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Clinical Study

Clinical outcome of posterior C1–C2 pedicle screw fixation and fusion for atlantoaxial instability: A retrospective study of 86 patients

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ABSTRACT

We retrospectively studied the clinical results of posterior C1–C2 pedicle screw fixation and fusion for 86 patients diagnosed with atlantoaxial instability from January 2002 to January 2013. The study population included 48 men and 38 women, with an average age of 42.6 (range, 16–69 years old). The causes of atlantoaxial instability could be divided into traumatic fracture (44 patients), congenital malformation (17 patients), rheumatoid arthritis (15 patients), and other causes (nine patients). The mean follow-up duration was 33.9 months (range, 13–72 months). The average operative time was 133.0 min (range, 90–290 min), and the mean blood loss during the operation was 185.7 ml (range, 110–750 ml). No patient experienced neurological function worsening related to the surgical procedure. In addition, 63% of the patients who presented with neurological symptoms reported improvement after surgery. Screw placement and reduction was achieved satisfactorily in all the patients and their neck pain was greatly relieved. Plain radiography and CT scans indicated solid fusion after 12 months in all the patients. We suggest that C1–C2 pedicle screw internal fixation is a reliable method for treating atlantoaxial instability.

1. Introduction

When the cervical C1–C2 complex undergo various situations, such as congenital deformity, trauma, degeneration, tumor and infection, it would present excessive or abnormal activity under normal physiological load and exhibit a series of clinical manifestations, namely, atlantoaxial instability. Atlantoaxial instability could endanger the upper cervical cord and cause serious complications, such as neurological dysfunction, respiratory distress, or even sudden death [1,2]. In this case, most surgeons would prefer to reconstruct the upper cervical spine and preserve its physiological function with operation.

With great improvements in instrumentation and growing knowledge of C1–C2 anatomy and biomechanics, various posterior fixation techniques have been applied in the upper cervical spine, such as wiring technique [3], interlaminar clamps technique [4], transarticular screws technique [5], and screws-rods system technique [6]. Atlantoaxial screws-rods fixation is regarded to be a safer and more applicable technique than the others. The C1 pedicle and C2 pedicle screws technique from screws-rods system was first reported by Resnick and Benzel in 2002 [7], which could provide stronger pullout strength than C1 lateral mass screw fixation and successfully limit bleeding from the venous plexus and irritation to C2 nerve root [8–10]. The aim of this study is to investigate the clinical results of posterior C1–C2 fixation using C1 pedicle and C2 pedicle screws technique.

2. Materials and methods

With approval of our Institutional Review Broad, we retrospectively collected 86 patients who suffered from atlantoaxial instability and underwent posterior C1 pedicle and C2 pedicle screw internal fixation with fusion in our hospital from January 2002 to January 2013. An atlantodens interval (ADI) on radiographs of >3 mm was classified as atlantoaxial instability. Among the 86 patients, 48 were men and 38 were women, with an average age of 42.6 (range, 16–69 years old). The causes were various: 44 patients with traumatic fracture, 17 patients with congenital malformation, 15 patients with rheumatoid arthritis, and nine patients with other causes.

All the patients were applied with cervical collar protection and vital sign monitoring once admitted to our hospital. After stabilizing the condition, the patients underwent cervical X-ray and three-dimensional CT scans. For patients presented clinical manifestations of spinal cord injury, MRI was conducted to evaluate the spinal cord injury or degeneration degree. Skull

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traction was conducted if necessary before surgery. Neurological status was assessed with the American Spinal Injury Association (ASIA) classification for preoperative and postoperative evaluation. Neck pain was assessed with Visual Analogue Scale (VAS) scores. Bone grafting fusion condition and internal instrumentation stability were assessed with X-ray and CT scanning. Operative time and blood loss during operation were recorded as surgery trauma. Postoperative complications included neurological injury, vascular injury, cerebrospinal fluid (CSF) leak, internal fixation loosening, graft unfusion, and infection.

2.1. Surgical techniques

After general anesthesia, the patients were placed at prone position. A posterior midline skin incision was made from the occipital region to C3 spinous process. C1 pedicle Screws were placed in accordance with Tan's technique [11]. The entry point was 18–20 mm lateral to the midline and 2 mm superior to the inferior border of posterior arch. The direction of screw placement was perpendicular to the coronal plane and about 5° cephalad to the transverse plane. The entry point for the C2 pedicle screw was in the cranial and medial quadrant of the isthmus surface, with 20° to 25° in a lateral-to-medial and cephalad trajectory. All pedicle screws were monocortical. X-ray imaging during surgery was applied to establish the correct cervical alignment. After connecting rods were fixed, the cortex of posterior arch of atlas and lamina of axis were drilled rough and fused with iliac grafting bone. We used autologous bone grafts harvested from the posterior iliac crest in all the patients. For patients with spinal cord compression, excision of C1 posterior arch (did not exceed 15 mm to the posterior tubercle bilaterally) was conducted, followed by closing in layers and suction drainage. After operation, patients were instructed to wear a rigid cervical collar for 1 month.

3. Results

The average operative time was 133.0 ± 43.5 min (range, 90–290 min). The mean blood loss during operation was 185.7 ± 70.5 ml (range, 110–750 ml). During surgery, seven patients presented venous plexus injury, which were treated with bipolar coagulation in combination with tamponade. After surgery, four patients with C2 nerve root injury, one patient with urinary tract infection, and one patient with wound infection occurred. All complications were successfully managed with appropriate therapy within the optimal times.

Among the 86 patients included in this study, the mean duration of follow-up was 33.9 months (range, 13–72 months). No patient suffered from neurological deterioration at the last follow-up according to ASIA grade. Of the patients who presented neurological symptoms, 63% showed improvement. VAS scores at the last follow-up were reduced significantly compared with the preoperative values (1.5 ± 0.7 vs. 4.5 ± 2.3, $p < 0.05$). There were two patients with fusion failure, and bone graft fusion was achieved after revision surgery. Each patient with fusion showed evidence of solid fusion after 12 months as indicated by X-ray and CT scans (Fig. 1). General information of the patients is listed in Table 1.

4. Discussion

With the development in spinal surgery technology and constant renewal of inner fixation materials, atlantoaxial fixation and fusion have become one of the major methods for treating atlantoaxial instability. In 1939, sublaminar wires and structural bone grafting was firstly reported for atlantoaxial fixation and fusion. Although the approach was reasonably safe, it could only fix the posterior arch of atlas and vertebral plate of axis. It could not provide appropriate stability in axial rotation [12], and nonunion rate was up to 30%, in which case, additional external stabilization during the immediate postoperative period was often required [13]. Therefore, currently, wiring techniques are rarely used alone for atlantoaxial fixation. In 1992, Jeanneret and Magerl [5] first reported atlantoaxial transarticular screw fixation for C1–C2 stabilization, namely, Magerl transarticular screw technique. Atlantoaxial transarticular screw fixation could provide excellent stability and contribute to a high fusion rate. It was generally regarded as the "gold standard" of posterior atlantoaxial fusion [14]. Although effective, atlantoaxial transarticular screw fixation required preliminary reduction of the atlantoaxial joint, and its disadvantages included the potential risk of injury to the vertebral artery, spinal cord, and hypoglossal nerve [5,15]. To overcome these pitfalls, in 2001, Harms and Melcher introduced the application of a screw-rod system for C1–C2 mobile segment stabilization [6]. This Harms's screw-rod system included inserting screws in the C1 lateral mass and the C2 pedicle, each connected with a rod. This technique gained its popularity as it could provide excellent immobilization with fewer complications [16]. In 2002, after Harms's C1 lateral mass technique, Resnick and Benzel reported C1 pedicle screw fixation technique, which in essence inserted the C1 lateral mass screw via the posterior arch [7], thus enabling the application of longer screws with a greater bone contact area compared with C1 lateral mass screws. C1 pedicle screws showed superior resistance to pullout compared with lateral mass screws and could successfully avoid bleeding from the venous plexus or irritation to C2 nerve root [8,9,17–19]. Thus, the C1 pedicle and C2 screw pedicle technique has become popular ever since.

In this study, we applied C1 pedicle and C2 pedicle screws-rod system for treating atlantoaxial instability. There are various strategies for C1 pedicle screw placement, with screw placement success rate ranging from 50% to 92% [20]. Here we followed Tan et al.'s C1 pedicle technique [11]: the entry point was 18–20 mm lateral to the midline and 2 mm superior to the inferior border of posterior arch, which has been shown to achieve the highest screw placement success rate compared with other techniques such as those of Resnick et al. [21], Ma et al. [22], and Christensen et al. [23]. But in reality, due to the individual difference and the intraoperative position change, the concrete direction could be hardly made accurately. We suggest the C1 entry point to be the sudden narrowing point of posterior arch, and the direction to be perpendicular to the coronary plane, pointing to the anterior arch. For C2 pedicle screw fixation, the entry point was midway between the superior and inferior articular process, the direction of the screw was 15°–30° medial and 20°–25°cephalad. Of the total of 86 patients, no screw failures presented in our study. As the technique of C1 pedicle screw placement do not require complete exploration of C1 lateral mass, incidence of venous plexus injury, vertebral artery injury or C2 nerve root injury was lower compared with other studies [24]. Among the patients with C1–C2 pedicle screw fixation in this study, there were six patients (7%) with C1–C2 venous plexus injury and four patients (4.7%) with C2 nerve root injury, which mainly occurred in earlier years of the study. This could be attributed to the surgeons' lack of surgery skills at the early stage. We thus recommend careful interpretation of the preoperative CT scans and careful operation to avoid screws malposition, velles and nerve injury.

The screw-rod system provided superior bony fusion rate to other C1–C2 fixation techniques like posterior wiring technique and transarticular screw fixation technique. It successfully achieved C1–C2 bony fusion in 100% of the patients [6]. As indicated by our study, successful bony fusion of the posterior elements of the cervical vertebrae was achieved in 97.7% (84/86) of