Anterior endoscopically assisted transcervical reconstruction of the upper cervical spine

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Abstract Anterior decompression and/or reconstruction can be an effective method for the surgical treatment of ventral spinal cord compression in the upper cervical spine. Options for traditional surgical approaches include transoral, transnasal, and extraoral. The risk and complex anatomy with the aforementioned approaches induces surgeons to use the transcervical route to expose the upper cervical spine. A traditional transcervical approach, however, carries the disadvantages of a deep operative field and steep trajectory. We performed a new endoscopically assisted method of anterior reconstruction for the treatment of ventral lesions in upper cervical spine. Six patients were treated from January 2005 to December 2007. Among those six patients, three patients were diagnosed with fixed atlantoaxial dislocations, two with plasmacytomas, and one with a giant cell tumor. All patients were treated by combined endoscopically assisted anterior reconstruction and posterior fusion. One patient with a fixed atlantoaxial dislocation sustained a cerebrospinal fluid leak in the immediate postoperative period, which spontaneously resolved 7 days after surgery. None of the patients had any neurologic deterioration following surgery, nor did any require admission to the intensive care unit for any reason. At the final follow-up, all patients were found to have evidence of a successful clinical outcomes and radiographic fusion. There were no implant failures or radiographic signs of implant migration or loosening. In conclusion, this study

demonstrates that an anterior transcervical decompression using endoscopic visualization combined with a posterior arthodesis can achieve good clinical and radiographic outcomes.

Keywords Endoscopy · Anterior transcervical approach · Upper cervical spine · Reconstruction

Introduction

Anterior decompression and/or reconstruction combined with a posterior fusion is an effective method for the surgical treatment of ventral spinal cord compression in the upper cervical spine [4, 10, 16, 19]. Anterior surgery can be performed via an open transoral–transpharyngeal approach using transmandibular, maxillary, and Le Fort osteotomies [22]. Approach-related complications with open procedures, however, are relatively frequent, and patients can often experience a prolonged postoperative recovery [11, 12]. In order to avoid the disadvantages of an open transoral procedure, endoscopically assisted transoral or transnasal anterior decompression techniques have more recently been introduced. The less invasive nature of these approaches and their efficacy have also been shown in some studies [2, 5, 7, 13, 14, 17, 23]. The complexity of the anatomy and risk of infectious complications must still be considered with these techniques.

The risks of transoral or transnasal surgery fosters the use of anterior open extraoral approach in the upper cervical spine. The extraoral approach involves prevascular or retrovascular retropharyngeal dissection [3, 8, 18], submandibular gland resection [20], or anterior transcervical retropharyngeal dissections [1, 6]. The advantages of an anterior open extraoral approach include straight-forward

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preoperative planning, avoidance of contaminated operative fields, and shorter postoperative recovery periods. These approaches have not been widely adopted due to difficulties with visualization secondary to the depth of the dissection narrow operative windows.

In this study, we introduce a novel approach in the upper cervical spine to avoid the potential pitfalls of the previously mentioned open approaches. Here, we present six cases of pathology involving the upper cervical spine to assess the technical feasibility and primary clinical outcomes using an endoscopically assisted transcervical anterior reconstructive technique.

Materials and methods

Patients

We conducted a retrospective cohort study at a single tertiary-care referral hospital. Approval was obtained from our Institutional Review Board before initiation of the study. Patients with a fixed atlantoaxial dislocation necessitating resection of the odontoid were included in the study as well as patients with pathologic lesions involving C2 without involvement of the anterior arch of C1. Those patients with an atlantoaxial dislocation reducible with an anterior release and those with involvement of the C1 anterior arch by tumor were excluded from this study. There were six patients treated using the endoscopically

assisted transcervical technique from January 2005 to December 2007. Among those six patients, there were four males and two females, with an average age of 44.2 years (range 21–69 years). Three patients were diagnosed with a fixed atlantoaxial dislocation. In the patients with a fixed atlantoaxial dislocation, reduction was attempted with skeletal traction and removal of the longus colli and the articular capsule of the atlantoaxial joint via an endoscopically assisted anterior transcervical approach. Failure of reduction necessitated an odontoidectomy and posterior occipitocervical fusion. In the tumor group, two patients presented with plasmacytomas treated with an anterior intralesional excision combined with a posterior C1–3 fusion, and one patient presented with a giant cell tumor managed with preoperative embolization, anterior intralesional excision, and posterior C1–3 fusion.

All of the patients presented with following symptoms to varying degree: suboccipital and axial cervical pain, limitation of cervical motion, extremity numbness, weakness, and gait disturbance. On physical examination, the patients also had varying degrees of paralysis, hyperreflexia, pathologic reflexes (e.g., Babinski sign) without sphincter dysfunction. The Visual Analog Scale (VAS) scores along with other parameters can be seen in Tables 1 and 2.

The interval from the onset of symptoms to surgical management ranged from 4 to 32 months, with the mean being 15 months. The presence of a neurologic deficit or myelopathic symptoms and lytic destruction of C2 were

Table 1 Clinical characteristics and neurological outcomes in atlantoaxial dislocation group

No case	Sex	Age	Diagnosis	Neck pain (VAS)		Bilateral babinski		Muscle weakness		Hypoesthesia		Fusion level	Follow-up time (month)	Complication
				Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop			
1	M	37	Fixed atlantoaxial dislocation	3.7	1.3	(+)	(–)	3	5	Yes	No	C1-3	36	No
2	M	21	Fixed atlantoaxial dislocation	3.3	1.1	(+)	(–)	4	4.5	Yes	No	C1-4	30	Cerebrospinal fluid leak
3	F	42	Fixed atlantoaxial dislocation	4.1	1.2	(+)	(–)	3	5	No	No	C1-3	24	No

Table 2 Clinical characteristics and outcomes in tumor group

No case	Sex	Age	Diagnosis	Neck pain (VAS)		Bilateral babinski		Muscle weakness		Hypoesthesia		Fusion level	Follow-up time (month)	Metastatic or recurrence
				Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop			
1	F	69	C2 Vertebral plasmacytoma	6.2	1.3	(+)	(–)	4.5	5	No	No	C1-3	39	No
2	M	55	C2 Vertebral plasmacytoma	6.5	1.5	(+)	(–)	3	4	Yes	No	C1-3	28	No
3	M	41	C2 Giant cell tumor	5.8	1.1	(+)	(–)	4	5	Yes	No	C1-3	47	No

indications for surgical treatment. All patients underwent an endoscopically assisted anterior decompression, reconstruction, fixation, and posterior fusion with instrumentation. Two of the tumor patients also underwent postoperative adjuvant radiotherapy.

Surgical technique

Surgical preparation

Following induction of general anesthesia and endotracheal intubation, the patients were placed in the supine position on a radiolucent table. A folded roll was then placed vertically between the scapulae to allow for neck extension (Fig. 1a). Skull traction with Gardner–Wells tongs was also

applied for the patients with atlantoaxial dislocations. Once positioning was deemed adequate, routine prepping and draping was performed.

Establishing operative portals

A 3- to 4-cm transverse incision was made just below the angle of the mandible along the anterolateral aspect of the neck with two-thirds of the incision medial to sternocleidomastoid muscle. Blunt dissection was carried out through the superficial fascia along the anterior border of the sternocleidomastoid muscle in-line with the skin incision. The sternocleidomastoid and carotid artery were mobilized laterally, and the suprahyoid muscles, trachea, and esophagus were retracted medially. The hypoglossal

Fig. 1 **a** The patient positioning supine with the neck in slight extension. The *red arrow* indicates the location of the skin incision. **b** The operative window is shown with retractors in place. The *white arrow* indicates the superior thyroid vessels, and the *blue arrow* indicates the transcervical retropharyngeal space. **c** The operative instruments are shown here. The *red arrow* indicates the endoscope, the *white arrow* indicates a special burr for endoscopic procedures, and the *blue arrow* indicates the suction. **d** The *white arrow* indicates the atlantoaxial facet joint after capsular release. **e** Resection of the odontoid using the burr: the *blue arrow* indicates the C1 anterior arch, the *white arrow* indicates the burr, and the *black arrow* indicates the remaining odontoid. **f** View through the endoscope after odontoid

resection. The *yellow arrow* points to the C1 arch, the *blue arrow* indicates the dura mater, the *black arrow* demonstrates the C3 vertebral body, and the *red arrow* points to the atlantoaxial joint. **g** The autogenous iliac bone graft shaped with a “V”-shaped notch. **h** Under-endoscopic visualization, the anterior reconstruction was completed using the structural bone graft and plate fixation. The *blue arrow* indicates the strut graft bridging the anterior arch of C1 to the cephalad endplate of C3. **i** A schematic diagram demonstrating the anterior reconstruction after odontoidectomy in the upper cervical spine: the *black arrow* indicates the C1 anterior arch, the *red arrow* indicates the iliac bone graft, and the *blue arrow* indicates the instrumentation

nerve and the superior thyroid vessels were then identified and protected (Fig. 1b). Once these structures were adequately protected, a 30° endoscope and manipulating instruments such as burr or curette were introduced (Fig. 1c).

Anterior release, odontoidectomy and reconstruction

The longus colli and the anterior arch of the atlas were exposed under endoscopic guidance. The longus colli was then cut and the articular capsule of the atlantoaxial joint incised using electrocautery. Next, the lateral masses of the atlas were exposed (Fig. 1d). The adhesions and bony overgrowth along the C1 anterior arch and lateral mass joint were thoroughly resected with a curette and high-speed burr which then allowed the odontoid to be visualized.

In the atlantoaxial dislocation group, an attempt was made to reduce the atlas by inserting a curette into the atlantoaxial joint and using it as a lever-arm under fluoroscopic guidance. In this study, none of the dislocations could be reduced in this manner, and therefore, it was deemed necessary to excise the odontoid to allow reduction.

In both groups, the odontoidectomy was started at the C2–C3 disc space, and the odontoid was removed with a high-speed drill (Fig. 1e). Under endoscopic visualization, a completed resection of the odontoid and C2 body could be performed while the dura mater was protected. The anterior arch of C1 was left intact throughout the process of the odontoidectomy. Extreme care was taken not to carry the dissection lateral to the atlantoaxial joint in order to prevent injury to the vertebral arteries and the ventral branch of the exiting spinal nerve root.

After the odontoidectomy and dural decompression was completed (Fig. 1f), tricortical structural autogenous iliac crest bone graft was harvested and a notch was fashioned in the graft (Fig. 1g). The graft was pre-drilled to facilitate the placement of anterior plate screws into the graft. The notch side of the graft was then inserted into anterior arch of C1, and the other side rested on the cephalad endplate of C3 or C4. An anterior plate was then used to stabilize the bone graft and vertebra (Fig. 1h, i).

Posterior arthrodesis

Posterior fixation was performed during the same anesthetic setting. In fixed atlantoaxial dislocation group, occipitocervical fusions were performed from occiput to C3 in two patients, and occiput to C5 in one patient due to lack of adequate fixation in the lateral masses. In the tumor group, two patients underwent posterior fusion with instrumentation C1–C3 and one patient C1–C4. For the

patient with a giant cell tumor, tumor involvement of the posterior elements of C2 necessitated resection prior to completing posterior arthrodesis. All of the posterior arthrodeses were achieved using additional autogenous iliac crest bone graft.

Postoperative care and evaluation

All patients were extubated immediately after completion of their procedure. All patients were advanced on the first postoperative day to a regular diet. A rigid cervical collar was worn for 6 weeks following surgery. In each case, the pre- and post-operative clinical evaluation included assessment of neck pain using the visual analogue scale (VAS), assessment of neurologic status both before and after surgery, and radiographic evaluation of fusion status. For tumor patients, we also evaluated the development of metastases or recurrence. The statistical calculations were obtained by using the SPSS17.0 for windows (SPSS Inc, Chicago, IL, USA). Paired *t* test was used for the comparison of preoperative and postoperative VAS data. Statistical significance was established at a *p* value less than 0.05.

Results

The mean operative time was 102 min (range 80–125 min) for the anterior portions of the operations and 95 min (range 75–120 min) for the posterior portion, while average blood loss was 320 mL (range 200–480 mL) and 240 mL (range 180–300 mL) for the anterior and posterior procedures respectively. The mean follow-up time was 34 months (range 24–47 months): 30 months (range 24–36 months) for the fixed atlantoaxial dislocation patients and 38 months (range 28–47 months) for the tumor patients. During the follow-up period, X-ray examination was performed in all patients. In addition, one patient underwent additional CT scan and one underwent magnetic resonance imaging. The radiographic results were evaluated by a senior radiologist and a spine surgeon who was not involved in the operative treatment of these patients. At the final follow-up, all patients were found to have evidence of a successful radiographic fusion.

In the fixed atlantoaxial dislocation group, preoperative VAS was on average 3.7 ± 0.4 (range 3.3–4.1) and improved to 1.2 ± 0.1 (range 1.1–1.3) postoperatively, there was significant statistical difference ($P = 0.007$). Sensory disturbance was present in two patients before surgery. After surgery, no patients experienced any sensory dysfunction. It was also notable that no patients developed new sensory deficits following surgical intervention. The degree of preoperative motor strength was on average 3.3

(range 3–4) on a 1–5 scale, which improved after surgery to 4.8 (range 4.5–5). Three patients who had positive Babinski signs preoperatively had resolution of this pathologic sign postoperatively.

In tumor group, preoperative VAS was on average 6.2 ± 0.4 (range 5.8–6.5) which improved to 1.3 ± 0.2 (range 1.1–1.5) postoperatively, there was significant statistical difference ($P < 0.001$). Two patients with sensory disturbance before surgery were improved to normal after surgery. The degree of preoperative motor strength was on average 3.8 (range 3–4.5) on a 1–5 scale, which improved after surgery to 4.7 (range 4–5). Three patients who had positive Babinski signs preoperatively had resolution of this pathologic sign postoperatively. Two patients underwent adjuvant radiotherapy 4 weeks after surgery. There was no evidence of metastases or recurrences at final follow-up.

In terms of complications, due to severe fibrosis adhesion between dura and odontoid, one patient with a fixed atlantoaxial dislocation (case #2) experienced a dural injury during the cord decompression. A cerebrospinal fluid leak occurred in this patient at postoperative day 1, the drainage volume from the wound was up to 350 ml. The patient felt no headache and cerebrospinal fluid leak spontaneously resolved 7 days after surgery by bedrest. No wound problems were encountered. There were no cases of infection, and none of the patients had any neurologic deterioration after surgery. No patients required admission to the intensive care unit for any reason. Furthermore, there were no implant failures or radiographic signs of implant migration or loosening (Figs. 2, 3). Last, no other complications occurred such as thromboembolism, dysphonia, or dysphagia in this study.

Discussion

Previously described difficulties with the approach to the upper cervical spine have led to the development of endoscopic techniques in anterior decompressions. Wolinsky et al. [22] described an endoscopic transcervical odontoidectomy for brainstem and spinal cord decompression in three patients with basilar invagination. In their study, there were no serious complications, no prolonged intubations, tracheotomies, or enteral tube feeding needed. McGirt et al. [15] performed an endoscopic transcervical odontoidectomy technique for the treatment of ventral pathology at the craniocervical junction in four pediatric patients. They also showed that there was no need for prolonged intubation or gastrostomy with an average hospitalization of 9 days and resolution or improvement of pain and/or neurologic deficits at final follow-up. Hsu et al. [6] described a case report of a 65-year-old with a recurrent chordoma of the upper cervical spine after previous combined anterior and posterior surgeries who underwent image-guided endoscopic anterior transcervical approach for tumor resection. The patient was discharged home on postoperative day 3 without any additional neurological deficits or evidence of cerebrospinal fluid leak.

The aforementioned studies along with a study by Baird et al. [1] showed that, when compared to endoscopic transnasal or transoral approaches, the transcervical anterior approach can provide an adequate operative field to perform an effective decompression without significant splitting or retraction of tissues. An anterior C2 resection without structural reconstruction and posterior fixation has been thought, however, to be insufficiently stable. A biomechanical study conducted by Scheer et al. [21] found

Fig. 2 A 42-year-old female with a fixed atlantoaxial dislocation and severe canal compromise. **a** The preoperative lateral X-ray. **b** The preoperative sagittal MRI indicating severe cord compression.

c, d Postoperative lateral and AP X-rays showing placement of anterior and posterior fixation. **e** Postoperative sagittal MRI demonstrating the decompression of the spinal cord

Fig. 3 Female, 69-year-old, diagnosed with a C2 solitary plasmacytoma. **a** A posterior fusion with instrumentation was performed C1-3 and same stage anterior reconstruction was performed with endoscopic assistance. **a** The preoperative lateral X-ray. **b** The preoperative coronal CT reconstruction demonstrating the lytic lesion in the C2 vertebral body. Of note, the right vertebral artery was encased in

tumor mass. **c** Preoperative sagittal CT reconstruction showing lack of posterior column involvement. **d, e** The postoperative lateral and AP X-rays demonstrating adequate placement of anterior and posterior fixation. **f** The postoperative sagittal CT reconstruction taken 19 months after surgery showing a solid anterior and posterior fusion

that either anterior C1-3 or clivus-C3 cages can provide immediate stability after C2 resection with supplemental posterior instrumentation.

Using endoscopy can decrease soft tissue trauma and provide adequate visualization, thus resulting in safer decompressions in the upper cervical spine [9]. The post-resection anterior reconstruction, however, can remain a significant challenge. Puttlitz et al. [16] demonstrated the biomechanical stability of a novel device consisting of a titanium mesh cage and T-shaped plate used in the upper cervical spine. Rhines et al. [19] performed a total spondylectomy of C2–4 through a transmandibular, retropharyngeal approach for the treatment of multilevel cervical chordoma with C2 involvement. Posterior decompression and occipitocervicothoracic fixation was performed first followed by a single-stage anterior decompression and reconstruction with a structural fibular allograft embedded into the residual dens. They then placed an anterior cervical plate from C1 to C5. Although Rhines et al. described a good clinical result with this approach, it can be problematic not only placing a long plate to C1 via a transcervical

anterior approach but by creating a potential instability after inserting a graft into the residual dens.

In this study, we described a novel method for anterior reconstruction using modified strut grafting and fixation. This technique differed from others in that the iliac crest bone graft was shaped as a V-shape at one end so that could be inserted onto anterior arch of C1 with the other end resting on the superior endplate of C3 or C4. The graft was pre-drilled to facilitate the placement of the anterior plate screws into the graft to provide immediate stability. The stability of the anterior arch of C1, strut bone graft, caudal vertebra, and plate construct were demonstrated by our cohort of patients. Our methods of bone-grafting was easily performed through an anterior transcervical approach assisted by an endoscope.

There were, however, some limitations to this study. First, there were a limited number of patients. Second, the anterior grafting technique requires an intact anterior arch of C1. In addition, we did not have a control group for comparison, such as patients undergoing a more traditional transoral odontoidectomy and fixation with other grafting

methods, such as strut bone graft or mesh cage, which is considered by many to be the current standard of care.

Our study indicates that anterior reconstruction with structural graft and anterior fixation through endoscopically assisted transcervical anterior approach and combined posterior fusion with instrumentation can be a safe and effective technique for the surgical treatment of lesions in the upper cervical spine. There were no significant perioperative complications. At the time of final follow-up, all patients had evidence of a radiographic union and maintenance of intact anterior and posterior fixation. Significant improvements in neurologic symptoms and motor function were also documented. Furthermore, there was no evidence of tumor recurrence, neurologic deterioration, infection, thromboembolism, dysphonia, or dysphagia.

Conclusion

This study presents an innovative surgical approach for the treatment of ventral lesions in the upper cervical spine. Under endoscopic visualization, anterior transcervical decompression and reconstruction with use of a modified “V” shaped bone graft with an anterior plate and posterior instrumentation can achieve successful clinical and radiographic outcomes.

Conflict of interest None.

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