Revista Argentina de Clínica Psicológica
2020, Vol. XXIX, N°5, 887-895
DOI: 10.24205/03276716.2020.1085

Multimodal Approach for Maximizing Facial Nerve Reservation in Large Acoustic Neuroma Surgery

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Abstract

Objective: To investigate technologies and methods for facial nerve function preservation during a large acoustic neuroma surgery.

Methods: Fifty-eight patients with large acoustic neuromas were recruited in the study. Each patient was treated by a microsurgery applied with suboccipital retrosigrnoid transmeatus approach under neurophysiological monitoring. All patients were followed up for one year and received post-surgical facial nerve function evaluation at post-surgery 7d and 90d.Retrospective analysis was carried out on the patients' clinical data and evaluations of treatment efficacy.

Results: A complete resection of the acoustic Neuroma was achieved in 39 patients (67.2%). while 13 case (22.4%) received subtotal resection and 6 cases (10.3%) received partial resection. Facial nerve anatomical preservation was achieved in all patients. Facial nerve H-B classification changes varied at different time point. post-surgical 7d: 9 cases Facial nerve H-B classification stayed at the same grade, 19 cases changed 1 grade, 18 cases changed 2 grade, 10 cases changed 3 grade, and 2 cases changed 4 grade; post-surgical 90d: 16 cases Facial nerve H-B classification stayed at the same grade, 19 cases changed 1 grade, 21 cases changed 2 grade, and 2 cases changed 3 grade. Pre-surgical tumor diameter showed significantly positive correlation with the Facial nerve H-B classification changes at post-surgical 7d (Pearson's Correlation, p <0.001) and 90d (Pearson's Correlation, p =0.007). As a result, Larger pre-surgical tumor diameter indicated worse prognosis of post-surgical facial nerve function($p<0.05$).

Conclusions: Meticulous microsurgical operation and consummate neurophysiological monitoring assistance are of great value for intraoperative facial nerve preservation. Pre-surgical tumor diameter can be used as a predictor of post-surgical facial nerve function prognosis.

Keywords: Large acoustic neuroma; Facial nerve; Neurophysiological monitoring; Tumor diameter

Introduction

Acoustic Neuroma is one of the most common intracranial tumors. The current mainstream view is that total resection of tumor, preservation of intact facial nerve function and increasing life quality of patient are the ultimate goals of acoustic neuroma surgery(Rosahl, et al.,2017). However, facial nerve dissection and maximal function preservation are still among the major difficulties in large acoustic neuroma surgery(Tokimura, et al.,2014). Minimal invasive microsurgery has been adapted world-wide as a routine procure to reduce the surgical trauma and facilitate recovery. The challenge of performing such a surgery is the judgment call between maximizing resection of the tumor while preserving the facia nerve and its function(Hong, et al.,2017; Simone, et al.,2018; Sai, et al.,2019). In this respect, many efforts have been devoted to improve the minimally invasive surgery operation and real-time neuroelectrophysiological monitoring technology. To date, real-time neuroelectrophysiological monitoring has gained wide recognition as a valuable assistant tool in preservation of facial nerve function in large acoustic neuroma excision operation. However, literature reported that the clinical outcomes and benefit of monitoring varied from hospital to hospital, due mainly to the lack of scandalization of

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the detailed procedure. To fill in this procedural gap, here we retrospectively investigated the relationship between the clinical data of tumor diameters and the outcome of post-surgical facial nerve H-B classification changes in fifty-eight patients with acoustic neuroma who were admitted into our department from 2011 March to 2019 February. We spent 6 months (From 2019 March to 2019 August) analyzing and summarizing, and finally came to a conclusion. The goal is to determine whether and to what extent the real-time monitoring helps to preserve facial nerve function. Here we report the techniques of surgical facial nerve preservation we used in these cases.

Methods

Patient information

Patient inclusion criteria included: i) diagnosis of acoustic neuroma by brain MRI scan, enhancement and bilateral internal auditory canal scan; ii) tumor size greater than or equal to 3 cm in diameter according to the international classification standard.; iii) Primary tumor. Exclusion criteria included: i) previous treatment with radiation therapy; ii) dysfunction of facial nerve before surgery, myasthenia gravis and peripheral facial paralysis; iii) patients who were lost at follow-up and had not undergone surgery. According to our inclusion and exclusion criteria. Fifty-eight patients (23 male and 35 female) were included in the study. The average age of patients is 49.76±12.19, ranging from 24 to 70 years old. Clinical symptoms reported by patients before the surgery including tinnitus and partial hearing loss (47 cases), complete hearing loss (5 cases), dizziness (22 cases), facial pains and hypaesthesia (20 cases), facial paralysis (4 cases), stumbling (17 cases), intracranial hypertension (13 cases), cephalalgia (3 cases), hoarseness, dysphagia and choking (2 cases), and ataxia (1 case).

Radiography examination

All patients received conventional craniocerebral MRI scan, craniocerebral enhanced MR imaging and thin-layer chromatographic scanning (TLCS) on bilateral internal auditory canal before surgery. The location, size, type and Koos grade of tumor varied. 36 cases were on left side whereas 22 cases were on the right side. Two types of tumors were identified: parenchymatous (24 cases) and cystic-solid (34 cases). The size of the tumor varied from 3.0 cm to over 4.0 cm, and we classified them into three categories: 3.0 - 3.4 cm diameter (30 cases), 3.5 - 3.9 cm (12 cases), > 4.0 cm (16 cases). Based on Koos Grading scale, 1 case was grade 2, 16 cases were grade 3 and 41 cases were grade 4.

Surgical operation procedure

Surgical operation was performed under continuous intravenous Propofol anesthesia after initial induction was carried out on patients. No muscle relaxant and inhalation anesthesia were used.

Suboccipital retrosigrnoid transmeatus method was used in the surgeries. Applied straight incision is posterior to straight mastoid with occipital fenestration area being about 4×4 cm^2. At the incision site, transverse sinus is exposed on the superior margin while sinus sigmoideus is visible on the exterior margin. After incision of endocranium, slowly release of the cerebrospinal fluid in cisterna magna and cerebellomedullary cistern until sufficient collapse of brain tissue is caused and cerebellopontine angle tumors is exposed. Electric coagulation incision is carried out on tumour after confirmation of no suspicious nerve trajecting through the tumour capsule surface using neuroelectrophysiological technology. Total resection is fulfilled along arachnoid palne using suction apparatus, bipolar electric coagulation and Cut-Ultrasound Aspiration (CUSA). Upper part of tumour, brain stem plane tumour part and lower part of tumour are excised sequentially after intracranial decompression. Afterwards, ground into the internal auditory canal and resect the base of the tumour. Finally, search for facial nerve trending direction according to electrophysiological recording in the operation. Residual tumour attaching to facial nerve is excised along the arachnoid plane. If any abnormal electrophysiological recording presents in the resection process, operation should be ceased at once and causes should be thoroughly examined in case of damaging vital nerve function.

Electrophysiological monitoring method

Electrophysiological monitoring was carried during operation. Axon-CR16 channel multi-function nerve monitoring system was used. Specifically, the monitoring items and methods include:

1) Facial-nerve motor evoked potential (FNMEP) is monitored through Transcranial Electric Stimulation (TES): Recording electrode is placed on mentalis. Anode is placed 1 - 2 cm superior and 0.5 - 1 cm anterior (the central anterior facial muscle motor area) to surface projection cross line of central sulcus and lateral fissure. Reference electrode is placed 1 - 2 cm beside Cz (according to

international electroencephalograph (EEG) 10/20 system standard, hereinafter inclusive). Band-pass filtering range: 30 - 1500Hz, analysis time-window: 100ms, sensitivity: 100 uV, stimulating wave range: 50 - 500 us, serial stimulus number: 4/cluster, stimulus intensity: 60 - 160V. Waves of FNMEP are superposed. The latency and amplitude are recorded and their changes are observed. Monitored data is preserved. Time point, anesthesia changes, hemorrhage in surgery, stimulus changes in surgery, etc. are labeled for each surgical procedure.

2) Electromyography monitoring: Both spontaneous and induced electromyography are included. Facial nerve monitoring electrodes are placed separately at orbicularis oculi muscle, orbicular muscle of mouth and mentalis. Trigeminal nerve motor branch monitoring electrode is placed at masseter muscle (one of the masticatory muscles). Vagus motor branch monitoring electrode is placed at cricothyreoideus. Band-pass filtering range: 30 - 1500Hz, sensitivity: 100uV (Figure 2). Induced electromyography is used for facial nerve trending recognition using bipolar nerve stimulation probe to apply electrical stimulation at probing site while it is recorded. The intensity of stimulating current increase gradually from 0.1mA to 2mA. Post-surgical nerve integrity examination is achieved through direct electrical stimulus on both brainstem and internal auditory canal end of facial nerve. The stimulating current starts from 0.1mA and increase gradually until 0.5mA if there exist no myoelectrical response (Figure 3).

Evaluation of facial nerve function

All patients received evaluation of facial nerve function at 1 day before surgery (pre-surgery 1d), 1week (post-surgery 7d) and 3 months (post-surgery 90d) after surgery. The evaluation results are shown in Table 1 & Table 2. House-BrackMann (H-B) facial paralysis scale is applied(Simone, et al.,2018):

Grade	Impairment
I	Normal
II	Mild dysfunction (slight weakness, normal symmetry at rest)
III	Moderate dysfunction (obvious but not disfiguring weakness with synkinesis, normal symmetry at rest) Complete eye closure w/ maximal effort, good forehead movement
IV	Moderately severe dysfunction (obvious and disfiguring asymmetry, significant synkinesis) Incomplete eye closure, moderate forehead movement
V	Severe dysfunction (barely perceptible motion)
VI	Total paralysis (no movement)

Statistical analysis

Software SPSS 19.0 was adopted for statistical analysis. The quantitative data was presented by mean ± standard deviation, the qualitative data was presented by cases, and relationship between paired data was examined by Pearson's correlation analysis, P < 0.05 indicated the statistical difference.

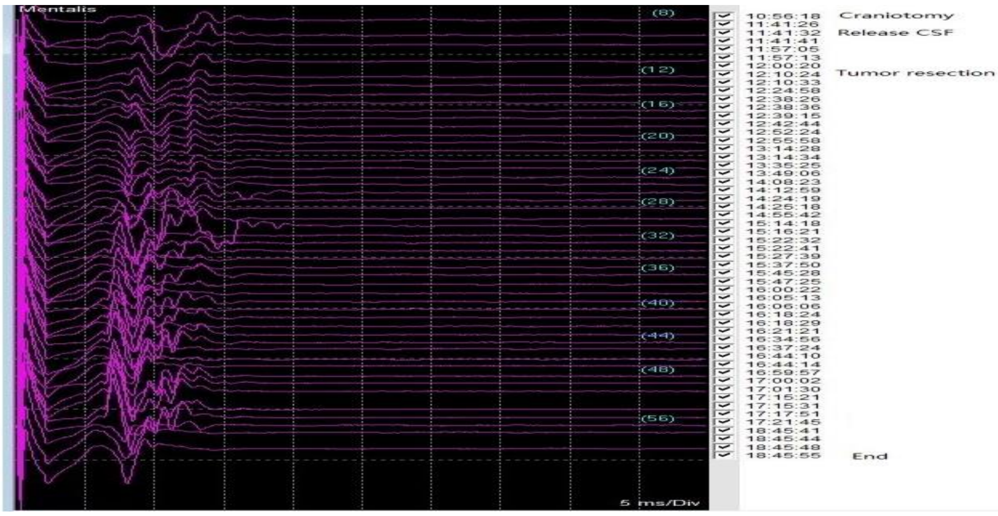

Figure 1. **Superposition graph of transcranial electric stimulation induced facial-nerve motor evoked potential（FNMEP）**

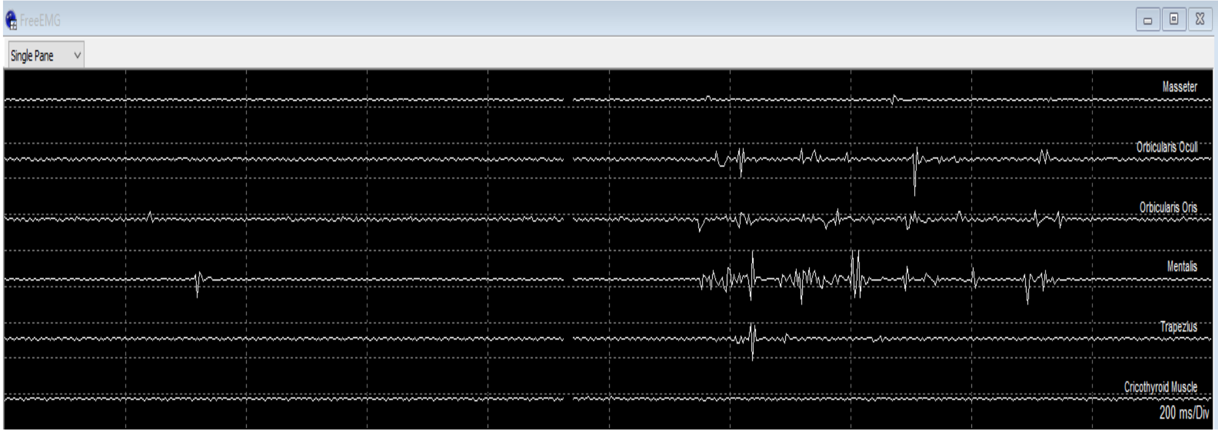

Figure 2. **Representative EMG signal during real-time intraoperative monitoring Electromyographic reaction occurred during facial nerve traction.**

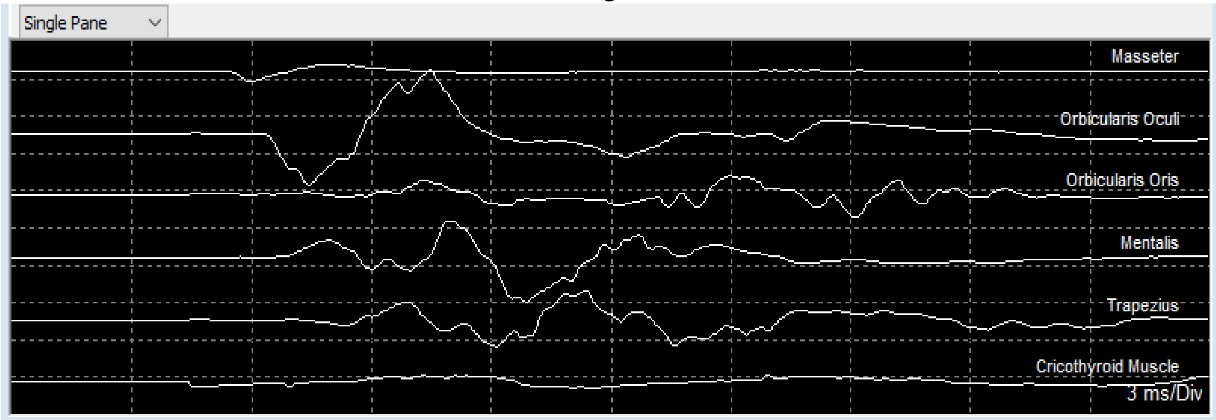

Figure 3. **Use Electric Stimulator to detect the Facial Nerve, Mentalis Trigger-EMG appeared**

Results

Completeness of tumour resection and post-surgical complications

The set of cases consist of 39 cases (67.2%) of total resection, 13 cases (22.4%) of subtotal resection and 6 cases (10.3%) of partial resection (Fig4). Post-surgical complications mainly include: 7 cases(12.1%) of facial numbness, 3 cases(5.2%) of hoarseness, 3 cases(5.2%) of dysphagia, 3 cases(5.2%) of cerebrospinal fluid leaks, 2 cases(3.4%) of transient contralateral limb dysfunction and 1 case(1.7%) of post-surgical hemorrhage (due to postoperative blood pressure fluctuation). No case of long-term coma or death is recorded.

Spatial relationship between the tumour facial nerve

We found that the spatial relationships between the facial nerve and tumor varied drastically. Out of 58 cases, 26 cases (44.83%) of the facial nerve located midanterior to the tumour, 23 cases (39.66%) located anteroinferior to the tumour, 6 cases (10.34%) located anterosuperior to the tumour, and 3 cases (5.17%) locates posteroinferior to tumour.

Facial nerve functional changes after surgery over time

In all the cases, we were able to preserve the facial nerve anatomically. Pre-surgery 1d facial nerve function H-B classification: 53 cases(91.38%) of grade I, 2 cases(3.4%) of grade II, 3 cases(5.2%) of grade III; Post-surgery 7d facial nerve function H-B classification: 25 cases(43.10%) of grade I and II, 30 cases(51.72%) of grade III and IV, 3 case(5.2%) of grade V and VI; Post-surgical 90d facial nerve function H-B classification: 32 cases(55.17%) of grade I and II, 25 cases(43.10%) of grade III and IV, 1 case(1.7%) of grade V and VI. Detailed classification condition is shown in Table 1.

In all the cases,Facial nerve H-B classification changes varied at different time point. post-surgical 7d: 9 cases Facial nerve H-B classification stayed at the same grade, 19 cases changed 1 grade, 18 cases changed 2 grade, 10 cases changed 3 grade, and 2 cases changed 4 grade; post-surgical 90d: 16 cases Facial nerve H-B classification stayed at the same grade, 19 cases changed 1 grade, 21 cases changed 2 grade, and 2 cases changed 3 grade. Detailed is shown in Table 2.

Table 1. **Comparison of facial nerve H-B classification Before & After Surgery**

Time point of Evaluation	Grade I	Grade II	Grade III	Grade IV	Grade V	Grade VI
pre-surgery 1d	53	2	3	0	0	0
post-surgical 7d	8	17	18	12	3	0
post-surgical 90d	14	18	22	3	1	0

Table 2. **Facial nerve H-B classification changes at 1 week & 3 months after surgery**

Time point of Evaluation	change 0 grade	change 1 grade	change 2 grade	change 3 grade	change 4 grade
post-surgical 7d	9	19	18	10	2
post-surgical 90d	16	19	21	2	0

Relationships between tumor diameter and post-surgical facial nerve function

Pre-surgical tumor diameters showed significantly positive correlation with the Facial nerve H-B classification changes at post-surgical 7d (Pearson's Correlation, $p<0.001$) and 90d (Pearson's Correlation, $p=0.007$). Statistical distribution was shown in Figure 4. As a result, Larger pre-surgical tumor diameter indicated worse post-surgical facial nerve function (More post-surgical facial nerve's H-B classification changes, $p<0.05$). r: Pearson's Correlation b: Slope of Trend P: Significance of r

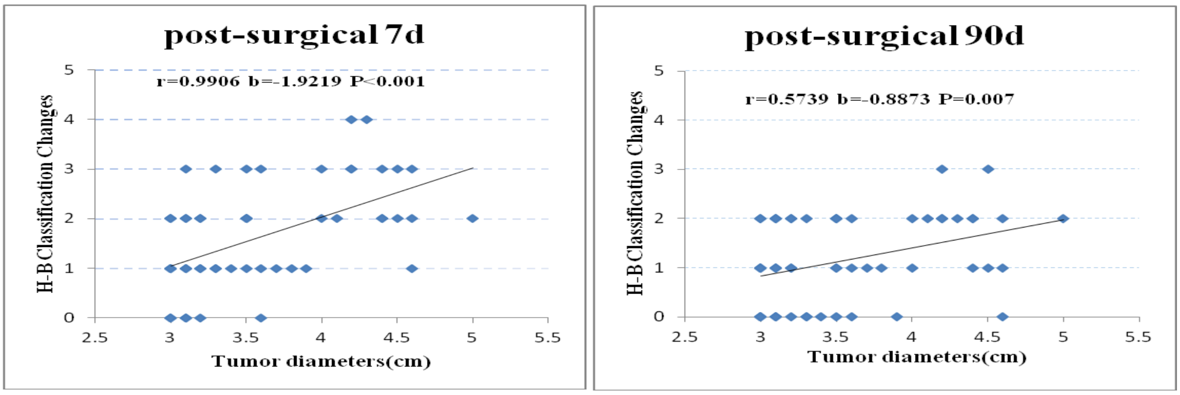

Figure 4. **Statistical distribution of Tumor diameters and Facial nerve H-B classification changes at post-surgical 7d & 90d. Black lines: linear regression results with the slope b.**

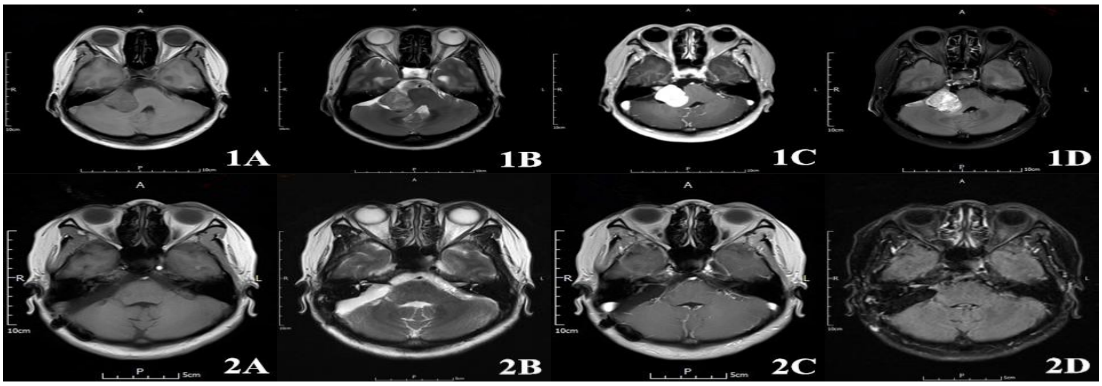

Figure 5. **Representative pre-operative and post-operative MRI scans of one female patient (49 years old). The patient was hospitalized with a history of right hearing loss & headache, achieved a complete tumor surgical resection. Pathology result confirmed a Right Cerebellopontine Angle Acoustic Neuroma. 1A-1D showed pre-operative MRI T1WI, T2WI, Contrast and T2 Flair images. 2A-2D showed corresponding post-operative images.**

Conclusion

Recent large case number studies showed that acoustic neuroma surgically can achieve a complete resection rate of 80.9% to 94.3% while preserving anatomically the facial nerve at rates of 89.7% to 95.3% (Hong, et al.,2017; Huang, et al.,2017; Xu, et al.,2017). Due to common coagulation between tumour and facial nerve, displacement of facial nerve caused by tumor oppression and relatively great difference between individual anatomical position can occasionally make the recognition of facial nerve hard during surgery, making facial nerve damage being the commonest complication in acoustic neuroma surgery. How to balance between as much as tumor resection, retention and recovery of facial nerve function has become the current key and difficulty in acoustic neuroma surgical therapy. Due to the improvement of minimally invasive operation and neuroelectrophysiological monitoring technology, great progress is made in preservation of facial nerve function in large acoustic neuroma resection operation.

Delicate microsurgical operation is the key for maximizing facial nerve function preservation.

We believe that delicate microsurgical operation is the key to achieve maximal resection of tumor while preserving facial nerve function. We recommend to pay extra-attention to the following points during operation.

1) Familiarity with anatomical position: Acoustic neuroma usually originate from vestibular nerve. During its growth, tumour will commonly squeeze facial nerve towards ventral side which explains why facial nerve usually resides midventral, anteroventral and posteroventral to tumour. The commonest condition is that the facial nerve resides midventral to tumour while the least common condition is the facial nerve resides on the dorsal or dorsolateral side of tumour which has a greater chance for facial nerve damaging(Huang, et al.,2017). Facial nerve has relatively fixed position at the cranial and brainstem end making it easy for recognition at early surgical stage. The cranial end can be recognized through internal auditory canal opening while brainstem end can be recognized through anatomical structures including spontomedullary sulcus, glossopharyngeal nerve, vagus, accessory nerve, Luschka hole, protruding choroid plexus and flocculus(Zhang, et al.,2016).

2) Formulate resection sequence: Intracranial decompression should be carried out first. Tumour volume should be reduced progressively along with gradual excision of tumour. The operation needs to reach the goal to reduce the compression of tumour upon surrounding neural vasculature structure and loose the anatomical structure. Sharp dissection should be carried out to separate nerve, vessels and tumour straight after along arachnoid gap between normal tissue and tumour. Peritumour wall then should be excised. After grounding into internal auditory canal's posterior parietal bone, tumour root should be excised finally(Hong, et al.,2017; Huang, et al.,2017, 2017; Xu, et al.,2017).

3) Excision according to hierarchy: Due to continuous growth of tumour, arachnoid covering tumour surface will be pushed towards brainstem side and bent into two layers forming deformed subarachnoid space. Most neural vessels extend between two layers of arachnoid while tumour resides beyond innate arachnoid. Thus the resection of tumour should be strictly positioned at arachnoid level keeping arachnoid attached to neural vessels which is favorable for protection of vital neural vasculature(Kunert, et al.,2015).

4) Cautious protection for vasculature: Vessel branches traversing or surrounding tumour should be carefully recognized and separated. Damages on vessels surrounding tumour or displaced vessels due to tumour oppression should be avoided. Anteroinferior cerebellar artery protection should be paid particular attention because of its nature being labyrinthine artery's origin which supplies blood for facial acoustic nerve and neighboring structure. Neuroischemia, infraction and permanent facial paralysis will be resulted once anteroinferior cerebellar artery is damaged(Zhang, et al.,2016).

5) Appropriate handling of remaining tumour: Total resection will be difficult if tumour is closely attached to facial nerve or brainstem causing anatomical structure chaos. Irreversible damage or vital signs chaos are easily resulted if forcible resection is carried out. Subtotal or partial resection are suggested with remaining tumour wall treated with bipolar weak current electric coagulation method. Closely attached portion of tumour should be given up excising for post-surgical facial nerve function preservation, vital signs and stable brainstem function maintainence(Mahboubi, et al.,2016).

Consummate neuroelectrophysiological monitoring is the crucial guarantee for facial nerve function preservation

Facial nerve electrophysiological monitoring should be carried out throughout surgery(Puanhvuan, et al.,2017, 2018; Tawfik, et al.,2019). Different neuroelectrophysiological techniques should be applied in each stage of surgery to avoid potential damage on facial nerve including:

(1) General estimation of facial nerve trending before excision: Continuous spontaneous electromyogram monitoring should be carried out in case of damages on facial nerve during tumour exposing process. Neural electric stimulator should be used to stimulate peritumour capsule for examination of facial nerve existence under peritumour capsule after tumour exposure. Stimulating intensity should grow gradually and early stage surgical damages on facial nerve can be reduced(Hou,2018).

(2) Real-time positioning of facial nerve location in tumour excision process: Continuous monitoring should be carried out on spontaneous electromyogram. Operator should be informed and surgical operation should be adjusted when various mechanical stimulus caused traction reaction exists especially the first time it happens on facial nerve. Electrical nerve stimulation is optional for detection of facial nerve trending. Electric stimulator can be used to real-timely locate facial nerve trending forward(leading fro brainstem end, locate brainstem exiting site of facial nerve) or backward(locate facial nerve in internal auditory canal after grounding into posterior wall of the canal) while spontaneous electromyogram monitoring goes on during resection of internal auditory canal tumour or brainstem tumour(Huang, et al.,2017; Hou,2018).

(3) Real-time confirmation of facial nerve integrity throughout surgery: Transcranial Electric Stimulation induced Facial-nerve motor evoked potential(FNMEP) is a reference of facial nerve integrity which should be recorded every 10 minutes before resection and every 2-3 minutes during resection operation. Stimulus should be applied after facial nerve traction reaction is observed for facial nerve function examination. Stimulation should be applied on facial nerve separately at its internal auditory canal end and brainstem end after excision of tumour. Prognosis condition of facial nerve can be evaluated according to stimulus threshold range(De Seta E, et al.,2010; Hou,2018).

Other conclusions are organized as follows: 1) Neuroelectrophysiological monitoring is easy to be affected by other electrical devices in surgery room. Particular attention should be paid to maskable facial nerve traction reaction covered up by bipolar electric coagulation interference during tumor excision. 2) Facial nerve is easily stimulated when normal saline is applied to tumour bed for washing after tumour resection. Traction reaction can be observed on spontaneous electromyogram which usually continues for 3-5 minutes then decrease gradually. Real traction reaction can be neglected if it happens during this period. 3) Recent research shows that genesis of spontaneous electromyogram A-train is related to facial nerve function damage. Thus operator should be informed first time when spontaneous electromyogram A-train is produced and A-train existing cause should be carefully checked to stop electromyographic response as soon as possible(Prell, et al.,2014).

Pre-surgical tumor diameter can be used as a predictor of post-surgical facial nerve function prognosis.

Current research shows that post-surgical facial nerve function prognosis of acoustic neuroma is closely related to pre-surgical tumour volume(Seo, et al.,2013; Hong, et al.,2017; Hadjipanayis, et al.,2018). Meta analysis carried out by Zanoletti E. etc. based on 34 case reports of acoustic neuroma from 2012 to 2015 shows that when pre-surgical tumour diameter is less than 1.5cm, post-surgical facial nerve function has a 94% - 96% portion rate grade I and II according to H-B classification. However, The portion is rapidly reduced to 83% for grade I and 70% for grade II when pre-surgical tumour diameter locates between the range of 1.5 - 2.5cm and 2.5-3.5cm. And the portion of cases graded grade I and II falls to 50% once the pre-surgical tumour diameter is larger than 3.5cm(Zanoletti, et al.,2016). In this set of cases, Pre-surgical tumor diameters showed significantly positive correlation with the Facial nerve H-B classification changes at post-surgical 7d (Pearson's Correlation, p <0.001) and 90d (Pearson's Correlation, p =0.007). Our result corresponds with the above literature showing statistical difference. Thus Larger pre-surgical tumor diameter indicated worse post-surgical facial nerve function. Pre-surgical tumor diameter can be used as a predictor of post-surgical facial nerve function prognosis.

In summary, delicate microsurgical operation and consummate neuroelectrophysiological monitoring can significantly increase facial nerve dissection success and function protection rate during acoustic neuroma surgery. And pre-surgical tumour diameter could hold as a predictive index of long-term post-surgical facial nerve function prognosis.

Acknowledgement

We greatly thank and acknowledge Dr. Li Min Chen, Associate Professor at Vanderbilt University Medical Center, USA, for her advice on the organization of the manuscript.

This work was supported by The Natural Science Foundation of Fujian Province, China (2018J01376 & 2019J01574) and the Natural Science Foundation for Youths of Fujian Health and Family Planning Commission, China (2017-2-100 & 2019-2-48).

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