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Combined transoral and endoscopic approach for cervical spine tumor resection

Jun Zhou, MD[a], Yong-Tian Lu, MD[b,*], Fei-Yan Lu, MM[b]

Abstract

This study aimed to explore the feasibility and clinical effectiveness of a combined transoral and endoscopic approach for the removal of benign cervical spine tumors.

First, we obtained detailed anatomical measurements of the atlantoaxial joint from 20 fresh cadaveric specimens and performed simulated surgeries with the combined transoral and endoscopic approach on 10 cadaveric specimens. Then, we applied the combined approach for the resection of benign cervical spine tumors in 8 patients at our hospital from October 2013 to October 2015. All patients underwent enhanced axial, coronal, and sagittal computed tomography (CT) examination before and after surgery. Preoperative 3-dimensional (3D) reconstruction and printing models were used in 5 cases.

On the basis of CT measurements of fresh cadaveric atlantoaxial anatomy and practical experiences from simulated surgeries on the cadaveric specimens with latex perfusion, cervical tumors were completely removed from 8 patients without complications. The average surgery time was 73 minutes, and the average intraoperative bleeding volume was 34 mL. The average hospital stay was 6.5 days. The average NRS score of patients was 2.25 points at 3 days postoperation. At the 12-month postoperative follow-up, the atlantoaxial vertebral bone had been largely repaired, and no recurrence was observed by cervical CT examination.

The combined transoral and endoscopic approach could be used safely and effectively to excise cervical spine tumors with substantial advantages, including direct surgical access, relatively simple operation, short operative time, quick postoperative recovery, a reliable curative effect, and few complications.

Abbreviations: CT = computed tomography, PVP = percutaneous vertebroplasty.

Keywords: cervical spine tumors, endoscopy, surgery, transoral approach

1. Introduction

A cervical spinal tumor is a growth that develops in the cervical spine or its adjacent structures. Metastatic tumors are the main source of cervical spinal cancer.[1–3] Cervical spinal tumors are usually asymptomatic and often misdiagnosed as cervical spondylosis until the development of spinal cord compression. In severe cases, paralysis, dyspnea, and other life-threatening symptoms develop at advanced stages.

Presently, the most effective treatment for cervical spinal tumors is surgical resection.[4] The main surgical methods can be classified as anterior, posterior, and combined approaches (anterior and posterior).[5] The most commonly used anterior approaches are the transoral approach through an oral mandibular splitting approach and the anterolateral approach. The posterior approach accesses the tumor through the ventral midline. Although the efficacy of surgical treatment for cervical spine tumors is certain, such surgeries can be traumatic and associated with complications such as damage to adjacent blood vessels, nerve injury, cerebrospinal fluid leakage, infection, throat irritation, and so on.[6,7] With the development of minimally invasive surgery, clinicians are now focusing on determining a way to safely and effectively expose and remove cervical spine tumors. Percutaneous vertebroplasty (PVP) was first used for the treatment of vertebral hemangiomas and recommended as one of the most promising minimally invasive surgical techniques.[8] However, disadvantages including incomplete tumor resection along the border due to a restricted window and the risk of postoperative infection still exist. Only limited reports have described surgical resection of cervical spine tumors via an endoscopic approach.

The aims of this study were to collect detailed anatomical data for the cervical spine by atlantoaxial computed tomography (CT) from 20 fresh cadaveric head specimens, to perform simulated surgery using the combined transoral and endoscopic approach to the cervical spine with 10 freshly perfused cadaveric head specimens, and finally, to evaluate the feasibility and clinical effectiveness of this combined approach in patients with benign cervical spine tumors.

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2. Materials and methods

2.1. Ethics statement

All study procedures were reviewed and approved by the Institutional Ethics Review Board of the Second People's Hospital of Shenzhen and conducted according to the principles expressed in the Declaration of Helsinki. Each patient signed an informed consent form before surgery.

2.2. CT measurements in cadaver specimens

Atlantoaxial CT (section thickness of 0.75 mm) was used to measure the detailed dimensions and anatomical variation in 20 fresh adult cadaver heads. The variants included the anterior arch length of the atlas, the anterior tubercle thickness of the atlas, the transverse diameter and sagittal diameter of the lateral mass from both sides, and the transverse foramen interior and exterior diameters of the atlas joint and axial joint (as indicated in Fig. 1).

2.3. Simulated surgery on cadaver specimens

Ten fresh cadaveric specimens were perfused with red latex from the common carotid artery. The endoscopic approach was used to simulate the vertebral body and related regions of the cervical spine. The pharyngeal space, anterior space, and cervical vertebral body structure as well as its adjacent important vascular nerves could be observed during endoscopic surgery according to the scope of the operation.

The operation steps for atlantoaxial simulation surgery using the transoral and endoscopic approach were as follows (Fig. 2): the cadaver head was fixed, the oral cavity was opened, and the soft palate was lifted to reveal the surgical cavity; the atlas was positioned before the anterior tubercle, soft tissue was separated, and the vertebral body was exposed; the atlantoaxial anterior arch was ablated, the odontoid process was exposed and removed, the atlas cruciate ligament was revealed and separated to expose the pia mater and the dura mater; and the endoscope was moved to expose the lateral mass, and the joint capsule was cut open to identify a vertebral artery.

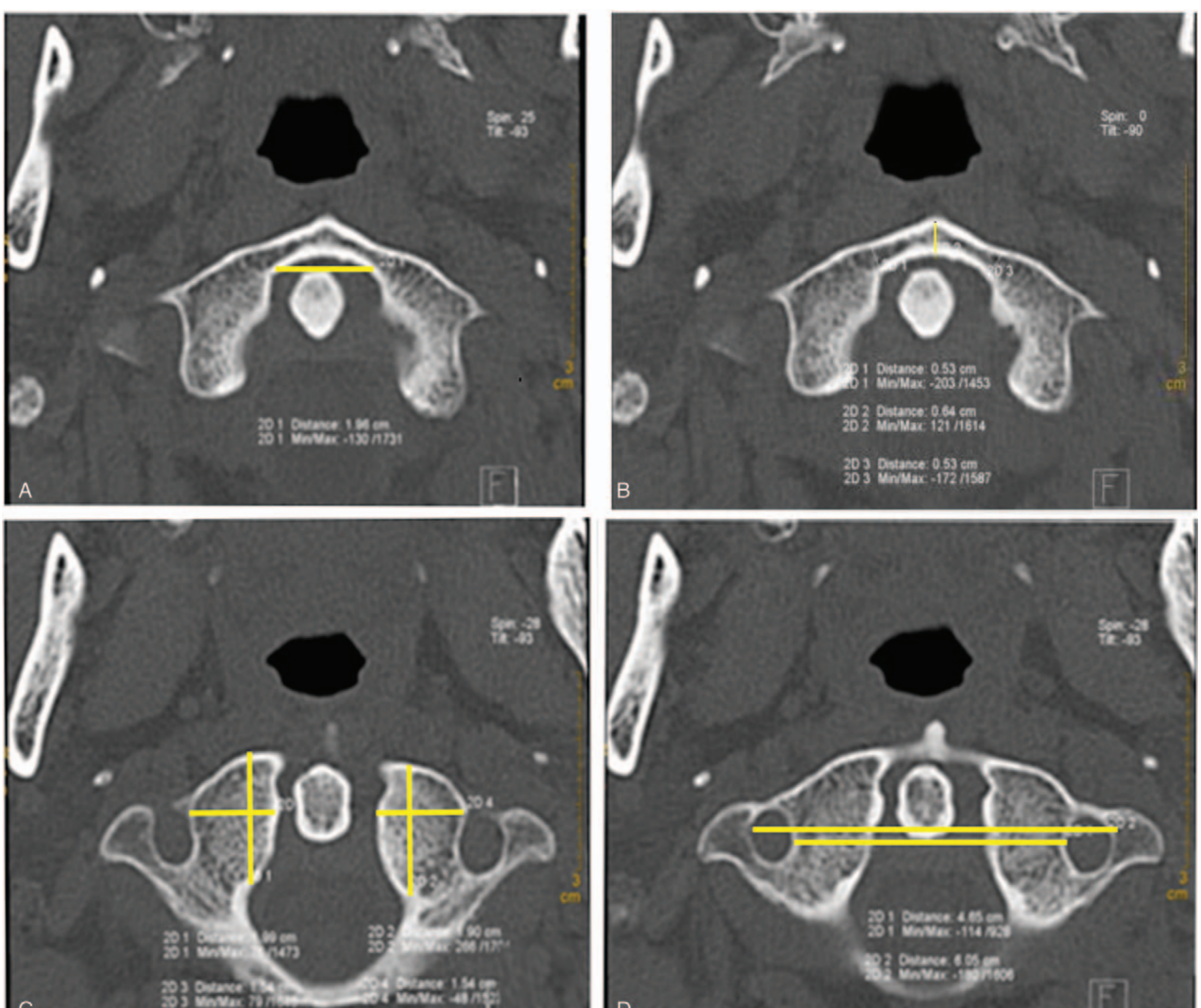

Figure 1. (A) Anterior arch of atlas length; (B) Anterior tubercle of atlas thickness; (C) Lateral mass sagittal diameter (D1)/transverse diameter (D2); (D) Transverse foramen interior diameter of atlas joint (D1)/exterior diameter of axial joint (D2).

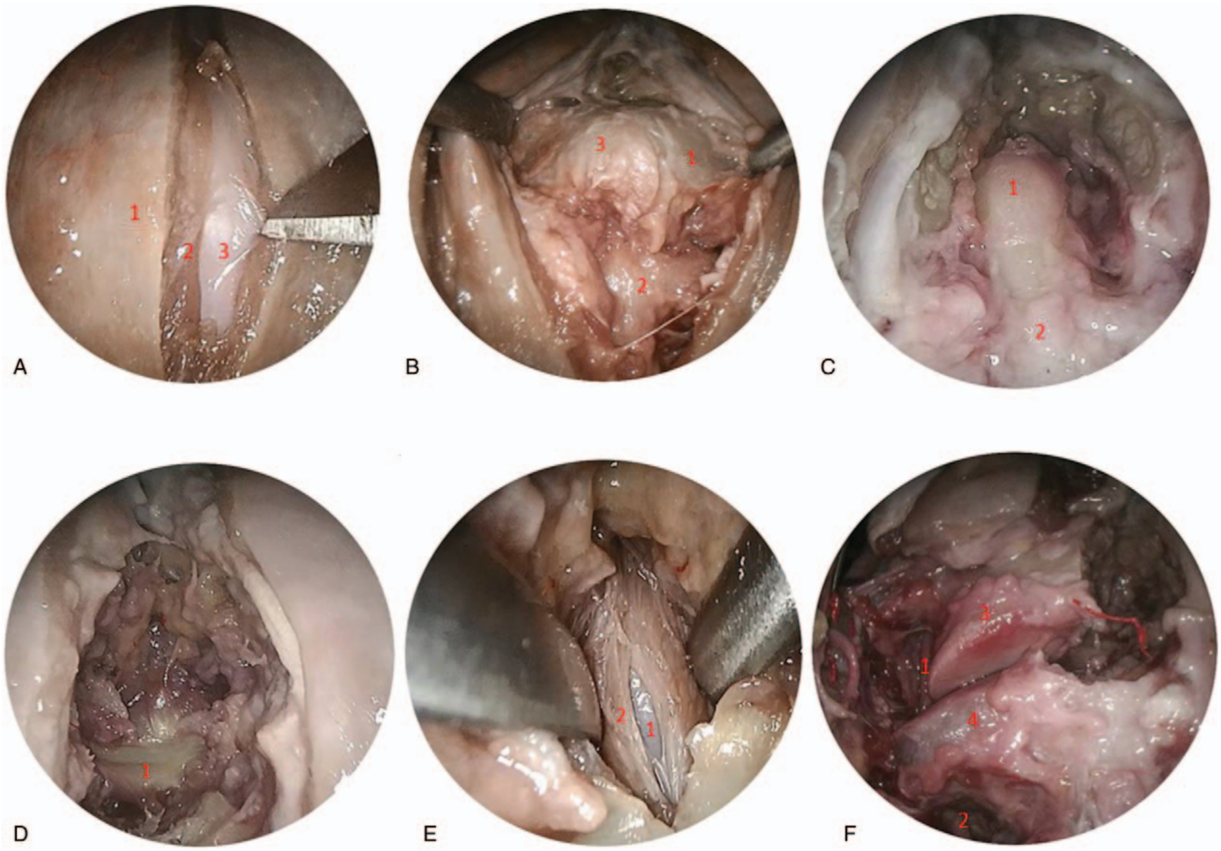

Figure 2. (A) A longitudinal incision is made over the pharyngeal soft tissue under the endoscope (1. posterior pharyngeal mucosa, 2. Muscle, 3. prevertebral fascia); (B) the atlantoaxial vertebral bone, anterior arch of atlas, anterior tubercle, and vertebral body are exposed (1. anterior arch of the sacral vertebra, 2. vertebral body, 3. anterior sacral nodule); (C) the lateral mass is exposed (1. odontoid, 2. vertebral body); (D) the atlas transverse ligament is exposed (1. transverse ligament of the atlas); (E) the pia mater and dura mater are exposed (1. dura mater, 2. pia mater); and (F) the atlantoaxial lateral joint and vertebral artery are exposed (1, 2 vertebral arteries, 3. lateral vertebral mass, 4. axial joints process).

2.4. Surgical methods

Chlorhexidine mouthwash was used for oral antisepsis, and Ofloxacin ear drops were administered 3 days before surgery to prevent infection. Antibiotics were administered 1 day before surgery. Preoperatively, patients were instructed to rest in bed, to avoid intense activity, and to protect the neck when out of bed.

2.5. Surgical equipment

The surgical equipment applied in this study included a sinuscopes system with a diameter of 4 mm × 0 or 30°, 18 cm wide angle endoscopy (Stryker, Kalamazoo, Michigan), a Davis mouth gag with a 25-cm extended skull base with a dedicated handle for surgery, and BIPOLAR COAG (ERBE, Germany).

2.6. Surgical procedures

Patients were placed in a supine position for general anesthesia through endotracheal intubation. The shoulders were stabilized, and the neck was stretched to the back. A head ring was used to fix the position of the head. Povidone-iodine was used to disinfect the face, nose, and mouth, which were then covered with sterile towels. The catheter for pediatric cases was placed through the nasal cavity to suspend the uvula and soft palate. The Davis mouth gag was used to prop up the oral cavity and reveal the posterior pharyngeal wall. A nasal endoscope at 0° was placed into the pharynx cavity, and povidone-iodine was used to disinfect the pharynx cavity. A 1-mL syringe needle was inserted into the posterior pharyngeal wall of the vertebral plane, and C-arm X-ray fluoroscopy was used for precise positioning of the needle. An electric knife was applied to make a longitudinal incision through the layers of pharyngeal mucosa, submucosal tissue, and anterior muscle. Vertebral tumors were exposed by blunt dissection. A portion of the tissue from the tumor was removed for later analysis by frozen section biopsy and pathological examination. Tumor curettage and complete removal of bone wall tumors were performed. After electric coagulation, iodine disinfection, saline lavage, and artificial bone implantation, the incision was closed with a 4–0 absorbable interrupted suture (Fig. 3).

2.7. Clinical outcome evaluation and follow-up

All patients underwent cervical CT examination during 12 months of follow-up. The degree of postoperative pain in each patient was assessed using the numerical rating scale (NRS) graded from 1 to 10 until 3 days postoperation.[12–14]

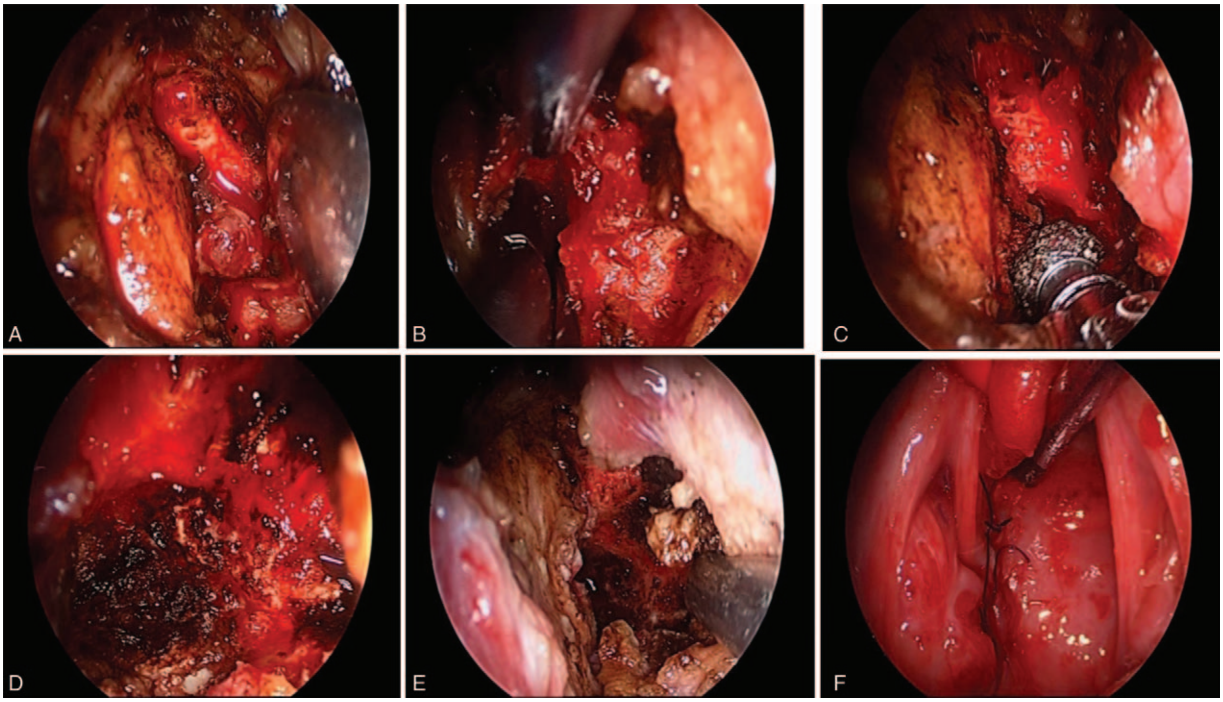

Figure 3. The surgical procedure is as follows: (A) a longitudinal incision is made over the pre-vertebral tissues to expose the involved cervical vertebrae and tissue; (B) the diseased tissue is scraped out; (C) a drill is used to grind the bone wall to ensure complete removal of diseased tissue; (D) electrocoagulation is applied to stop bleeding; (E) the surgical cavity is closed after tumor resection; and (F) the incision is sutured.

2.8. Statistical analysis

The measurement results are expressed as mean ± standard deviation (SD), and significance among NRS scores at 4 time points was analyzed using repeated measures analysis of variance (ANOVA) and followed by LSD *t* test for comparison between each time point and the 0-hour using the SPSS19.0 statistical package (SPSS Inc., Chicago, IL). $P < .05$ and $\alpha = 0.05$ were considered indicative of a statistically significant difference.

3. Results

3.1. CT measurements and results from simulated surgery

As summarized in Tables 1 and 2, the results of the simulated surgery by perfusion of cadaver specimens showed that the endoscopic approach can reveal the anterior view of atlantoaxial joint, including atlas, axial vertebral body, anterior arch, lateral mass, both sides of the vertebral artery, and spinous process; the top of the exposed window can be revealed to the upper edge of the anterior arch of atlas or the lower part of the slope, and the lower part can be exposed to the C2/3 intervertebral disc or the upper part of the C3 vertebral body. The safety margin can be defined by the outer edge of the atlantolateral mass, and the outer edge of the vertebral body.

Table 1

CT measurements of the atlantoaxial joint in 20 cadaver heads.

Items	Mean ± SD, mm
Length of anterior arch of atlas	19.5 ± 2.6
Thickness of anterior tubercle of atlas	8.1 ± 0.7
Left lateral mass transverse diameter	12.8 ± 2.6
Right lateral mass transverse diameter	12.8 ± 1.9
Left lateral mass sagittal diameter	14.9 ± 2.4
Right lateral mass sagittal diameter	15.2 ± 1.6
Transverse foramen interior distance of atlas joint	47.1 ± 1.5
Transverse foramen exterior distance of atlas joint	60.6 ± 1.6
Transverse foramen interior distance of axis joint	29.1 ± 1.5
Transverse foramen exterior distance of axis joint	44.2 ± 1.8

3.2. Patients' characteristics

The basic characteristics of the patients are summarized in Table 3. All patients underwent enhanced axial, coronal, and sagittal CT examination before and after surgery to determine the location of the tumor, its scope, and its relationship with the surrounding structures. In 5 of the 8 cases, the tumor invaded the atlas vertebrae, and in the other 3 cases, it invaded the third cervical vertebral body. None of the tumors infiltrated the dura or the spinal cord. Three-dimensional (3D) reconstruction and 3D printing models were used preoperatively in 5 cases and aided the design of the preoperative treatment plan.

3.3. Preoperation evaluation and postoperation outcomes

Atlantoaxial vertebral bone destruction filled with soft tissue was revealed in the preoperative enhanced CT of the axial cervical spine and cervical spine 3D reconstruction (Fig. 4).

Table 2

Measurements of transverse diameter of lateral mass on both sides (n = 20, mean ± SD).

Items	Left, mm	Right, mm	*t*	*P*
Transverse diameter of lateral mass	12.8 ± 2.6	12.8 ± 1.9	−0.029	>.05
Sagittal diameter of lateral mass	14.9 ± 2.4	15.2 ± 1.6	−0.368	>.05

Table 3

General characteristics as well as intraoperative and postoperative clinical events for 8 patients.

Case no.	Gender	Age, y	Symptoms	Pathology examination	Operative time, min	Intraoperative blood loss, mL	Hospital stay, d
1	M	6	Headache and loss of balance for 2 mo	Eosinophilic granuloma	78	40	7
2	M	30	Neck pain and headache for 14 mo	Eosinophilic granuloma	90	50	6
3	F	5	Neck pain and loss of balance for 1 mo	Lipoma	65	35	7
4	M	7	Neck pain for 6 mo	Eosinophilic granuloma	55	25	6
5	F	17	Neck pain and restricted range of motion for 3 mo	Eosinophilic granuloma	30	10	6
6	M	37	Neck pain and discomfort on movement for 9 mo	Eosinophilic granuloma	120	60	7
7	M	19	Restricted range of motion of the neck for 2 mo	Eosinophilic granuloma	40	15	6
8	F	42	Neck pain for 6 mo	Eosinophilic granuloma	105	35	7

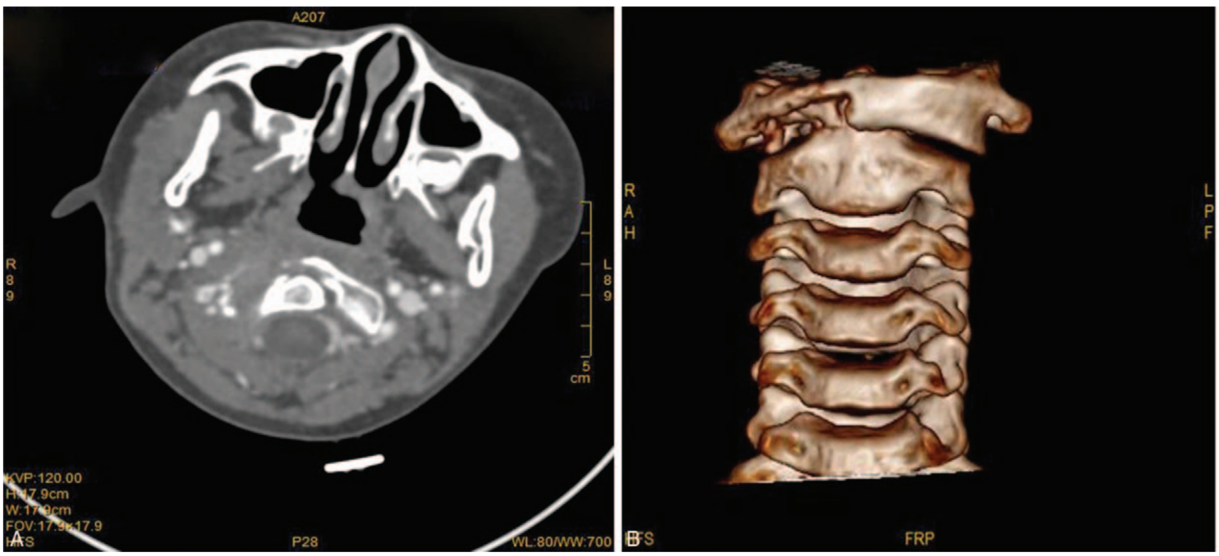

Figure 4. (A) Preoperative enhanced CT of the axial cervical spine suggested bone destruction in atlantoaxial vertebral bone filled with soft tissue. (B) Preoperative cervical spine 3D reconstruction showed atlantoaxial vertebral bone destruction.

The average surgery time was 73 minutes, and the average intraoperative bleeding volume was 34 mL. The average hospital stay was 6.5 days (Table 3). For all 8 patients, pain was evaluated for the first 3 days after the operation (Fig. 5). The average NRS score was 2.25 points. Compared with the 0-hour score, the NRS scores at 24, 48, and 72 hours were significantly decreased ($P = .021$, $P < .001$, $P < .001$, respectively). Preoperative symptoms disappeared in all 8 patients, and no intraoperative or postoperative complications occurred. Postoperative pathology reports suggested eosinophilic granuloma in 7 cases and lipoma in 1 case.

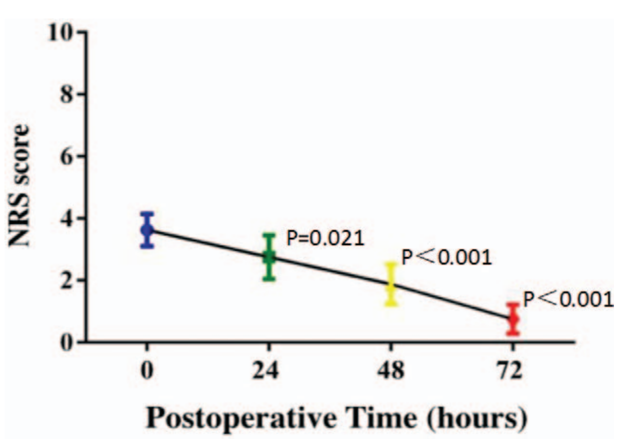

Figure 5. Evaluation of pain using NRS in 8 patients until 3 days postoperatively.

3.4. Follow-up

Eight patients were followed up for 3 to 12 months and evaluated by cervical CT. During the follow-up, we found that the tumors were completely removed without recurrence in all patients, and the reported clinical symptoms disappeared. At the 3-month postoperative follow-up, no necrosis in the artificial implantation was observed and it was partly fused with the atlantoaxial vertebral with no evidence of tumor recurrence as suggested by the enhanced CT of the axial cervical spine. At the 12-month postoperative follow-up, the atlantoaxial vertebral bone had been largely repaired and no recurrence was observed (Fig. 6).

4. Discussion

This study presents our successful experiences from bench side to clinic with a combined transoral and endoscopic approach for the

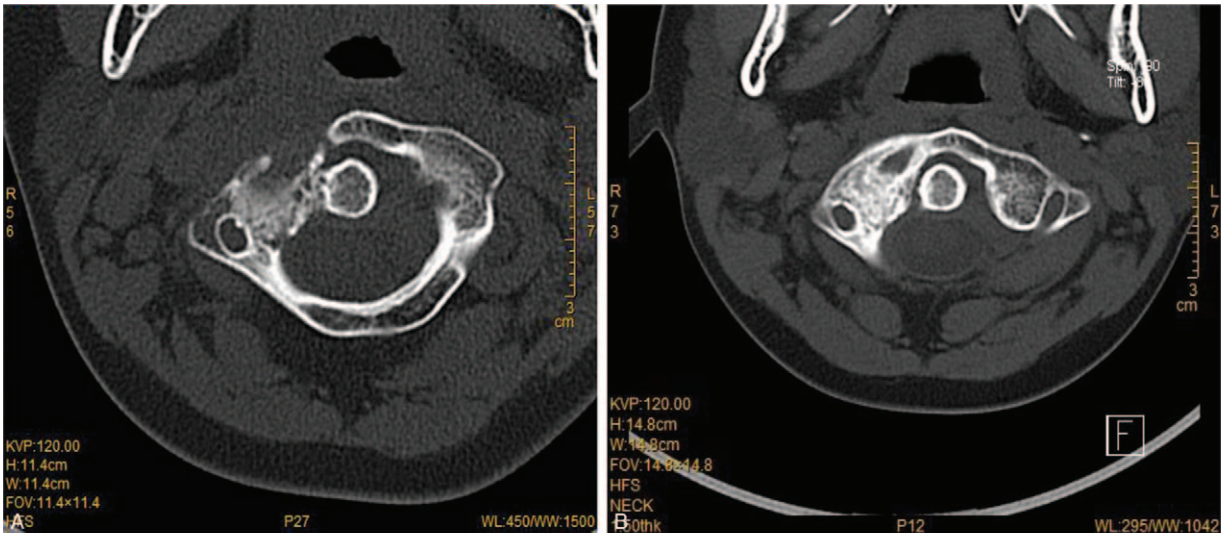

Figure 6. (A) At the 3-month postoperative follow-up, enhanced CT of the axial cervical spine suggested there was no necrosis in the artificial implantation and it was partly fused with the atlantoaxial vertebral bone bed with no evidence of tumor recurrence. (B) At the 12-month postoperative follow-up, the atlantoaxial vertebral bone had been largely repaired and no recurrence was observed.

removal of benign cervical tumors. We obtained atlantoaxial CT measurements from 20 fresh cadaveric heads and used these data to define the operational boundaries during atlantoaxial vertebral tumor curettage, while performing scraping of the vertebral tumors and grinding of the bone under endoscopy. During the simulated surgeries, our experience suggested that to avoid damaging the vertebral artery and spinal cord, the drill depth in the atlas lateral mass should not exceed the minimum sagittal diameter of the atlas lateral mass and the drill width should not exceed the minimum transverse diameter of the atlas lateral mass. Finally, we successfully performed the transoral and endoscopic approach in the treatment of 8 cases of benign cervical spinal tumors.

According to our observations obtained from simulated surgeries on 10 cadaver specimens with the multiangle endoscopic and transoral approach, the following anatomical structures can be clearly exposed: atlas, axial vertebral body, anterior arch, lateral mass, anterior tubercle, and vertebral arteries. This approach provides access to the anterior arch or lower anterior slope from the top as well as the C2/3 intervertebral disc or the upper C3 vertebral body to the bottom. This is consistent with recent studies that used cadaver heads to show that the endoscopic transoral approach provides more direct exposure and access to the craniovertebral junction.[15,16] Also, a safe surgical margin for the excision of cervical vertebral tumors was determined with this approach: the atlantoaxial lateral mass for the lateral joint and the vertebral body lateral axis. After this safety margin is defined, we can safely perform vertebrectomy through the endoscopic and transoral approach.

The vertebral artery running near the lateral joint of the atlantoaxial lateral mass and the spinal cord located posterior to the atlantoaxial mass are the most vulnerable structures during surgery to remove cervical vertebral tumors via an endoscopic approach.[17] Complications such as infection of the pre-vertebral space, bleeding, and spinal cord injury may occur during the removal of benign cervical spine tumors via an endoscopic approach.[18,19] To avoid intraoperative injury to the vertebral artery and spinal cord, we recommend that the safety margin for the surgery with this approach extends from the lateral edge of the atlantoaxial lateral mass join to the lateral edge of the axis vertebral body. Within this safe area, we can perform endoscopic surgery while avoiding serious surgical complications. In this study, in all 8 patients, including 5 cases of atlantoaxial vertebral body invasion and 3 cases of third cervical spine invasion, none of which involved invasion to the dura or spinal cord, spinal vertebral tumors were well exposed during the operation and successfully excised within the safety margin. Complete removal of the tumors was achieved with no leakage of cerebrospinal fluid, infection, or other complications.

Our experience can be summarized as follows. First, preoperative CT and MRI examination are recommended to clearly determine the scope of a cervical vertebral tumor, particularly whether it affects the spinal canal and spinal cord.[16] The endoscopic approach to the removal of vertebral tumors is indicated for cases with no spinal cord involvement or spinal cord disease. Second, due to the characteristics of children who develop tumors of the cervical spine, it is important to position the intraoperative C-arm X-ray machine properly, reduce incision errors, and prevent unnecessary trauma. Third, after exposure of the cervical vertebral tumors, biopsy and diagnosis can be made. Then, curettage of the tumors was performed while using a drill to grind the bone. It is necessary to be gentle during the operation, to use water for cooling, and to be careful not to enter the spinal canal and cause spinal cord injury. Fourth, bone graft substitutes could be used for the repair of cervical vertebral bone defects to promote healing.[20] Lastly, we should pay attention to the differences between the endoscopic view and direct vision with the naked eye during cervical spine surgery. To avoid unnecessary damage, the surgeon should not only have a wealth of surgical experience and be familiar with the cervical vertebra and the surrounding anatomical structures but also must master the use of the endoscopic techniques.

5. Conclusion

The presented transoral endoscopic approach is suitable for patients with benign cervical vertebral tumors that do not invade into the spinal canal or spinal cord. This approach can be used to safely and effectively expose the vertebral body tumors and has advantages of direct access, relatively simple operation, short operative time, quick recovery, a reliable curative effect, and few complications. However, a study with a larger sample size and long-term follow-up is warranted.

Author contributions

Conceptualization: Jun Zhou, Fei-Yan Lu.
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Formal analysis: Jun Zhou, Yong-Tian Lu.
Funding acquisition: Jun Zhou, Yong-Tian Lu, Fei-Yan Lu.
Investigation: Yong-Tian Lu, Fei-Yan Lu.
Methodology: Jun Zhou.

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