Inside-outside technique for posterior occipitocervical spine instrumentation and stabilization: preliminary results

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Object. The authors present a series of 16 patients who underwent inside-outside occipital and posterior cervical spine stabilization.

Methods. In this technique, the screw was placed from the inside of the occiput to the outside. An articular (lateral) mass plate was contoured to the shape of the occipital bone and the cervical spine and affixed to the occiput with a flat-headed screw or stud placed through a burr hole in the calvaria with the flat head of the screw in the epidural space and the threads facing outward. The bone plate was then secured with a nut to the occipital screw and the cervical plate was attached to the spine with a bone screw that coursed through the plate and into the articular pillar. Our series included six children and 10 adults. In five patients, previous fusion had failed; in two patients spinal instability was secondary to Down's syndrome; two patients' instability was related to developmental anomalies; and in five patients spinal instability was due to the presence of tumor. One patient with rheumatoid arthritis had undergone a transoral procedure. Two patients had suffered traumatic fracture. Three patients died of causes unrelated to the procedure, one patient died of metastatic cancer, and one patient died in a long term care facility of cardiopulmonary complications. One patient with renal failure suffered a hemorrhage from an arteriovenous fistula after being treated with dialysis. In one child, a nut backed off after 3 months. The nut was reseated, and a maturing arthrodesis was present.

Conclusions. The authors conclude that the inside-outside occipitocervical fixation is an effective technique for stabilizing the cervical spine.

Key Words: wire fixation · occiput · cervical spine · posterior spinal instrumentation · screw fixation · inside-outside technique · screw

Occipitocervical fixation procedures have always presented a challenge to the neurosurgeon because the anatomical complexity in this area requires a thorough understanding of the important bony and soft-tissue elements. Any type of instrumentation must accommodate the anatomical structures and satisfy the biomechanical needs and the kinematics of the craniovertebral junction. To meet such demands, occipitocervical stabilization techniques have undergone continuous refinement. Early techniques in which only bone grafts were used demonstrated a high rate of failure. Wire-securing techniques, which secure the bone struts with suboccipital and sublaminar wires, became popular because of their ease of use and low cost. These procedures are a better alternative to the bone graft methods; however, failure rates still range between 5% and 30%. Wire-securing procedures often failed to provide the rigid fixation needed to promote long-term arthrosis, and advancements in metallic fixtures (cables, pins, rods, screws, and plates) have since provided a more successful, rigid craniovertebral system. However, these screws must be placed from the outside to the inside of the occiput, and the surgeon must be careful to avoid intradural penetration of the screws. To help prevent screw penetration, we have developed a technique of placing the screw from the inside of the occiput to the outside.

Clinical Material and Methods

For this technique, an articular mass (lateral mass) plate is contoured to fit the shape of the occipital bone and the cervical spine, and the plate is affixed to the occiput by means of a flat-headed screw or stud placed through a burr hole in the calvaria so that the head of the screw is in the epidural space and the threads face outward. The bone plate is then secured with a nut to the occipital screw. The cervical plate is attached to the spine with a bone screw that courses through the plate and into the articular pillar (lateral mass). Such stabilization provides immediate rigid fixation for bone fusion.

All 16 patients (10 adults, six children) underwent post-
gel cushions under the chest, the head was fixed in the Mayfield headrest, and alignment of the cervical spine was monitored by fluoroscopy. If we anticipated having to use transarticular screw fixation, the cervical spine was exposed via a standard midline incision. The skin incision extended from two fin-

TABLE 1

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Prefixation History</th>
<th>Follow Up (mos)</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>F</td>
<td>osteoblastoma in skull base &amp; C1-3; pro: pos excision &amp; stabilization preoperative technique via ant approach</td>
<td>18</td>
<td>returned to school &amp; active lifestyle</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>F</td>
<td>dev defects, suboccipital craniectomy, failed fusion</td>
<td>14</td>
<td>returned to school; solid fusion after resecting loosened nut; active lifestyle stabilized; no further episodes of quadriparesis</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>M</td>
<td>Down's syndrome; repeated episodes of transient quadriparesis</td>
<td>11</td>
<td>stabilization achieved; no further episodes of quadriparesis</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>M</td>
<td>gait disturbance; chordoma in CVJ; pro: transcondylar resection &amp; halo brace</td>
<td>6</td>
<td>completed proton beam therapy; returned to school</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>M</td>
<td>upper thoracic pain, Chiari malformation, large syrinx w/ other dev anomalies; pos fossa exploration, dural closure w/ graft, IO fixation, &amp; transoral approach to resect basilar invagination</td>
<td>4</td>
<td>treated in rehab; home, anticipating return to school</td>
</tr>
<tr>
<td>6</td>
<td>18</td>
<td>F</td>
<td>Down's syndrome; 1st pro: transcondylar odontoidectomy, continued instability; 2nd pro: OC onlay bone fusion w/ wire fixation, still unstable</td>
<td>18</td>
<td>completed school &amp; entered workforce</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>F</td>
<td>severe neck pain, breast cancer metastasis at C-2 w/ ant comp; pro: ant C-2 corpectomy</td>
<td>1</td>
<td>died of primary disease</td>
</tr>
<tr>
<td>8</td>
<td>57</td>
<td>F</td>
<td>diffuse ossification of PLL, myelopathy; unable to walk; 1st pro: multilevel decompression w/ arthrodesis &amp; ant plate, halo placed; pseudarthrosis &amp; plate migration; myelopathy worse, CT shows continued compression; 2nd pro: ant plate &amp; strut graft removed; 3rd pro: pos cervical laminectomies &amp; IO fixation</td>
<td>14</td>
<td>gait improved; walking independently &amp; resumed activities at home</td>
</tr>
<tr>
<td>9</td>
<td>36</td>
<td>F</td>
<td>severe incomplete SCI from OA dislocation, slight movement in rt arm</td>
<td>3</td>
<td>died of cardiopulmonary complications in long-term care facility</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>F</td>
<td>rheumatoid arthritis; progressive weakness due to ant compressive lesion at C1-2; pro: transoral approach for decompression</td>
<td>10</td>
<td>improved</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>M</td>
<td>renal failure on dialysis, diabetes, cervical spondylosis; 1st pro: multi ant &amp; pos cervical pros for spondolysis; fall w/ type II odontoid fracture; 2nd pro: pos atlantoaxial stabilization w/ Brooks pro, failed fusion w/ continued instability</td>
<td>1</td>
<td>died of rare aneurysmal hemorrhage at arteriovenous dialysis shunt site</td>
</tr>
<tr>
<td>12</td>
<td>81</td>
<td>F</td>
<td>obese, multitrauma w/ pulmonary complications, type II odontoid fracture &amp; multi cervical spine fractures</td>
<td>4</td>
<td>undergoing rehab</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
<td>F</td>
<td>chordoma in skull base; extended transmaxillary resection, halo brace</td>
<td>4</td>
<td>transferred to long-term care facility</td>
</tr>
<tr>
<td>14</td>
<td>73</td>
<td>M</td>
<td>multi myeloma involving C-2, severe pain, prior radio- &amp; chemotherapy</td>
<td>4</td>
<td>pain decreased; undergoing oncological therapy</td>
</tr>
<tr>
<td>15</td>
<td>58</td>
<td>F</td>
<td>type II odontoid fracture; pro: Sonnag pos atlantoaxial wire &amp; bone graft (transarticular C1-2 fixation not possible due to VA locations), followed by hard cervical collar &amp; rehab, failed fusion</td>
<td>3</td>
<td>pain decreased; at home, resumed daily activities</td>
</tr>
<tr>
<td>16</td>
<td>51</td>
<td>M</td>
<td>odontoid, failed fusion after OC fusion w/ Luque rectangle; C1–2 fixation not possible due to distorted anatomy</td>
<td>2</td>
<td>pain decreased; wearing collar, anticipating return to work</td>
</tr>
</tbody>
</table>

Operative Anteroposterior and Lateral Radiography with Dynamic Studies to Evaluate for any Motion Segment Abnormalities and for Screw Fixation and Cervical Spine Alignment. Over a period of 18 months, (July 1996 through December 1997), all patients underwent inside-outside occipitocervical fusion. Data on patient history and treatment are shown in Table 1.

Surgical Technique

For this procedure, the patient was placed prone with gel cushions under the chest, the head was fixed in the Mayfield headrest, and alignment of the cervical spine was monitored by fluoroscopy. If we anticipated having to use transarticular screw fixation, the cervical spine was flexed under an image intensifier to provide the best angle for the drill to enter. The back the patient's head and neck were shaved and prepared, and the posterior occipitocervical spine was exposed via a standard midline incision.

The median skin incision extended from two fingers' breadth above the external occipital protuberance to the level of fusion. The nuchal ligament was divided in the midline, and the occipital and cervical muscles were stripped from their bony attachments through subperiosteal dissection. The suboccipital and cervical paraspinal muscles were retracted laterally to expose the underlying bony architecture. Gentle operative technique was used so as not to disturb important anatomical structures or move unstable bone. The posterior tubercle of the atlas was palpated, its midline defined, and the muscles attached to it were gently swept laterally.

The dissection was continued laterally, maintaining bone contact to prevent injury to the horizontal segment of the vertebral artery that is cushioned in the suboccipital cavernous sinus. Any bleeding from the suboccipital cavernous sinus was stopped with Gelfoam and thrombin. The atlantocervical membranes, ligamentum flavum, and vertebral arches were exposed with curettes and dissectors. The articular masses (lateral cervical masses) of the lower cervical vertebrae were cleaned of soft tissue in preparation for screw fixation. If transarticular screws were to be placed or C-2 pars interarticularis fixation was to be performed, the pars, ganglion, and nerve of C-2 were defined.
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After the occiput and cervical spine were exposed, the operative field was prepared for instrumentation. We describe the surgical procedures in 10 steps.

Step 1: Marking the Occiput and Cervical Spine With a Template

A malleable template is placed over the occiput and cervical spine and contoured to the correct shape (Fig. 1A). The sites of cervical screw fixation determine the entry and exit points of the inside–outside occipital screw. The reconstruction template is positioned over the articular (lateral cervical) masses; the holes of the template must be positioned to allow the proper angle for the drill to enter. Transarticular C1–2 or C-2 pars fixation sites are the first to be determined; the C-2 screw site is not as adjustable as the occipital and articular (lateral cervical) masses. After the C-2 site has been determined, the template is adjusted over the articular (lateral cervical) masses to allow the screw to enter the superior lateral quadrant (the safe quadrant). With the template in position, the hole over the occiput, which corresponds to the correct cervical position, is marked with a colored pen. This hole will be the exit site of the inside–outside screw (Fig. 1A). The entry site is marked above the exit site either laterally or medially.

Step 2: Creating the Entry Site

With a craniotome, a burr hole is made at the marked entry site. This point can also be made with a surgical drill (Fig. 1B). Bone dust from the drilling is saved to be used

G: The rib grafts are secured to the plate with wire fixation. H: Intraoperative photograph demonstrating the inside–outside screw and spine screws after tightening and the rib grafts after being secured with sutures.
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Step 3: Establishing the Keyway

The keyway, which is cut with either rongeurs or a surgical drill with a fraise (footplate), extends to the marked exit site. The entry and exit sites are enlarged to allow safe and easy passage of the inside-outside screw (Fig. 1B).

Step 4: Positioning the Inside-Outside Screw With the Guide Rod

The inside-outside screw is attached to the guide rod (Dyna-Lok T-bolt and Nut; Sofamor Danek, Memphis, TN) and then carefully placed epidurally into the entry site and guided to the exit site (Fig. 1C).

Step 5: Checking the Template

The template is placed over the inside-outside screw and the contour of the plate is checked. The template is again aligned to allow for correct cervical screw fixation.

Step 6: Placing the Reconstruction Plate

The reconstruction plate (Axis System; Sofamor Danek, Memphis, TN; and AO/Synthes Posterior Cervical Plating System; Synthes Spine, Paoli, PA) is bent to match the template. The surgeon must be careful not to twist the plate while bending it. If the plate is twisted, it may not rest flatly on the bony surfaces, and the holes for the penetrating screws may be misaligned; in addition, the fit of the implant and bone interfaces may also be affected. Part of the lamina of C-2 may need to be drilled down to allow better surface-to-surface contact between the plate and bone.

Step 7: Anchoring the Articular Mass Screw and Establishing Transarticular or C-2 Pars Interarticularis Fixation

The transarticular or C-2 pars interarticularis fixation is the first site of the cervical spine to be anchored to the reconstruction plate. The bony morphology of the atlas and axis are carefully studied on computerized tomography scans. Subluxations of C1–2 are reduced to allow correct alignment. The vertebral artery is studied on either standard angiograms or magnetic resonance angiograms obtained in patients with tumors.

The neurovascular elements coursing over the pars of C-2 are defined a second time. Using a bone awl, a purchase site is placed approximately 2 to 3 mm lateral to the medial border of the C-2 pars. The trajectory of the drill is checked fluoroscopically, and the drill is directed toward the dorsal cortex of the anterior arch of C-1. The screw length needed is determined from the drill and checked after the drill is tapped. The cervical spine screws are placed into the superior lateral quadrant of the articular (lateral) masses.

Step 8: Preparing the Cross Link (Optional)

In one patient, we used a cross-linked plate to achieve greater stabilization of an occipitotlantal dislocation. To develop a linking unit, a small inside-outside screw (stud) is placed under and through the axial reconstruction plate. This placement allows another plate to be secured to the primary plate.

Step 9: Attaching the Reconstruction Plate to the Inside-Outside Screw and Inserting the Cervical Spine Screws or Sublaminar Cables

The reconstruction plate is placed over the inside-outside screw and a nut is then placed and tightened slightly with a socket wrench, although the nut is not secured firmly at this stage in the procedure (Fig. 1D). The plate is then positioned over the entry site of the C-2 screw, and the transarticular screw is directed into the prepared bone. Advancement of the screw is closely monitored on continuous fluoroscopy. Like the nut on the inside-outside screw, this screw is not completely tightened. The next screw is placed in the most caudal site and is the last screw of the construct. The remaining fixation points are then secured (Fig. 1E).

The inside-outside screw is firmly tightened, and any

FIG. 2. Left: Preoperative sagittal computerized tomography scan obtained in a 9-year-old girl with osteoblastoma (asterisk). Right: Postoperative sagittal computerized tomography scan obtained after tumor resection. Note the position of the construct (solid arrows), and bone graft (open arrows).
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sublaminar cables or wires are secured to the plate. A screwdriver is inserted through the socket wrench into the hex in the inside-outside screw to provide countertoque (Fig. 1F).

Step 10: Finishing the Arthrodesis

The arthrodesis is completed with a rib or bone taken from the iliac crest. The occiput and cervical spine surfaces are decorticated, and the rib is secured to the plate with sutures or wire for good surface-to-surface contact (Fig. 1G and 1H). The keyway is then filled with bone. The operative field is amply irrigated, and the incision is closed in layers. Antibiotics are administered throughout the surgical procedure.

Results

Six children and 10 adults (aged 4-81 years) underwent inside-outside occipitocervical fixation and fusion. The follow-up period ranged from 1 to 18 months. We used the Axis system for plate fixation in all adult patients, but because it is too wide to be used in children, the narrower AO system, which better matches the smaller articular masses, was used in the six children.

In patients with tumors, we could not perform atlantoaxial fixation because the lesions had destroyed bone. Patients with developmental anomalies could not undergo screw fixation because the bone had matured poorly.

One child who was placed in a halo brace postoperatively was the only patient to have one nut loosen from the inside-outside screw (after 3 months). This nut had been placed without the use of countertoque. During a second surgery in which the nut was reseated without difficulty, the bone fusion was noted to be maturing. The patient was then placed in a firm collar and has since returned to normal levels of activity. All other children were placed in firm collars and showed no radiological evidence of instrument movement or failure. A 9-year-old girl who underwent anterior resection of an osteoblastoma has returned to school (Fig. 2). A 12-year-old boy has completed a course of proton radiation therapy for a chordoma (Fig. 3). A 14-year-old boy with a Chiari malformation underwent transoral resection of the odontoid. The other two children also improved and are living actively. An 18-year-old woman with Down’s syndrome was initially placed in a firm collar. Because of her vigorous head movements, however, her chin became chafed and the skin around the incision abraded. She was placed in a halo for approximately 6 weeks. At follow-up examination, solid fusion mass was confirmed without evidence of a pseudarthrosis. She finished school and is now employed.

One woman with ossification of the posterior longitudinal ligament no longer requires a wheelchair and is walking without assistance. A patient who sustained an occipitoatlantal dislocation died of cardiopulmonary complications after being transferred to a long-term care facility. One patient died of cancer that metastasized to the spine. A third patient with renal disease died of a hemorrhage after undergoing dialysis for a rare aneurysm in an arteriovenous fistula in his arm. An 81-year-old woman, a multiple trauma victim with an odontoid fracture, was transferred to a rehabilitation center. One 22-year-old woman with an aggressive chordoma developed bacterial meningitis after her first surgery; when she was medically stable, she underwent occipitocervical fixation and was transferred to a long-term support facility. A man with multiple myeloma is undergoing further treatment for his disease, but he can hold his head erect without pain. A 58-year-old woman, who suffered multiple injuries from an automobile accident, returned home and resumed daily activities; she can walk with assistance. A 51-year-old man in whom a C1–2 fusion failed was discharged home wearing a collar; his pain has improved, he is becoming more active, and he anticipates returning to work.

The inside-outside instrument was the only type of occipital fixation needed. No other types of adjuvant fixation such as wire or other screws were utilized. Because we recognized the thinness of the occipital bone prior to treatment in the children, there was never need to abandon the operation. In such a situation, the inside-outside screw diameter was increased to accommodate the thickness of the bone. In addition, there were no fractures of the occipital bone during screw tightening. We found no evidence
of screw migration through the keyhole. The dura in the elderly patients also did not cause any problem. We had no dural tears or cerebrospinal fluid leaks.

Discussion

Occipitocervical instability may be caused by tumor, inflammation, trauma (bone or ligamentous injury), congenital anomalies, and degenerative lesions.1,2,7,10,13,14,16,19,21,22,24,26,30,38,40,43-48,50,53,54 Because radiological methods of diagnosis have improved, these abnormalities have been identified earlier. Increasing appreciation of the anatomical defects and better ways to determine spinal stability or instability prompted the refinement of surgical techniques used to cure these lesions.1,3,5,11,13,14,16,19,21,22,24,26,30,32,33,39,40,48,50,53,54

Internal fixation and fusion procedures for the treatment of occipitocervical instability have undergone numerous changes.1,3,5,11,13,14,16,19,21,22,24,26,30,32,33,39,40,48,50,53,54 Improvements in metallurgy and a better understanding of biomechanics have helped surgeons to improve occipitocervical stabilization techniques.12,30,38

In any occipitocervical fixation procedure, the surgeon must address the complex bony anatomy of the region, namely the occiput, the occipital condyles, C-1, and C-2. The occiput does not easily accommodate instrumentation. In fact, the area available for the fixation of implants is limited. Bone thickness is also of concern when any internal fixation is needed. Traditional “outside-inside” screws can be anchored laterally into only a shallow shelf of bone or into the thicker midline keel. When such screws are used, the thickness of the occiput must be measured to assess the anticipated screw length and prevent injury to the underlying cerebellum.29 In this type of fixation the surgeon relies on radiological images to confirm that the screws did not inadvertently penetrate the brain. In a series in which occipitocervical fusion was performed using internal fixation, Heywood and colleagues32 did not encounter cerebral complications, but they avoided penetration of the inner table.

The Geschwind and method of occipitocervical fixation involves placing a wide-headed, flat screw from the outside to the inside of the occiput. A wire is then placed around the necks of both screws, passed under the arch of C-1, and secured around a spinous process.33 As with the standard outside-inside technique, the strength of the construct greatly depends on the bone purchase achieved with the occipital screws. A similar pullout problem is encountered when wire is used for fixation or for attaching posterior instrumentation. wire or cables may easily pull out through the occipital bone. Because of the thin bone in children, this problem becomes particularly worrisome.

The inside–outside method for the provision of occipitocervical fixation offers several advantages over the outside–inside techniques. Screws are not placed in a blinded fashion. The surgeon sees the entire screw; in fact, the screw points toward the surgeon. The flat surface of the screw head, not the threads, is next to the dura. Furthermore, the surgeon need not be concerned about the thickness of the occiput when determining screw length. The inside–outside screw avoids the hazards of the cutting effect of wire or cable. If articular mass (lateral mass) screw fixation cannot be performed in the spine, sublaminar wires can be attached to the reconstruction plate.

Conclusions

We have used the inside–outside technique for the treatment of occipitocervical instability in 16 patients. The instrumentation has remained well seated in all but one patient. One patient, whose fixation device demonstrated loosening of the nut, was the only patient placed in a halo brace immediately after surgery. Any stabilization technique should be simple and safe. The instrumentation should be designed to prevent injury to nearby structures while providing maximum stabilization and promoting solid maturation of the arthrodesis. Inside–outside occipitocervical fixation fulfills these demands.

Acknowledgments

The authors thank Julie Yamamoto for her editorial assistance and excellent suggestions. We are indebted to Kim Vognet, R.N., for gathering patient data and records. We are grateful to Jamie Tillman, Graphic Artist, for the artistic illustrations, and to Ron Tribell, Chief Medical Illustrator, for his invaluable assistance in preparing figures for this paper. We are also grateful for the typing talents of Betty Patterson and Amy Keeland in preparing this manuscript.

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Manuscript received February 3, 1998.
Accepted in final form July 17, 1998.
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