Treatment of basilar invagination by atlantoaxial joint distraction and direct lateral mass fixation

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Object. The author discusses the successful preliminary experience of treating selected cases of basilar invagination by performing atlantoaxial joint distraction, reduction of the basilar invagination, and direct lateral mass atlantoaxial plate/screw fixation.

Methods. Twenty-two patients with basilar invagination—in which the odontoid process invaginated into the foramen magnum and the tip of the odontoid process was above the Chamberlain, McRae foramen magnum, and Wackenheim clival lines—were selected to undergo surgery. In all patients fixed atlantoaxial dislocations were documented.

The 16 male and six female patients ranged in age from 8 to 50 years. A history of trauma prior to the onset of symptoms was documented in 17 patients. Following surgery, the author observed minimal-to-significant reduction of basilar invagination and alteration in other craniospinal parameters resulting in restoration of alignment of the tip of the odontoid process and the clivus and the entire craniovertebral junction in all patients. In addition to neurological and radiological improvement, preoperative symptoms of torticollis resolved significantly in all patients. The minimum follow-up period was 12 months and the mean was 28 months.

Conclusions. Joint distraction and firm lateral mass fixation in selected cases of basilar invagination is a reasonable surgical treatment for reducing the basilar invagination, restoring craniospinal alignment, and establishing fixation of the atlantoaxial joint.

Key Words • atlantoaxial dislocation • basilar invagination • craniovertebral anomaly • atlas • torticollis

We have discussed the subject of basilar invagination and described a classification for these anomalies based on the presence or absence of Chiari I malformation.3,7 Based on the possibility of pathogenetic factors, we had suggested a specific treatment protocol for each of the two groups. With our improved understanding of the subject, we reclassified basilar invagination into two groups based on parameters that determined an alternative treatment strategy. In Type A basilar invagination, there was a fixed atlantoaxial dislocation and the tip of the odontoid process invaginated into the foramen magnum and was above the Chamberlain line, McRae line of the foramen magnum, and Wackenheim clival line. Basilar invagination defined as prolapse of the cervical spine into the skull base, as suggested by Von Torklus and Gehle,16 was present in this group of patients. In Type B invagination, the entire complex of the clivus, basiocciput, and the CVJ was rostrally located and the tip of the odontoid process was superior to the Chamberlain line but inferior to the McRae and the Wackenheim lines.7 In this group there was no atlantoaxial dislocation.

Our group has described a method for lateral mass plate and screw fixation8 and later described our 14-year experience with 160 cases in which this technique was used to treat mobile and reducible atlantoaxial dislocations.8 Biomechanical advantages were conferred by opening the atlantoaxial joint, drilling the articular cartilage, filling the joint with autograft bone, and directly implanting the screws into the lateral atlantal and axial masses. We used this lateral mass atlantoaxial fixation technique as well as joint distraction and attempted reduction of the basilar invagination in patients with Type A basilar invagination. All relevant experience with this alternative treatment modality is presented.

Clinical Material and Methods

Between October 1999 and August 2002, 22 consecutive patients with Type A basilar invagination underwent surgery in which the aforementioned technique was used, and data were accrued and analyzed prospectively. The follow-up period ranged from 1 to 4 years (mean 28 months). All patients underwent MR imaging, CT scanning, and dynamic plain radiographic evaluation.
Results

The clinical features of the cases are presented in Table 1. Traumatic injury of varying severity was the principal precipitating factor in 17 cases. The duration of symptoms ranged from 12 days to 18 months (mean duration 3 months).

Radiographic Studies

Radiological measurements are summarized in Table 2. Measurements were made on all available studies, and mean values were determined. The landmarks for measurements of various indices have been previously described and were based on a review of original papers by Van-Gilder, et al. There was no clear radiographic evidence of mobile subluxation with flexion resulting in an increase in the atlanto- or clivodental interval, increased compromise of the canal diameter, or reduction in the girth of the brainstem. In terms of the defined parameters there was an element of fixed atlantoaxial dislocation in all patients. Chiari I malformation was present in four patients. Syringomyelia was not identified in any case. Partial or complete occipitalization of the atlas was observed in all cases, and C2–3 fusion was demonstrated in nine cases. Os odontoideum was evident in seven patients.

Joint Distraction and Reduction of Fixed Atlantoaxial Dislocation

All patients underwent joint manipulation surgery (Figs. 1–3). No patient underwent transoral decompression as a first-stage operation. Two patients with Chiari I malformation had previously undergone foramen magnum decompression according to our policy of treatment published earlier.7 The basic steps of the joint manipulation surgery have been detailed in our papers on lateral mass plate and screw fixation of the atlantoaxial joint (Fig. 4).8,9 Cervical traction is undertaken prior to induction of anesthesia, and the weights are progressively increased to approximately one fifth of the total body weight. The patient is placed prone with the head end of the table elevated to approximately 35°. An operating microscope facilitates the dissection and adds a measure of safety to screw implantation. The atlantoaxial facet joints are widely exposed bilaterally after sectioning of the large C-2 ganglion. Exposure of the atlantal facet is difficult; in all the present cases there was an assimilation of the atlas resulting in rostrally located C-1 facet. The joint capsule is excised and the articular cartilage is widely removed using a

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* The values represent the distance of the odontoid tip in relationship to the lines. Abbreviations: ADI = atlantodental interval; Alt = alteration; CL = Chamberlain line; Dt = distraction; ML = McRae line; WL = Wackenheim line.
Reduction of basilar invagination

FIG. 1. Imaging studies obtained in a 15-year-old boy. Upper Left: Preoperative T1-weighted image revealing basilar invagination, fixed atlantoaxial dislocation, and indentation of the brainstem. Os odontoideum can be observed. Upper Right: Preoperative CT scan demonstrating marked basilar invagination and fixed atlantoaxial dislocation. Fusion of the C2–3 vertebral bodies, occipitalization of the atlas, and os odontoideum are apparent. Lower Left: Postoperative CT scan revealing reduction of the basilar invagination and the atlantoaxial dislocation. Note the change in the osseous alignment of the CVJ. The alteration in the relationship of the anterior arch of the atlas and the clivus to the C-2 body and odontoid process can be appreciated. Metal artifacts can also be seen. Lower Right: Lateral plain radiograph demonstrating plate and screw fixation.

microdrill. The joint is distracted bilaterally by using an intervertebral spreader common in the anterior cervical disc surgery. The status of the dislocation and of basilar invagination is evaluated by intraoperative control radiography. Large pieces of corticocancellous bone graft harvested from the iliac crest as well as hydroxyapatite block (eight cases) or metal plate spacer (four cases) are used as strut graft and packed into the joints (Fig. 3). The size of the spacers depends on the space available within the distracted joint space. The mean size of the spacer in this study was 12 mm in length, 10 mm in width, and 3 mm in height. The titanium metal spacers have multiple small holes and are tapered at one end for easier placement in the joint cavity (Fig. 5). Bone graft was packed in the distracted joint space in multiple pieces on all the sides of the spacer. Small bone chips were placed evenly in the space available within the sheaths of the titanium metal spacer. Plate-and-screw fixation is then conducted using the interarticular technique. A two-holed stainless steel plate (measuring 15–20 mm in length) was applied and 2.4- to 2.6-mm-diameter and 16- to 22-mm-long screws were used in the present study. Screws are passed bilaterally through the holes in the plate into the atlantal and axial lateral mass (Figs. 1–3). The site and angle of the implanted screws are modified to suit the local anatomy. Although the preferred site of screw insertion is the center of the posterior surface of the atlantal lateral mass, 1 to 2 mm above the articular surface, when occipitalization made exposure difficult, screws were inserted through the articular surface. In the pars of the axis we prefer to insert the screw in its medial and superior third. The medial surface of the pars is identified before implanting the screw. The devices used to cut and mold the small metal plates are commercially available. The atlantal and axial lateral masses are firm and cortical in nature, and, although preferable, it is not mandatory that the screws engage both the anterior and posterior cortices. In four cases, the lateral mass plate system could not be completely applied on one side because of the difficulty of exposing the region. Thus, the Magerl C1–2 transarticular screw fixation method10.
FIG. 2. Preoperative and postoperative CT scans obtained in a 16-year-old boy. Left: Preoperative study demonstrating basilar invagination, fixed atlantoaxial dislocation, atlantal occipitalization, and C2–3 fusion. Right: Postoperative study revealing the changes in the alignment of the craniovertebral region. Note the alteration in the relationship of the odontoid process with the clivus. Atlantoaxial fixation was performed unilaterally and occipitoaxial fixation was conducted on the contralateral side.

FIG. 3. Imaging studies obtained in a 36-year-old man. Upper Left: Preoperative MR image revealing severe basilar invagination, fixed atlantoaxial dislocation, and Chiari I malformation. Posterior decompression was undertaken at an earlier stage. Upper Center: Computerized tomography scan demonstrating basilar invagination and fixed atlantoaxial dislocation. Also evident is C2–3 fusion. Upper Right: Lateral sagittal cut obtained through the joint, revealing the dislocation. Lower Left: Postoperative CT scan demonstrating reduction of the basilar invagination and atlantoaxial dislocation. Lower Center: Postoperative CT scan demonstrating the plate and screw fixation as well as the distracted joint in which a metal spacer has been placed. Note the reduction of the dislocation. Lower Right: Postoperative radiograph demonstrating results after plate and screw fixation. A metal spacer can be seen between the screws.
was performed in three cases, and in one case an occipitoaxial fixation was conducted (Fig. 2). The point of entry and the direction of the transarticular screw were altered to suit the complex local anatomy in these cases. Additional bone graft was placed between the posterior elements of C1–suboccipital bone complex and C-2 after decorticating the host bone area by using a burr. Postoperatively traction is discontinued, and the patient is placed in a four-post hard cervical collar for 3 months, and all physical activities involving the neck are restrained during the period.

Surgery-Related Results
The follow-up period ranged from 1 to 4 years (mean 28 months). Symptoms improved to varying degrees in all cases following surgery, and patients were independent and active in their lives (Table 1). There were no intra- or postoperative vascular, neurological, or infection complications. The changes in the various radiological features are listed in Table 2. No patient suffered a delayed neurological worsening sufficient to warrant a transoral or a posterior decompressive surgery or any other type of operative procedure. No patient required a reexploration for failure of implant fixation. Immediate postoperative and follow-up radiography confirmed fixation and fusion as well as reduction of the basilar invagination. Fusion was considered successful when the implant was shown to maintain the distraction and reduction of the basilar invagination on dynamic radiography 6 months after surgery. Successful and sustained distraction and reduction of basilar invagination was observed in all patients. Torticollis improved significantly following surgery in all patients and in four patients there was a complete symptomatic recovery. There was at least some degree of C-2 sensory loss in all cases.

Discussion
In this study factors in a selected group of patients with basilar invagination were analyzed. The manipulation and distraction of the atlantal and axial facets and attempts at reducing the basilar invagination and stabilization of the atlantoaxial joint are discussed.

Most patients (77%) had a history of minor-to-major head injury prior to the onset of the symptoms. The pyramidal symptoms formed a dominant component. Kinesthetic sensations were affected in 55% of cases. The incidence of spinothalamic dysfunction was less frequent (36%). Neck pain was a major presenting symptom observed in 77% of cases. Torticollis was present in 41% of the patients. Analysis of clinical features indicated that the symptoms and signs were a result of odontoid process–induced brainstem compression.

Evaluation of the radiological findings indicated that the odontoid process directly compressed the brainstem. Analysis of findings related to the Chamberlain line showed that the basilar invagination was mild to severe in these cases. The odontoid process had tilted horizontally rather than rostrally, based on examination of modified omega angle measurements. No atlantoaxial mobility could be identified on dynamic radiography in any case.

The standard and most accepted form of treatment of patients with Type A basilar invagination is a transoral decompression. Most authors have recommended a posterior occipitocervical fixation after the anterior decompression. It is our opinion that, in such cases, the atlantoaxial joint is in an abnormally inclined position as a result of congenital bone abnormality, and progressive worsening of the dislocation is likely secondary to increasing subluxation of C-1 onto C-2. This slippage appears to be accentuated by trauma. Based on our management of atlantoaxial joint lesions, we have found that the joint in these cases is not fixed or fused but is mobile and, in some cases, is hypermobile; thus, it is probably the primary cause of the basilar invagination. The history of trauma preceding the clinical events, predominant complaint of neck pain, and the improvement in neurological symptoms after cervical traction indicates vertical instability of the craniovertebral region.

Our group has previously attempted to reduce basilar invagination by performing occipitocervical fixation after cervical traction; however, in all four patients transoral decompression was required because the implant could not continue to sustain the reduced basilar invagination.
and atlantoaxial dislocation. Basilar invagination and atlantoaxial dislocation can be reduced by wide removal of the atlantoaxial joint capsule and articular cartilage (using a drill) and manual manipulation to distract the joint. Distraction and reduction were maintained with the help of bone graft and spacers. The subsequent biomechanically firm fixation of the joint was achieved using interarticular screws and a metal plate. The fixation was strong enough to sustain the vertical, transverse, and rotary forces of the most mobile region of the spine. The biomechanical advantage conferred by this technique is underscored by the successful fusion results in the present series and in a previously reported series. Postoperatively, the odontoid process and the clival alignment as well as the entire CVJ improved. The tip of the odontoid process receded in relationship to the Wackenheim clival, Chamberlain, and MacRae lines, indicating reduction in basilar invagination. The posterior tilt of the odontoid process, as indicated by a modified omega angle, was decreased postoperatively. Reduction of the basilar invagination and atlantoaxial dislocation was achieved in varying degrees. The extent of joint distraction and the subsequently reduced basilar invagination were more significant in younger patients.

Because an occipitalized or assimilated atlas was present in all cases, dissection and exposure of the fused atlantal facet was significantly more difficult. Based on our initial experience with neuronavigation, this modality appears to reduce associated risks significantly with regard to the vertebral artery and the selection of the best trajectory for screw implantation. That sustained neurological improvement of varying degrees was observed in all patients is indicative of the overall effectiveness of the operation. All patients with preoperative torticollis experienced symptomatic improvement, although no deliberate differential manipulation of the joints bilaterally was performed. Resection of the C-2 ganlion is necessary to achieve the exposure. Based on our present and past experience, we believe that resection of the C-2 ganglion causes an area along the nerve distribution to become numb; however, the area of numbness became progressively smaller in time and was not disabling in any case. All the activities related to neck movements were restricted for a 3-month period to allow for bone fusion in the joint. Stainless steel plates, nonlocking-type screws, and custom-made spacers were used to avoid the higher costs of branded material.

Conclusions

Although experience with the aforesaid technique is limited (a mean follow-up period of 28 months) in cases involving such a complex craniovertebral lesion, our results are promising and have encouraged us to undertake further study. Although the procedure is technically demanding and anatomically precise, if it is learned adequately and performed successfully, the neurological outcome is extremely gratifying.

References


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