New Clinical Classification System for Atlantoaxial Dislocation

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abstract

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The purpose of this study was to define a new clinical classification of atlantoaxial dislocation based on its clinical manifestations, namely reducible atlantoaxial dislocation (RAAD), irreducible atlantoaxial dislocation (IAAD), and fixed atlantoaxial dislocation (FAAD). A total of 107 patients with atlantoaxial dislocation were respectively treated based on this clinical classification, including 66 patients with RAAD, 39 patients with IAAD, and 2 patients with FAAD. Six of the 66 patients with RAAD with rotatory atlantoaxial dislocation were treated with traction and a cervical collar, 9 with fresh type II dens fracture were treated with cannulated screw fixation, and 51 were treated with posterior atlantoaxial or occipitocervical arthrodesis. Thirty-eight patients with IAAD received a transoral atlantoaxial reduction plate system, and 1 with a giant cell tumor was treated with lesion resection and vertebral reconstruction by a shaped titanium mesh system followed by posterior occipitocervical screw–rod fixation. The 2 patients with FAAD underwent anterior decompression and received a transoral atlantoaxial reduction plate system. Follow-up data were obtained for a minimum of 6 months. All patients’ neurological symptoms improved postoperatively. Bony union was accomplished by 3-month follow-up. Donor-site infection was found in 1 patient, with no occurrence of other complications.

This article proposes a new classification of atlantoaxial dislocation indicating the severity and difficulty in reduction of the atlantoaxial joint. The classification system assists with decision making regarding therapeutic options. Transoral atlantoaxial reduction plate fixation and posterior atlantoaxial screw–rod fixation are commonly performed for atlantoaxial dislocation.

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Figure: Preoperative lateral radiograph of a reducible atlantoaxial dislocation (A). Postoperative lateral radiograph after posterior atlantoaxial screw–rod fixation (B).
Atlantoaxial dislocation is commonly encountered by clinicians, and its routine clinical classification has been based on its pathogenesis or on diagnostic imaging. Although various classifications are used, they are not detailed enough to account for all dislocation types. In addition, they neither provide prognostic information nor account for the neurologic status of the patient and therefore do not provide enough information to adequately guide the surgical options. To indicate the severity and difficulty of reduction, the current authors created a new classification system of atlantoaxial dislocation to assist with surgical decision making for favorable surgical outcomes.

**Materials and Methods**

**General Data**

A prospective study was conducted using a new clinical classification system for atlantoaxial dislocation in 1 hospital. A total of 107 patients admitted between January 2010 and December 2011 were classified based on the new system and received corresponding treatment. Patients included 59 men and 48 women with an average age of 37 years (range, 8-63 years). General patient data, including complaints, symptoms, and signs, are shown in Table 1. One hundred one patients underwent surgical treatment and 6 underwent conservative treatment. The patients were observed prospectively for a minimum of 6 months (range, 6-30 months).

**Clinical Classification of Atlantoaxial Dislocation**

Three types of clinical manifestations of atlantoaxial dislocation were indentified. The classification of atlantoaxial dislocation as reducible or irreducible was based on the reduction status after skull traction or biaxial skull–cervical traction (Figure 1). Biaxial skull–cervical traction provides a vertical force, which maintains the lordosis of the cervical spine. According to the authors’ clinical experience, biaxial skull–cervical traction facilitates atlantoaxial reduction and is preferable to simple skull traction. When the dislocation was defined as irreducible, the authors predicted the reduction outcomes by conventional transoral release. Preoperative imaging commonly reveals bony fusion between C1-C2, which facilitates the prediction of the outcome of conventional transoral release. If conventional transoral release would work for reduction, the authors defined the dislocation as reducible. Otherwise, it was defined as fixed atlantoaxial dislocation.

The 3 types of atlantoaxial dislocation are as follows:

- **Reducible Atlantoaxial Dislocation.** In reducible atlantoaxial dislocation (RAAD), the atlantoaxial joint can be favorably reduced in extension or by traction. Based on the difficulty of reduction, RAAD can be further divided into 2 subtypes, namely self-reduction (reduced in extension) and gradual reduction (reduced after traction).
- **Irreducible Atlantoaxial Dislocation.** In irreducible atlantoaxial dislocation (IAAD), skull traction or biaxial skull–cervical traction fails to reduce the atlantoaxial joint, and the surgical option is conventional transoral release, which immediately achieves reduction of the atlantoaxial joint intraoperatively.
- **Fixed Atlantoaxial Dislocation.** In fixed atlantoaxial dislocation (FAAD), the atlantoaxial joint does not respond to skull traction or biaxial skull–cervical traction and conventional transoral release. The atlantoaxial joint must be reduced via a deep grinding technique using a high-speed burr to excise the bony callus between C1-C2 or by osteotomy. For most cases of FAAD, preoperative computed tomography scanning demonstrates extensive bony fusion between C1-C2.

Sixty-six patients were classified with RAAD. Of these, 6 were diagnosed with rotatory atlantoaxial dislocation, 9 with type II dens fracture, and 51 with atlantoaxial dislocation. Thirty-nine patients were classified with IAAD, and 2 were classified with FAAD. Pathogenic factors included trauma in 47 cases, inflammation in 15 (4 rheumatoid arthritis, 1 osteomyelitis, 5 osteoid osteoma, and 1 Paget disease of bone), and 2 (1 associated with meningitis and 1 with osteosarcoma of the atlas). Preoperative imaging commonly reveals bony fusion between C1-C2 or by osteotomy. For most cases of FAAD, preoperative computed tomography scanning demonstrates extensive bony fusion between C1-C2.

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**Table 1**

<table>
<thead>
<tr>
<th>Clinical Finding</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor weakness or spasticity</td>
<td>19</td>
</tr>
<tr>
<td>Distal upper-limb wasting</td>
<td>13</td>
</tr>
<tr>
<td>Spinothalamic tract involvement</td>
<td>47</td>
</tr>
<tr>
<td>Cerebellovestibular dysfunction</td>
<td>13</td>
</tr>
<tr>
<td>Vertigo</td>
<td>6</td>
</tr>
<tr>
<td>Sphincteric dysfunction</td>
<td>6</td>
</tr>
<tr>
<td>Poor respiratory reserve</td>
<td>5</td>
</tr>
<tr>
<td>Transient loss of consciousness</td>
<td>11</td>
</tr>
<tr>
<td>Neck pain</td>
<td>73</td>
</tr>
<tr>
<td>Stigmata of craniovertebral anomaly</td>
<td>32</td>
</tr>
<tr>
<td>Neck movement restriction</td>
<td>69</td>
</tr>
<tr>
<td>Torticollis</td>
<td>11</td>
</tr>
<tr>
<td>Transient quadriaparesis after minor trauma</td>
<td>43</td>
</tr>
</tbody>
</table>

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**Figure 1:** Diagram (A) and photograph (B) of a biaxial skull–cervical traction table.
Tuberculosis, and 6 spontaneous dislocations caused by local inflammation), congenital malformation in 44, and tumor in 1.

### Treatment Options

For self-reduction and gentle reduction of RAAD, posterior atlantoaxial fixation and fusion, mostly posterior pedicle screw–rod fixation, was performed. However, for those with fresh type II odontoid fractures with atlantoaxial dislocation, cannulated screw fixation was preferred. Traction and a cervical collar or Halo vest was used for children with spontaneous dislocation caused by local inflammation.

For IAAD with anterior compression of the spinal cord, transoral atlantoaxial reduction plate (TARP) fixation was performed. When preoperative imaging showed rotational displacement (Fielding type I or II) or posterior dislocation of the atlas (Fielding type IV), reduction was achieved by leverage of the atlantoaxial joint with an elevator intraoperatively.

For patients with FAAD, anterior decompression of the spinal cord was achieved through deep grinding or excising the anterior arch of the atlas and the dens or through anterior subtotal vertebral resection of the axis. Posterior decompression of the spinal cord was achieved by removal of the posterior edge of the foramen magnum or posterior arch of C1 and lamina of C2. For concurrence of anterior and posterior compression, anterior and posterior decompression and posterior occipitocervical fixation and fusion were performed. Transoral atlantoaxial reduction plate fixation was always the first priority of surgical treatment.

### RESULTS

All patients received bilateral skull traction as inpatients. Surgical treatments were chosen based on each patient’s atlantoaxial dislocation classification (Table 2). Of the 66 patients with RAAD, 9 with type II dens fracture were treated with cannulated screw fixation, and all achieved bony union by 3-month follow-up, with only a slight limitation to cervical motion. Fifty-one patients with RAAD were treated with posterior C1-C2 (n = 45) or occipitocervical arthrodesis (n = 6). Of the 51 patients, 50 obtained complete atlantoaxial reduction and bony fusion during the follow-up period. Traction and a cervical collar were used for 6 children with RAAD with spontaneous dislocation caused by local inflammation.

Of the 39 patients with IAAD, 38 were treated with transoral release, reduction, TARP fixation, and fusion (Figure 3). One patient with giant cell tumor was treated with lesion resection and vertebral reconstruction with a shaped titanium mesh system, followed by posterior occipitocervical screw–rod fixation. All patients obtained atlantoaxial reduction and bony fusion during the follow-up period. Donor-site infection occurred in 1 patient, with no other complications found intra- or postoperatively.

The 2 patients with FAAD were treated with anterior release and decompression...
sion by excising the anterior arch of the atlas and the dens. Transoral atlantoaxial reduction plate fixation and fusion were performed (Figure 4). Postoperatively, their atlantoaxial joints remained slightly dislocated, but posterior magnetic resonance imaging showed favorable decompression.

**Discussion**

The C1-C2 vertebrae are deep within the upper cervical area, protecting the spinal cord and vertebral artery. Atlantoaxial dislocation is a pathological state of instability occurring in the occipitocervical region. If left untreated, it leads to a gradual deterioration of this region, ultimately resulting in paralysis, respiratory failure, and death by compressing the spinal cord and vertebral basilar artery.\(^8,9\)

Surgical treatment for atlantoaxial dislocation is intended to restore the normal anatomic relationship of the atlantoaxial joint, decompress the spinal cord, and reestablish vertical stability in this region. However, its treatment is complex and dangerous. In the past 30 years, developments in surgical procedures, instruments, and understanding of the related anatomic structures and biomechanical relationships have improved the therapeutic effects of surgery.

**Transoral Atlantoaxial Reduction Plate Fixation**

Transoral decompression, reduction, fixation, and fusion with TARP are appropriate procedures for patients with irreducible atlantoaxial dislocation and cervical compressive myelopathy caused by various diseases. The surgical techniques have been described in detail.\(^4-7\)

In combination with atlantoaxial reduction instrumentation, TARP can achieve immediate reduction of the atlantoaxial joint and provide direct anterior fixation. The procedures of release, decompression, reduction, internal fixation, and fusion can be finished in 1 surgical stage. Posterior fixation techniques can be...
avoided. The atlantoaxial joint is unstable after anterior release. The potential risk of fatal spinal cord injuries while moving the patient or rotating the patient into a prone position is thereby avoided.

**Significance of Clinical Classification for Treatment Options**

The primary causes of atlantoaxial dislocation are trauma, inflammation, tumor, congenital malformations, and metabolic diseases. Different causes have different clinical manifestations. The same etiology may also have different clinical manifestations. This study proposed a new clinical classification with the intention of clarifying the clinical manifestations of dislocation. Each type of atlantoaxial dislocation is related to a specific etiology and mechanical stability. A comprehensive understanding and analysis of atlantoaxial dislocation is significant for surgical options.

**Reducible Atlantoaxial Dislocation.** The causes of reducible atlantoaxial dislocation include type II dens fracture, atlantoaxial rotary dislocation, and rheumatoid arthritis. For RAAD, the atlantoaxial joint can be favorably reduced in extension or by traction.

When RAAD is caused by type II odontoid fractures, cannulated screw fixation is preferred. In 1982, the anterior odontoid screw procedure was performed in cases of dens fracture after reduction of the atlantoaxial joint. The application of this procedure to type II dens fractures can maintain C1-C2 articulation and help remove external hardware as soon as possible postoperatively. This technique is considered to be an effective treatment for dens fractures. Traction and a cervical collar or Halo vest are used for children with spontaneous dislocation caused by local inflammation.

In addition to the aforementioned procedures, posterior atlantoaxial fixation and fusion are always the top priority for surgical treatment. After reduction, the screw–rod fixation system allows restricted redilocation and may provide rigid fixation of the atlantoaxial joint.

**Irreducible Atlantoaxial Dislocation.** Surgical treatment of IAAD, especially old atlantoaxial dislocations, creates unique challenges. The gradual contraction of the bilateral longus colli muscles, articular capsules, and ligaments; scar formation; lateral mass joint deformity; and odontoid fracture malunion make reduction impossible using only skeletal traction. The C1 vertebra and skull in patients with this condition are generally displaced anteriorly, and the center of gravity of the head has a forward migration. As a result, swan-neck deformity occurs, with upper cervical kyphosis and lower cervical lordosis. Due to the forward motion of the head and the concurrent backward and upward bulging of the axis, pressure is generated by the odontoid process and the C2 vertebra interaction. This pressure compresses the ventral spinal cord at the spinobulbar junction. In some cases of severe dislocation or basilar invagination, it may cause the posterior arch of C1 and the posterior margin of foramen magnum to compress the dorsal spinal cord.

The authors define IAAD as atlantoaxial dislocation that does not respond to skull–cervical traction and must be treated with conventional transoral release. According to their clinical experiences and literature reviews, most cases of IAAD are reduced after transoral release without odontoid resection. The reduction procedure has almost identical effects to transoral release and decompression. Most of literature reports occipitocervical or atlantoaxial fixation after transoral release and decompression. At the authors’ institution, surgical options for IAAD include transoral anterior release, single-stage anterior TARP fixation, and anterior release followed by first- or second-stage posterior arthrodesis, such as C1-C2 pedicle screw–rod fixation or occipitocervical fixation. Transoral atlantoaxial reduction plate fixation is the first priority. A single-stage stabilization procedure would obviate the need for additional surgery for posterior fusion. If reduction is achieved after release screws are not placed, posterior atlantoaxial or occipitocervical arthrodesis should be performed.

**Fixed Atlantoaxial Dislocation.** Patients with FAAD have a long illness history and do not respond to skull traction or biaxial skull–cervical traction and conventional transoral release. Preoperative computed tomography scanning shows extensive bony connection between C1-C2. For such cases, deep grinding techniques or even osteotomy for release may achieve favorable decompression and anatomic reduction. The deep grinding techniques include excising the bony connection of the atlantoaxial joint and extensive anterior release, such as excising the dens and the anterior arch of the atlas. During this procedure, the hand should be supported when holding the burr to avoid burr bounce. Grinding should be stopped when the burr reaches the dural sac or the deeper cortex of the dens to avoid cerebrospinal fluid leakage or spinal cord injury. When the atlantoaxial joint is not anatomically reduced after excising the bony connection, excision of the dens and the anterior arch of the atlas can provide adequate decompression. An outward-bulged dural sac is considered an indicator of effective decompression.

After successful excision of bony connections of the atlantoaxial joint or the anterior arch of the atlas and the dens, anterior or posterior atlantoaxial arthrodesis should be performed. For cases of successful reduction after release and placing screws, TARP fixation can be performed. For cases with successful reduction after release but failed screw placement, posterior atlantoaxial or occipitocervical arthrodesis should be performed. For cases with failed reduction after release, posterior atlantoaxial or occipitocervical arthrodesis should be performed.

Computer-aided design and rapid prototyping play an important role in the reduction and correction of complicated abnormalities. A 1:1 three-dimensional rendering is fabricated to aid the surgeon in real-time visual representation of the surgical plan.
prototype immediately preoperatively can provide a 3-dimensional reconstruction of lesions. Simultaneous surgery can be performed after reconstruction to simulate the bony resection, implant selection, and screw insertion.

For patients with a lesion located higher, the conventional transoral approach does not provide enough exposure, and an extended transmaxillary approach after maxillarotomy should be performed. When trismus as a result of various etiologies precludes normal exposure of the posterior pharyngeal wall, the extended transmandibular approach can achieve adequate exposure of the posterior pharyngeal wall.

The authors observe the following principles for surgical treatment based on their clinical classification: (1) the function of the atlantooccipital joint should be preserved as much as possible; (2) C1–C2 arthrodesis is recommended for RAAD; (3) TARP fixation is recommended for IAAD; and (4) anterior or posterior decompression with anterior or posterior fixation is recommended for FAAD.

CONCLUSION

The authors propose a classification system for atlantoaxial dislocation based on the severity and difficulty of reducing the atlantoaxial joint. The classification system assists with decision making regarding therapeutic options. Transoral atlantoaxial reduction plate fixation and posterior atlantoaxial screw–rod fixation are commonly performed to address atlantoaxial dislocation.

REFERENCES