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Microsurgery via modified far-lateral approach for giant dumbbell-shaped jugular foramen tumors

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[Abstract] Background and Objective: During the resection of jugular foramen tumors via the basic far lateral approach, the jugular foramen tumor area as well as its adjacent structures, especially the intracranial part, can be better exposed, which avoids stripping of the petrous part of temporal bone and displacement of facial nerve, and protects the patient´s hearing from damage. However, when applied in tumors developed from ventral to the brain stem and middle fossa, with extracranial tumors, this surgical approach seems to be inadequate and limited. This study was to explore the microsurgical technique and clinical value for treating giant dumbbell-shaped tumors at jugular foramen (JF) via a modified far lateral approach. **Methods:** A retrospective analysis was performed in 16 patients with huge dumbbell-shaped tumors at JF which were removed through the modified far lateral approach (suboccipital transjugular-jugular tubercle-jugular process) between January 2001 and December 2008. The process of operation, and pre-and postoperative clinical data were included in the analysis. **Results:** Gross total tumor removal was achieved in 14 cases, subtotal removal in 1 case, and partial removal in 1 case. Follow-up examinations in most patients demonstrated that the patient with an obvious preoperative deficit had a good recovery. During the follow-up from three months to seven years, 10 (76.9%) cases with lower cranial nerve involvement showed obvious improvement of symptom after operation, 8 (80.0%) cases with facial palsy obtained various degrees of alleviation, and 7 (77.8%) cases with hearing impairment at different levels restored hearing. Two patients developed new lower cranial nerve palsies after operation, and underwent functional rehabilitation in the three-month follow-up. **Conclusions:** Modified far lateral approach is helpful for removing the huge tumors at JF, especially for tumors extending to the petroclival region ventral part of pontomedullary junction. It has a higher rate of total resection, preoperative cranial nerve function impairment is expected to restore, and also has the advantage of protecting the facial nerve, labyrinth and vertebral artery structure from unnecessary damage.

Key words: Modified far lateral approach, jugular foramen, dumbbell-shaped, microsurgery

The incidence of jugular foramen (JF) tumor is low, and the surgical procedure has been carried out for many years. However, due to its deep location and complex connections with adjacent tissues, the surgical resection rate is low and the postoperative complications are remarkable. Numerous studies on the anatomic access of this site, and many novel surgical approaches have been developed. Nonetheless, with respect to giant dumbbell-shaped tumors, especially those extending to the petroclival region and ventral part of craniocervical junction, the choice of an appropriate approach that can resect the tumor completely at the first stage and minimally damage the surrounding vessels and nerves is still the biggest challenge at present. A total number of 20 patients with giant dumbbell-shaped tumors were admitted to and treated in the neurosurgery department of West China Hospital, Sichuan University from January 2001 to October 2008, and 16 patients underwent operations by modified far-lateral approach. The clinical outcomes were optimal and reported as follows.

Data and Methods

General data

Of the 16 patients undergoing operations with modified far-lateral approach, there were five men and 11 women with the age ranging from 29 to 59 years (median, 45). The disease courses were from six months to 150 months. The clinical manifestations were primarily the symptoms of involvement of the posterior cranial nerves, including hoarseness (9 cases), dysphagia (3), laryngopharyngeal discomfort (3), hearing

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impairment and vertigo and tinnitus (9), abnormal sensation and movement in contralateral limbs (4), facial paralysis (8), coughing at drinking (5), jugular mass (4), atrophy of the sternocleidomastoid muscle (1), atrophy of tongue muscle (1) and multiple masses over the body (1). The long and transverse axes of the tumor were 4–12 cm and 2–5.5 cm, respectively. The tumors were streak in ten cases, nodular in two cases and irregular in four cases. The locations of the intracranial tumors were primarily in the lateral ventrum of the lower brain stem, and the outside part grew downward to anterolateral part of the neck. The consistency of the tumors was mostly soft, and some was slightly tough.

Preoperative considerations

Cranial and cervical CT (including bone window) and contrast MRI scanning were performed for all patients preoperatively to determine whether the JF tumor was giant and dumbbell-shaped. The tumor was categorized into type C or D (Figure 1) based on the classification system recommended by Samii *et al.*[1] Additionally, the bone damage of the JF, blood supply of the lesion, and the relationship of the tumor to internal jugular vein and artery, vertebral artery and sigmoid sinus were studied carefully before operation. Preoperative digital subtraction angiography (DSA) was performed in six cases with the tumor of more than 5 cm in diameter and showing marked contrast in MRI, which revealed one case with ipsilateral internal jugular artery compression and contralateral compensation, one case with internal jugular vein compression and two cases with sigmoid sinus obstruction. The blood supply of the tumor was primarily by the ascending pharyngeal artery and occipital artery. Tumor arteries were selectively embolized during DSA procedure. Electro-audiometry and facial nerve evaluations were performed for all patients before and after operation (House-Brackmann grading system). Posterior cranial nerve was monitored for all patients during operation. The nervous monitoring electrodes were inserted into the soft palate and tongue margin to monitor the glossopharyngeal and hypoglossal nerves, and the electrode carrying intubation tube was used to monitor vagus nerve. These attempted to protect cranial nerves during operation.

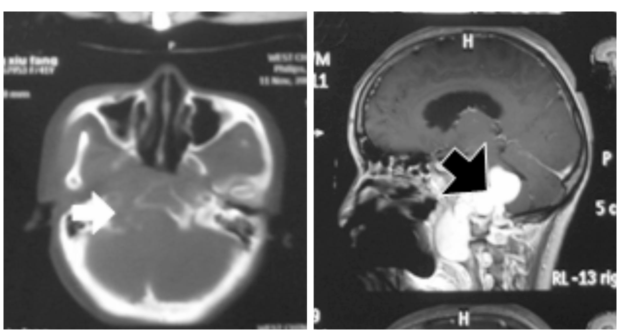

Figure 1 Preoperative images of giant dumbbell-shaped tumors at jugular foramen

A, axial un-enhanced CT scan demonstrates bone destruction of the jugular foramen (white arrow); B, T_1-weighted sagittal MRI scan with gadolinium enhancement demonstrates a giant dumbbell-shaped tumor at the jugular foramen (black arrow)

Surgical procedures

Positions and incisions The patient assumed lateral recumbent position with the head flexed and turning contralaterally and obliquely, the face was toward ventral part. The neck was slightly flexed to expose the ipsilateral external auditory canal and mastoid part of temporal bone and widen the gap between foramen magnum and atlas. Meanwhile, the shoulder was dragged toward patient's feet to expose the neck. The head was fixed with Mayfield. Inverse L-shaped incision was made under occipita (Figure 2). The incision began from the point in lateral midline of the lesion and 0.5 cm over the transverse process, extended laterally to the superior part of mastoid bone, and then turned downward along the sternocleidomastoid muscle for about 6 cm, which was lower than the projection of the atlas on the neck. The skin, subcutaneous tissue and superficial muscle were excised, and the sternocleidomastoid muscle was cut off closely to the mastoid root. The deep muscles were excised to expose the suboccipital triangle, extending downward to the C1 and C2 transverse processes. The inferior and superior oblique muscles were cut off at the transverse process of the atlas and superior oblique muscle and rectus capitis posterior major were striped beneath the bone membrane at the inferior nuchal line. Vertebral artery and the surrounding venous plexus in the triangle were exposed. Facial nerve was passed out of the anterior margin of the posterior belly of digastric muscle, and the internal jugular vein was in the medial belly and anterior transverse process of the atlas. Thus, the preservation of this muscle could protect important deep structures. Rectus capitis lateralis is a short and flat muscle that initiates from superior surface of atlas transverse process and ends at occipital jugular vein process. Posterior cranial nerves, sympathetic stem and internal jugular vein and artery travel anteriorly to the atlas transverse process and rectus capitis lateralis. Thus the rectus capitis lateralis is an important anatomic marker in this operation.

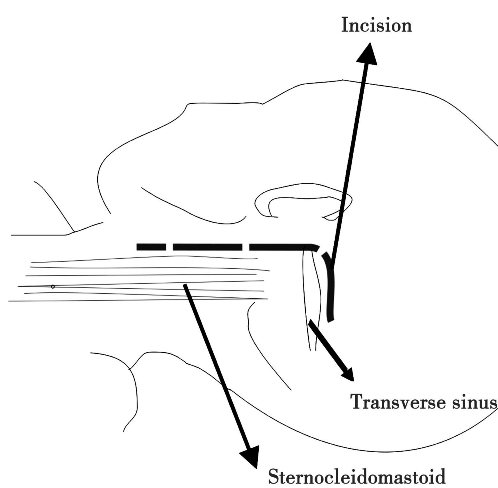

Figure 2 Diagram of incision approach

Bone window creation The sigmoid sinus was completely exposed up to the transverse sinus margin, medially to 1 cm off the midline and downward to the foramen magnum. The whole sigmoid sinus was exposed by removing part of the mastoid, and structures around the jugular foramen were exposed along the extension of the sigmoid sinus. Bone block of 1 cm in width in the posterolateral foramen magnum was excised to the posterior margin of the occipital condyle. Jugular process (attach point of the rectus capitis lateralis) at the posterior wall of JF was exposed by abrading. And the jugular tubercle was abraded over the hypoglossal canal with a close monitoring of posterior cranial nerve functions. The creation of this bone window could make the visualization of JF from posterior, lateral and inferior perspectives very easy.

Resection of tumors The extra-cranial part was firstly excised. The step by step resection method was adopted to expose enough space. With respect to the intra-cranial part, the preoperative MRI or DSA was carefully studied, and if the sigmoid sinus was infiltrated or blocked by the tumor, the sigmoid sinus was ligated at both ends and the dura mater was cut off across the sinus. In contrast, the dura mater was cut off along posterior and anterior sigmoid sinus. Benign tumor accounted for most tumors in this region and there was a layer of arachnoid space between benign tumor and normal brain tissues. Separation of the tumor along this space could protect normal tissues to the highest degree while resecting tumor completely. For chordoma and malignant tumors, the involved bone and dura mater were excised. Finally, every effort was made to suture the dura mater, and those with dura mater defect were repaired with artificial materials. The suture site was closed with biological fibrin glue to ensure there was no cerebrospinal fluid leakage. The mastoid air cells were filled with bone wax and bone window was covered with titanium plate. The muscle was closely sutured.

Results

Fourteen patients underwent total tumor resection, one underwent subtotal resection (a case with chordoma, and the bone damage was severe, the tumor was adhered to the internal jugular vein and posterior cranial nerves which was difficult to separate) and one underwent partial resection (with bilateral lesions). No intraoperative mortality was reported. Symptoms of ten of the 13 patients with severe posterior cranial nerve involvement were remarkably improved (seven were improved at six months, two at eight months and one at 11 months). Eight patients were at HB stage I to II, and the rest two patients remained at stage III without deterioration. Two patients reported no improvement or deterioration. Symptoms of one patient (chordoma) were exacerbated because of the large size of the tumor and severe damage of the bone and nerves. Besides, the patient was weak in constitution and he could not take food because of cough reflex. To prevent pulmonary infection, tracheotomy was performed and nasogastric tube was placed. The intubation was removed after two weeks. However, he remained dysphagia and nasogastric feeding was given after three months. Gamma knife radiosurgery was performed on this patient, but he lost to follow-up postoperatively. Seven of the nine patients with hearing loss were improved in various degrees within the three months follow-up after operation (examined by electro-audiometry). Two patients reported new symptoms of the posterior cranial nerve involvement, presenting the jugular foramen syndrome (hoarseness, cough at drinking, dysphagia and laryngopharyngeal discomfort). They were instituted with nasogastric feeding and were encouraged to eat more frequently but less in amount each time after improvement of coughing. As a result, they all can eat after three months (Table 1). During the follow-up period from three months to seven years, except for one case lost to follow-up, no recurrence was reported. And there was no cerebrospinal fluid leakage or intracranial infection.

Pathological results: there were seven cases of schwannoma, three cases of meningioma, one case of solitary fibrous tumor, one case of paraganglioma, one case of adenoid cystic carcinoma, one case of salivary gland tumor, one case of chordoma and one case of fibromatosis.

Table 1 Number of cranial nerves (CN) involved before and after operation

Cranial nerve	Preoperative involvement (patient No.)	Postoperative involvement (patient No.)			
		Progression	Catabatic	New CN deficit	No change
V	1	0	1	0	0
VII	10	0	8	0	2
VIII	9	0	7	0	2
IX	13	1	10	2	2
X	13	1	10	2	2
XI	1	1	0	0	1
XII	2	1	0	0	1

Discussion

Since Moe *et al.*[2] reported a total resection rate of tumor of 80% in 119 patients, the reported tumor total resection rates in large-scale studies have been increasing[3,4]. And the total resection rate of giant dumbbell-shaped JF tumor by modified far-lateral approach was 87.5% (14/16). The facial nerve was not displaced and the hearing was preserved for the patient. This approach has little impact on the posterior cranial nerves, and does not impair the jugular-cranial stability, which carries less risk of postoperative complications. This approach is therefore, valuable for the clinicians in dealing with JF lesions.

With the development of cranial base anatomy and micro-neurosurgery, efforts should be made to protect the brain stem and important vessels and preserve the functions of facial and auditory nerves and posterior cranial nerves, and the choice of surgical approaches according to the tumor location, size, extending direction, hearing ability and posterior cranial nerve function becomes widely accepted. Varieties of surgical approaches addressing the JF lesions have been proposed (Table 2).

The approach used in the present study was modified from the approach described by Rhoton[5] according to the characteristics of the giant dumbbell-shaped tumor (extending to petroclival region and ventral part of cranial-jugular junction). The

Table 2 Surgical approaches to the jugular foramen: indications, advantages, and disadvantages

Approach	Indicated for	Exposure range	Disadvantages
Posterior approach			
Suboccipital retrosigmoid	A or B	Cerebellopontine angle	Limited access to craniocervical junction and extracranial
The far-lateral suboccipital[a]			
Transcondylar	C or D	Craniocervical junction	Destroid craniocervical stability if stripping occipital condyle
Supracondylar	C or D	Lower clivus	Risking of CN and vessels injury, CSF leak
Paracondylar	C or D	Posterior of JF	Limited access to medial part of the JF and FM
Lateral posterior approach			
Postauricular approach (translabyrinthine, infra-retrolabyrinthine presigmoid)	B and C	Fossa infratemporalis	Limited access to posterior fossa, risk of facial palsy, hearing loss, CSF leak
Lateral anterior approach			
Anterauricular approach (transorbitozygomatic-infratemporal fossa)	C	Anterior and lateral of JF	Needed to displace temporomandibular joint

a, that quoted in Reference 5 on the far lateral approach of Rhoton sub-categories; A,B,C,D, quoted in Reference 1 according to Samii´s categories about JF tumor; JF, jugular foramen; FM, foramen magnum; CSF, cerebrospinal fluid; CN, cranial nerve.

extended cranial opening via sigmoid sinus under occipita was combined with supracondylar and paracondylar accesses. Features of this approach were as follows:

Choice of incision

There are varieties of incisions reported in literature, including C-shaped incision concaved anteriorly (most widely reported), inverse horseshoe-shaped incision with the long branch protruding medially or laterally[6], straight incision[7], crutch shaped incision with the long branch in the midline[8] and S-shaped incision posterolaterally to the occipita[9]. The advantage of the inverse L-shaped straight incision above the mastoid was that it travels through inter-muscular space and the muscles need not to be cut off extensively. This incision can fully expose the jugular foramen region with minimal invasion, less hemorrhage and the time required for opening and closing cranium was short. The incidence of cervical discomfort reported by the patients was low. No case of cerebrospinal fluid leakage or intracranial infection or subcutaneous fluid was reported in our patients. Nonetheless, the close suturing of dura mater (if the dura mater has defect, the artificial dura mater or biological glue should be used), the filling of mastoid air cells with bone wax and stepwise suturing of muscles and fascia are of vital importance.

Treatment of occipital condyle and jugular tubercle

We adopted the superacondylar and paracondylar approach instead of the transcondylar approach, because how to maintain the stability of occipital-cervical joint is still contraversial. The transcondylar approach should abrade the occipital condyle, which can increase the exposure of jugular foramen (especially the ventral part of brain stem). However, if the jugular tubercle is large, the surface protuberance may interfere with the visual field of the far-lateral approach and the attempt to increase the exposure is compromised. In addition, there are different viewpoints about the abrasion of occipital condyle. Dowd *et al.*[10] contended that, provided that the atlanto-occipital joint stability is maintained, the occipita should be abraded to increase the exposure to a maximum extent. In contrast, Samii *et al.*[11] opposed the abrasion of occipital condyle, proposing that the completeness of occipital condyle was essential to the craniocervical stability. Choosing this approach is also because that the resection of occipital condyle is not essential for the operation involving JF region. Jugular tubercle is located medially to the JF. To increase the JF exposure while sparing excessive damage to the occipital condyle, the jugular tubercle can be resected upward, especially when JF tumor extends to the petroclival region and ventral part of craniocervical junction, and the existence of jugular tubercle may block the visual field. In this circumstance, the jugular tubercle can be partly or completely resected, which may increase the operating space for the surgeon. Numerous studies demonstrate that the abrasion of jugular tubercle can significantly increase the exposure of JF and petroclival regions[5,12]. The dura mater covering the tubercle can be pushed anteriorly to obtain the access to the frontal region of the medulla oblongata and pons-medulla junction. The resection of jugular tubercle can not only increase the JF exposure but eliminate the bone block in the access to the foramen magnum, which thereby increases the exposure and provides accesses to the hypoglossal canal, lateral side of lower clivus and JF region while avoiding nerve dragging. This approach combines the advantages of superacondylar and paracondylar approaches, which not only directly exposes the inner and outer opening of JF but also makes the visualization of JF region from inferior, posterior and lateral perspectives possible. Meanwhile, it avoids the resections of occipital condyle and vertebral lamina of atlas, and the facial and auditory nerves are not impacted and sigmoid sinus and internal jugular vein are not ligated. Consequently, this approach can remarkably reduce the injury from the operation and avoid its damage to the atlanto-occipital joint, thereby solving the problem of stability of craniocervical joint. And the operation time is also shortened. However, the resections of jugular tubercle and part of the mastoid depend largely on the correct localization of anatomic markers such as rectus capitis lateralis. The abrasion of jugular tubercle is likely to damage the jugular bulb, posterior cranial nerve, vertebral artery and its branches, posterior inferior cerebellar artery, which will lead to serious consequences. Nonetheless, the jugular tubercle abrasion is the key step in this approach, which should be performed with a close monitoring of the nerves and by experienced surgeon who is familiar with the anatomy of this region.

The treatment of extra-cranial lesions of giant dumbbell-shaped tumor in JF region is relatively simple. As for the intracranial lesion, it can extend upward to influence the facial and auditory nerves, or even extend to the middle cranial fossa. In some circumstances, it may extend to the petroclival region and foramen magnum region, and some even progress to the contralateral side. The complete resection rate of giant dumbbell-shaped tumor that extends to the petroclival region and ventral part of craniocervical junction can be high with modified far-lateral approach (Figure 3). This approach can fully expose the region and the damages to the surrounding nerves are minimal. Most patients presented nerve function recovery postoperatively. And the surrounding structures such as facial nerve, labyrinth and vertebral artery can be preserved. Nevertheless, for the lesions extending anteriorly from jugular foramen, those within the temporal bone and those grew to the middle cranial fossa, the exposure with this approach is not enough, and the combination with infratemporal fossa is necessary. With the development of micro-neurosugery, nerve imaging and the surgical techniques, and the use of state-of-the-art equipment of nerve navigation and ultrasound knife, the treatment of giant JF tumor with modified far-lateral approach has achieved a high complete resection rate and the surgical mortality and morbidity are significantly reduced. However, the consistency of the giant tumor and its relationship with surrounding tissues are still the important factors influencing the complete resection rate. If the tumor adheres closely to surrounding nerves and vessels and the separation is difficult, the complete resection should be abandoned and the residual or recurrent lesion can be managed with stereotactic radiotherapy.

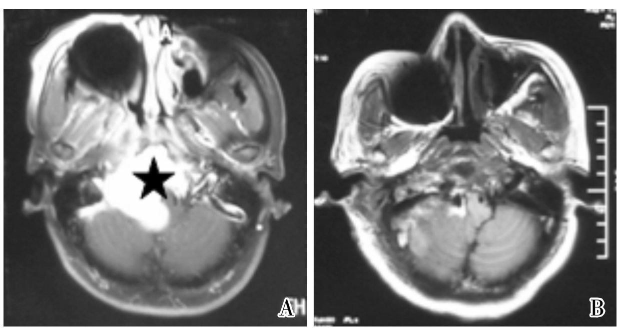

Figure 3 Postoperative images of giant dumbbell-shaped tumors at jugular foramen

A, T1-weighted axial MRI scan with gadolinium enhancement demonstrates the tumor extended to petroclival region (black star); B, The axial image taken at three days postoperatively shows no evidence of residual at the jugular foramen.

In conclusion, no single surgical approach can fit for a great variety of JF tumors nowadays. To better resect the tumor and minimize the complications, the surgeon should fully understand the anatomy of this region and the surrounding structures. Additionally, the surgeon should be familiar with the indications of each approach, the anatomy that may be encountered in the access and the possible or inevitable complications. The tumor should be maximally resected under the prerequisite of preserving the nerve functions.

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