit was thought to be secondary to an overaggressive foraminotomy. The operative incidence of neurologic injury of any cause was 0.7%, but it must be emphasized that there were no screw-related neurologic injuries. There was one deep infection in an 84-year-old man undergoing an occipitocervical fusion that required debridement and regrafting, but no removal of hardware was required. Three patients experienced screw pullouts. All cases were elderly with advanced facet joint disease where cannulation of the lateral masses was technically difficult partially because of the size of the lateral masses. All were with screw/plate constructs with pullout of cranial C3 or C4 screws noted at 6 weeks. Kyphosis occurred in two patients, but no further surgery was required. A typical patient with construct failure is shown in Figure 7. No screw pullouts occurred with polyaxial screw/rod constructs. There was one plate breakage in a 26-year-old man undergoing occipitocervical fusion for an os odontoideum that occurred 2 years after surgery. This occurred with the Cervifix (Synthes Spine) occipitocervical plate, with breakage at the point of change of rod curvature between the occiput and C1. The hardware was removed without incident, and the patient did well. Of the four deaths, two were associated with malignancy and occurred some time after surgery. One patient with bilateral subaxial facet subluxations experienced a posttraumatic vertebral artery dissection and subsequent posterior fossa stroke. Despite simultaneous posterior fossa decompression and subaxial reduction and stabilization, the patient died. Finally, one patient had a massive pulmonary embolus 3 days postoperatively and eventually died. There was one clinically significant postoperative wound hematoma in a 76-year-old woman with severe myelopathy who underwent a C2–C5 laminectomy and fusion. This was evacuated 5 days postoperatively, manifest by worsening myelopathy. After evacuation, her clinical condition continued to improve. The overall complication rate was <3%.

The results of the postoperative CT scan evaluation of screw position are shown in Table 2. Significantly, 92.4% of screws were bicorticate, although in 88% of cases, 14-mm screws were used, based on an estimate from the preoperative axial CT or MR scan (Figure 8). Eight screws, typically at the C7
level, had violated the inferior facet joint. Twenty screws (1.9%) breached the foramen transversarium by 0–1 mm. No screw violated the foramen transversarium by >1 mm. No case entered the neural foramen or canal.

Only one patient to date has developed symptomatic adjacent-segment degeneration. In that case, a 36-year-old man underwent a C3–C6 laminectomy and fusion and 13 months later presented with an acute C7 radiculopathy secondary to an acute foraminal disc protrusion that responded well to a posterior keyhole foraminotomy. Sixteen months later, he has not developed any C6–C7 instability and remains well. One patient with severe stenosis required a delayed extension of his laminectomy by one level because of posterior drift of the spinal cord, which led to compression at a caudal spinal level that was not compressing the spinal cord prior to the initial surgery. This was uneventfully performed.

**DISCUSSION**

This report shows that after placement of 1026 lateral mass screws in 143 patients of various ages and undergoing surgery for various pathologies, no screw-related injuries to the vertebral artery or nerve roots occurred. This is the largest reported series of consecutive lateral mass screws to date.

Extensive work has been done both clinically and in the laboratory on lateral mass fixation. The various trajectories have been assessed in terms of their likelihood to cause neurovascular injury. Ebraheim et al have looked specifically at this in the cadaver and shown the foramen transversarium lies in line with the midpoint of the lateral mass. As a result, a laterally directed screw will likely miss the vertebral artery. Further work by Xu et al suggested that the potential risk of nerve root violation is higher with the Magerl and Anderson techniques than with the An technique. Heller
et al. predicted a maximum 3.6% incidence of nerve root injury using the Roy-Camille and Magerl trajectories, well above that found in this series, presumably because of the screw length used and more lateral trajectories.

Pait et al. divided the lateral masses into quadrants with the upper outer quadrant being the eventual target for screw placement with the lowest risk of vertebral artery or nerve root injury. In terms of screw trajectory, Roy-Camille et al. advocated that the starting point be located in the midpoint of the lateral mass and the drill be oriented perpendicular to the posterior aspect of the cervical spine and 10° lateral. Magerl recommended starting the drill hole 2–3 mm medial and superior to the midpoint of the lateral mass and angling 30° upward and 25° outward. Anderson proposed that the starting point for screw insertion be 1 mm medial to the midpoint of the lateral mass and that the screw be angled 30–40° cranial and 10° lateral. Finally, An et al. suggested angling 15–18° superiorly and 30–33° laterally, with a starting point 1 mm medial to the center of the lateral mass. In this series, we found that by using Anderson’s starting point and then angling 25° laterally rather than 15°, this was an easily remembered, taught, and reproducible angle and reduced the risk of vertebral artery injury as well as captured the upper and outer quadrant as described by Pait et al.

Most of the screws placed in this series were 14-mm screws. An et al. have suggested a screw length of 11 mm is safe. Roy-Camille et al. recommended 14–17 mm. The average vertical distance between the posterior midpoint of the lateral mass and the vertebral foramen from C3 to C6 has been found to be approximately 9–12 mm. Consequently, 14 mm obliquely should adequately span the lateral mass. Of note in our study was that 90% of screws were bicorticate in nature when 14-mm screws were placed. This knowledge considerably quickened the duration of procedures as incremental drilling was not routinely performed. It was evident on the postoperative CT scans that 14-mm-length screws did not pass the posterior lip of the foramen transversarium, lowering the risk of vascular injury. Heller et al. performed cadaveric studies looking at screw pullout and found that bicorticate fixation with large-diameter non-self-tapping screws had the greatest resistance to pullout. Coupled with this, Seybold et al. have suggested that 14-mm screws are equal to bicorticate screws in terms of pullout strength when tested in cadaveric spines, a finding that would be in agreement with our technique. It seems in most cases that 14-mm screws achieve bicorticate fixation and using non-self-tapping screws improves screw pullout.

The low failure rate of the lateral mass screws with low complication rate suggests more dangerous techniques such as cervical pedicle screws are for the most part not required to attain adequate fixation. Of note in this series is that in most cases, the C7 lateral mass could be drilled with a steeper trajectory with no need for a C7 pedicle screw.

The screw pullouts occurred only in patients who underwent screw/plate constructs as opposed to the newer polyaxial screw/rod construct. The former constructs are

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**TABLE 2. Screw Position on CT (n = 1026)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicorticate purchase</td>
<td>948</td>
<td>92.4</td>
</tr>
<tr>
<td>Violation of facet joint</td>
<td>8</td>
<td>0.8</td>
</tr>
<tr>
<td>0- to 1-mm foramen transversarium breach</td>
<td>20</td>
<td>1.9</td>
</tr>
<tr>
<td>&gt;1-mm foramen transversarium breach</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Intervertebral foramen entry</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Canal violation</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
screw systems. An option to prevent this may have been to take the construct up to C2 at the time of initial surgery, but this would sacrifice another motion segment.

CONCLUSION

Lateral mass fixation is a safe and reliable method of posterior stabilization suitable for a wide range of pathologies. In most cases, 14 × 3.5–mm screws can be used. The risk of vertebral artery or nerve root injury should approach zero.


