A novel technology for the treatment of irreducible atlantoaxial dislocation by transoral anterior approach: Mini Compressive Cervical Frame with Lateral Mass Cage

Xiao-bao Zou¹, #, Yu-peng Zheng², #, Hong Xia¹, Qing-shui Yin¹, Zeng-hui Wu¹, Min Yang¹, Xiang-yang Ma¹, *

Abstract

Objective  To investigate the clinical effect of transoral anterior anastomosis with C-JAWS and lateral joint cage for the treatment of irreducible atlantoaxial dislocation. Method  From June 2012 to June 2015, 20 patients with irreducible atlantoaxial dislocation admitted to our hospital were included. Cervical X-ray, CT and MRI scans were utilized for the assessment of atlantoaxial dislocation and spinal cord compression before and after operations. The ADI was measured before and after the surgery, and the neurological status was assessed using JOA score. Regular follow-ups are conducted based upon X-ray, CT evaluation of reduction, internal fixation and fusion. Results  Twenty patients underwent surgery successfully without neurovascular injuries. One patient complained of neck discomfort and another complained of throat foreign body sensation, while both were relieved after symptomatic treatments. ADI improved from 8.88 ± 2.13 mm to 1.53 ± 1.55 mm and the difference was statistically significant (t= 14.471, P = 0.000) before and after surgery. The JOA score improved from 10.60 ± 1.23 preoperatively to 14.65 ± 1.95 postoperatively and the difference was statistically significant (t= -16.480, P = 0.000) before and after surgery. Follow-up period is from 3 to 24 months with an average of 12 months. Cervical X-ray and CT showed no recurrence of dislocation. Cage locations were satisfied, and C-JAWS were fixed well. Bony fusion was gained from 3 to 6 months after the operation. Conclusions  Transoral anterior C-JAWS plus lateral joint Cage surgery is an effective and alternatively operative method for the treatment of irreducible atlantoaxial dislocation.

¹.Department of Orthopedics, Guangzhou General Hospital of Peoples Liberation Army, Guangzhou 510010, Guangdong, PR China.
².Department of Orthopedics, Huizhou First People’s Hospital, Huizhou 516001, Guangdong, PR China.
# These authors contributed to this work equally.
* Corresponding to Xiang-yang Ma, Department of Orthopedics, Guangzhou General Hospital of Peoples Liberation Army, Guangzhou 510010, Guangdong, P R China. Tel./Fax: +86 (020) 653534. E-mail: maxy1001spine@126.com.
Introduction

Irreducible atlantoaxial dislocation may have a variety of causes, such as congenital malformations, trauma, tumors etc. It often leads to spinal cord compression resulting in nerve damage or death, which needs surgical treatments [1]. The purpose of surgery is to reduce, decompress, fix, and fuse the atlantoaxial joint by means of anterior or posterior surgical approaches [2]. Transoral surgery has been gradually widely used with the continuous developments of upper cervical spine surgery, treating irreducible atlantoaxial dislocation in one-time surgery. At present, the transoral atlantoaxial reduction plate (TARP) system developed by Yin et al [3-7] is the most widely used operation, which has a remarkable clinical effect. However, there are still many defects of this system in its applications. In this study, we tried a novel approach for transoral surgery using mini compressive cervical frame (C-JAWS) combined with lateral joint cage for the treatment of 20 patients with irreducible atlantoaxial dislocation in order to explore its initially clinical efficacy.

Materials and Methods

Patients

From June 2012 to June 2015, 20 patients with irreducible atlantoaxial dislocation admitted to our hospital were enrolled, including 10 patients with pure irreducible atlantoaxial dislocation, 2 patients of them old odontoid fractures, 2 patients with recurrent old atlantoaxial dislocation after posterior operation (internal fixation has been removed), 6 patients with basilar invagination combined with atlantoaxial dislocation, and 2 patients with recurrent basilar invagination combined with atlantoaxial dislocation after occipitocervical fusion. There were 12 males and 8 females, with ages ranging from 8 to 41 years old. Patients showed different clinical symptoms with numbness (17/20, 85%), dysxia (10/20, 50%), occipital neck pain (15/20, 75%) and partial paralysis (4/20, 20%) (Table 1).

Preoperative Evaluation

All patients underwent preoperative cervical X-ray, CT and MRI examination to confirm the diagnosis. They were treated with one week of preoperative skull traction with traction weight of 4-12 kg. The atlantoaxial of 20 patients could not be reset, and they were all diagnosed as irreducible atlantoaxial dislocation. Preoperative MRI showed that they suffered C1/2 horizontal spinal cord ventral compression. Their preoperative JOA score was 10.60 ± 1.23 and ADI was 8.88 ± 2.13 mm.

Surgical Techniques

Under general anaesthesia with transnasopharyngeal intubation, the patient was positioned supine with skull traction of 4-12 kg. After conventional oral cleaning, the face and oral and pharyngeal cavities were disinfected repeatedly with an iodophor, normal saline, hydrogen peroxide, and chlorhexidine before and after placement of the surgical drapes. A longitudinal incision of about 3-4 cm was made in the median posterior pharyngeal wall to incise the mucosa and muscle and expose the anterior structure of
the C1-C2 vertebrae after subperiosteal exfoliation. To achieve an ideal reduction of C1-C2 in patients with atlantoaxial nonfusion or partial fusion, it is important to sufficiently release the anterior scar tissue and hyperplastic callus of C1-C2 and to thoroughly resect the soft tissues between the odontoid and anterior arch of C1. After the articular capsule of the bilateral mass was cut open, the adherent intra-articular tissues and articular surface cartilage were removed with a curette and grinding drill. The lateral masses of C1-C2 were then levered in the posterosuperior and anteroinferior directions, respectively, so that the atlantoaxial joint was completely loosened. If the release was unsatisfactory, the extent of the release was expanded, even if it was necessary to cut the odontoid and alar ligaments or even the odontoid process. Then the joint articular surface of the bilateral mass was ground off with a high-speed bur in preparation for bone grafting. After the trial mode, appropriate size of cervical anterior cage was selected. After cage being dressed properly by grinding drill, autologous iliac cancellous bone was put into the cage, which was then put into the bilateral lateral joints. After inserting the cage, the joint space was expanded to further reset atlantoaxial. Then the nail point on atlantoaxial was determined and two right size C-JAWS were chosen and putted into the front of the bilateral cage. After opening C-JAWS arms on both sides, C-JAWS became diamond shaped and pressured the joint space. If C-JAWS and cage were checked to be in good positions through perspective of C-arm X-ray machine, then the muscular and mucosal layers of the incision were sutured with nonabsorbable silk sutures.

**Postoperative Management and Follow-up**

After surgery, the nasal trachea cannula was removed in 24~48 h, and the nasogastric feeding tube was removed in 7 days. Oropharyngeal ultrasonic nebulisation and 0.02% chlorhexidine acetate gargling were performed 3-5 times daily until 7 days. Postoperative intravenous antibiotics were applied for 3 days. The flexion-extension lateral X-ray radiographs, CT scans and MRI scans were obtained 1-week postoperatively and then at each follow-up. The patients' neurological status was evaluated using the JOA scoring system. Bone fusion was confirmed by bone bridge formation showed on CT scan and no movements under dynamic cervical radiographs. Patients were asked to wear a rigid cervical collar for 3 months and were followed up preparation for bone grafting. After the trial at 3, 6 and 12 months and then once per year or mode, appropriate size of cervical anterior cage whenever needed.

**Statistical Analysis**

SPSS 19.0 software (IBM, Armonk, NY, USA) was used for the statistical analysis. Measurement data were expressed as mean and standard deviation. ADI and JOA scores before and after surgery were compared using pair-wised t test, and P value < 0.05 was considered statistically significant.

**Results**

All patients successfully completed the operations, which last for 90-300 min with an average of 156 ± 69 min. The bleeding amount was 50-
250 ml, with an average of 9l ± 57 ml. There was no spinal cord or vascular injuries during the operations. After the surgery, one patient complained neck discomfort and one patient complained of throat foreign body sensation, while both got relieved after symptomatic treatments. Postoperative imaging showed that 18 cases of atlantoaxial reduction are satisfactory. 2 cases of atlantoaxial reduction are not perfect (Figure 1 and 2). Spinal ventral compression improved significantly in all cases. ADI improved from 8.88 ± 2.13 mm preoperatively to 1.53 ± 1.55 mm postoperatively and the difference was statistically significant (t= 14.471, P= 0.000) before and after surgery (Table 2). The follow-up period is from 3 to 24 months with an average of 12 months. Cervical X-ray and CT showed no recurrent dislocation, satisfied cage locations and was well fixed C-JAWS. Bony fusion was gained after the operation (Figure 1 and 2).

Table 1. Clinical Symptoms in the 20 Patients Before Surgery

<table>
<thead>
<tr>
<th>Clinical Symptoms</th>
<th>No. (%) of Patients</th>
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<tbody>
<tr>
<td>Numbness</td>
<td>17 (85%)</td>
</tr>
<tr>
<td>Dystaxia</td>
<td>10 (50%)</td>
</tr>
<tr>
<td>Occipital and neck pain</td>
<td>15 (75%)</td>
</tr>
<tr>
<td>Partial paralysis</td>
<td>4 (20%)</td>
</tr>
</tbody>
</table>

Table 2. Pre- and Postoperative Clinical Data of 20 Patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADI (mm)</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>8.88 ± 2.13</td>
</tr>
<tr>
<td>Postoperative</td>
<td>1.53 ± 1.55</td>
</tr>
<tr>
<td>t</td>
<td>14.471</td>
</tr>
<tr>
<td>P</td>
<td>0.000</td>
</tr>
<tr>
<td>JOA score</td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.60 ± 1.23</td>
</tr>
<tr>
<td>Postoperative</td>
<td>14.65 ± 1.95</td>
</tr>
<tr>
<td>t</td>
<td>−16.480</td>
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<tr>
<td>P</td>
<td>0.000</td>
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Discussion

Traditional method of surgical treatments for irreducible atlantoaxial dislocation usually employ the transoral anterior release plus posterior screw-rod reduction fixation fusion [8-10]. However, the integration of anterior and posterior surgery is more traumatic. And in the case of extreme atlantoaxial instability, body position conversions will suffer the risk of nerve damage [7]. In addition, for some patients with dysplasia of posterior atlantoaxial anatomical
structures, placements of pedicle screw will have high difficulties, which will have high risks of damaging the vertebral artery and nerves [11-15]. C1 lateral screw [16-18] and C2 lamina screw [19-23] can only provide a limited extent of pulling reset, which often lead to poor reduction performance. And postoperative recovery of neurological function is not so ideal. Even for some of the patients, due to their dysplasia or missing of posterior atlantoaxial anatomical structures, the second surgical revision cannot achieve posterior placement of the screw. In those cases, downward expansions of the fixation and fusion segments are needed, which will result in serious loss of cervical activity range [24].

At present, for the treatment of irreducible atlantoaxial dislocation, transoral anterior surgery can accomplish reduction, decompression, fixation, and fusion at one-time, which is superior to the traditional anterior plus posterior surgery. The fixation approach of transoral anterior operation includes Harms plate, modified SAALP plate [25] and TARP system [26]. The most widely used TARP system is applied not only for fixation, but also for the atlantoaxial anatomical reduction via reset devices, which is the effective surgical approach for treatments of various irreducible atlantoaxial dislocation [27, 28]. However, the TARP system also has its disadvantages such as: (1) Comparing with the small oropharyngeal space, the volume of the TARP plate is relatively large and the implantation as well as fixation processes are relatively difficult and complicated; (2) TARP currently inserts autologous iliac into the atlantoaxial lateral X-ray showed atlantoaxial dislocation; (B-D) Preoperative CT scans showed old odontoid fracture with atlantoaxial dislocation; (E) Preoperative MRI showed C1 horizontal spinal cord compression and degeneration; (F-H) After surgery, X-ray and CT indicated basic atlantoaxial reduction, and C-JAWS and cage were in good position; (I) MRI showed significant improvement of C1 spinal cord compression after surgery; (J-L) X-ray and CT showed that well fixed C- JAWS, no recurrence of dislocation, and bony fusion in 6 months after the operation.

![Figure 1](image_url)

**Figure 1** | A male patient, aged 12, with irreducible atlantoaxial dislocation combined with an old odontoid fracture, underwent a transoral anterior C-JAWS surgery together with lateral mass cage surgery. (A) Preoperative cervical lateral X-ray showed atlantoaxial dislocation; (B-D) Preoperative CT scans showed old odontoid fracture with atlantoaxial dislocation; (E) Preoperative MRI showed C1 horizontal spinal cord compression and degeneration; (F-H) After surgery, X-ray and CT indicated basic atlantoaxial reduction, and C-JAWS and cage were in good position; (I) MRI showed significant improvement of C1 spinal cord compression after surgery; (J-L) X-ray and CT showed that well fixed C- JAWS, no recurrence of dislocation, and bony fusion in 6 months after the operation.
eral mass [29], while the lateral mass has a certain inclination angle on both sides and therefore bone graft displacement may occur when the bone graft is absorbed; (3) Severe osteoporosis patients may have occasions of screws loosening; (4) The implantation of TARP system requires good pharyngeal mucosa coverage, and for patients with thinner posterior pharyngeal mucosa, poor incision healing, incision infection, and pharyngeal foreign body sensation as well as other complications may occur [6, 27].

The volume as well as thickness of C-JAWS is smaller than that of traditional transoral anterior plates. C-JAWS is mostly used for anterior surgery of inferior cervical. Fiere et al [30] showed that C-JAWS has good biomechanical stability, which can support easy intraoperative implantation and can shorten the operation time. At present, there is no report of C-JAWS application to atlantoaxial surgery. And the application of atlantoaxial lateral mass cage can improve the fixation stability and graft fusion rate [31-37].

In this study, we originally tried to use transoral anterior C-JAWS combined with atlantoaxial lateral mass cage for the treatment of irreducible atlantoaxial dislocation and dissociative odontoid process, underwent an transoral anterior C-JAWS in combination with lateral mass cage surgery. (A-C) Preoperative cervical lateral CT showed basilar invagination, irreducible atlantoaxial dislocation and dissociative odontoid process; (D) Preoperative MRI showed C1 horizontal spinal cord compression; (E) Perspective during the surgery found that C-JAWS was placed well; (F-H) Postoperative X-ray and CT showed that atlantoaxial got basically reduction, and C-JAWS and cage were in good position; (I) Postoperative MRI showed there was significant improvement of C1 horizontal spinal cord compression; (J-L) After 12 months from the operation, X-ray and CT showed that well fixed C-JAWS, no recurrence of dislocation, and bony fusion.

Figure 2 | Patient is a child, 8 years old, with a basilar invagination, irreducible atlantoaxial dislocation and dissociative odontoid process, underwent a transoral anterior C-JAWS in combination with lateral mass cage surgery. (A-C) Preoperative cervical lateral CT showed basilar invagination, irreducible atlantoaxial dislocation and dissociative odontoid process; (D) Preoperative MRI showed C1 horizontal spinal cord compression; (E) Perspective during the surgery found that C-JAWS was placed well; (F-H) Postoperative X-ray and CT showed that atlantoaxial got basically reduction, and C-JAWS and cage were in good position; (I) Postoperative MRI showed that there was significant improvement of C1 horizontal spinal cord compression; (J-L) After 12 months from the operation, X-ray and CT showed that well fixed C-JAWS, no recurrence of dislocation, and bony fusion.
During fixation, which can make atlantoaxial lateral articular surface and cage fit closer to promote bony fusion; (3) C-JAWS has small bulk, so only small spaces are required for operation, which makes it easy to insert, and operation time is shortened and surgical infection rate is reduced in this regard; (4) Since C-JAWS occupies few space, it is easy to cover and suture the posterior pharyngeal muscle and mucous membrane, which could in theory reduce the rate of poor incision healing, infection, pharyngeal foreign body sensation and other complications; (5) It avoids combined posterior fixation, which can achieve transoral release, decompression, fixation, fusion, and reduce surgical trauma; (6) Instead of simple iliac bone graft, the power of opening C-JAWS from both side atlantoaxial lateral mass cage can open the joint space, with a reset function, and meanwhile, it has good biomechanical stability, which avoids the possibility of iliac bone graft displacement and improves graft fusion rate [29].

However, compared with TARP system, C-JAWS still has its own deficiencies, which mainly due to: (1) It has no reset effects, and it is less effective in maintaining the reset state; (2) Removal of the inverted-tooth nail is difficult once it has been inserted; (3) C1 will be pulled forward during the pressurizing, which will make the reset effect get lost. The results of our study in 2 patients showed that atlantoaxial reduction is not consummate from postoperative imaging. Possible causes for that are: (1) Part of the irreducible atlantoaxial dislocation after transoral release can be reset, but still there is a great recurrence force, and it is difficult to maintain the

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