Unilateral C1 Lateral Mass and C2 Pedicle Screw Fixation for Atlantoaxial Instability in Rheumatoid Arthritis Patients: Comparison with the Bilateral Method

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Objective: Bilateral C1 lateral mass and C2 pedicle screw fixation (C1LM-C2P) is an ideal technique for correcting atlantoaxial instability (AAI). However, the inevitable situation of vertebral artery injury or unfavorable bone structure may necessitate the use of unilateral C1LM-C2P. This study compares the fusion rates of the C1 lateral mass and C2 pedicle screw in the unilateral and bilateral methods.

Methods: Over five years, C1LM-C2P was performed in 25 patients with AAI in our institute. Preoperative studies including cervical X-ray, three-dimensional computed tomography (CT), CT angiogram, and magnetic resonance imaging were performed. To evaluate bony fusion, measurements of the atlanto-dental interval (ADI) and CT scans were performed in the preoperative period, immediate postoperative period, and postoperatively at 1, 3, 6, and 12 months.

Results: Unilateral C1LM-C2P was performed in 11 patients (44%). The need to perform unilateral C1LM-C2P was due to anomalous course of the vertebral artery in eight patients (73%) and severe degenerative arthritis in three patients (27%). The mean ADI in the bilateral group was 2.09 mm in the immediate postoperative period and 1.75 mm in 12-months postoperatively. The mean ADI in the unilateral group was 1.82 mm in the immediate postoperative period and 1.91 mm in 12-months postoperatively. Comparison of ADI measurements showed no significant differences in either group (p = 0.893), and the fusion rate was 100% in both groups.

Conclusion: Although bilateral C1LM-C2P is effective for AAI from a biomechanical perspective, unilateral screw fixation is a useful alternative in patients with anatomical variations.

Key Words: Atlantoaxial · Bilateral · C1–2 · Harm’s Technique · Instability · Unilateral.

INTRODUCTION

Atlantoaxial instability (AAI) may be caused by trauma, arthritis, tumor, infection, or congenital malformation. Atlantoaxial stabilization resulted from bony fusion is needed to correct deformities and prevent neurological impairment. The surgical method of C1–2 transarticular screw fixation was introduced by Margerl and has been the main technique for wire fusion of C1 and C2 vertebrae. However, fusion rates may be altered by the depth of the vertebral artery (VA) groove of the lateral mass and the width of the C2 pedicle. Additionally, screw fixation might be challenging due to the high risk of injury to the VA, which can lead to massive bleeding and cerebral infarction. Therefore, Goel and Laheri introduced C1 lateral mass and C2 pedicle screw fixation (C1LM-C2P), which was popularized by Harms and Melcher, to reduce the risk of injury to the VA. Furthermore, in the inevitable situation of injury to the VA or in the case of unfavorable bone structures, C1LM-C2P cannot be performed using the bilateral method. Therefore, the aim of this study is to compare the fusion rates of the unilateral and bilateral methods using the C1LM-C2P technique.

MATERIALS AND METHODS

Between March 2009 and December 2013, 25 consecutive patients in our institution underwent C1LM-C2P to address AAI.
due to rheumatoid arthritis. Among those patients, basilar invagination was found in two.

Preoperative radiologic imaging studies were performed to obtain accurate information on the anatomy of the atlas and axis. Cervical X-rays, including hyperextension and hyperflexion views, were obtained to confirm the instability of the C1–2 complex. The atlanto-dental interval (ADI) was examined to determine the instability status at the preoperative; immediate postoperative; and 1, 3, 6, and 12-month postoperative periods. Moreover, computed tomography (CT) scans with 1-mm slices were performed to examine the potential insertion pathway of the C1 lateral mass screw and C2 pedicle screw, and CT angiography in the area of C1–2 was used to visualize the pathway of the VA for examining potential anomalies and reducing the possible complication of VA injury. Magnetic resonance (MR) images were studied to evaluate cervicomedullary compression.

Posterior C1LM-C2P screw fixation, the surgical technique of Harms and Melcher\(^6\), was performed in all patients in this study group. After discharge, patients reported to an outpatient clinic at postoperative months 1, 3, 6, and 12 to measure ADIs as the index of bony fusion. The evaluation of bony fusion was performed 12 months after the operation. Bony fusion was defined as a bony bridge which was seen at the C1–2 inter-spinous space on lateral radiograph images, no difference of ADI between the immediate postoperative period and the 12 month time point, and no instrument failure during the follow-up period\(^21\).

**Operative technique**

After wide exposure of the C1–2 posterior structures, the starting point in the C1 lateral mass was formed with a high speed drill at the connection point of the posterior arch and the lateral mass. After tapping the drilled pathway, screws with a diameter between 3.5 mm and 4.0 mm were inserted into the lateral mass. Before marking the entry point of the C2 screw, the medial border of the C2 pedicle was identified to prevent screw malposition in the spinal canal. After identification of the transitional corner, which is the more cephalad portion of the lamina and C2 isthmus, an entry point was made 4 mm lateral and 4 mm caudal to the transitional corner using a drill. The direction was 20° to 30° medial and cephalad, with palpation of the medial border of the C2 pars interarticularis. After drilling and tapering, a polyaxial screw with the proper length and diameter was inserted. An interlaminar spacer and wiring between C1 and C2 were tightly fastened, and the rod was applied to the screw head.

**Statistical analysis**

Preoperative and postoperative ADIs were measured on lateral plain radiographs using a Picture archiving and communication system (PACS) and then compared side-by-side to evaluate the time of bony fusion and differences between unilateral and bilateral screw fixation. Statistical analyses were performed with SPSS version 18.0 (SPSS, Chicago, IL, USA). Non-parametric analysis was performed in the both unilateral and bilateral screw fixation groups. If the \( p \)-value was greater than 0.05, bony fusion was assumed. The Mann-Whitney U test was used to compare the bony fusion rate between the unilateral and bilateral screw fixation methods.

**RESULTS**

Unilateral C1 lateral mass and C2 pedicle screw fixation was performed in 11 patients (44%) in this study (Fig. 1A). The mean age of the unilateral screw fixation group was 53.1 years (range 30–74) with female predominance (90.9%). An anomalous course of the VA was the main reason for unilateral screw fixation, which was required in eight patients. The other three patients harbored a narrowed pathway of screw insertion. Meanwhile,
in the bilateral screw fixation group, the mean age was 55.9 years (range 40–72) with a female predominance (85.7%) (Table 1, Fig. 1B). Of the total patients, one showed VA stenosis compressed by the pedicle screw on digital subtraction angiography, but no other complications, such as neurologic impairment, massive bleeding, or infection, were found on further evaluation.

In the 11 patients in the unilateral screw fixation group, the preoperative mean ADI was 8.14 mm, and the mean immediate postoperative ADI was reduced to 1.82 mm. Moreover, measurements of mean ADI at 1, 3, 6, and 12 months postoperatively were 1.99 mm, 1.99 mm, 1.92 mm, and 1.91 mm, respectively. On the other hand, in the 14 patients in the bilateral screw fixation group, the mean preoperative ADI was 8.48 mm, and that at postoperative 1, 3, 6, and 12 months was 1.99 mm, 1.96 mm, 1.91 mm, and 1.90 mm, respectively (Table 1).

The postoperative ADI values at the immediate versus 1 month postoperative time points were not statistically different (unilateral group, \(p=0.241\) and bilateral group, \(p=0.520\)). Similar results were found in the immediate versus 6 month time points unilateral group, \(p=0.859\) and bilateral group, \(p=0.052\). Moreover, when comparing the whole follow-up period of 12 months for both techniques, no meaningful postoperative changes in ADIs were found, and atlantoaxial fusion was seen in all patients included in the study (100%). According to the Mann-Whitney test, there was no statistically significant difference between the unilateral and bilateral screw fixation groups \((p=0.893)\) (Table 2).

When evaluating bony fusion at 12 months, instrument-related failure was not noted in any case. Bony bridge between the interlaminar space of C1–2 was demonstrated on C1 scans in all patients. Differences in ADI between the immediate postoperative and 12 month time points were not statistically significant. Therefore, all enrolled patients achieved bony fusion without severe complications.

### DISCUSSION

AAI may be caused by trauma, arthritis, or congenital malformations\(^5,6\). Chronic nuchal pain with or without neurological deficits may be encountered, and improperly treated upper cervical cord injury may trigger severe neurologic impairment.

The surgical method of C1–2 complex fixation has been introduced by many surgeons, and bilateral transarticular screw fixation using the wiring technique of Gallie or Brooks-Jenkins has achieved the highest stability and stiffness\(^7,12\). However, bilateral transarticular screw fixation (TAF) is not always possible because of VA anomalies or fracture of the C1–2 complex\(^5,14\). Therefore, stability achieved through bilateral TAF has been compared with that of unilateral TAF in a previous study. Hue et al.\(^14\) mentioned that there were no differences in fusion rate as measured by AAI may be caused by trauma, arthritis, or congenital malformations\(^5,6\). Chronic nuchal pain with or without neurological deficits may be encountered, and improperly treated upper cervical cord injury may trigger severe neurologic impairment.

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To overcome the major complication of vascular and neural injuries, C1LM–C2P was introduced by Goel and Laheri in 1994 and modified by Harms and Melcher in 2001\(^15,20\). The superiority of C1LM–C2P fixation compared to TAF is a lower risk of VA injury due to the use of individual screw systems. The pathway of the screws in the TAF method, which crosses C2 through C1, is relatively complex and narrow compared with that of C1LM–C2P, which uses individual screw systems. However, some problems have been encountered in bilateral screw

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**Table 1. Demographic characteristics and atlanto-dental interval of patients with atlantoaxial instability surgically treated with C1 lateral mass and C2 pedicle screw fixation either unilateral or bilateral method**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Unilateral</th>
<th>Bilateral</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (range)</td>
<td>53.1 years (30–74)</td>
<td>55.9 years (40–72)</td>
<td></td>
</tr>
<tr>
<td>Male:Female</td>
<td>1:10</td>
<td>2:12</td>
<td></td>
</tr>
<tr>
<td>Mean ADI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>8.14</td>
<td>8.48</td>
<td>0.534</td>
</tr>
<tr>
<td>Immediate postoperative</td>
<td>1.82</td>
<td>2.09</td>
<td>0.342</td>
</tr>
<tr>
<td>1 month after operation</td>
<td>1.99</td>
<td>1.99</td>
<td>0.993</td>
</tr>
<tr>
<td>3 months after operation</td>
<td>1.99</td>
<td>1.96</td>
<td>0.869</td>
</tr>
<tr>
<td>6 months after operation</td>
<td>1.92</td>
<td>1.91</td>
<td>0.931</td>
</tr>
<tr>
<td>12 months after operation</td>
<td>1.91</td>
<td>1.90</td>
<td>0.964</td>
</tr>
</tbody>
</table>

ADI: atlanto-dental interval

**Table 2. Statistical analysis between unilateral and bilateral groups on the basis of atlanto-dental interval measurement of bone fusion**

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Unilateral</th>
<th>Bilateral</th>
<th>(p) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate vs. 1 month</td>
<td>0.241</td>
<td>0.520</td>
<td></td>
</tr>
<tr>
<td>Immediate vs. 3 months</td>
<td>0.350</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>Immediate vs. 6 months</td>
<td>0.859</td>
<td>0.052</td>
<td></td>
</tr>
<tr>
<td>Immediate vs. 12 months</td>
<td>0.919</td>
<td>0.041</td>
<td></td>
</tr>
<tr>
<td>1 month vs. 3 months</td>
<td>0.959</td>
<td>0.346</td>
<td></td>
</tr>
<tr>
<td>1 month vs. 6 months</td>
<td>0.475</td>
<td>0.378</td>
<td></td>
</tr>
<tr>
<td>1 month vs. 12 months</td>
<td>0.260</td>
<td>0.140</td>
<td></td>
</tr>
<tr>
<td>3 months vs. 6 months</td>
<td>0.574</td>
<td>0.382</td>
<td></td>
</tr>
<tr>
<td>3 months vs. 12 months</td>
<td>0.574</td>
<td>0.300</td>
<td></td>
</tr>
<tr>
<td>6 months vs. 12 months</td>
<td>0.683</td>
<td>0.889</td>
<td></td>
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</tbody>
</table>

Mann-Whitney test \(p=0.893\)

There were no statistically significant differences in all of the comparison between unilateral and bilateral groups for the follow-up periods. \(p\) value is less than 0.05, the statistically significant difference can be found between two groups.
ever, these navigation systems have limitations with regard to accuracy when determining screw trajectory.ган


C2 lateral mass and C2 pedicle screw fixation can be performed if a neurovascular contraindication is predicted. In our study, by means of ADI changes, unilateral fixation showed similar strength to the bilateral fixation with bone fusion. Radiologic images, such as CT angiography with cervical three dimensional CT and MR images, should be performed to reduce the complications of C1LM-C2P prior to surgery.

CONCLUSION

ACKNOWLEDGMENTS

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