Novel treatment of basilar invagination resulting from an untreated C-1 fracture associated with transverse ligament avulsion

Case report and description of surgical technique

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The authors describe the case of a traumatic C-1 ring fracture and transverse ligament injury in an otherwise healthy adult woman; the lesion was essentially untreated for 3 months and resulted in basilar invagination. On presentation 3 months postinjury, the patient complained of severe increasing suboccipital pain and a grinding sensation in her upper neck. Axial computerized tomography (CT) scans revealed a C-1 ring fracture, basilar invagination with the dens abutting the clivus, and significant lateral splaying of the C-1 lateral masses. Flexion–extension radiography demonstrated abnormal motion at the atlantoaxial junction. A unique surgical technique was used to address simultaneously the C1–2 instability, the displaced C-1 fracture, and basilar invagination without having to perform occipital fixation. The authors believe that an understanding of the mechanism of the cranial settling in this case (further splaying of the C-1 lateral masses and downward migration of the occipital condyles) permitted full reduction of the deformity; this was accomplished by performing a horizontal reduction of the C-1 lateral masses, using direct C-1 lateral mass screws, a rod compressor, and a cross-link. Postoperative CT scanning confirmed the success of reduction. The results in this report highlight a rare but important complication of untreated C-1 fracture and ligament disruption, and the authors describe a novel treatment technique with which to restore vertical alignment and preserve occipital C-1 motion. A variation of this technique may also be used to treat Type II transverse ligament injuries associated with C-1 ring fractures as an alternative to halo immobilization.

Key Words • basilar invagination • atlantoaxial fixation • transverse ligament avulsion

Fractures of C-1 account for approximately 5% of acute cervical fractures. Pure axial loading forces are thought to compress the atlas between the occipital condyles and axial joint surface, usually resulting in a burst-type injury involving two or more fractures through the C-1 ring. Secondary bending forces may produce multiple different fracture patterns. Severe compression injuries may also result in rupture or avulsion of the transverse ligament which causes atlantoaxial instability and further disruption of the C-1 ring integrity. It has been reported that a chronically untreated Jefferson-type fracture can result in basilar invagination. Typically basilar invagination associated with C1–2 ligamentous instability has been treated with occipitocervical fusion, which results in significant loss of cervical motion. We present a second case of basilar invagination caused by an untreated C-1 fracture associated with transverse ligament rupture. In addition, we describe a new treatment for this type of sagittal and vertical instability, based on the biomechanical mechanism of the cranial settling, that avoids the need for occipital fixation and thus preserves motion.

Case Report

History and Presentation. This 46-year-old otherwise healthy, previously asymptomatic woman was involved in a motor vehicle accident approximately 3 months prior to presentation. At that time, limited plain radiography demonstrated findings that were interpreted as normal. During the next week, the patient complained of increasing neck pain, and CT scanning revealed a C-1 fracture and normal vertical alignment (no basilar invagination) and a normal occipitoatlantal joint. The patient was placed in a cervical collar and told to attend follow-up examination for repeated CT scanning in 3 months.

Examination. The patient returned to our facility 3 months later. At the time of our examination, she complained of worsening severe suboccipital pain, a feeling of "instabili-
ty,” and left arm numbness, which was new. On physical examination the patient was neurologically intact. Motor strength, sensation, and reflexes were normal. Head position was normal. Flexion–extension radiography demonstrated 4 mm of motion of the atlantodental interval (Fig. 1 upper left and right). A new CT scan demonstrated basilar invagination, a displaced C-1 fracture, laterally displaced C-1 lateral masses, and downward migration of the occipital condyles with respect to C-2 (Figs. 1 lower left and right, and 2). No associated skull base, occipital condyle, C-1 ring, or C-2 fractures were identified. Using a transverse ligament prototype, MR imaging demonstrated transverse ligament rupture and spinal cord kinking at the cervicomedullary junction (Fig. 3). No other soft-tissue findings were seen on the MR images. Imaging of other ligaments and joint capsules revealed no abnormal signal. No direct evidence of occipitotoantal instability was identified. Intraoperative preincision traction under continuous fluoroscopy did not result in distraction of the occipitotoantal joint but did cause partial reduction of the basilar invagination.

Operation. The patient was positioned prone in a Mayfield headholder. In-line distraction force was placed on the head under fluoroscopic guidance to decrease downward pressure of the occipital condyles on the displaced C-1 lateral masses. A standard midline incision was made from the occiput to C-3. The C-1 lateral masses and the C-2 pars were cleaned of soft tissue; the C-2 nerve roots were ligated and transected to create a wide exposure of the C-1 lateral masses, C-1–2 junction, and C-2 pars and pedicle, according to the technique described by Goel and colleagues (Fig. 4). Atlantal screws were placed under fluoroscopic guidance according to the Harms–Melcher technique. Bicortical C-2 pedicle screws were then placed using image guidance. The joints were then incised, and distraction was placed across the atlantoaxial junction to open the joint space for further decoronation using a Midas rex burr. A collagen sponge soaked in recombinant human bone morphogenetic protein–2 was wrapped around a compression-resistant tricalcium phosphate hydroxyapatite carrier (Mastergraft; Sofamor Danek, Memphis, TN) and was packed into the joint space. Distraction was then released. Rods were attached to the C1–2 screws, and the C-2 screws were tightened. Axial screws were tightened to a gentle friction glide. The rods were contoured such that a 1-cm portion extended bilaterally above C-1 but 1 cm of subjacent space was left to allow free occipital motion. A cross-link was then placed on this 1-cm portion of the rod above C-1, and a compressor was placed on the cross-link. The C-1 lateral mass screws were then compressed medially (Fig. 5), reducing the C-1 lateral mass lateral displacement and, by doing so, pushing the occipital condyles superiorly. The C-1 locking nuts and cross-links were tightened. The C-2 locking nuts were loosened, and compression across the C1–2 joint space was then performed, thus preloading the fusion material. The undersurface of the C-1 ring, lateral masses,
and C-2 pars were then decorticated, and local spinous process bone, harvested from the superior edge of the C-2 spinous process, was packed into the space between the C-1 pedicle and the C-2 pars. The C2–3 interspinous ligaments were not disrupted (Fig. 6).

Postoperative Course. Postoperative CT scanning demonstrated significant near-complete reduction of the basilar invagination, partial reduction of the C-1 lateral mass lateral displacement, and improved clival cervical angle (Fig. 6). A Miami-J collar was used for immobilization for 6 weeks. The patient was discharged on postoperative Day 3 with significant improvement in neck pain and normal neurological status. Axial CT scanning at 3 months demonstrated maintenance of reduction and bridging bone across the C1–2 joint, confirming the presence of fusion.

At the 6-month follow-up examination, the patient reported no neck pain and denied any neurological symptoms. Flexion–extension radiography performed at 6 months demonstrated no C1–2 motion.

Discussion

The relatively recent advance of direct C-1 screw fixation introduced by several authors has dramatically expanded our surgical capabilities in stabilizing the atlantoaxial joint. This technique has proven safe and effective for reducing atlantoaxial subluxation. Its advantages include elimination of the requirement of an intact C-1 ring (an advantage over wire fixation); the ability to use screws to achieve deformity reduction in all planes by direct and independent manipulation of C-1 and C-2; the ability to use screw fixation in cases of mesial vertebral artery location through the use of shorter C-2 pars screws (compared with transarticular screws); facilitation of load-bearing fusion construction due to the ability to distract the joint for fusion preparation (insertion of graft material) and then compression to preload the graft; and finally, as this study underscores, the ability for direct reduction of unstable C-1 fractures through compression in the coronal plane and cross-linkage.

It has been our experience, as has been previously reported by Goel and colleagues, that sacrifice of the C-2 root is very well tolerated and creates a significantly greater area for fusion by allowing decortication of the entire posterior surface of the C-1 lateral mass and dorsal surface of the C-2 pars. The rod forms a very convenient posterior buttress for containing additional bone graft packed
into this region. Because of the load-bearing nature of the fusion, we have found it unnecessary to place a wired interspinous graft. In our case we stabilized a traumatic, unstable C-1 fracture, which caused delayed vertical instability resulting in basilar invagination.

Although an MR image was not obtained at the time of the initial injury, CT scanning at that time demonstrated no abnormality of the occipitoatlantal joint. Furthermore, given the immobility of this joint during preoperative distraction, we believe it is unlikely that this joint was primarily damaged. It seems more likely that as C-1 splayed farther laterally with time, the occipitoatlantal joint capsules were slowly stretched as the cranium settled.

It has been reported that in cases of transoral surgery for odontoidectomy every attempt should be made to spare a portion of the C-1 ring to decrease the chance of postoperative cranial settling after C1–2 fusion, especially if an axial laminectomy is needed.4 The technique reported here of direct C-1 fixation with cross-linkage could also be performed in this situation, thereby eliminating the attempt to spare any of the anterior C-1 ring. Even if mild cranial settling occurred in between stages, this could be easily reduced using our technique if the C-1 lateral masses are not eroded by the disease process.

It should be emphasized that to conduct our technique a distraction force must first be placed on the head to unload the occipitoatlantal joint. This may be achieved using traction, by using a standard Mayfield headholder with shoulder taping (as we did in this case), or even by using temporary occipital screws placed in line with the C-1 screws as a point of force application for a distractor. These distraction screws would of course be removed after reduction of the C-1 lateral masses to their normal location under the occipital condyles. The final reduction will be maintained by the cross-link until the C1–2 fusion mass is solid.

Fig. 6. Postoperative imaging studies. Upper Left, Center, and Right: Various images demonstrating hardware positions and reduction of the C-1 lateral mass displacement at the occipitoatlantal and atlantoaxial joints. Lower Left and Right: Sagittal CT reconstruction after reduction and placement of instrumentation. The odontoid tip is no longer impacting the clivus, and the cranial cervical angle is improved.
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References


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