Research Article

Surgical Treatment of Acoustic Neuroma Inside Internal Auditory Canals

Zhao YAODONG*, Xue YAJUN*, Chen XIANZHEN, Zhang QUANBIN, Yin JIA, Lou MEIQING

*These Authors Contributed Equally to this Work

Department of Neurosurgery, Shanghai 10th People's Hospital, Tongji University, School of Medicine, Shanghai, China

Summary

Objective: This paper aims to investigate an approach to increase the total excision rate of tumor mass and the preservation rate of facial-acoustic nerve.

Methods: A total of consecutive 43 patients with acoustic neuroma were reviewed in this retrospective study. In all cases, the suboccipital retrosigmoid approach was used. Preoperatively, patients accepted thin layer CT scanning through posterior cranial fossa and os petrosum. Intraoperatively, the internal auditory canals (IAC) of 31 patients were opened; and electrophysiologic monitoring on the cranial nerve VIII was progressed.

Results: Thirty-seven cases of tumors were totally removed (86.1%), and the rest 6 cases had subtotal resections. Facial nerves were anatomically preserved in 41 cases (95.3%). Four cases had a facial nerve function of House-Brackmann (H-B) grade I, and 24 cases were H-B grade II to III, and 4 cases were Grade IV. Two in four patients having preoperative hearing retained hearing postoperatively. No postoperative death.

Conclusion: To be familiar with the pathologic anatomy relationship between cranial nerve VII and VIII inside IAC, to skillfully grasp the technique of microdrill, together with the application of intraoperative electrophysiological detection technology and microsurgical technique, are the key points for the preservation of cranial nerve VII and VIII when resecting acoustic neuroma tumors intraoperatively.

Key words: Acoustic neuromas, internal auditory canals, facial nerve, microsurgical technique

İnternal Oditör Kanal İçersindeki Akustik Nörinomların Cerrahi Tedavisi

Özet

Giriş: Bu makalede amaç tümör kitlesinin total ekşizyonu ve yüz ile işitme sinirlerini azami korumayı amaçlayan bir cerrahi yaklaşımı araştırmaktadır.


INTRODUCTION

Acoustic neuroma (AN) is a common benign tumor, accounting for 8-9% of intracranial tumors, its complete resection could result in permanent cure; However, even the most experienced surgeon may be unable to achieve total tumor removal without significant morbidity; meanwhile, subtotal resections are associated with high recurrence rates(5). Especially, large acoustic neuromas undergoing surgical resection have significantly poorer rates of favorable House-Brackmann (H-B) grade of long-term postoperative facial nerve function(5) and loss of hearing.

In order to overcome these problems, various operation approaches have been developed to remove AN. The translabyrinthine(23,1), retrosigmoid suboccipital(16,18,11), and middle fossa approaches(22,6) are the three basic approaches for the removal of these tumors. Among them, the middle fossa approach has often been reserved for small tumors confined to the internal auditory canal (IAC)(20). For tumors that extend into the lateral recess of the internal auditory canal cannot be completely exposed via either the posterior fossa or middle fossa approaches, translabyrinthine approaches are generally available(2). As well, translabyrinthine approaches has minimal morbidity and is especially suitable for elderly patients or tumors larger than 2 cm(2). However, the translabyrinthine exposure always destroys remaining hearing, if any(12). Meanwhile, planned staged removal of large tumors was explored via the same or different approaches because serviceable hearing or FN functions could rarely be preserved, especially with large tumors(9,21,3,17).

However, two or more stages of operations are bound to be more painful to patients. In this paper, we aim to describe their experience with the technique (and results) of tumor dissection at the internal auditory canal by a retrospective study on 43 cases of AN. In this group of cases, most ANs were big and complicated tumors, and although some patients' tumors were small, they also had residual hearing and hoped to keep this hearing postoperatively. Moreover, we have used the suboccipital retrosigmoid approach for over 20 years for the removal of ANs of all sizes. So, we summarized the surgical experience from 43 cases of AN patients, especially for patients with high location of jugular bulbs, accepting tumor removal by suboccipital retrosigmoid approach between March 2009 and June 2011. In this paper, we detected the hearing and brain stem functions with a 16-lead electrophysiologic monitor intraoperatively, which was seldom reported before.

MATERIAL AND METHODS

Patients

A total of 43 patients (18 men and 25 women, aged from 28 to 72 years, mean of 45.1 years; 19 at right side and 24 at left side) with definite acoustic neurilemoma between March 2009 and June 2011 were chosen for the study. Their disease courses ranged from one month to ten years, with an average of 3.2 years. There were no difference of lesions locating in left and right sides.

Symptoms and signs

Most patients have symptoms of progressive hearing loss and tinnitus. The main clinical symptoms and signs were: ①
Cochlear vestibular symptoms of irritation or damage: 27 cases having tinnitus and 39 cases having hearing decrease or loss; 13 cases having vertigo and/or imbalance; ② Involvement symptoms of adjacent cranial nerve, especially the trigeminal nerve, including 19 cases of facial numbness, and 4 cases of choking swallowing. ③ Symptoms of brain stem and cerebella involvement: 20 patients having ataxia and 5 having muscle strength decline; ④ Symptoms of intracranial hypertension: Four patients having hydrocephalus and ten having headache and papilledema.

Auxiliary examination

All patients underwent magnetic resonance images (MRI) examination and computed tomography (CT) scanning (including thin slice CT of posterior cranial fossa and os petrosum). CT showed round or lobulated mass with a relatively clear border. The plain CT imaging showed hypodense lesions in eight cases, isodense or hyperdense lesions in 24 cases, and mixed density lesions in 11 cases. Enhanced CT scan showed significant contrast enhancement. CT scan of bone windows showed lip-like enlargements of entrance to the internal auditory canal. MRI scans indicated that most tumors extended into cerebellopontine angles with their centers at the entrance to IAC. T1-weighted MRI scans revealed hypointensity or homogeneous isointensity to brain; and T2-weighted MRI showed hyperintensity or iso-hyper-intensity, and both had marked gadolinium-diethylenetriaminepentaacetate (Gd-DTPA) enhancement. Tumors had clear boundaries, smooth and intact edges, and were usually surrounded by a ring of hypointensity. Some tumors had hypointensity lesions on the surfaces of ponds. Cystic degeneration occurred in 19 cases.

Size of tumors

Complying with the recommendations of the Committee on Hearing and Equilibrium of the American Academy of Otolaryngology–Head and Neck Surgery, tumor size was estimated on axial enhanced-T1 MRI by excluding the intracanalicular segment and measuring only the size of the cerebellopontine angle (CPA) component. Among all the 43 tumors, the diameters of 22 cases were more than 4cm (from 4.0 to 6.7 cm), that of 10 cases were between 3-4cm (from 3.0 to 4.0 cm), and that of 11 cases were less than 3cm (from 2.0 to 3.0 cm).

Facial nerve and acoustic nerve outcome measures

Facial nerve function was assessed using the House-Brackmann (H-B) facial nerve function grading scale. Facial nerve function was evaluated immediately postoperatively (within 48 h), at the time of discharge and at follow-up 1 year after surgery. Patients who had lost facial nerve function prior to surgery were not included in this group. Data analysis was performed using the statistical program package SPSS 13.0 (IBM, USA) for Windows. The rate of good FN function was expressed as the percentage of grade II and better result. Acoustic nerve function was evaluated by detecting the hearing thresholds as the mean of the pure tone average thresholds by air conduction and bone conduction at 0.25, 0.5, 1, 2, 4 and 8 kHz one year after surgery.

Surgical Technique and highlights

1. Exposure of tumors

All operations were done by a single neurosurgeon (L MQ), using the suboccipital retrosigmoid approach in the lateral position. Muscles and skulls in posterior fossa were dissected in turn. Irrespective of the tumor size, a retrosigmoid suboccipital craniotomy of 3 cm length and 2.5 cm width was made to expose the posterior part of the sigmoid sinus and the inferior part of the transverse sinus. The foramen magnum was not usually opened. Intraoperative monitoring of facial nerve function was performed.
with a motor nerve function monitor (Medtronic). After the dura was opened, the operative microscope was positioned. Then cisterna magna and cerebellomedullary cistern were opened, followed with the slow release of cerebrospinal fluid (CSF) from cerebellomedullary cistern. After the recovery of cerebellum, its lateral was gently retracted to expose CPA adequately. For those having preoperative hydrocephalus, external ventricular drainage was performed first.

2. Treatments of the posterior wall of IAC

(1) Opening of IAC. For large tumors (tumors' diameter >3cm), first, internal decompression was undertaken with an ultrasonic surgical aspirator (CUSA EXcel, Vallylab, Boulder, Colorado, USA). And after tension of tumors decreased, we drilled the posterior lip of IAC with a high speed drill. For those middle or small tumors (Φ <3cm), first, we drilled the posterior wall of IAC, and then removed tumors inside and outside IAC stepwise.

(2) Stripping of the posterior wall of IAC. First, a Horseshoe-shaped incision on the dura of posterior wall with about 1.3cm at depth was made, then the posterior wall was opened with a drill at a total depth about 7-9mm. The stripping process could be divided into two stages: for the first stage, a watermelon-like bit of 3 millimeter in diameter was recommended; when the dura of IAC appeared, a diamond -like bit of 2 millimeter in diameter was used. Scope of grinding should be controlled between the superior and inferior walls of IAC, without opening semicircular canals. The wide exposure of IAC bottom would greatly facilitate the surgery.

(3) Removal of tumors in IAC. Open IAC dura with a vertical incision, and then dissociate arachnoids surrounding tumors in IAC with a nerve hook. Meanwhile, pull out the headend of tumors in IAC with a nerve hook, at this time, you might find the adherence of nervus vestibularis with tumors. After identification and confirmation of facial nerve with a nerve stimulator, shear the adherence. If the tumors in IAC were comparatively big, we could remove tumors by internal decompression and later separation their boundaries from the nerves. (4) Monitoring of brain stem auditory evoked potential. Intraoperatively, we identified the boundary of tumors and acoustic nerves by recording and analyzing the waveforms of brain stem auditory evoked potential with a stimulator electrode. As soon as the wave III and V became low, and the intermediate stage between wave I and V being prolonged, we stopped our dissociation temporarily and changed the operation dissection skills until the all waves restored step by step (Fig 1A). Postoperatively, we gave an immediate monitoring of brain stem auditory evoked potential again, and found all the five waveforms could be evoked (Fig 1B).

(5) Postprocessing of ICA after tumors' removal. When the bottoms of IAC were drilled, mastoid air cells were easily opened, which would lead to leakage of CSF. Therefore, in order to avoid the probable postoperative leakage of CSF, we stuffed IAC with comminuted muscles and seal ICA bottoms with medical adhesive bioprotein glue (FAL, Beijing Fuaille, China) and absorbable hemostatic gauzes (Synthes, Shanghai, China) or spongia gelatinosa (Yongning, Nanjing Jinling, China).

(6) Treatments of Jugular bulbs in high position. If preoperative thin layer CT scanning of os petrosum showed Jugular bulbs in high position, only diamond -like bit could be used to drill out IAC intraoperatively. However, as soon as sclerotin took a blue look, which indicated the Jugular bulb being just below, we should drill out IAC from its supracerest and carefully made it outlined. In case of hemorrhage of Jugular bulbs, we could block it with spongia gelatinosa as well as bone wax, and then to pull tumors out with a nerve hook or a strippers.

3. Removal of tumors
Under the monitoring of brainstem auditory evoked potential (BAEP), which can indicate the probable locations of and auditory nerve or facial nerve by detecting wave amplitudes and latency intervals of the brain stem response (Fig 1). Internal tumor resection was procedure until the capsule walls of tumors were as thin as possible and later separation of capsule walls from anus perineum of tumors up along a clockwise or counterclockwise. Reduce the tumor volume as soon as possible, block the tumor blood supply, and protect lower cranial nerves and anterior inferior cerebellar artery (AICA) and its branches by the combination of internal tumor resection and capsule wall dissociation.

4. Principle of Resection of Tumors

Internal tumor resection as far as possible, dissociate the lateral part of facial nerve (i.e. the part in IAC) and then inner end (i.e. the cistern part), gradually reduce the size of the tumors, followed by the separation of the tightest adhesive part of tumor to the entrance of IAC, and finally complete removal of tumors, as well as layered suture.

Figure 1: Monitoring of brainstem auditory evoked potential. a, the intraoperative monitoring, arrows show the wave III and V becoming low, an arrowhead shows the prolonged interval (4.56ms). b, the monitoring immediately after operation, showing evoked potential and descendent interval (3.88ms).
RESULTS
General
Tumor removal was complete in 37 patients (86.1%) and subtotal in 6 (13.9%). The extent of tumor removal was initially judged by the surgeon and confirmed by postoperative CT or MRI (Fig. 2). Among the six subtotal resections, four tumors were so tightly adhered to the entrance of IAC that the residual were unavoidable for the reservation of facial nerves; the other two cases had tight adhesions with pons resulting in oedema of pons surfaces, and there were obvious blood pressure fluctuations during the process of separations, which resulted in unavoidable residual. Among the entirely removed, IAC in 31 cases were drilled out, and tumors inside IAC of all the 31 patients got complete removal. Skull flaps reseated in thirty patients, and the number of hospital days was 7-20 with an average of 13 days.

Two of 27 patients having preoperative tinnitus still had tinnitus postoperatively, but disappeared in only one week. All those symptoms of adjacent cranial nerve, especially the trigeminal nerve, vanished immediately after operation. Symptoms of brain stem and cerebella involvement gradually improved after operation and disappeared one week later. No patient had permanent and severe headache during the follow-up of 6-24 months.

Facial nerve and acoustic nerve outcome
The facial nerve was anatomically intact at the end of surgery in 41 (95.3%) patients. At discharge, 4 patients (9.3%) kept the facial nerve function at House-Brackmann (H-B) Grades I, the facial nerve function of 22 patients (51.2%) was H-B Grades II and III, and 5 patients (11.6%) were H-B Grades IV. For the outcome of acoustic nerve function, two of the 4 patients having pre-operative hearing kept post-operative hearing one year after operation. For the monitoring of acoustic nerve of the two patients with post-operative hearing, audiograms performed one year postoperatively revealed sensorineural hearing impairments in the sick side, however, hearing loss happened only at high frequency stage (e.g. 8000 Hz) according to the guidelines of the AAOHNS Committee on Hearing and Equilibrium (Fig 3A, B). Speech audiometry also showed good hearing remained after operations (Fig 3C).

Major postoperative complications
CSF leak occurred in 2 patients (4.7%), and 2 patients (4.7%) developed subcutaneous hydrops. For the 2 patients with CSF leak, they were kept at seated leaning-forward positions with continuous lumbar CSF drainage; one week later, after the CSF leak stopped automatically, drainage tube were pulled out, and the 2 patients restored self-positions. Subcutaneous hydrops were generally found 5-7 days after operations; for the complications, hydrops were drawn out with injectors for once followed by local pressure dressing for 3 days; both were cured. During the follow-up of 6-24 months, all patients could take care of themselves. The patients, who accept subtotal removal of tumors, suffered recurrence during follow-up, were treated by stereotactic radiosurgery.
DISCUSSION

1. Anatomy and stripping of IAC

A full preoperative preparation was very necessary, especially a routine thin layer CT scanning of os petrosum (containing the bone windows) to measure the angle and length of IAC, to make clear the pneumatization status of pyramis ossis temporalis, as well as the locations of cochlea, semicircular canal and jugular bulb. The scope of our stripping of IAC is usually 6-9mm, which depends on the depth of tumors intruding into IAC. When treating with the IAC, we drilled out not only the posterior wall, but also superior and inferior walls, so that the IAC became fully open. It could also enlarge the

Figure 2: Case illustration. a, this patient is a 57-year-old man, whose preoperative MRI shows a huge mass in the left CPA, extending into IAC. b, coronal MRI shows marked compressions and deformations of brain stem tumor and fourth ventricle. c, axial CT scan shows the left IAC being filled with tumors and that the IAC has been expanded significantly with its posterior wall having a lip-like change. d and e, postoperative axial and coronal enhancement MRI scan shows a total resection of tumors in CPA (arrows indicating the residual cavity after tumor resection). f, T2-weighted MRI scan of head shows a good protection of cerebellar hemisphere, and edema in part brachium pontis. The post wall of IAC has been opened (a vertical arrow) with the reservation of facial nerve. The bone flap was set back (a transversal arrow) with no subcutaneous hydrops.

Figure 3: Pure tone audiograms performed one year after operation. a showed the hearing level of bone conduction at sick side pre- and post-operation; b showed the hearing level of air conduction at sick side pre- and post-operation. c showed the speech audiometry results after operation, for the right ear (the normal one), the speech reception threshold (SRT) was 14 dB and the speech discrimination score (SDS) was 100%; however, for the left ear, the SRT was 37dB and the SDS was also 100%.
operating angle and make the total removal of tumors and the protection of facial nerve much more convenient. It is a prerequisite for a complete resection of acoustic neuroma to drill out the posterior wall of IAC. In this paper, two patients, whose mastoid air cells were opened intraoperatively, had light CSF leakage 2 weeks after operations. Therefore, postoperative seal of IAC with biological glue and muscle pieces could prevent the occurrences of CSF leakage.

2. Treatments of arachnoid in IAC

The location relationship between IAC tumor and arachnoid is still controversial. In 1970's, Yasargil considered that the origin of IAC tumors is located outside arachnoid space. However, with the growth of the tumor, arachnoid around pontine side pool was pushed to tumor surface; finally, there was no interval of arachnoid between IAC tumors and facial nerve. Lescanne insisted that the dura mater and the arachnoidal membrane invaginated into the IAC from the porus to the fundus, creating a lateral extension of the cerebello-pontine cistern. This cistern contained the entire vestibulocochleofacial complex including the vestibular ganglion, from which acoustic neuromas originate. Ohatta argued that the tumor originated subarachnoidally within the IAC and grown in the CPA. Rearrangement of the arachnoid began with its adhesion on the medial pole of the tumor along the porus, resulting in the arachnoidal invagination into the cerebello-pontine cistern and covering the surface of tumors with further growing of the tumors. What we had seen in operation also corroborated this point. There were arachnoid inside or even at the bottom of IAC, and it was relatively easy to treat tumors along arachnoid. So, tumors are most probably located inside arachnoid. Basing on this, while treating tumors locating at the entrance or inside IAC, we first separated tumors from the two sides of arachnoid space towards the center, and then monitored facial nerves; or separated tumors from the entrance to IAC towards the bottom of IAC, by which the functions of facial nerves could have a better reservation.

3. Removal of tumors inside IAC

The total removal of tumors in IAC depends on the sufficient stripping of posterior wall of IAC, and adequate preoperative preparations may indicate the high position of jugular bulbs. There were 6 patients, whose Jugular bulbs were at high positions, and we drilled out their IAC in the direction towards suprameatal ridges, which could make Jugular bulbs outlined and reduce the residual of tumors in IAC. When removals of tumors in IAC, we had better pay attentions to following: (1) Cranial nerves in IAC have a constant position relationship, and the facial nerve is located in a fixed position. (2) Although tumors invaginated into IAC, there was a layer of arachnoid covering tumors. Therefore, after internal decompressions of tumors, later separations along arachnoid boundary were indispensable. Moreover, arachnoid invagination into IAC and that outside IAC are continuous. So, only if the internal decompression was adequate, tumors in IAC and tumors at the entrance of IAC could be removed together. (3) Cotton pieces can not be around an engaged high-speed electric drill. (4) The use of bipolar electrocoagulation should be cautious when resecting tumors in IAC, especially for those tumors having close adherence to facial nerves. It is preferable that separating tumors from facial nerve rather than separating facial nerve from tumor tissues.

There were two directions to dissociate tumors, i.e. from brain stems to IACs and from IACs to brain stems. Our choice mainly based on the adhesion degree of tumors and brain stems, the damage of IACs and the locations of bulbus venae jugularis. If the adhesions were very serious and the IACs had suffered from severe damage, we dissociated tumors
from IAC; however, if the position of bulbus venae jugularis was high, we would open the IAC only after bulks of tumors were dissociated.

4. Resection of tumors and protection and monitoring of Nerve Ⅶ/Ⅷ

The anatomic preservation of facial nerve is the basis of its function. Tumors are covered by layers of arachnoids, i.e. the outside one of CPA cistern and the inside one on the surface of facial nerve. We had better keep the integrity of arachnoids, and separate tumors between the two layers of arachnoids, which could make the separation of tumors from their surrounding structures much easier; consequently, it is conducive to the protection of nerve function and reduces bleeding.(20)

How to make sure the exact location of facial nerve and to avoid damage to it? (1) To locate the part of facial nerve inside IAC. The anatomical relationship between facial nerve and tumors in IAC is comparatively constant, so as soon as IAC was opened, we could easily find facial nerve. (2) To locate facial nerve of the cistern part. Firstly, we separated the lower pole of tumor capsule in the direction towards IAC, and then abducent nerve appeared, inside which we could find the trunk and branches of anterior inferior cerebellar artery (AICA). Basing on the location of AICA or its loop, we could identify and confirm facial nerve by combining the use of facial nerve stimulators. The blood supply of acoustic neuroma is mainly from the branch of AICA and dura of IAC. So, a proper treatment of blood supply at the two places will greatly reduce the blood supply of AN. Meanwhile, any injury to the branches of AICA will probably be lethal; however, a clear operating field is very helpful to avoid the danger.

How to keep hearing is the difficulty of acoustic neuroma surgery, and only about 23.7% patients with ANs had postoperative hearing(14), what's more, these ANs varied in sizes; however, in this group of cases, 50% (2/4) patients kept hearing postoperatively, even if the sizes of their ANs were between 2.5 and 3.0 cm. Intraoperatively, we could detect the location of acoustic nerve by monitoring of brain stem auditory evoked potential, with whose help the hearing could get most preservation. In conclusion, we think that the suboccipital retrosigmoid approach could minimize the destruction to labyrinthus oticus but not decrease the total resection of tumor masses; therefore, we apply only this approach.

Acknowledgments: The current research was supported by National Natural Science Foundation of China (No. 81101909), and the Doctoral Program of Higher Education (Specialized Research Fund) of China under Grant No. 20110072120055.

Declaration of Interest: None declared.

Correspondence to:
Lou Meiqing
E-mail: dm0920@gmail.com

Received by: 17 December 2012
Revised by: 03 April 2013
Accepted: 30 April 2013

The Online Journal of Neurological Sciences (Turkish) 1984-2013
This e-journal is run by Ege University Faculty of Medicine, Dept. of Neurological Surgery, Bornova, Izmir-35100TR as part of the Ege Neurological Surgery World Wide Web service.
Comments and feedback:
E-mail: editor@jns.dergisi.org
URL: http://www.jns.dergisi.org
REFERENCES