Instrumentation for Occipitocervical Fusion

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The indications and techniques for the fusion of the occiput to the subaxial spine have evolved significantly over the last decade for stabilization of atlanto-occipital and atlanto-axial instability patterns of various etiologies. Although trauma and rheumatoid arthritis are the most common causes of atlanto-axial instability, many other metabolic and systemic disorders may contribute to instability patterns of the upper cervical spine. Congenital, infectious (tuberculosis and pyogenic), metabolic and neoplastic related diagnoses have also been known to cause significant upper cervical spine instability that may require an occipitocervical fusion.

Cervical spine pathology secondary to rheumatoid arthritis has been well documented in the literature. Instability related to this disorder, ie, basilar invagination and excessive motion at the C1-C2 articulation, is often progressive and may result in significant pain and potential loss of neurological function if not treated appropriately. General indications for surgical decompression and stabilization in these patients include a progressive neurological deficit, progressive instability, myelopathy, and intractable pain.

Congenital disorders and syndromes that may or will lead to atlanto-axial instability have been well identified. These include the skeletal dysplasias such as Morquio and Marfan's syndrome, characterized by extreme ligamentous laxity, Down's syndrome as well as some patients with Klippel-Feil anomalies who may present with agenesis or hypoplasia of the dens. Other congenital conditions associated with upper cervical instability patterns include the presence of an Os Odontoidium as well as occipitalization of the atlas. Basilar impression secondary to metabolic diseases such as osteomalacia, rickets, renal osteodystrophy, osteogenesis imperfecta and Paget's disease also may lead to instability patterns of the upper cervical region requiring stabilization. Osteoporosis is also a common cause of atlantoaxial instability leading to degenerative arthritis of the atlantoaxial joint.

Unlike the lower cervical, thoracic and lumbar spine, the upper cervical spine does not have intervertebral discs between its bony components. The atlanto-occipital and atlantoaxial joints rely on cartilaginous articulations rather than intervertebral discs for the transmission of fluid motion. The occipitoatlantoaxial joints are usually considered as one movement complex.

Fifty percent to 60% of axial rotation occurs at the occipitoatlantal complex, whereas the remaining rotation is divided by the subaxial or lower cervical region. The majority of isolated rotation occurs at the C1-C2 articulation. The atlanto-occipital portion contributes only approximately 5 to 8° of upper cervical axial rotation.

Unlike axial rotation, flexion and extension is distributed equally between the atlanto-occipital and the atlantoaxial segments of the upper cervical spine. Studies have determined that lateral bending at the atlantoaxial joint may range anywhere from 0° to 12°.

The type of reconstruction chosen to stabilize the occipital cervical junction is dependent on the concomitant need for a decompression of the neural elements, the presence or absence of posterior bony elements, availability of grafting substance as well as the degree of instability.

There are five general techniques described for performing a posterior occipitocervical fusion: (1) in situ onlay bone grafting, (2) wire or cable fixation of bone graft to the occiput and upper cervical spine, (3) methylnmethacrylate alone or with internal fixation, (4) rod and wire or rod and screw fixation, and (5) plate and screw fixation.

The first occipitocervical fusion was performed by Forster in 1927. In 1933 Kahn and Yglesias first used onlay iliac crest bone graft between the occiput and upper cervical spine for failed conservative treatment of a dens fracture. Libscomb reported, in
1957, nine cases of occipital-cervical arthrodesis with a 33% non-union rate.14 Ten years later, Hamblen reported successful fusion in all 15 of his cases of occipitocervical fusion. Clinically, eight patients did well, four improved, and one deteriorated.9

The earliest and most basic technique in fusing the occiput to the upper cervical spine consisted of simple in situ onlay application of cancellous bone graft.31 The basic tenets of this procedure included a complete exposure of the desired posterior elements to be fused, ie, occipital skull, lamina, and lateral masses of the upper cervical spine, followed by a thorough decortication before placement of autogenous bone graft. Postoperatively, patients often needed to be placed in long skeletal traction for 4 to 6 weeks or some type of external fixation device, usually a halo vest or minerva jacket, for 3 to 6 months.1 Newman and Sweetman, in 1969, reported successful fusion with this technique in eight of nine patients.6 Postoperatively, 22 of their patients were placed in a halo, 5 in a Minerva cast, and 1 in long traction.3

The choice of an in situ fusion is not as common today as it was in the past primarily due to the morbidity related to postoperative immobilization. Prolonged periods of traction and halo vest immobilization along with high rates of pseudoarthrosis have led to the investigation of various internal fixation techniques for stabilizing this complex junction.15 This is especially important in the elderly frail patient population, especially with rheumatoid disease, in which recumbency may be detrimental to their recovery.3,5

In 1969, Grantham and Dick modified existing wiring techniques used to fixate bone to the occiput by preparing a trough on either side of the occipital protuberance in preparation for wire passage. After connecting both troughs with a drill hole, wires were passed through one or multiple holes serving as an anchorage point for bone graft attachment to the occiput without violating the intracranial space with internal fixation. Additional wires were then placed in the upper cervical spine for graft attachment in this region. The investigators reported successful fusion in eight of their nine patients. The one failed arthrodesis in their study was in a patient in which banked allograph bone was used.16

At present, there are two popular methods for wire fixation to the occiput. One involves drilling holes through both cortices of the calvarium, and the other consists of burring a unicortical trough on either side of the occipital protuberance for wire passage as described by Grantham and Dick. The latter method only penetrates the outer cortex and thus decreases the risk of injury to the epidural veins and dura.13 Grantham's technique was further modified by Wertheim and Bohlman and is at present the most popular wiring technique used today (Fig 1).16-18 This technique involves the burring of a trough in the occiput commencing at a point 2 cm above the foramen magnum on either side of the occipital protuberance. A towel clip is used to connect the trough for passage of 20 gauge wires, avoiding intracranial penetration. A second 20-gauge wire is looped around the arch of the atlas in the manner described by Gallie.19 A third wire is passed through the spinous process (base) of the axis. The wires are then passed through two corticocancellous struts (one on each side of the spine) and secured over the decorticated posterior elements of the occiput and upper cervical spine. This technique offers many advantages over the application of bone graft without internal fixation. Immediate stability is attained, early mobilization is permitted avoiding prolonged recumbency and its associated morbidity, and the procedure is easily modified to specific deformities and various anatomic variations. Wertheim and Bohlman noted a solid arthrodesis in all 13 of their patients. The postoperative immobilization period was reduced compared with previous cases of fusion with onlay bone graft alone. Patients were either placed in a rigid two-poster orthosis or halo for 6 to 16 weeks followed by placement in a soft collar.18 In 1991 McAfee reported an 85% fusion rate in 37 patients treated with the triple-wire technique. These patients were treated postoperatively in a halo for 3 weeks, in which recumbency may be detrimental to their recovery.5

Figure 1. A diagram of the triple wire occipitocervical fusion technique described by Wertheim and Bohlman.
months and a two-poster orthosis for 1 month after halo removal.3

Methylenmethacrylate has been used alone and as an adjunct to various methods of internal fixation. Using methylenmethacrylate and mesh, Bryan and Inglis noted solid fusion in all 11 of their patients. Although methylenmethacrylate may allow the surgeon to obtain immediate fixation, frequent reports of wound draining, infection, and dehiscence as well as delayed loss of fixation with cement and wire breakage have been reported.2 Zygmunt reported a wound infection rate of 15% and a wire breakage rate of 13% of his cases using methylenmethacrylate.

In 1978 Luque introduced the use of a contoured steel rod attached to the upper cervical spine and occiput by wires as an alternative to wiring fixation alone.30 Ransford and Crockard in 1986 reported the use of an anatomically contoured steel loop secured to the spine in a similar manner (Fig 2).32 The use of metal loops in the shape of a rectangle or square have also been reported.7 The advantages of loop and wire fixation over wire alone include greater rigidity of fixation, the ability to manipulate the spinal alignment with rod contouring, and less reliance on cumbersome external immobilization.14 High successful fusion rates have been reported by Itoh and Fehling in 92% and 93% of their patients, respectively.4 A potential drawback to the use of sublaminar cervical wire placement with this technique is the risk of neurological injury by incidental cord compression.

Recently, Apostolides and Dickman presented the use of a wide diameter, contoured, threaded Steinmann pin that is wired to the occiput and cervical laminae or facets. Ninety-eight percent of the patients had a stable construct at follow-up with 35 successful radiographic fusions, 2 fibrous unions, and 1 case of nonunion.10

In 1966, Cregan first showed the use of a plate and screw fixation to the skull for obtaining an occipitocervical fusion.20,21 Roy-Camille later developed a plate fixation device that was morphometrically contoured to the occipitocervical junction. The sagittal contouring of the plate was approximately 105° with spacing for the cervical lateral mass screws of 16 or 19 mm. Bicortical occipital screw fixation using 3.5-mm screws was recommended by the author.22 Heywood and Learmonth, in 1988, used a “Y”-shaped plate with the single stem of the plate secured to the inion of the occiput with three unicortical screws (Fig 3). Fusion was successful in 12 of their 14 patients. To improve cervical fixation, Grob and Dvorak used a combined C2-C1 facet screw fixation via the Magerl technique with plate and screw attachment to the occiput. They noted satisfactory outcomes and solid bony fusion in all 14 of their patients with minimal complications as compared with past experience with the triple-wire technique.23 The investigators subsequently compared the use of screw and Y-plate fixation with wiring techniques in patients with rheumatoid arthritis. A fusion rate of 73% was observed with the wiring technique, whereas a fusion success rate of 94% was shown by the plating technique. Eighty-six percent of the Y-plate patients improved neurologically, whereas only 40% of the wire fixation group improved.24

Fusion success rates as high as 100% using plate and screw fixation have been reported by Smith et al and Sasso et al.25,26 Obrien and Sutterlin biomechanically compared three methods of internal fixation to the occiput: the Axis plate and screw fixation system (Sofamor Danek, Memphis), the Y-plate, and a Luque rectangle with wire fixation. The plate and screw constructs showed an improvement in torsional control as compared with an intact spine, whereas the rod (Luque rectangle) system did not.

Figure 2. A diagram of Ransford and Crockard’s anatomically contoured loop. The loop is fixed to the occiput by wires through burr holes in the calvaria. Sublaminar wiring secures the loop to the cervical spine.
A plate and screw device designed at Thomas Jefferson University has been developed to improve fixation to the occiput by medializing occipital screw placement toward the inion with bilateral plates, as well as affording ease of placement of C2 isthmus or pedicle screw fixation through a horizontal variable screw slot design (Fig 4). The subaxial cervical plate design is identical to the Axis plate, allowing medial, lateral, superior, and inferior screw angular variability with the option of three screw spacing patterns (11, 13, and 15 mm). The occipital portion of the plate may be shortened depending on the anatomy. The system allows improved fixation to the occiput with newly designed 3.5-mm cortical screws with lengths as short as 6 mm.

Anatomic Consideration for Screw Fixation to the Occiput

Due to the proximity of the intracranial venous sinuses to the occiput, care must be taken during drill or screw penetration of the inner calvarium. Anatomically, the central venous sinus plexus lies just below the external occipital protuberance, a potential point of screw fixation. Anatomic studies show that the rostrocaudal level of the transverse sinus lies at the level of the superior nuchal line. Heywood found that the thickest portion of posterior skull is the external occipital protuberance (11 to 17 mm). The skull thickness at the level of the foramen magnum was found to be approximately 9 mm, with the skull the thinnest at the level of the cerebellar fossa. Because of the proximity of the venous sinuses, the authors recommended unicortical screw placement below the superior nuchal line.

Zipnick and Merola found that the thickest portion of the occipital bone was along a line connecting the internal occipital protuberance to the external occipital protuberance (17.55 mm). This point was located midline at the level of the superior nuchal line (SNL) at a 43.33° angle from the horizontal. The thickness of the bone for screw purchase was found to be inversely proportional to the purchase angle. They also found that the thickness of the calvarium above the SNL was significantly greater than below the SNL. The thickness distribution of bone was found to be 45% outer table, 45% middle table, and 10% inner table. The investigators concluded that unicortical screw purchase at or above the superior nuchal line is possible with low risk of penetration of the intracranial venous plexus. Caruso also concluded that unicortical screws placed in this region presented fewer complications in terms of risk to vascular structures with reasonable screw pullout strength. The greatest difficulty encountered in occipital screw placement above the SNL is screw head prominence.

At Thomas Jefferson University, all screw fixation (minimum of three screws on each side) is performed between the inferior and superior nuchal lines with screw lengths varying between 6 to 14 mm in length.

Conclusion

The upper cervical spine’s anatomic and biomechanical complexity makes stabilization of this junction (occipito-atlanto-axial region) a challenging surgical endeavor. The biomechanical stresses that need to be neutralized in this region (flexion and extension of the atlantooccipital and atlantoaxial joints and axial rotation at the C1-C2 articulation) demand a rigid segmental internal fixation implant to achieve a successful fusion. In addition, the anatomic location of the venous sinuses and the thickness of the

Figure 3. A diagram of the Y-plate allowing midline screw fixation to the occiput.
occipital bone in this region also impose certain technical challenges to the application of any fixation device.

Many techniques for posterior occipitocervical fusion have been developed, ranging from simply onlay bone graft to versatile plate and screw devices. At Thomas Jefferson University, we have found that plate and screw implants provide the greatest versatility, the most successful fusion rates with the least risk to underlying neurovascular structures, if properly performed.

References
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