Bilateral C1 laminar hooks combined with C2 pedicle screws fixation for treatment of C1–C2 instability not suitable for placement of transarticular screws

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Abstract The study design described here is a posterior C1–C2 fusion technique composed of bilateral C1 hooks and C2 pedicle screws. In addition, the clinical results of using this method on 13 patients with C1–C2 instability are reported. The objectives are to introduce a new technique for posterior C1–C2 fusion and to evaluate the clinical outcome of using it to treat C1–C2 instability. From October 2006 to August 2008, 13 patients (9 men and 4 women) with C1–C2 instability were included in this study: 3 had acute odontoid fractures, 4 had obsolete odontoid fractures, 4 had os odontoideum and 2 had traumatic rupture of the transverse ligament. All patients underwent posterior atlantoaxial fixation with bilateral C1 hooks and C2 pedicle screws. The mean follow-up duration was 25 months (range 13–30 months). Each patient underwent a complete cervical radiograph series, including anterior–posterior, lateral, and flexion–extension views, and a computed tomographic scan. The clinical course was evaluated according to the Frankel grading system. No clinically manifested injury of the nerve structures or the vertebral artery was observed in any of these cases. Five patients with neurological symptoms showed significant improvement in neurological function postoperatively. Bony fusion and construction stability were observed in all 13 patients (100%) on their follow-up radiographs, and no instrument failure was observed. Bilateral C1 hooks combined with C2 pedicle screws can be used as an alternative

treatment method for C1–C2 dislocation, especially in cases not suitable for the use of transarticular screws. The clinical follow-up shows that this technique is a safe and effective method of treatment.

Keywords Atlantoaxial · Instability · Internal fixators · Spinal fusion

Introduction

Various posterior stabilization methods have been developed to manage C1–C2 instability, including wire, clamp, and screw techniques [1]. The recently developed C1–C2 fixation technique using C1 lateral mass screws and converging C2 pars screws is much more technically demanding than previous methods. In addition, it is not suitable for placement of C1 pedicle screws when the screw trajectory is broken and when anatomic anomalies are present [e.g., anomalous vertebral artery (VA), internal carotid artery (ICA), posterior arch, and lateral mass of the atlas] [2, 3]. We previously introduced a novel posterior C1–C2 fusion technique composed of C1 laminar hooks and transarticular screws for use in cases not suitable for C1 pedicle screws [4]. When properly performed, it can safely provide good bony fusion and satisfactory clinical results. However, the use of transarticular screws is not suitable for some patients because of unsatisfactory reduction, the presence of a high-riding VA, or failure to successfully implant screws during surgery.

To address this issue, we developed a supplementary method of C1–C2 stabilization using bilateral C1 hooks combined with C2 pedicle screws. Herein we describe the fixation technique and report the clinical results for 13 patients treated with the new technique.

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Materials and methods

Patients

From October 2006 to August 2008, 13 consecutive patients (9 men, 4 women) with atlantoaxial instability were included in this study. Their ages ranged from 32 to 65 years (average age, 48.5 years). Three patients had acute odontoid fractures which were not suitable for anterior odontoid screw fixation because of unsatisfactory reduction after skull traction, four had obsolete odontoid fractures, four had os odontoideum and two had traumatic rupture of the transverse ligament.

The use of transarticular screws was not suitable for these 13 patients for the following reasons: two patients had a medially located VA. In nine patients, attempts to implant transarticular screws during surgery were unsuccessful; if the position of the guide pin was found to be poor twice during the fluoroscopy operation, we had to abdicate the transarticular screw technique and use another fixation method. The last two patients had cervical kyphosis, which would aggravate spinal cord compression when placing the patients on the operation table.

All patients suffered from mechanical upper cervical neck pain and a neurological examination was performed. Preoperative Frankel grades were C degree in 2 cases, D in 3 and E in 8 (Table 1). All patients underwent functional radiographs in flexion and extension and lateral cervical roentgenograms before surgery. MRI revealed compression of the upper cervical spinal cord with or without intramedullary hyperintensity on T2-weighted images. A CT scan with sagittal and coronal reconstructions was used to assess VA and ICA anomalies. If we suspected the

presence of anomalies, MRI imaging of the VA was performed. Skull traction was performed for 1 week in each patient preoperatively (using 2.5–4.5 kg weights). Preoperative functional radiographs in flexion and extension were used to judge the situation for C1–C2 reduction.

Surgical procedure and postoperative care

The vertex fixation system was used during the surgery. All of the implants used were described in Guo and Ni [4]. The fixation system consists of cervical laminar hooks, polyaxial screws, and implants such as rods and lateral connectors. The polyaxial screws have a freedom of 60° of axile motion and 30° in other directions. Each polyaxial screw may be implanted independently and does not need to be preconnected to the rod. The lateral connector is able to connect screws that do not align to each other to the rod.

Under general anesthesia, the patient was placed in the prone position while maintaining C1–C2 reduction as much as possible; the reduction was confirmed with C-arm fluoroscopy. A midline incision was made from the occiput to C3, and the C1 facet posterior arch, C2 lamina, and C3 lamina were exposed. The C2 pedicle screws (diameter, 3.5 mm; length, 22–26 mm) were inserted using the technique described by Abumi et al. [5]. The laminar hook-testing module was used to strip away the soft tissue above and below the posterior arch of C1. The adept situation between the vertex laminar hood-testing module and the posterior arch of C1 was inspected. The laminar hook was placed so that it would hang on the posterior arch of the atlas. Connecting rods (diameter, 3.2 mm) were then loaded into the C1 laminar hooks and the C2 pedicle screw heads on both sides. For patients with poor reduction, we

Table 1 General information about the 13 patients in this study

Patient	Diagnosis	Direction of dislocation	Intermedullary hyperintensity on T2 images	Follow-up (months)	Initial Frankel grade	Follow-up Frankel grade	Graft bone status
1	Obsolete odontoid fractures	Anterior	No	30	E	E	Healed
2	Os odontoideum	Posterior	No	28	E	E	Healed
3	Acute odontoid fractures	Anterior	No	26	C	D	Healed
4	Os odontoideum	Anterior	No	26	E	E	Healed
5	Os odontoideum	Anterior	No	13	E	E	Healed
6	Obsolete odontoid fractures	Anterior	Yes	24	C	D	Healed
7	Acute odontoid fractures	Anterior	No	30	D	E	Healed
8	Traumatic rupture of the transverse ligament	Anterior	No	26	E	E	Healed
9	Obsolete odontoid fractures	Anterior	No	18	D	E	Healed
10	Obsolete odontoid fractures	Anterior	No	22	E	E	Healed
11	Traumatic rupture of the transverse ligament	Anterior	Yes	28	D	E	Healed
12	Os odontoideum	Posterior	No	30	E	E	Healed
13	Acute odontoid fractures	Anterior	No	24	E	E	Healed

adjusted the cervical in the hyperextension position in order to perform the atlas reduction. Finally, the nuts were twisted to achieve temporary fixation.

The caudal rim of the posterior arch of C1, the cranial edge of the C2 lamina, and the spinous process were decorticated using a high-speed drill. A bicortical bone graft from the posterior iliac crest was notched to fit on the decorticated posterior elements of the C1 posterior arch and the C2 lamina. The grafted bone has restricted extension and the hooks restrict flexion in the patient. Pliers were used to compress the inner fixation systems on the left and right sides simultaneously to lock the bone graft between the C1 posterior arch and the C2 lamina. In this compression process, the system can play the role of suspended reduction to the anterior dislocation atlas. Finally, the rod was cut to the appropriate size and fitted into the top of the C1 laminar hook and the top of the polyaxial transarticular screw. A claw-shaped temporary fixation instrument was used to stabilize the laminar hook while the connecting rod was fixed. Finally, the nuts were twisted to achieve fixation. The wound was closed in a standard fashion over a suction drain.

The patients were mobilized on the first postoperative day; they wore a Philadelphia collar for 3 months. A postoperative CT scan was performed to assess the position of the C1 hooks and C2 screws and the reduction of the dislocation. Patients were followed up prospectively at 6 weeks, 3 months, 6 months and 12 months after surgery, with assessment of neurological status and with plain antero-posterior and lateral cervical spine radiographs. CT scans with sagittal and coronal reconstructions were performed at 6 months after surgery to evaluate the fusion. The mean follow-up was 25 months (range 13–30 months).

Results

The mean duration of the procedure was 130 min (range 80–210 min) and the average estimated blood loss was 450 ml (range 180–750 ml). The mean length of C2 pedicle screws was 24 mm (range 22–26 mm). No vascular or neurological complications were noted. CT scans with sagittal and coronal reconstructions and flexion–extension, anterior–posterior and lateral cervical spine radiographs revealed bony fusion in all cases without screw or rod loosening or breakage (Fig. 1). Plain radiographs during follow-up showed no change in screw position or loss of reduction in any patient when compared with the postoperative radiographs. Overall, no instrument failures occurred in any patient. The patient with cervical myelopathy experienced partial neurological recovery at the 12-month follow-up. Postoperative Frankel grades were D degree in 2 cases and E in 11 (Table 1).

Fig. 1 A 34-year-old woman with atlantoaxial dislocation and os odontoidum was treated using bilateral C1 hooks and C2 pedicle screws. **a** Preoperative lateral plain film showing atlantoaxial dislocation and obsolete odontoid fracture. **b** MRI image showing the compression of the spinal cord. **c** AP, **d** lateral, **e** flexion and **f** extension cervical spine plain films and **g** CT scan obtained at day 90 after surgery demonstrating solid fusion with obvious bridging

Discussion

This paper introduces a fixation technique for posterior C1–C2 stabilization using bilateral C1 hooks combined with C2 pedicle screws for use in cases for which transarticular screws are not suitable. We performed this surgery on 13 patients, and the result was excellent bony fusion and clinical outcomes. Furthermore, no screw-related injuries of the VA or spinal cord occurred.

Various methods of fixation have been described and used in the treatment of patients with C1–C2 instability, but each has its shortcomings and defects. The Gallie and Brooks technique carries a neurological risk when sublaminar wires are passed under the C1 arch [6, 7]. The Apofix laminar clamp, which uses laminar hooks to fix the C1–C2 posterior structure, has little mechanical stability, but it is still a simple atlantoaxial posterior structure fixation method [8, 9]. The use of transarticular screw fixation offers biomechanical advantages, but it requires anatomic

reduction of atlantoaxial dislocation and high technical expertise of the surgeon [10].

The recently developed C1–C2 fixation technique that uses C1 lateral mass screws and converging C2 pars screws [11, 12] is technically demanding, and it is not suitable for placement of C1 pedicle screws when the screw trajectory is broken and when anatomic anomalies are present. Anatomic anomalies, such as anomalous VA or ICA, anomalous posterior arch, and the presence of a lateral mass in the atlas, have been reported [3]. Sometimes a broken C1 pedicle screw trajectory occurs, especially for surgeons without much experience with C1 screw placement. To address these problems, we combined the use of C1 laminar hooks with transarticular screws to treat an unstable bursting atlantal fracture and obtained satisfactory clinical result [2].

However, the use of transarticular screws is still not suitable for some patients, such as those with unsatisfactory reduction, the presence of a high-riding VA, or failure to successfully implant screws during surgery. Xiao et al. [13] reported a method that uses C2 pedicle screws and a plate combined with C1 titanium cable fixation to treat atlantoaxial instability for which placement of C1 screws is not suitable. However, the surgical procedures required are much more complicated than those of other fixation techniques, such as C1 hooks. In addition, C1–C2 fixation with posterior wiring does not provide adequate stability to resist rotation, thus the bone-fusion rate is low [14].

This paper describes a method of C1–C2 fixation that uses a hook-screw system, which is simple and safe. Reduction of atlantoaxial dislocation can be achieved during surgery for patients with poor reduction, as previously described; additionally, the fusion rate is improved because compression of the bone graft is considered to be a positive factor for fusion. In our cases the chance of pseudarthrosis was not high for the following reasons: The bone bed was carefully prepared and a modified block bone graft was inserted between the C1 posterior arch and the C2 lamina to restrict extension motion, and it was compressed during surgery. Furthermore, the patients were mobilized in a Philadelphia collar postoperation for 3 months. In addition, there were only 13 patients in our group; the rate of nonunion needs to be studied in a large clinical series.

The contraindications of this new technique include congenital spinal stenosis of C1–C2, failure of C1–C2 reduction, and absence or fractures of the C1 posterior arc. The premise for using this method is that the space between the dura sac and the C1 posterior arc is large enough to accommodate the C1 hook. Use of this technique is indicated only for C1–C2 dislocation due to trauma, congenital malformations or RA, failure of the Magerl technique, and the developmental tiny of C1 pedicle that not suitable for Goel technique.

We treated 13 cases of C1–C2 dislocation using this fixation technique from October 2006 to August 2008 and obtained excellent clinical outcomes. There were no spinal cord and VA injuries during surgery and no spinal cord or nerve deterioration after surgery. This indicates that the operation is safe. According to preoperative and postoperative Frankel grades, this supplementary fixation technique played an important role in improving nerve function. These clinical results confirm that the use of bilateral C1 hooks combined with C2 pedicle screw fixation is safe, provides good biomechanical stability, and can improve the patient's neurological function. However, this technique is still a two-point fixation method, and the biomechanical strength is lower than that of three-point fixation methods, such as transarticular screws combined with Gallie, so a neck collar is needed to enhance stability after surgery.

In conclusion, bilateral C1 hooks combined with C2 pedicle screws can be used as a new treatment for C1–C2 dislocation, especially for cases not suitable for placement of transarticular screws. The preliminary clinical follow-up data show that this method is safe and effective.

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