



Electrophysiological mapping and assessment of facial nerve functioning during acoustic neuroma operations

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Background: Electrophysiological monitoring is used routinely to protect the facial nerve during acoustic neuroma surgery. This study aimed to clarify the relationship between the facial nerve's electrophysiological monitoring parameters and its function after surgery.

Methods: Fifty-two patients with acoustic neuroma who underwent surgery were included. After localizing the facial nerve, its monitoring results during surgeries performed at our center were analyzed. Postoperative nerve functioning was correlated with the stimulation threshold of the facial nerve's proximal segment, proximal-to-distal amplitude ratio of the facial nerve, and proximal stimulation amplitude. Receiver-operating characteristic curves of the three parameters were calculated.

Results: Electrical stimulation accurately described the facial nerve's anatomic distribution after the depth of anesthesia was assessed via accessory nerve stimulation. The data recorded after resection showed that a higher proximal-to-distal amplitude ratio was associated with better facial nerve functioning ($P=0.037$). A lower stimulation threshold of the proximal segment correlated with better facial nerve functioning ($P=0.038$).

Conclusions: The most sensitive index to predict postoperative nerve functioning is the facial nerve's proximal-to-distal amplitude ratio. Accessory nerve stimulation can determine the appropriate depth of anesthesia, Electromyography (EMG) monitoring of the facial nerve during acoustic neuroma surgery can protect it effectively.

Keywords: Facial nerve; Electrophysiological monitoring; Acoustic neuroma; Electrical stimulation

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Introduction

Presently, electrophysiological monitoring is used routinely to protect the facial nerve during acoustic neuroma operations (1-4). Protecting the facial nerve comprises locating it and predicting its functioning (5,6).

During surgery, electromyography (EMG) monitoring is used to determine the facial nerve's location. After tumor resection, nerve stimulation findings derived from intraoperative monitoring can predict nerve functioning.

Currently, two main facial nerve monitoring methods

during acoustic neuroma surgery are used: EMG and motor evoked potential (MEP) (7). EMG is either free-running or stimulated. Free-running EMG is based on the A-train pulses' duration to predict facial nerve functioning (8). Meanwhile, MEP predicts facial nerve functioning based on the determined potential's amplitude (9).

However, there is no unified standard on which method to use for predicting facial nerve functioning. This matter requires exploration via multi-center research (10). Stimulated EMG at present is the most commonly used method for predicting facial nerve functioning. The indices

used for prediction include the stimulation threshold of the facial nerve's proximal segment, the nerve's proximal-to-distal amplitude ratio, and stimulation amplitude of the nerve's proximal segment.

Intraoperative electrophysiological monitoring should achieve two goals to protect the facial nerve. The first is to locate the facial nerve, and the second, to predict its postoperative functioning (1); both A-train and MEP methods can achieve the latter but not the former. Thus, free-running and stimulated EMGs, which can do both, are still indispensable in facial nerve monitoring during acoustic neuroma surgery.

Several electrophysiological technology reports have predicted the facial nerve's postoperative functioning (11). However, few have detailed the procedures used to locate the nerve accurately. This study aimed to compare the electrophysiological findings with postoperative nerve functioning and summarized our center's methods in locating the facial nerve.

We present the following article in accordance with the STROBE reporting checklist (available at <http://dx.doi.org/10.21037/atm-20-6858>).

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by ethics committee of Xuanwu Hospital, Capital Medical University (No.: [2019]075) and individual consent for this retrospective analysis was waived.

Study participants

Between June 2016 and March 2018, 52 patients with acoustic neuroma who underwent surgery in our center were included. The retrosigmoid approach was used in all patients. The tumoral size, as determined via MRI, was recorded. The patients' preoperative symptoms included hearing loss, facial pain, and tinnitus. A senior specialist performed the surgery on all patients.

Anesthesia

Midazolam (1–2 mg), etomidate (0.15 mg/kg), and sufentanil (0.3 µg/kg) were used for anesthesia induction. After induction, the muscle relaxant use was discontinued. To maintain anesthesia, remifentanil (0.2–0.4 µg/min), metomidine (0.2 µg/kg/h), and propofol (2–5 mg/kg/h) were used. During the operation, the Bispectral Index (BIS)

was used to monitor the depth of anesthesia; BIS values were maintained between 40 and 60.

Neurophysiological monitoring

A Nicolet system (Natus Neuro, Middleton, Wisconsin, USA) was used to perform intraoperative electrophysiological monitoring. Needle electrodes were placed after anesthesia induction and fixation of the head holder system. Two-needle electrodes were placed in the orbicularis oculi, orbicularis oris, masseter, and sternocleidomastoid to record EMG and monitor the different facial nerve branches, trigeminal motor branch, and accessory nerve. A bipolar disposable probe was used to stimulate the facial nerve. A single stimulation was emitted with a 300 µs wave width.

Accessory nerve stimulation for depth of anesthesia determination

After the acoustic neuroma was exposed, the accessory nerve was identified. If a 0.1–0.2 mA stimulus generated a response with an amplitude of greater than 300 µV, the depth of anesthesia was considered appropriate. A response amplitude less than 300 µV required a reduction of superficial anesthesia and accessory nerve restimulation: 5 of the 52 patients required this reduction. After the appropriate adjustments, the patients exhibited satisfactory accessory nerve waveforms (*Figure 1*).

Facial nerve mapping

After appropriate depth of anesthesia was determined, 1.0 mA stimuli were applied in all tumor surface directions to determine whether the facial nerve traversed the tumor. This procedure must be performed prior to resection to avoid facial nerve injury. Close attention must be paid to the free-running EMG during tumor resection (*Figure 2*). When an obvious response occurs, the tumor's corresponding portion should be stimulated immediately. Special attention should also be paid during tumor removal from the internal auditory canal.

When using electrical stimulation for facial nerve mapping, the first stimulus should be a 1.0 mA pulse, which should be reduced afterward. An obvious response to a less than 0.3 mA stimulus is indicative of the facial nerve's direct stimulation. The facial nerve distribution, from the proximal to distal segments, should be described accurately, utilizing stimulated and free-running EMG findings.

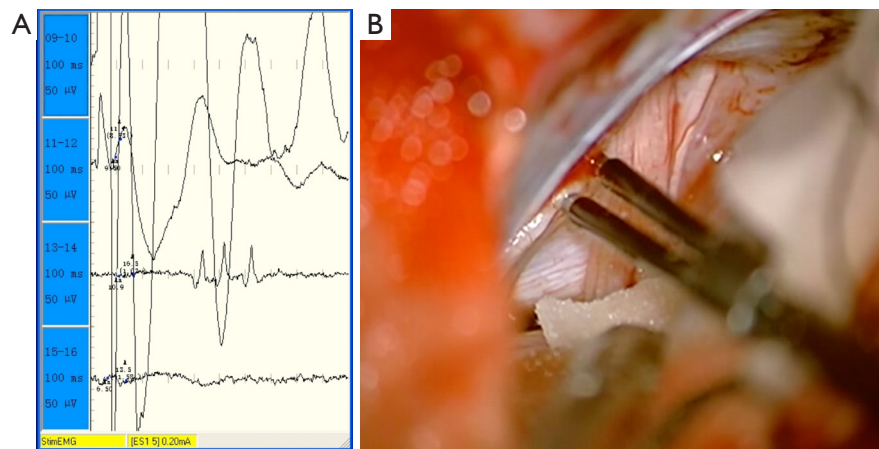


Figure 1 EMG response after accessory nerve stimulation (A) and microscopic observation of accessory nerve stimulation during an operation (B).

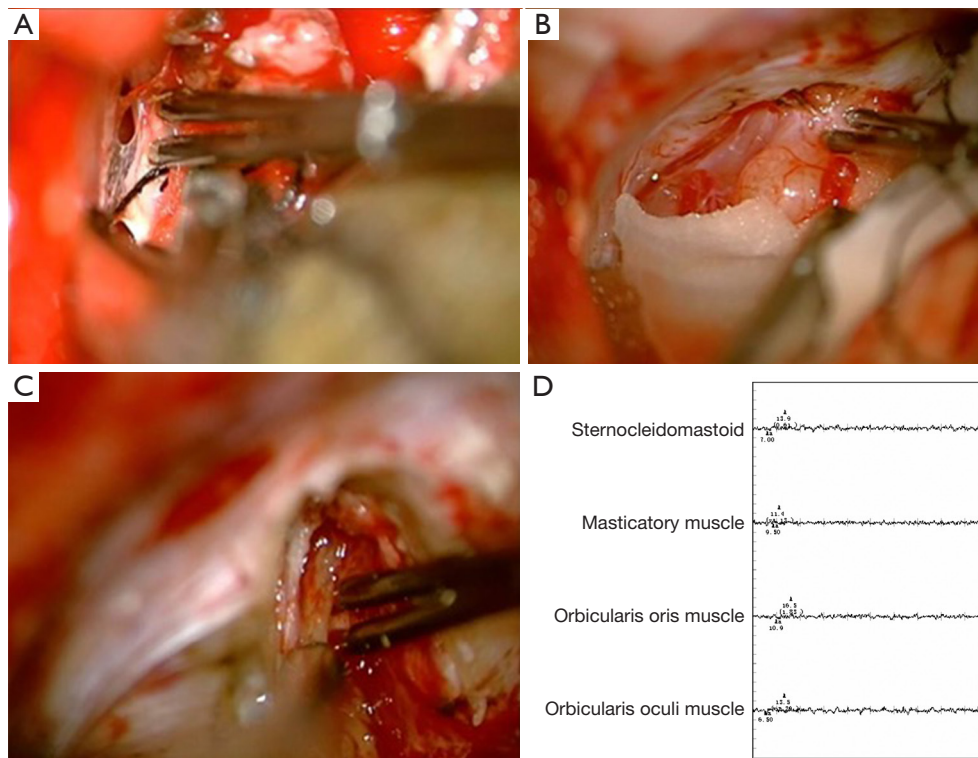


Figure 2 Stimulation of different tumor surface sections (A,B,C) with a 0.5–1 mA pulse and EMG response (D) before resection.

Continuous free-running EMG evaluation throughout resection is commonly performed. If the facial nerve distribution has been mapped successfully via electrophysiology, we can ensure that the nerve does not cross relevant regions and will be unaffected by resection.

As such, continuous facial nerve reactions can be ignored. However, if the distribution patterns cannot be determined (as in the continuous free-running EMG), surgery can only be performed once the reaction has ended to avoid iatrogenic injury to the facial nerve (Figure 3).

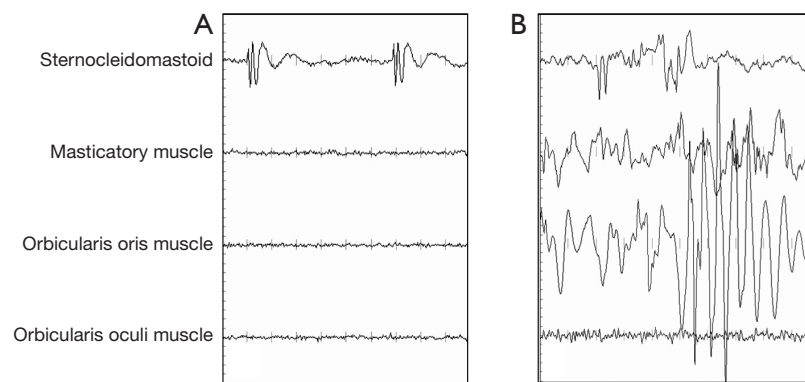


Figure 3 Small (A) and large (B) EMG responses observed via free-running EMG when performed near the facial nerve.

After the facial nerve was located, three repetitions of suprathreshold stimulation (0.5 mA) were performed. The maximum amplitude and stimulation threshold were recorded. The average maximum values of the orbicularis oculi and oris were used for statistical analysis.

Facial nerve function after acoustic neuroma resection

House-Brackmann (H-B) scores (12) were used to evaluate facial nerve functioning in patients at different time points: preoperatively, 3–7 days after surgery, 1 month after surgery, and 1 year after surgery. According to the level of facial nerve functioning 3–7 days after surgery, patients were divided into two groups: patients with good levels of facial nerve functioning (levels 1–2), and patients with poor levels of facial nerve functioning (levels 3–6).

Statistical analysis

SPSS version 24.0 (SCR_002865) was used to analyze the data. Spearman correlation analysis was used to assess the correlation between facial nerve functioning and its proximal stimulation threshold, proximal-to-distal amplitude ratio, and proximal amplitude. Receiver-operating characteristic (ROC) curves were calculated to assess the three parameters' diagnostic efficacy in predicting postoperative neurological functioning. The statistical significance was set to $P < 0.05$.

Results

Characteristics of the sample

Fifty-two patients with acoustic neuroma were included in

this study (n=25 males; n=27 females) The average age was 47.9 ± 13.3 , ranging between 15 and 74 years. According to the preoperative MRI results, the tumor size was 28.5 ± 11.0 (11–48) mm. Twenty-eight patients had tumors that measured less than 30 mm, while 24 patients had tumors measuring greater than the said value.

Facial nerve preservation

Anatomic preservation of the facial nerve was achieved in 49 of the 52 patients, resulting in a 94.2% overall anatomic preservation rate.

Among these 49 patients, 6 lacked complete facial nerve stimulation data. Of the six, three had too hyperreactive nerve responses for nerve stimulation data extraction. Meanwhile, for the remaining three, one had a closed internal auditory canal that prevented the collection of distal nerve stimulation data; two had tumor-driven facial nerve compression into a membrane, making it difficult to identify the nerve's specific location. Finally, 43 patients were included in the statistical analysis.

The postoperative neurological function of the patients was as follows:

Among the 52 patients, 48 patients achieved anatomic preservation of facial nerve. Among them, 26 patients' facial nerve function were grade 1 after operation, and it was still grade 1 at 3 months follow-up; 14 patients were grade 2 after operation, and it was found that 10 patients recovered to grade 1, 3 patients were still grade 2, and 1 patient decreased to grade 3; 8 patients' facial nerve function were grade 3, one patient recovered to grade 1, 4 recovered to

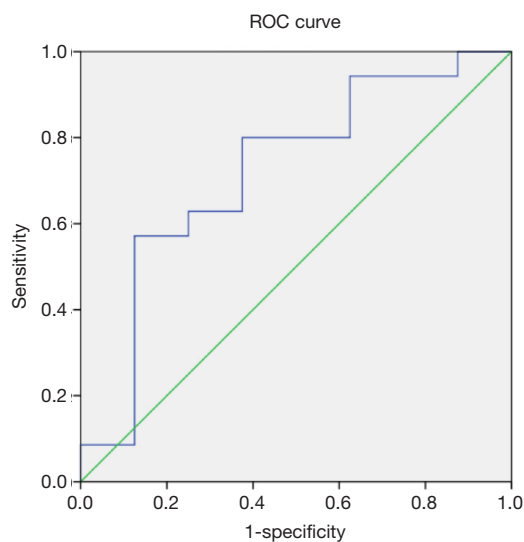


Figure 4 Capacity of proximal stimulation amplitude to predict nerve functioning post-surgery as determined by ROC curve analyses. This ROC curve has an area under the curve of 0.721. Asymptotic significance was 0.053; a value greater than 0.05 means that not all the test's cut-off values are statistically significant.

Table 1 Proximal stimulation amplitude cut-off value of 345.5

	Grade 1–2	Grade 3–6	Total
<345.5	15	7	22
≥345.5	20	1	21
Total	35	8	43

Sensitivity =57.14%, specificity =87.50%, positive predictive value =95.24%, negative predictive value=31.82%.

grade 2, and 2 remained at grade 3; one patient had grade 4 facial nerve function immediately after operation and recovered to grade 2 three months after operation; three facial nerves failed to be preserved, which was grade 6 after operation. One patient underwent facial nerve hypoglossal nerve anastomosis one week later, and the facial nerve function of the three patients was still grade 6 at 3 months follow-up.

Three electrophysiological indices were analyzed in this study: proximal amplitude, proximal-to-distal amplitude ratio, and proximal stimulation threshold. As a result of ROC curve analyses, it was determined that a good cut-off value for proximal amplitude was 345 μ V, with sensitivity and specificity values of 57.14% and 87.50%, respectively ($P=0.053$; *Figure 4*; *Table 1*). The best proximal stimulation

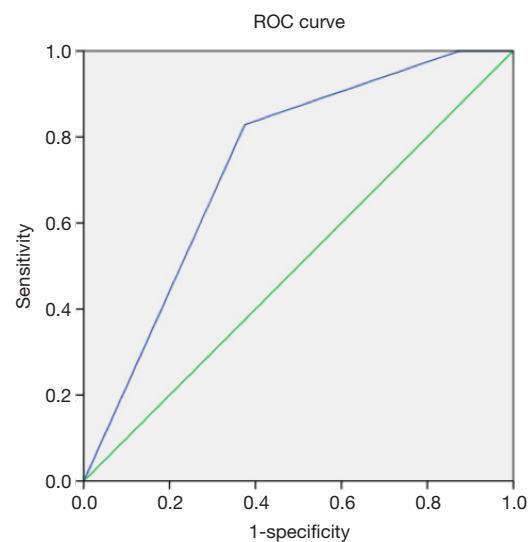


Figure 5 Capacity of proximal stimulation thresholds to predict facial nerve functioning post-surgery as determined by ROC curve analyses. This ROC curve has an area under the curve of 0.737. Asymptotic significance was 0.038; a value lower than 0.05 means that all the test's cut-off values are statistically significant ($P<0.05$).

Table 2 Proximal stimulation thresholds cut-off value of 0.15

	Grade 1–2	Grade 3–6	Total
<0.15	29	3	32
≥0.15	6	5	11
Total	35	8	43

Sensitivity =82.86%, specificity =62.50%, positive predictive value =90.63%, negative predictive value=45.45%.

threshold cut-off value was 0.15, and sensitivity and specificity values were 82.86% and 62.50%, respectively ($P=0.038$; *Figure 5*; *Table 2*). Regarding proximal-to-distal amplitude ratio, 0.765 was the cut-off value, and sensitivity and specificity values were 82.86% and 75.00%, respectively ($P=0.037$; *Figure 6*; *Table 3*).

Case study

A 43-year-old female presented with left-ear hearing loss for 3 months and paroxysmal tinnitus for 2 months. During surgery, electrophysiological monitoring was performed following our center's standard methods. First, the accessory nerve was stimulated to determine the appropriateness of the depth of anesthesia. Before resection,

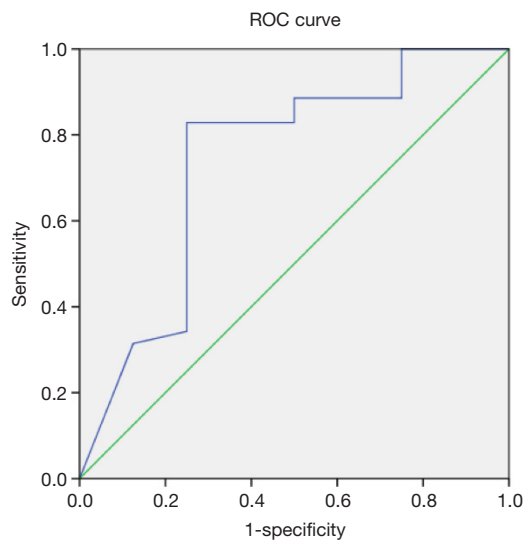


Figure 6 Capacity of the facial nerve's proximal-to-distal amplitude ratio to predict nerve functioning post-surgery as determined by ROC curve analyses. This ROC curve has an area under the curve of 0.739. Asymptotic significance was 0.037; a value lower than 0.05 means that all the test's cut-off values are statistically significant ($P < 0.05$).

Table 3 Proximal-to-distal amplitude ratio cut-off value of 0.765

	Grade 1–2	Grade 3–6	Total
<0.765	6	6	12
≥ 0.765	29	2	31
Total	35	8	43

Sensitivity =82.86%, specificity =75.00%, positive predictive value =93.55%, negative predictive value =50.00%.

a 1.0 mA stimulation of the tumor surface was performed. During the operation, free-running EMG and stimulation were used to trace roughly the facial nerve's distribution pattern. After tumor resection, the proximal threshold was 0.1 mA, average amplitude of orbicularis oris and orbicularis oculi was 381 μV , and proximal-to-distal amplitude ratio was 0.77. An H-B score of grade 1 was used to describe the patients' postoperative neurological functioning.

Discussion

This study showed that the proximal stimulation threshold, proximal-to-distal amplitude ratio, and proximal amplitude could, to some extent, predict facial nerve functioning

within seven days after acoustic neuroma resection. All three indicators were similar to those reported previously (11,13).

This study's sensitivity and specificity results indicated that the proximal-to-distal amplitude ratio was the best predictor of facial nerve functioning.

It is particularly important to standardize the facial nerve's electrophysiological monitoring during acoustic neuroma surgery. Effective electrophysiological monitoring must include the following: (I) depth of anesthesia determination, (II) thorough nerve stimulation prior to resection, and (III) facial nerve distribution mapping.

In previous studies, stimulations were performed repetitively on the orbicularis oris and oculi, and the maximum amplitude obtained was used for statistical assessment (13-15). However, this study used the average value of the maximum amplitudes of the orbicularis oris and oculi for all analyses. The average values were found to best describe the facial nerve's overall functioning. This method has not been reported previously.

Most previously published studies have focused on monitoring results and have rarely described specific mapping technology. In addition to comparing the relationship between facial nerve functioning and electrophysiological parameters, this study also summarized the methods used to locate the said nerve. It is crucial to determine the depth of anesthesia using an accessory nerve EMG because the train of four (TOF) method is inaccurate. In this study, the accessory nerve's stimulation amplitude was used to determine whether an appropriate depth of anesthesia had been achieved, another method this study introduced.

However, it remains impossible to locate the facial nerve with these two monitoring methods; hence, they cannot replace the role of stimulated-EMG in acoustic neuroma surgery (16). In short, A-train and MEP can predict facial nerve functioning to some extent (17) but cannot map the facial nerve (18-20). The monitoring method in use the longest comprises a combination of traditional free-running and stimulated EMGs. Although its criteria for predicting facial nerve functioning are not uniform, such a combination can locate the facial nerve and avoid injury. Thus, it remains the main method for facial nerve activity monitoring; the other two methods—A-train and MEP—are only supplementary.

Our center has achieved good facial nerve preservation by using the stimulated and/or free-running. The anatomical preservation rate is 94.2%, slightly lower than that reported internationally. Likewise, the functioning

preservation rate is 92.3%, higher than the 70% reported in the literature (10). Most of the patients in the current study who achieved anatomical preservation have a grade 3 or higher facial nerve functioning. Our findings show that both the stimulation amplitude and thresholds can reflect postoperative nerve functioning. The stimulation amplitude ratio was the best predictor of nerve functioning; stimulation threshold data can be obtained throughout an operation in real time.

The surgical team's capacity to preserve facial nerve functioning depends on two factors. First, on resection technology and the surgeon's experience. Second, on whether the nerve monitoring team can effectively trace the facial nerve's distribution.

Several things are needed for successful facial nerve monitoring, including adequate, reproducible surgical parameters and methods, an experienced surgeon, adequate technology, and mutual trust between the monitoring team and surgeon.

This study has some limitations. First, no control group was included. Second, MEP and A-train were not analyzed together.

Conclusions

The proximal-to-distal amplitude ratio of the facial nerve is the most sensitive index to predict postoperative nerve functioning. When combined with the accessory nerve's stimulation, EMG monitoring can determine the appropriate depth of anesthesia. Facial nerve EMG monitoring during acoustic neuroma surgery can protect the nerve effectively from damage. Adequate mapping of the facial nerve (achieved by standardized electrophysiological monitoring) is highly important because knowing the facial nerve's accurate location during resection can improve its functioning preservation rate.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <http://dx.doi.org/10.21037/atm-20-6858>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by ethics committee of Xuanwu Hospital, Capital Medical University (No.: [2019]075) and individual consent for this retrospective analysis was waived.

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