A Posterolateral Approach to Occipitoatlantoaxial Ventral Lesions

A Report of the Long-term Follow-up of 23 Cases

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Study Design: A retrospective study of consecutive patient series.

Objectives: To report a technique of odontoidectomy using a transoccipitocervical posterolateral approach for occipitoatlantoaxial ventral lesions in a long-term follow-up study.

Summary of Background Data: Occipitoatlantoaxial malformation and old traumatic dislocation usually cause compression of the high cervical spinal cord from a variety of different directions and angles, leading to high morbidity. The main objective of treatment is to relieve the anteroposterior compression and to restore the stability of the occipitocervical region. Currently, there are 2 approaches to perform the surgical procedure: (1) posterior decompression by suboccipital and occipitocervical fusion and internal fixation; and (2) decompression by a transoral approach to an odontoid resection. However, there are some short points, which need to be changed, such as the incomplete decompression (the former), narrow view, cerebrospinal fluid leakage, and the high infection rates.

Methods: From 1999 to 2006, 23 patients with occipitoatlantoaxial ventral lesions were treated using a transoccipitocervical posterolateral approach for decompression. The procedure included an expansion of the foramen magnum, a resection of the posterior arch of atlas, a lateral occipitocervical epidural exposure to the odontoid and the C_2 vertebra, and an excision of the odontoid. Thus, an anteroposterior decompression and occipitocervical spinal fusion was achieved. Neurological function, daily living ability, and the work ability of patients were assessed in a follow-up study.

Results: A 28-year-old woman died of respiratory and circulatory failure 10 hours after operation. The remaining patients survived without postoperative infection. The neurological injury in 17 patients did not deteriorate, whereas 5 patients had decreased sensation in the upper limbs, and the elbow flexor muscle strength in 2 patients declined by 1 grade on the operation side. Short-term follow-up (3–6 mo, 22 cases) indicated that 19 patients recovered normal sensation with decreased limb muscle tension. Motor function was improved by >1 grade (5 patients with postoperative nerve injury recovered to preoperative levels or better). Long-term follow-up (> 4 y) of 15 patients (10 patients by clinic visit and 5 patients by correspondence) indicated that the occipitoatlantoaxial regions were stable without local discomfort or loss of nerve function. Fourteen patients were able to care for themselves and some patients regained their ability to work. One patient felt no significant improvement after surgery and had no improvement in the quality of life.

Conclusions: Transoccipitocervical posterolateral approach to occipitoatlantoaxial ventral lesions provides a broad and sterile operating field to perform anteroposterior decompression and occipitocervical spinal fusion simultaneously. Neurological improvement is significant, and the long-term follow-up results are satisfactory.

Key Words: occipitoatlantoaxial region, ventral lesions, posterolateral approach, treatment effect

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Occipitoatlantoaxial malformation is the abnormal development and dysplasia of the foramen magnum, atlas, axis vertebrae, nervous system, and surrounding soft tissues. Occipitoatlantoaxial malformation accounts for about 2%–9% of central nervous system diseases. With the popularization of computed tomography (CT) and magnetic resonance imaging (MRI), the detection rate of atlantooccipital malformation could be higher. Occipitoatlantoaxial malformation and old traumatic dislocation can cause compression of the high cervical spinal cord from a variety of different directions and angles, leading to a high morbidity. Patients can hardly maintain a normal life, even suffer from life threatenings. The main objective of treatment for such disorders is to relieve the anteroposterior compression of the spinal cord and to restore the stability of the occipitocervical region. Because this region is located in the central skull base surgery is difficult and mortality is high because of the deep location of the injury and the complicated anatomy.

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Currently, there are 2 approaches to perform the surgical procedure: (1) posterior decompression by suboccipital and occipitocervical fusion and internal fixation, and (2) decompression by a transoral approach to an odontoid resection. For the former technique, the surgical risk is relatively small; unfortunately, the decompression is not complete, and anterior compression still exists. The posterior decompression could result in the backward movement of the brain and the spinal cord, which will exacerbate the condition. The transoral approach can reduce the anterior compression but fails to reduce the posterior compression and restore the stability of the occipitocervical region. In addition, the narrow view, cerebrospinal fluid leakage, the high infection rates of the wound and intracranial areas, and additional complications are also problematic. The prolonged use of an external fixation for reconstruction because of poor stability is another drawback of this procedure.[1–4]

In 1997, in the perspective of applied anatomy, we explored the resection of the odontoid process using a transoccipitocervical posterolateral approach to achieve anteroposterior decompression and to restore the stability at the same time.[5] From 1999 to 2006, we treated 23 cases with the posterolateral approach for occipitoatlantoaxial lesions (malformations and old injury). The treatment efficacies in these patients were assessed by a follow-up study and are summarized below.

MATERIALS AND METHODS

A total of 23 patients were included in study, including 12 males and 11 females, aged from 13 to 68 years with an average age of 35.5 years. The duration of the disease ranged from 2 months to 10 years (mean 2.15 y). One patient presented with an atlas tumor. Nineteen patients presented with basilar invagination: 3 patients had occipitocervical fusion, 1 patient had occipitocervical fusion and an atlantoaxial dislocation, 1 patient had dens dislocation, 1 patient had cervical fusion, 7 patients had atlantoaxial dislocation, and 6 patients had Arnold-Chiari malformation. Three patients had an old odontoid fracture with atlantoaxial dislocation. Two patients received suboccipital decompression but failed occipitocervical fusion. Except for 6 patients with a minor head-fall history, the etiologies and gradual exacerbation of the condition in the remaining patients were unclear. Fifteen patients had occipitocervical discomfort and restricted movement due to pain. Seventeen patients had limb numbness, weakness, and gait ataxia. Three patients had urinary retention. Two patients had cough and could not speak clearly. All patients suffered from a diminished shallow physical sensation below C3-C4, high muscle tension, and tendon hyperreflexia. The limb muscle strength was graded as III–IV in 8 patients, and was graded as IV in 15 patients. Fifteen patients were positive for bilateral Hoffmann's sign or Babinski's sign.

Indications for operation were the following: (1) congenital malformation of the atlantooccipital region with a significant compression of the spinal cord; or (2) atlas dislocation with poor skull traction and a significant compression of ventral. All the operations were performed in the Department of Orthopedics, West China Hospital of Sichuan University.

Surgical Procedures

Position, Exposure, and Decompression of the Foramen Magnum

The patient was placed in a lateral position (symptomatic side facing up) tilting to the ventral by 10–15 degrees. Skull traction was maintained during surgery if any.

A level connection line was drawn from the ear mastoid to the occipital protuberance, and down from the midpoint of the line, a longitudinal arc of 10–15 cm length was drawn. For exposure of the occipital protuberance, a transverse extension of the up-segment of the incision to form a "フ" shape was performed (Fig. 1). Along the incision, the trapezius, head and neck splenius, semispinalis muscle, and other rear neck muscles were longitudinally separated. The external occipital protuberance, foramen magnum, posterior arch of the atlas, and structures behind C_2-C_3 were exposed. For patients with foramen magnum stenosis and severe posterior compression, the postmargin of the foramen magnum and the posterior arch of the atlas were excised to relieve the oppression of the backbone. A "Y"-shaped or mesh-shaped incision was used for the thickened dura of the posterior margin of the foramen magnum and the arch of the atlas. For patients associated with cerebellar almond-shaped herniation, a resection of the cerebellar tonsils, dural repair, and cistern formation were performed.

Odontoid Resection

The posterior arch on the atlas on the operation side was cut in a forward-to-transverse manner. The forward cut detached the C_2 lamina and the transverse and lateral atlantoaxial joints (Fig. 2). The vertebral artery was exposed from the C_2 transverse foramen. After these procedures, posterior decompression was achieved. A gentle backward retraction of the dura with a nerve retractor and a forward retraction of the vertebral artery and the C_2 nerve root were performed, thus exposing the C_2 vertebra, the posterior odontoid, and the clival skull base. If the C_2 nerve root could not be retracted, it was cutoff with a sharp blade.

The C_2 odontoid on the operated side was ground and cut gradually to the opposite side with an infinitely variable spherical 4-mm-diameter burr to achieve anterior decompression. Patients with no atlantoaxial dislocation but only an upper odontoid inside the brain required the grinding to maintain atlantoaxial stability and to achieve anteroposterior decompression.

Occipitocervical Fusion Surgery

For patients with atlantoaxial dislocation and occipitocervical instability, an occipitocervical fusion and internal fixation were performed simultaneously.

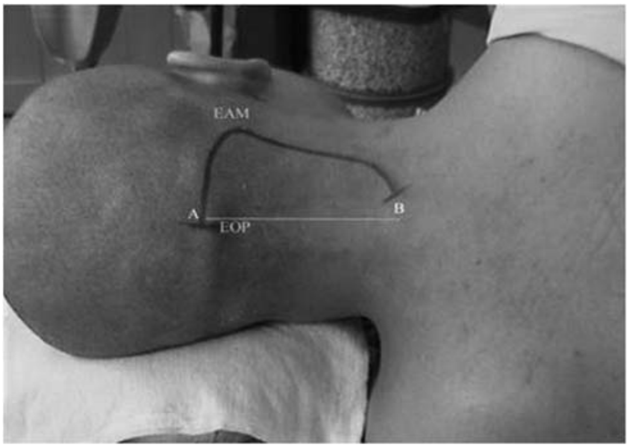

FIGURE 1. Schematic diagram of the incision. A level connection line was drawn from the ear mastoid to the occipital protuberance and down from the midpoint of the line in a longitudinal arc of approximately 10–15 cm in length. For occipitocervical fusion, a transverse cut extended the upper segment of the incision. EAM indicates ear mastoid; EOP, external occipital protuberance.

RESULTS

All patients underwent the expansion of the foramen magnum, resection of the posterior arch of the atlas and odontoid, and occipitocervical fusion with an iliac bone graft. A 28-year-old woman (4.35%) could not spontaneously breathe and required ventilator support. She developed circulatory failure 6 hours after surgery and died 10 hours postoperatively. The other patients survived with stable vital signs. One patient had a tracheotomy due to lung infection that was controlled within 20 days. One patient with vertebral artery injuries (too much lateral grinding and cutting of atlas) bled about 300 mL, which was blocked by compression for half an hour. Nineteen patients underwent resection of the C_2 nerve roots on the operative side for exposure of the odontoid, but the local skin behind the ipsilateral occipital was numb after surgery. Twenty-two patients (all patients except the one died) were free of postoperative infection. Seventeen patients' neurological injury did not aggravate after surgery, whereas 5 patients (21.74%) had decreased sensation in the upper limbs and the elbow flexor muscle strength in 2 patients (8.70%) declined by 1 grade after decompression surgery. Postoperative MRI and CT showed that the anteroposterior decompression was complete and that the spinal canal was significantly enlarged. Neurological function and an x-ray examination at the short-term follow-up (3–6 mo, 22 patients) indicated that 19 patients recovered well with normal sensation and decreased limb muscle tension; and muscle strength was recovered by 1 or more grades. The neurological injury in 5 patients aggravated postoperatively and then recovered to preoperative levels or better. Sensation in the muscles of 2 patients did not change. Three patients with dysuria were restored to normal, and 2 patients with coughing symptoms recovered. Eleven patients (47.83%) were able to live by themselves, and some patients regained the ability to return to work. An x-ray examination [some patients with 3-dimensional (3D) CT] confirmed the occipitocervical fusion.

The long-term follow-up study included 15 patients and was conducted 4 years after surgery. Ten patients went to the clinic for functional assessment and imaging studies, and 5 patients were reviewed by correspondence. The remaining patients were lost to follow-up because of migration and changes in mailing addresses. Fourteen patients could walk without local tenderness and discomfort of atlantooccipital region and could move without any sensation of pain except for neck activity. When compared with preoperative conditions, neurological function recovered significantly: sensations of the body were restored; muscle strength was graded as IV–V, muscle tension decreased, and precision hand movement improved. One patient felt no improvement in walking, limb sensations, flexibility; and no significant improvement in the quality of life. In 10 of the outpatients followed up, the x-ray and 3D CT showed that the relative positions of the occipital, atlanto, and axial were stable; the posterior ilial graft bone fusion was achieved; and the cervical lordosis was normal. In these 10 patients, 3D CT found no signs of ossification in the odontoid removal region, and that the spinal canal between the foramen magnum and axis was not obstructed or stenotic (Table 1). In this study, we had performed an Japanese Orthopaedic Association (JOA) cervical myelopathy evaluation for the 15 patients. It was found that the preoperative JOA number was lower, implying that the quality of life was not dissatisfactory and the ability of self-dependence was lowlihead. After the surgery, espe-

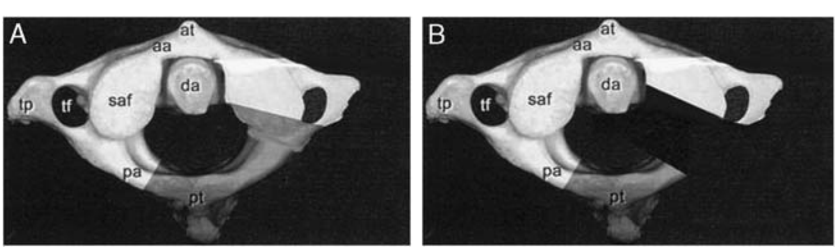

FIGURE 2. Schematic diagram of the surgical approach. A, The gray area indicates the part of the atlas that should be removed. B, The missing area displays the canal for odontoid resection. tp indicates transverse process; tf, transverse foramen; saf, superior articular facet; aa, anterior arch; at, anterior tuberosity; pa, posterior arch; pt, posterior tuberosity; da, dens apex.

TABLE 1. Demographic Data and Function Status of Patients Before and After Surgery

						Nervous System		Life Capability		Working Capability				
No.	Sex	Age	Diagnosis	Surgery	Follow-up Time	Before Surgery	After Surgery	Before Surgery	After Surgery	Before Surgery	After Surgery	Follow-up Imaging Inspection	Fusion	Discomfort
1	F	36	Basilar invagination and old atlantoaxial dislocation	11/1999	03/2009	Diminished sensation of limbs, muscle strength III–IV, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension increased slightly	No walk, no self-care	Walk and self-care	Lost	Light manual	No atlantoaxial dislocation, patency of occipitocervical spinal canal	Fusion	Poor performance of precision in hand movement
2	F	17	Basilar invagination	12/2005	05/2009	Diminished sensation of limbs, muscle strength III–IV, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension increased slightly	Difficulty for walk and self-care	Self-care	No school	School and light manual	Patency of occipitocervical spinal canal	Fusion	—
3	M	36	Basilar invagination	07/2006	04/2009	Diminished sensation of limbs, muscle strength III–IV, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension normal	Walk and self-care	Normal walk and life	Difficulty in manual	Normal	No atlantoaxial dislocation, patency of occipitocervical spinal canal	Fusion	Normal
4	F	62	Old odontoid fracture and atlantoaxial dislocation irreducible	06/2000	03/2010	Diminished sensation of limbs, muscle strength II, muscle tension increased	Diminished sensation of limbs, muscle strength II–III, muscle tension increased	No walk, no self-care	Slow walk, need nursing for life	Lost	Retired	Atlantoaxial dislocation (ADI about 5 mm), but spinal canal is patency (sagittal diameter 12 mm)	Fusion	Poor walk and life ability, need accompany to go out
5	M	33	Basilar invagination and atlantoaxial dislocation	02/2006	08/2009	Diminished sensation of limbs, muscle strength III–IV, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension normal	Restricted walk and self-care	Normal walk and life	Light manual	Mental and manual	Atlantoaxial dislocation improved, patency of occipitocervical spinal canal	Fusion	—
6	M	27	Basilar invagination	11/2000	04/2009	Diminished sensation of limbs, muscle strength III–IV, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension normal	Restricted walk and self-care	Normal	Difficulty in manual and mental	Mental and manual	No obvious atlantoaxial dislocation, patency of occipitocervical spinal canal	Fusion	Stated long-term of neck discomfort
7	F	55	Basilar invagination and atlantoaxial dislocation	07/2006	06/2009	Diminished sensation of limbs, class IV–V muscle strength, muscle tension increased	Normal sensation of limbs, muscle strength V, muscle tension normal	Self-care but a little difficult to walk	Normal walk and life	Light manual	Retired, nor mal community activities	Atlantoaxial dislocation improved, patency of occipitocervical spinal canal	Fusion	No discomfort
8	F	50	Old odontoid fracture and atlantoaxial dislocation	03/2001	06/2009	Diminished sensation of limbs, muscle strength III–V, muscle tension increased	Normal sensation of limbs, muscle strength, muscle tension normal	Self-care but a little difficulty for walk	Normal walk and life	Partial lost	Retired, normal community activities	No change of imaging of atlantoaxial, spinal canal is patency	Fusion	Long-term of neck discomfort, proposed removal of internal fixation

(*Continued*)

TABLE 1. Demographic Data and Function Status of Patients Before and After Surgery (*continued*)

9	M	36	Basilar invagination and atlantoaxial dislocation	02/2006	05/2009	Diminished sensation of limbs, muscle strength III–V, muscle tension increased	Diminished sensation of limbs, muscle strength III–V, muscle tension increased	Restricted walk and self-care	Same as before operation	Lost	Lost	No obvious atlantoaxial dislocation, patency of occipitocervical spinal canal	Fusion	Satisfactory with surgery
10	M	35	Congenital odontoid nonunion and atlantoaxial dislocation	09/2000	03/2009	Diminished sensation of limbs, upper limbs muscle strength II, muscle tension increased, lower limbs muscle strength III	Slightly diminished sensation of limbs, muscle strength IV–V, muscle tension increased slightly	No walk, no self-care	Walk and self-care	Lost	Light manual	Complete resection of odontoid, patency of occipitocervical spinal canal	Fusion	Stated long-term neck discomfort, proposed removal of internal fixation
11	F	41	Basilar invagination and C2-3 fusion and atlantoaxial dislocation	03/1999	Correspondence	Diminished sensation of limbs, muscle strength II–III	—	No walk	Walk and self-care	Lost	Light manual	—	—	Body tilt to the left side when walking
12	M	13	Odontoid fracture and atlantoaxial dislocation	10/1999	Correspondence	Diminished sensation of limbs, muscle strength I–II	—	Rotary walk	Walk and self-care	Partial school	School	—	—	Poor finger flexibility, slightly stiff gait
13	M	15	Basilar invagination and atlantoaxial dislocation	12/2002	Correspondence	Diminished sensation of limbs, upper limbs muscle strength II, lower limbs muscle strength III, muscle tension increased	—	No walk, no self-care	Walk and self-care	Lost	School	—	—	No discomfort
14	F	22	Basilar invagination and congenital occipital fusion	07/2000	Correspondence	Diminished sensation of limbs, muscle strength II–III	—	No walk	Walk and self-care	Lost	Light manual	—	—	No discomfort
15	M	13	Basilar invagination and atlantoaxial dislocation	2003	Correspondence	Diminished sensation of limbs, muscle strength II–III	—	Rotary walk	Walk and self-care	School	School	—	—	No discomfort

ADI indicates atlas-dens interval.

TABLE 2. The JOA Cervical Myelopathy Evaluation

	Upper Extremity Function	Lower Extremity Function	Sense	Bladder Function	Total Evaluation
Before operation	1.87 ± 0.92	1.33 ± 1.23	3.20 ± 0.94	2.47 ± 0.83	8.87 ± 2.90
Follow-up 3 mo	2.27 ± 0.88	1.93 ± 1.16	4.07 ± 1.10	2.87 ± 0.35	11.13 ± 2.33
Follow-up long time	3.33 ± 0.72	3.26 ± 0.80	5.22 ± 1.22	2.93 ± 0.26	14.80 ± 2.46

The improvement rate (group 1 and 3) of JOA was 72.94%.
JOA indicates Japanese Orthopaedic Association.

cially the long-term follow-up, the number of JOA increased significantly. The differences in the JOA number between group 1 (before surgery) and group 3 (long-term follow-up) were changed distinctly (Table 2). The improver rate (group 1 and 3) of JOA was 72.94%. All data suggest that the decompressed surgery had markedly improved the neural function of patients.

The follow-up study found that most patients felt discomfort in the back of the neck, especially with the larger internal fixations, and 8 patients explicitly proposed the removal of the internal fixation (Figs. 3, 4).

DISCUSSION

The major goals of surgical treatment for an occipitoatlantoaxial ventral lesion are decompression of the spinal cord and restoration of the stability of the occipitocervical region. The classic surgical treatment is anterior decompression using a transoral approach for the resection of the odontoid.[6–11] This approach has been widely reported in the literature and has been regarded as a gold standard, and the main advantage of this procedure is that the odontoid resection is performed under direct vision.[6,9,10,11] However, there are also many drawbacks, including the deep and narrow surgical field, poor exposure of the odontoid, cerebrospinal fluid leakage, intracranial infection, high incidence of oropharyngeal dysfunction, risk of neurological deterioration, and sudden death.[10,12] This approach also requires the removal of the anterior tubercle of the atlas, which decreases the stability of the atlantoaxial region. The high rate of complication and mortality of this approach discouraged physicians and patients. Odontoid resection using a lateral occipital condyles approach is a commonly reported surgical approach, and an improvement of this approach has been reported by others.[13,14] The main advantages of this approach are the narrower exposure of the odontoid and surrounding tissue and a sterile operating environment. It has been suggested that if $>50\%$ of the occipital condyles are removed, the fixation of the occipitocervical bones and the fusion to restore stability will be essential.[15] The potential risks of this approach are vertebral artery injury and brain stem ischemia, as well as damage to the side of the hypoglossal nerve. Although there are many detailed reports about methods and the details of vertebral artery exposure, the risks remain high.[14,16] Turkish scholars have reported good results using the occipitocervical lateral approach for the odontoid resection process.[17] The advantages were as follows: a large incision to create relatively shallow operation with clean surgical field; and the retraction of the vertebral artery that adequately ensured a safe resection of the odontoid. Surgical results and the short-term follow-up studies of 5 patients were reported here. However, this approach required the excision of bone around the lateral mass of C_1-C_2 and the corresponding vertebral artery to fully expose the vertebral artery. These procedures rendered the operation difficult, and local anatomy complexity increased the surgical risk. In addition, the operation did not perform the fusion and fixation of the occipital posterior cervical bones and the restoration of stability of the atlantooccipital region simultaneously.

Advantages of the Posterolateral Approach for the Removal of the Odontoid for Treatment of Occipitoatlantoaxial Ventral Lesions

Three problems were resolved using 1 operation: (1) excision of the foramen magnum and the posterior arch of the atlas that decompressed posterior spinal cord; (2) excision of the odontoid and the upper edge of the posterior axis that decompressed the anterior spinal cord; and (3) most importantly, the occipitocervical fusion restored the stability.[15] The anteroposterior decompression was satisfactory in this group of patients. There are several advantages of this approach: (1) a lateral position for patients can avoid the forward and backward movement of the atlantoaxial area, which is normally caused by position flipping and gravity during the traditional operation using a prone position that could increase the risk for spinal cord injury (the back-and-forth movement is greater than the left-right movement); (2) a wider surgical envelope compared with the previous approach with a shallower operation field; (3) the structures of the surgical field are simpler; the exposure process is a routine operation familiar to most surgeons and no specific exposure of the vertebral artery is required. Therefore, the risks for exposure are lower than previous approaches; (4) the surgical field is sterile so the risk of intracranial infection and wound infection are reduced; and (5) the broad fusion region and bilateral fixation can improve the stability which is critical to the subsequent stabilization.[18,19]

The Possibility of Avoiding Spinal Cord Injury Using the Posterolateral Approach

Anatomic studies suggest that after the cutting of the C_2 nerve, a light retraction of the dural sac between the C_2 ganglion and the atlantoaxial joint can expose the odontoid (after posterior decompression, the dural sac can be easily retracted).[2] It has been reported that

FIGURE 3. Data of patient no. 3. Patient no. 3 is a 36-year-old male. Operation time: July 2006. Diagnosis: basilar invagination. A, Preoperative computed tomography (CT) and magnetic resonance imaging (MRI) shows long odontoid into the foramen magnum caused the compression of the medulla oblongata and an enlargement in the cervical region in the spinal cord. B, Postoperative x-ray, CT, and MRI shows that bone graft and plate fixation were satisfactory. CT and MRI shows that the resection of the odontoid and the significantly enlarged neural canal. C, An x-ray and MRI performed 34 months after surgery shows that the canal of the occipital nerve was significantly enlarged; the signal from the local spinal cord and fusion was good.

FIGURE 4. Data of patient no. 1. Patient no. 1 is a 36-year-old female. Operation time: November 1999. Diagnosis: basilar invagination with an old atlantoaxial dislocation. A, Preoperative x-ray and magnetic resonance imaging shows long odontoid, spinal cord compression by the odontoid process caused by atlantoaxial dislocation. B, Postoperative 2-dimensional computed tomography (CT) shows that the odontoid had been removed, and the neural canal was normal. C, An x-ray and CT performed 10 years after surgery shows the fusion was completed; the occipitocervical and atlantoaxial regions were stable without further aggravation. CT indicates that the neural canal was normal after odontoid resection.

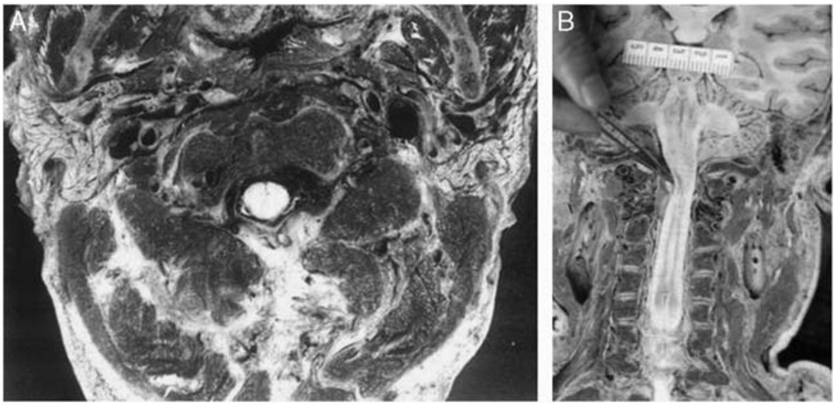

FIGURE 5. The feasibility of posterolateral odontoid removal. A, The upper cervical spinal canal and dural sac were relaxed, and the spinal cord diameter and anteroposterior diameter were about 1/2 of the sac. There were loose connective tissues around the dural sac. The odontoid was accessible by slightly pushing the dural sac from the atlantoaxial joints and the lateral mass of the atlas without spinal traction. B, The anterior branch of the C_2 nerve was involved in the innervation of the infrahyoid muscle groups. The posterior branch of the C_2 nerve was involved in the innervation of the occipital skin and the muscles between the occipital and the C_2. The second anterior branch of the cervical nerve or the whole nerve branch was cutoff and this did not have a significant effect on the function (the occipital bone and C_2 were fused after surgery and the muscle had no function).

amputating the C_2 nerve did not have a significant effect on the function [2,13,20] (Figs. 5A, B). For patients with an anterior dislocation of the atlas, the forward movement of the atlas facet is helpful for the exposure of the odontoid.[9] To expand the exposure of the odontoid and reduce the traction of the spinal cord, part of the posterior arch of the atlas below the vertebral artery was rubbed off in an upward fashion, and the inside part of the atlantoaxial joints was rubbed off using a forward movement. While grinding and cutting the posterior odontoid, a nerve retractor was used to protect the dura mater, thereby avoiding dura and spinal cord injury (a burr with a protection device would be preferred). While performing the odontoid resection, it was best to maintain the spontaneous breathing of the patients, so respiratory frequency and tidal volume could be observed to alert of a possible injury to the medulla oblongata.

The Results of the Long-term Follow-up Study

Patients were satisfied with the outcome of the surgery that resulted in a marked neurological improvement in 14 patients, including decreased muscle tension, a significant improvement in walking, and fine movement. As the patients get rid of their dependence on the nursing staff, they significantly improved their social participation. The hand movement was improved and the work ability was restored. The outcome of this study was comparable to that previously reported. The major postoperative discomfort for patients was a stiff neck and intermittent pain of the neck and shoulder. Eight of the 15 patients would like the removal of the posterior fixation. The resection of the odontoid and the partial posterior arch of the atlas decreased the stability of atlantoaxial region to some extent. However, the stability of the region after fusion was good enough to support the daily life and work of the patients.

CONCLUSIONS

When applying the transoccipitocervical posterolateral approach to treat patients with occipitoatlantoaxial lesions, the following points should be noted: (1) the odontoid is exposed and resected and a surgical field is fully exposed without complex anatomy; (2) the anteroposterior decompression and occipitocervical spinal fusion can be performed simultaneously; (3) the mortality and complication rates are relatively low; and (4) the results of the long-term follow-up regarding neurological function and stability are satisfactory.

REFERENCES

1. Gluf WM, Schmidt MH, Apfelbaum RI. Atlantoaxial transarticular screw fixation: a review of surgical indications, fusion rate, complications, and lessons learned in 191 adult patients. *J Neurosurg Spine*. 2005;2:155–163.
2. Lapsiwala SB, Anderson PA, Oza A, et al. Biomechanical comparison of four C1 to C2 rigid fixative techniques: anterior transarticular, posterior transarticular, C1 to C2 pedicle, and C1 to C2 intralaminar screws. *Neurosurgery*. 2006;58:516–521.
3. Melcher RP, Puttlitz CM, Kleinstueck FS, et al. Biomechanical testing of posterior atlantoaxial fixation techniques. *Spine*. 2002; 27:2435–2440.
4. Menezes AH, Traynelis VC, Gantz BJ. Surgical approaches to the craniovertebral junction. *Clin Neurosurg*. 1994;41:187–203.
5. Luo FM, Huang SQ, Pei FX, et al. The clinical anatomy of the posterolateral approach to dens axis. *Chin J Orthop*. 2000;20:75–78.
6. Crockard HA, Sen CN. The transoral approach for the management of intradural lesions at the craniovertebral junction: review of 7 cases. *Neurosurgery*. 1991;28:88–97.
7. Greenberg AD, Scoville WB, Davey LM. Transoral decompression of atlanto-axial dislocation due to odontoid hypoplasia. Report of two cases. *J Neurosurg*. 1968;28:266–269.
8. Hadley MN, Spetzler RF, Sonntag VK. The transoral approach to the superior cervical spine. A review of 53 cases of extradural cervicomedullary compression. *J Neurosurg*. 1989;71:16–23.
9. Menezes AH. The anterior midline approach to the craniocervical region in children. *Pediatr Neurosurg*. 1992;18:272–281.

10. Perrini P, Benedetto N, Guidi E, et al. Transoral approach and its superior extensions to the craniovertebral junction malformations: surgical strategies and results. *Neurosurgery*. 2009;64: 331–342.
11. Youssef AS, Sloan AE. Extended transoral approaches: surgical technique and analysis. *Neurosurgery*. 2010;66:126–134.
12. Bharucha EP, Dastur HM. Craniovertebral anomalies (a report on 40 Cases). *Brain*. 1964;87:469–480.
13. McLoughlin GS, Sciubba DM, Suk I, et al. Resection of a retropharyngeal craniovertebral junction chordoma through a posterior cervical approach. *J Spinal Disord Tech*. 2010;23:359–365.
14. Sen C, Shrivastava R, Anwar S, et al. Lateral transcondylar approach for tumors at the anterior aspect of the craniovertebral junction. *Neurosurgery*. 2010;66:104–112.
15. Frankel BM, Hanley M, Vandergrift A, et al. Posterior occipitocervical (C0-3) fusion using polyaxial occipital condyle to cervical spine screw and rod fixation: a radiographic and cadaveric analysis. *J Neurosurg Spine*. 2010;12:509–516.
16. Karam YR, Menezes AH, Traynelis VC. Posterolateral approaches to the craniovertebral junction. *Neurosurgery*. 2010;66:135–140.
17. Ture U, Pamir MN. Extreme lateral-transatlas approach for resection of the dens of the axis. *J Neurosurg*. 2002;96:73–82.
18. Anderson RC, Ragel BT, Mocco J, et al. Selection of a rigid internal fixation construct for stabilization at the craniovertebral junction in pediatric patients. *J Neurosurg*. 2007;107:36–42.
19. Puttlitz CM, Melcher RP, Kleinstueck FS, et al. Stability analysis of craniovertebral junction fixation techniques. *J Bone Joint Surg Am*. 2004;86-A:561–568.
20. Rhines LD, Fourney DR, Siadati A, et al. En bloc resection of multilevel cervical chordoma with C-2 involvement. Case report and description of operative technique.. *J Neurosurg Spine*. 2005;2: 199–205.