Posterior revision surgery using an intraarticular distraction technique with cage grafting to treat atlantoaxial dislocation associated with basilar invagination

Wanru Duan, MD,1 Dean Chou, MD,2 Bowen Jiang, MD,3 Zhenlei Liu, MD,1 Xinghua Zhao, MS,1 Zhiyuan Xia, MS,1 Fengzeng Jian, MD, PhD,1 and Zan Chen, MD, PhD1

1Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, China; 2Department of Neurological Surgery, University of California, San Francisco, California; and 3Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, Maryland

OBJECTIVE The treatment of atlantoaxial dislocation (AAD) and basilar invagination (BI) is challenging, especially in symptomatic patients with a history of previous surgery. Although seldom reported, posterior revision surgery to revise prior constructs can be advantageous over an anterior or combined approach. The authors describe their experience in performing posterior revision surgery using Goel’s technique.

METHODS The authors reviewed patients with AAD and BI who had undergone previous posterior surgery at the cranio-cervical junction between January 2016 and September 2017. All of these patients underwent revision surgery from a posterior approach. The Japanese Orthopaedic Association (JOA) score was used to assess clinical symptoms before and after surgery. The distance from the tip of the odontoid to Chamberlain’s line, atlantodental interval (ADI), and clivus-canal angle (CCA) were used for radiographic assessment before and after surgery.

RESULTS Twelve consecutive patients were reviewed. Prior surgeries were as follows: 4 patients (4/12) with posterior osseous decompression without fusion, 7 (7/12) with reduction and fusion without decompression, and 1 (1/12) with posterior osseous decompression and reduction and fusion. With the use of Goel’s technique for revision in these cases, distraction using facet spacers afforded release of the anterior soft tissue from a posterior approach. The occiput was fixated to C2 using a cantilever technique, and autologous cancellous bone was grafted into the intraarticular joints. In all 12 patients, complete reduction of BI and AAD were achieved without injury to nerves or vessels. All patients had evidence of bony fusion on CT scans within 18 months of follow-up.

CONCLUSIONS Posterior revision surgery using Goel’s technique is an effective and safe revision salvage surgery for symptomatic patients with AAD and BI.

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KEYWORDS atlantoaxial dislocation; basilar invagination; revision surgery; irreducible; posterior approach; reduction; cervical

atlantoaxial dislocation (AAD) and basilar invagination (BI) are not uncommon in Asia, with congenital AAD and BI being the third most encountered etiology after trauma and degenerative spondylosis. Anatomical challenges such as deformed osseous structures, contracted anterior soft tissue, and abnormal vertebral artery anatomy make surgical treatment difficult. In some symptomatic patients, BI-AAD can persist and recur despite previous surgery. Distorted anatomy, presence of a prior fusion mass, and need to revise previous cranio-cervical instrumentation make revision surgery risky, with some reported complication rates of up to 50%.10

Few published reports have focused on revision surgery for AAD.6,8,10,11,14 Commonly reported approaches for re-
vision surgery include the anterior transoral approach or combined anterior and posterior approaches. In these reports, 68.8% to 90% of patients achieved complete reduction after revision surgery, and complications such as deep infection, screw loosening, or pulmonary infections had been reported.\textsuperscript{10,14} However, an issue with the anterior approach is that transoral surgery has a narrow surgical corridor because of the oropharynx anatomy. In our series, we preferentially performed our revision surgeries through a posterior approach using Goel’s technique, described in 2004,\textsuperscript{4} which involves intrafacet distraction and insertion of bone grafts or cages. In each case, we performed a revision operation, revised the posterior instrumentation, and implanted facet spacers to distract and release the anterior vertebral ligaments. The final reduction was performed using a cantilever technique. Here we describe our experience with 12 patients treated using this method.

**Methods and Case Materials**

This is a retrospective study of prospectively collected data. This study was conducted under the approval of the ethics committee board of our hospital. Informed consent was obtained from each patient.

**Patient Population and Exclusion Criteria**

We reviewed adult patients (age $> 18$ years) with BI-AAD who underwent revision surgery from a posterior approach at the cranio-cervical junction during the period from January 2016 to September 2017 at Xuanwu Hospital. Indications for revision surgery included the following: 1) worsened or persistent clinical symptoms after the index surgery; 2) radiographic findings of AAD and BI; and 3) progressive instability from pseudarthrosis. AAD was defined as having an atlantodental interval (ADI) of more than 3 mm. BI was defined as having the tip of the odontoid process more than 5 mm above Chamberlain’s line. Patients were excluded if they had any of the following: 1) rheumatoid arthritis, 2) os odontoideum, 3) trauma at the cranial-cervical junction, 4) osteoporosis, 5) infection, or 6) tumor.

**Clinical and Radiographic Assessment**

Japanese Orthopaedic Association (JOA) neurological scores were used to evaluate motor, sensory, and autonomic functions as a preoperative baseline and postoperatively after 1 year. Patient outcomes assessments such as health-related quality of life (HRQOL) were measured using the 36-Item Short-Form Health Survey (SF-36). These forms were collected before surgery and at 12 months after surgery. Dynamic plain x-ray, CTA, CT, and MRI studies were obtained for all patients preoperatively. All radiographic measurements were performed using these studies.

The radiographic indices measured included the following. 1) The distance from the tip of the odontoid to Chamberlain’s line (normal 2.3 ± 2.6 mm) was used to assess BI. The determination of Chamberlain’s line for an occipitalized atlas was done in accordance with the method published by Xia et al.\textsuperscript{13} 2) The atlantodental interval (ADI) (normal < 3 mm in adults) was used to evaluate the severity of AAD. 3) The clivus-canal angle (CCA) (normal $157.92^\circ ± 8.99^\circ$) was measured as the angle between the superior aspect of the dorsum sella and the posterior wall of the C2 body on midsagittal CT reconstruction images. 4) Bony fusion was defined as an osseous bridge seen in sagittal and coronal reconstruction CT scans.

All patients underwent plain radiographs, CTA, and CT imaging between 3 and 7 days after surgery and had MRI 3 months after surgery. Plain radiographs and CT scans were performed at 6 and 12 months postoperatively. If bony fusion was not seen, a CT was performed every 6 months until the osseous bridge could be identified.

**Surgical Technique**

**Exposing the Occipital Bone, Lateral Facet Joints, and Prior Fusion Mass**

All patients were placed in the prone position with the neck slightly extended. Cervical traction was utilized with one-eighth the body weight (maximum 18 kg) once the prior internal fixation system was removed. The previous incision was used in all cases, and subperiosteal dissection was carried out to the occipital bone. In patients with large occipital cranial defects from their previous surgery, we dissected from lateral to medial along the occipital bone to avoid unintentional durotomy or sinus injury.

The C2 nerve root ganglion was excised if it was still intact from the prior surgery. Some patients had allograft bone from prior surgery covering the facet joints. In these cases, a high-speed drill was used to remove the fusion mass until the lateral facet joints were exposed. Special care was taken to avoid injury to the vertebral arteries, particularly when the arteries were situated dorsally to the joint. In these cases, the vertebral arteries were skeletonized and retracted laterally. After adequate exposure was achieved, the prior instrumentation (if present) was removed.

**Releasing the Anterior Soft Tissue Through a Posterior Approach**

Intraarticular distractors (Wego Medical Systems) were implanted into the facets to distract the joints. Starting with a small distractor with counterclockwise rotation within the facet, the joint space was sequentially opened with larger and larger intraarticular distractors. Continued expansion and distraction were performed until the facet joint was opened to a distance that was planned preoperatively (based on the distance from the odontoid to Chamberlain’s line).

**Intraarticular Spacer Implantation**

After distraction, interfacet spacers (Wego Medical Systems) filled with autologous iliac crest bone were implanted into the intraarticular spaces. The spacer size (height 7–9 mm, width 9 mm, and length 18–23 mm) was determined by the intraarticular release and the resulting height. Intraoperative fluoroscopy was used to confirm adequate position.

**Fixation and Cantilever Technique**

For cases without large occipital defects, an occipital plate (DePuy Synthes) with reduction screw heads was placed on the occiput using midline screws. For cases in
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<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>27</td>
<td>Klippel-Feil syndrome; C1 assimilation</td>
<td>Pst reduction &amp; fixation (OCP–C2 fusion)</td>
<td>18</td>
<td>Weakness in extremities persisted</td>
<td>Inadequate reduction</td>
<td>OCP–C2 fusion</td>
<td>No</td>
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<td>2</td>
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<td>57</td>
<td>C1 assimilation</td>
<td>Pst reduction &amp; fixation (OCP–C2 fusion)</td>
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<td>Neck pain improved but reappeared 2 wks after prior op</td>
<td>AAD recurred w/in 3 mos</td>
<td>OCP–C2 fusion</td>
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<tr>
<td>3</td>
<td>M</td>
<td>31</td>
<td>C1 assimilation</td>
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<td>Neck pain &amp; gait instability aggravated</td>
<td>Inadequate reduction</td>
<td>OCP–C2 fusion</td>
<td>No</td>
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<td>4</td>
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<td>C1 assimilation</td>
<td>Foramen magnum decompression</td>
<td>24</td>
<td>Neck pain &amp; numbness in hands aggravated</td>
<td>Aggravated instability w/o fusion</td>
<td>O condyle–C2 fusion</td>
<td>Large</td>
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<td>Klippel-Feil syndrome; C1 assimilation</td>
<td>Pst reduction &amp; fixation (OCP–C2–3 fusion)</td>
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<td>Gait instability persisted</td>
<td>Inadequate reduction</td>
<td>OCP–C2–3 fusion</td>
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<td>49</td>
<td>C1 assimilation</td>
<td>Foramen magnum decompression</td>
<td>40</td>
<td>Aggravated extremity numb-ness</td>
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<td>C1 assimilation</td>
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<td>30</td>
<td>Weakness &amp; gait instability persisted</td>
<td>Inadequate reduction</td>
<td>OCP–C2 fusion</td>
<td>No</td>
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<td>8</td>
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<td>26</td>
<td>Klippel-Feil syndrome; C1 assimilation</td>
<td>Pst reduction &amp; fixation (OCP–C2 fusion)</td>
<td>56</td>
<td>Gait instability persisted</td>
<td>Inadequate reduction</td>
<td>OCP–C2 fusion</td>
<td>No</td>
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<td>9</td>
<td>F</td>
<td>59</td>
<td>C1 assimilation</td>
<td>Foramen magnum decompression</td>
<td>72</td>
<td>Aggravated extremity numb-ness &amp; weakness</td>
<td>Aggravated instability w/o fusion</td>
<td>OCP–C2 fusion</td>
<td>Small</td>
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<td>57</td>
<td>C1 assimilation</td>
<td>Pst reduction &amp; fixation (OCP–C2 fusion)</td>
<td>156</td>
<td>Neck pain &amp; gait instability persisted</td>
<td>Inadequate reduction</td>
<td>OCP–C2 (lamina) fusion</td>
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<td>11</td>
<td>F</td>
<td>51</td>
<td>C1 assimilation</td>
<td>Foramen magnum decompression</td>
<td>240</td>
<td>Aggravated gait instability</td>
<td>Aggravated instability w/o fusion</td>
<td>O condyle–C2 fusion</td>
<td>Large</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>27</td>
<td>Klippel-Feil syndrome; C1 assimilation</td>
<td>Pst decompression, reduction &amp; fixation (C2 lamina screw–OCP)</td>
<td>68</td>
<td>Gait instability persisted</td>
<td>Inadequate reduction</td>
<td>O condyle–C2 fusion</td>
<td>Large</td>
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O condyle = occipital condyle; OCP = occipital plate; NA = not applicable; Pst = posterior; Pt = patient; Rev = revision; Sx = symptom.
which an occipital plate could not be used, occipital condyle screws were placed instead, with care to avoid injury to the vertebral arteries and hypoglossal canals.

Pedicle screws were then placed into the C2 pedicles in cases without prior C2 fixation. For cases with preexisting C2 pedicle screws, we elected only to remove loosened implants and replace those with larger diameter screws. For cases with small C2 pedicles, we placed C2 translaminar screws.

Rods were cut to the required length and shaped into the desired contour of the occipital cervical junction. The rods were first placed into the C2 screw heads, and the C2 set screws were then tightened, locking the distal end of the rod into C2. Next, using a cantilever technique, the rod was reduced into the occipital reduction set screws (or occipital condyle screws), angling the C2 body forward and pushing the dens ventrally. The set screws in the occipital plate or occipital condyle screws were gradually tightened, and in combination with the cantilever of the rod, the dens was rotated ventrally away from the spinal cord. After confirmation of reduction of the ADI and BI using an O-arm (Medtronic), the set screws were tightened, and the tabs of the reduction screws were broken off.

Bone Grafting

For every case, we used autologous cancellous bone in the intraarticular joint spaces for fusion.

Statistical Analysis

Continuous variables are expressed as mean and 95% CI. Two-sample t-tests with equal variances were used to compare preoperative and postoperative data. The t score is the ratio of difference between groups and difference within the groups. The larger the t score, the more distinction between groups. The T score is an indicator of statistical value derived from the standard T distribution plot. P (|T| > |t|) is the p value that indicates the probability that the findings from the study occurred by chance. Two-tailed tests were performed in our study and a p value < 0.05 was considered statistically significant in all tests. Statistical analyses were performed using Stata version 14.1 (StataCorp LP).

Results

Population

A total of 12 consecutive patients were included in this study, all of whom were diagnosed with congenital BI and AAD with assimilated C1 and had undergone a previous posterior surgery. All of the patients had 18 months of follow-up. There were 8 females and 4 males, with a mean age of 40.3 years (95% CI 31.6–49.0 years). Among our cohort, 4 patients had undergone previous osseous decompression without fusion, 7 had undergone previous reduction and fusion, and 1 patient had undergone both osseous decom-

### Table 2. Preoperative and postoperative JOA scores, distance from the odontoid tip to Chamberlain’s line, ADI, and CCA

<table>
<thead>
<tr>
<th></th>
<th>JOA Score</th>
<th>DCL, mm</th>
<th>ADI, mm</th>
<th>CCA, °</th>
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<tr>
<td>Preop</td>
<td>10.4 (9.38–11.5)</td>
<td>10.9 (8.15–13.62)</td>
<td>4.36 (3.43–5.28)</td>
<td>115.7 (104.5–127.0)</td>
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<tr>
<td>Postop</td>
<td>14.5 (14.1–15.0)</td>
<td>1.76 (0.117–3.40)</td>
<td>1.16 (0.457–1.86)</td>
<td>145.8 (137.8–153.9)</td>
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<tr>
<td>Improvement</td>
<td>4.08 (3.02–5.14)</td>
<td>9.12 (6.12–12.1)</td>
<td>3.20 (2.10–4.29)</td>
<td>30.08 (17.06–43.09)</td>
</tr>
<tr>
<td>t</td>
<td>7.9968</td>
<td>6.2955</td>
<td>1.76 (0.117–3.40)</td>
<td>1.16 (0.457–1.86)</td>
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<td>P (</td>
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DCL = distance from the odontoid tip to Chamberlain’s line.
Values are expressed as mean (95% CI) unless otherwise indicated; p < 0.05 was considered statistically significant.

FIG. 1. A 57-year-old woman presented with neck pain for 10 years. The prior operation was reduction and posterior fusion with an occipital plate and C2 fixation. The symptoms improved but recurred 2 weeks after the index surgery. A: CT obtained 12 months after the revision surgery demonstrating solid bony fusion in the atlantoaxial facet joint. B and C: Dynamic radiographs demonstrating no instability between the occiput and cervical spine.
pression with reduction and fusion in their initial index surgeries. Symptoms included weakness or numbness of the extremities, gait instability, and neck pain. Five patients had worsened symptoms after their index surgeries. In 1 patient symptoms improved but subsequently recurred, and 6 patients had persistent symptoms after the index operation. Radiographically, inadequate reduction was noted in 7 cases, recurrent AAD in 1 case, and progressive instability due to pseudarthrosis in 4 cases (Table 1).

Surgery

The mean surgical time was 130.2 (92.1–168.2) minutes, and mean blood loss was 169.1 mL (120.5–217.7 mL). On exposure, we were able to preserve the dura without durotomy in the 12 patients, including 2 patients with large defects in the occipital bone. Seven patients had fusion masses covering the lateral facet joints, and these were removed with a high-speed burr. One patient was noted to have an aberrant vertebral artery which coursed dorsally to the facet joint, and this artery was safely manipulated without injury based on preoperative planning.

For all patients, the articular joints were opened to a distance that was determined preoperatively to be the distance from the odontoid tip to Chamberlain’s line. The average height of the interfacet spacers that were inserted was 8.4 mm (7 mm for case 6; 8 mm for cases 2, 4, 5, 8, and 10; and 9 mm for cases 1, 3, 7, 9, 11, and 12). An occipital plate was implanted in 9 cases, and bilateral occipital condyle screws were placed in 3 cases in which the patients had large occipital defects. No hypoglossal canal violations were observed by postoperative CT scan.

For the 4 cases in patients without prior instrumented fusion, C2 pedicles screws were placed in 3 cases, and C2 translaminar screws were implanted in 1 case because of small C2 pedicles.

Clinical Outcome

The average JOA score improved by 4.08 (3.02–5.14) at 1-year follow-up, which was indicative of improvement of motor, sensory, and autonomic functions. Two patients complained of moderate neck pain after surgery, but they recovered in 1–2 weeks postoperatively. None of the patients had neurological decline, vertebral artery injury, infection, or dislocation of the implants. None of the patients had unplanned reintubation or reoperation. SF-36 scores were available from 8 patients at their 12-month postoperative follow-up. Average SF-36 scores were 42 (preoperative) and 68 (postoperative) (Supplemental Table 1).

Radiographic Follow-Up

Based on standard postoperative CT performed within 1 week after surgery, complete reduction of AAD and BI (defined as ADI < 3 mm and the odontoid tip < 5 mm above Chamberlain’s line postoperatively) was achieved in all 12 patients. The mean ADI decreased from 4.36 mm preoperatively to 1.16 mm postoperatively. The mean clival-canal angle also showed improvement, from 115.7° preoperatively to 145.8° postoperatively (Table 2). Six patients had syrinxes identified by MRI before surgery, and reduction of the syrinx size was observed in 4 patients 3 months after revision surgery. All of the 12 patients achieved bony fusion during their follow-up period (4 patients at 6 months, 7 at 12 months, 6 at 18 months, and 1 at 24 months).

FIG. 2. A 27-year-old man presented with gait instability for 1 year. The prior surgery was posterior atlantoaxial reduction and occipital–C2 (translaminar screw) fusion. The patient’s symptoms persisted after the index operation. A: Preoperative CT scan (parasagittal view) showing loosening of the C2 translaminar screw. B: Postoperative CT (parasagittal view) showing interfacet spacer placement and occipital condyle screws with C2 pedicle screws. C: Preoperative CT (midsagittal view) showing AAD and BI with a large defect in the occiput. D: Postoperative CT showing complete reduction of both BI and AAD. E: Three-dimensional CT reconstructive image showing the large defect on the occipital bone. F: Intraoperative image demonstrating the occipital condyle and C2 pedicle fusion following Goel’s technique. Figure is available in color online only.
and 1 patient at 18 months) (Fig. 1). At last follow-up, no patients had implant failure or spacer subsidence.

**Discussion**

Treatment of BI-AAD is challenging, especially for patients with previous posterior cranial-cervical junction surgery. A large occipital defect, obtrusive fusion mass from prior surgery, implant loosening, and loss of anatomical planes from scar tissue pose significant challenges.

Anterior transoral decompression has been a standard procedure for treating irreducible AAD. As such, revision surgery through an anterior transoral approach is frequently utilized. Tan et al. reported 16 revision cases using an anterior transoral release with posterior instrumented fusion. In 12 cases complete reduction was achieved, and only 1 case of superficial infection was reported. Yang et al. reported 30 revision cases using a transoral atlantoaxial reduction plate (TARP) system through a transoral approach. Satisfactory radiographic reduction was achieved in all cases, but 1 patient had pulmonary infection and 1 patient underwent screw revision in the postoperative period. Although the anterior approach can achieve satisfactory results, transoral surgery has its drawbacks. These include risk of infection due to the nonsterile nature of the oropharyngeal defect.

![FIG. 3. A 31-year-old man presented with progressive neck pain and gait instability for 5 years. The prior operation was posterior atlantoaxial reduction with occipital-C2 pedicle screw fusion. The symptoms worsened after the index operation. A: CT before the first operation (parasagittal view) demonstrating abnormal facet joints. B: CT after the index operation (parasagittal view). C2 pedicle screws and occipital plate were placed. C: CT after revision surgery (parasagittal view). C2 screws were replaced with new placement of C3 lateral mass screws. D: CT before the index surgery (midsagittal view) showing BI and AAD with an assimilated C1. E: CT after the index operation (midsagittal view) demonstrating adequate reduction of AAD with no change in BI. F: CT after the revision operation (midsagittal view) demonstrating complete reduction of AAD and BI. G: MR image indicating syringomyelia from C2 to C6. H: MR image after the index operation showing slight enlargement of the syrinx. I: MR image after the revision surgery showing shrinkage of the syrinx.](image-url)
ynx, a narrow corridor through which to work because of the size of the oropharynx, and oral-gastric or nasogastric tube placement for enteral feeding in the postoperative period. Furthermore, in some cases with prior posterior fixation and bony fusion, the prior surgery prevents sufficient reduction through an anterior-only approach. In addition, in cases with implant failure and screw loosening, surgery from a posterior approach is necessary for instrumentation revision. Because of these reasons, we prefer a posterior revision strategy as opposed to an anterior one.

In our cohort, we included 12 BI-AAD patients who had undergone previous posterior cranio-vertebral junction surgery. In terms of indications for revision surgery, 7 patients had inadequate reduction after the index operation, 1 patient had recurrence of BI-AAD during follow-up, and 4 patients had symptoms due to inadequate posterior fossa decompression without fixation. Despite previous surgery, we were able to distract the atlantoaxial joints and place intraarticular spacers to allow for anterior soft-tissue release with reduction of AAD. The cantilever technique also allowed for horizontal reduction by pushing the dens ventrally, away from the spinal cord. We achieved complete

FIG. 4. A 57-year-old woman presented with neck pain for 10 years (the same patient shown in Fig. 1). The index operation was reduction and posterior fusion with an occipital plate and C2 fixation. The symptoms improved but reappeared 2 weeks after the prior surgery. A: CT scan before the index operation (parasagittal view). B: CT scan 1 week after the index operation (parasagittal view) indicating C2 pedicle screws and occipital plate were implanted. C: CT 3 months after the index operation (parasagittal view) indicating that the rod shifted due to implant loosening. D: CT after revision surgery (parasagittal view). Larger occipital screws were placed, and C3 screws were implanted to strengthen the fixation. E: CT before the index operation (midsagittal view) indicating BI and AAD with an assimilated C1. F: CT obtained 3 days after the index operation (midsagittal view) showing that complete reduction was achieved. G: CT 3 months after the index operation (midsagittal view) showing that AAD and BI reappeared. H: CT obtained 6 months after the revision surgery (midsagittal view) indicating that reduction was achieved for both AAD and BI. I: MR image before the index operation indicating ventral compression of the spinal cord and edema in the medulla. J: MR image 3 months after the first operation indicating not much change in spinal cord compression. K: MR image 3 months after the revision surgery indicating complete decompression and resolution of the edema.
vertical and horizontal reduction in all the cases without complications, and bony fusion was achieved within 18 months. These data suggest that revision surgery for BI-AAD can be achieved through a posterior-only approach.

In the 7 cases in which patients had inadequate decompression and reduction from the index surgery, all had an assimilated atlas and abnormal atlantoaxial joints. Contraction of anterior soft tissue also hindered sagittal height movement and may have been a major reason for the incomplete vertical reduction. Therefore, sufficient distraction of the intraarticular facet joint is the first step during the revision surgery, both to release the anterior soft tissue and to gain vertical space for horizontal reduction. Using this strategy, we achieved a complete reduction in all 7 cases of anterior soft-tissue contraction (Figs. 2 and 3). The key technique to releasing anterior scarring and tissue is to insert a joint scraper to the anterior edge of the facet joint and sequentially open the interarticular space, as described by Goel.3 Care must be taken during distraction to avoid undue force on the bony surfaces, which may lead to fracture of the cortices.

Other challenges for these cases include bony fusion mass and prior instrumentation. The fusion mass from prior surgery obscures the atlantoaxial joint anatomy; thus, careful drilling should be performed until the anatomical facet joint is exposed. Special care should also be taken if there is an abnormally coursing dorsal vertebral artery, and thus a preoperative CT angiogram is critical for planning this surgery.

For the 1 case in which AAD recurred within 3 months after the index surgery, the index surgery did not use intraarticular spacers or an iliac crest graft (Fig. 4). Although the facet joint was released and a complete reduction was achieved immediately after the primary surgery, biomechanical stress led to implant failure due to lack of intraarticular support. In the revision surgery, we placed spacers intraarticularly after we released the facet joints. Thus, the biomechanical stress was spread out evenly over the spacers, which reduced the stress on the posterior fixation system and facilitated bony fusion according to Wolff’s law.2,3,7 For the 4 patients who underwent posterior decompression without fusion in the index operation, all of them suffered from worsened symptoms after the primary surgery. The primary surgery disrupted the posterior tension band, which resulted in settling at the cranial-cervical junction. The strategy we used was to distract the facet joints and then restore the lost vertical height and reduce the horizontal translation. Three patients were instrumented with C2 pedicle screws and 1 patient with C2 translaminar screws, and 1 patient had an occipital plate (Fig. 5). The main surgical challenge in these cases was the presence of an occipital defect.

Ever since atlantoaxial joint distraction was described by Goel,4 some cases of “irreducible” AAD have become “reducible.” A single-stage posterior approach offers many advantages over the classic combined treatment (anterior decompression followed by posterior fusion). Although this is a small series, the use of revision cranial cervical junction surgery for AAD or BI is not common, and the techniques for revising these surgeries through a completely posterior approach may be useful for surgeons to know.

It is also important for a surgeon to understand the key factors that hinder reduction. Etiologies for the failed index surgeries are multifactorial. For cases with inadequate reduction, an insufficient releasing of high-tension soft tissue is likely the culprit. For cases with recurrent AAD, the lack of articular support can frequently lead to the failure of the prior operation. For patients who underwent decompression without fusion in their index operations, the lack
of stabilization and disruption of the posterior tension may have led to the failure of their initial surgery.

A detailed surgical strategy based on anatomy and preoperative planning is important in order to avoid injury to nerves and vessels. Surgeons should pay special attention to the abnormality of the facet joints and the course of the vertebral arteries when applying this technique. Although there were no major complications in our case series, careful surgical technique is required. Moreover, our technique is not applicable for cases with severely ankylosed or completely fused C1–2 facet joints because attempting to release the intraarticular joint may simply lead to destruction of the facet articular surface. Another contraindication is osteoporosis, because the intraarticular distraction maneuver might lead to fracture of the cortical articular surface, leading to failure of reduction or implant settling.

Conclusions

Distraction of the atlantoaxial joint followed by intraarticular spacer placement and cantilever reduction is a feasible option for performing revision posterior surgery for AAD associated with BI. This method can be an effective and safe procedure but demands careful analysis and planning for each case.

References

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Disclosures

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Author Contributions

Conception and design: Chen. Acquisition of data: Chen, Duan, Zhao, Xia. Analysis and interpretation of data: all authors. Drafting the article: Chen, Duan, Chou, Jiang, Liu, Zhao, Xia. Critically revising the article: Chen, Duan, Chou, Jiang, Jian. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chen. Statistical analysis: Duan, Liu, Zhao, Xia. Administrative/technical/material support: Chen, Duan, Jian. Study supervision: Chen, Duan, Jian.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.


Correspondence

Zan Chen: Xuanwu Hospital, Capital Medical University, Beijing, China. chenzan66@163.com.