

Retrospective Study on Predicting Postoperative Facial Nerve Function Using Intraoperative Microcurrent Combined with Facial Nerve Motor Evoked Potentials in Vestibular Schwannoma Surgery

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Abstract

Background

The most commonly used method for monitoring facial nerve function is electromyography and facial nerve motor evoked potentials. This study aims to conduct a retrospective study on 176 cases of vestibular schwannoma, compare the two electrophysiological monitoring methods, and find an optimal clinical model combining the two to predict postoperative facial nerve function.

Results

All patients underwent intraoperative monitoring using electromyography and facial nerve motor evoked potentials. Differences in general clinical data and intraoperative neuroelectrophysiological monitoring results were compared between the two groups at 3 days, 1 month, 3 months, and 1 year postoperatively. Multivariate logistic regression analysis revealed that $\geq 50\%$ decrease in mentalis muscle and microcurrent > 0.05 mA were independent risk factors 3 days and 1 month postoperation. $\geq 50\%$ decrease in mentalis muscle, microcurrent > 0.05 mA, and age were independent risk factors 3 months postoperation. $\geq 50\%$ decrease in orbicularis oris muscle, microcurrent > 0.05 mA, and age were independent risk factors 1 year postoperation. Prediction model at 1 year postoperatively had the largest area under the receiver operating characteristic curve, showing the best predictive ability.

Conclusions

In this study, a 50% decrease in facial nerve motor evoked potentials of the orbicularis oris muscle and mentalis muscle could serve as an independent indicator for predicting postoperative facial nerve function. Combination of microcurrent and facial nerve motor evoked potentials can improve the prediction rate of postoperative facial paralysis and provide more accurate guidance for subsequent treatment.

Introduction

Facial paralysis is a relatively common complication after vestibular schwannoma surgery, which significantly affects the quality of life [1, 2]. Intraoperative protection of the anatomical structure and function of the facial nerve is particularly important in the treatment of vestibular schwannoma [3]. However, sometimes good intraoperative anatomical preservation of the facial nerve does not mean good postoperative facial nerve function, and there is a lack of evidence on whether patients with poor postoperative facial paralysis recovery can undergo nerve anastomosis as early as possible to restore facial nerve function [4]. At present, intraoperative electrophysiological monitoring has been widely used, and how to use intraoperative electrical nerve monitoring to predict postoperative facial nerve function is of great value.

Previous reports have shown that the most used method to predict postoperative facial paralysis is using electromyography (EMG) to monitor the current at the brainstem segment of the facial nerve during surgery. It is generally believed that the higher the stimulation current threshold, the more severe the facial nerve injury [5–8]. In the previous studies of our team, it has also been confirmed that the postoperative facial paralysis in the intraoperative microcurrent group (≤ 0.05 mA) is significantly better than that in the non-microcurrent group [9].

In addition, facial nerve motor evoked potential (FNMEP) is another electrophysiological monitoring technique for facial nerve function, which is also commonly used in intraoperative facial nerve function monitoring and postoperative facial paralysis prediction at present [10]. Compared with microcurrent, FNMEP can monitor the entire facial nerve conduction pathway, and monitoring can be performed even without exposing the facial nerve. Currently, a 50% decrease in intraoperative motor evoked potential is generally used as a reference value to predict postoperative facial paralysis [11, 12].

As the two most commonly used methods for intraoperative facial nerve monitoring and the most important indicators for postoperative facial paralysis prediction, there is no clear report in the current literature on whether the combination of the two can become a better model for predicting facial paralysis. This study aims to conduct a retrospective study on 176 cases of vestibular schwannoma, analyze and organize intraoperative electrophysiological monitoring data, compare the two electrophysiological monitoring methods, conduct statistical analysis, and find an optimal clinical model combining the two to predict postoperative facial nerve function.

Methods

Experimental Design and Patient Selection

General Information: This study is a case series study. A total of 176 patients who underwent resection of acoustic neuroma via the suboccipital retrosigmoid approach were included. Inclusion criteria: (1) Patients with initial diagnosis of schwannoma, which was confirmed by pathology after surgery. (2) All patients had a preoperative facial nerve function grade of House-Brackmann (HB) Grade I. Exclusion criteria: Patients with recurrent tumors and those who received preoperative radiotherapy. This study was approved by the Ethics Committee

of Huashan Hospital Affiliated to Fudan University (Approval No. : KY2015-256), and all patients or their family members were fully informed, consented, and signed the informed consent form.

Tumor Evaluation Criteria: All patients underwent routine preoperative thin-slice cranial CT scan and MRI plain scan plus contrast-enhanced scan. The maximum diameter of the tumor was measured based on the imaging results. Tumors were classified according to the Samii classification: Grade 1: Tumors confined to the internal auditory canal; Grade 2: Tumors located both inside and outside the internal auditory canal; Grade 3: Tumors growing into the cerebellopontine angle (CPA), filling the CPA cistern, or growing medially and having touched the brainstem; Grade 4: Tumors compressing the brainstem, causing severe brainstem displacement and compression-induced deformation of the fourth ventricle.

Surgical Method

All operations were performed by the same senior surgeon. The patients were placed under general anesthesia, and the suboccipital retrosigmoid approach was adopted. The patients were in the lateral decubitus position, with a straight postauricular incision made. For tumors involving the internal auditory canal, the canal was fully drilled to ensure complete tumor resection. Postoperative enhanced magnetic resonance imaging (MRI) was performed within 3 days to confirm total tumor removal. (Figure1)

Intraoperative Neuroelectrophysiological Monitoring Methods

All patients underwent intraoperative monitoring of facial nerve function using EMG and FNMEP (Figure1). **Facial Nerve Electromyography:** All patients were monitored for facial nerve activity using the NIM-ECLIPSE neuroelectrophysiological monitoring system (16 channels, Medtronic, USA), which integrates EMG and FNMEP. After complete tumor resection, a neuroelectrophysiological probe was used to explore the entire length of the facial nerve, including the brainstem origin segment and the internal auditory canal segment of the facial nerve. The minimum stimulation current required to elicit valid action potentials (with an amplitude $> 100 \mu\text{V}$) in 4 channels of the facial nerve's brainstem origin segment was recorded as the stimulation threshold. Initially, a current of 0.35 mA was used to stimulate the facial nerve, and the stimulation current was adjusted based on the amplitude of the EMG waveform. The adjustment method was as follows: if a stimulation current of 0.35 mA still could induce an action potential $> 100 \mu\text{V}$ (defined as a valid action potential), the current was reduced to 0.05 mA; if this reduced current still could elicit an action potential $> 100 \mu\text{V}$, the current was further lowered to 0.03 mA; this process was repeated until the stimulation threshold was reduced to 0.01 mA. The minimum current that could induce a valid action potential was recorded as the microcurrent value. This study mainly recorded the minimum current at the brainstem segment of the facial nerve. **Transcranial Electrical Stimulation for FNMEP Monitoring:** During the operation, the aforementioned neuroelectrophysiological monitoring system was used to perform FNMEP monitoring, as well as routine evoked EMG and free-run EMG monitoring. After the dura mater was incised to expose the tumor, FNMEP was stimulated and recorded when the muscle relaxant was completely metabolized, and this recording was used as the baseline value. At the end of the operation, FNMEP was recorded again and compared with the preoperative baseline value. **Placement of FNMEP Stimulation Electrodes:** The anode was placed at the facial functional area of the precentral gyrus, which was located 1.0–2.5 cm above and 0.5–1.5 cm anterior to the intersection of the surface projection lines of the central sulcus and the lateral fissure (measured on the body surface); the cathode was placed at the midline. Recording electrodes were placed on the orbicularis oculi superioris muscle, orbicularis oculi inferioris muscle, orbicularis oris muscle, masseter muscle, and mentalis muscle; the ground electrode was placed on the deltoid muscle of the upper arm. **FNMEP Stimulation Parameters:** Constant-voltage biphasic square-wave stimuli in trains of 4 were used to activate the intracranial segment of the facial nerve, and single-pulse stimuli were delivered at 60-second intervals to verify the peripheral segment of the facial nerve. The pulse duration was 200 μs , and the filtering range was 150–3,000 Hz. If the train of 4 stimuli induced a facial nerve action potential with a latency $\geq 2 \text{ ms}$, it was considered an action potential of the intracranial segment of the facial nerve; if a single pulse elicited a facial nerve action potential with a latency $\leq 10 \text{ ms}$, it was regarded as an action potential of the peripheral segment of the facial nerve. A $< 50\%$ decrease in FNMEP amplitude at the end of the operation was used as an indicator of a favorable facial nerve function prognosis, while a $\geq 50\%$ decrease in FNMEP amplitude or disappearance of FNMEP indicated a risk of severe facial paralysis. Since transcranial electrical stimulation may cause body movements, which could interfere with the surgeon's operation, communication with the attending surgeon was required before performing the stimulation. In this study, the action potentials of the orbicularis oris muscle and mentalis muscle were selected as the indicators for statistical analysis. The specific criteria for defining central-origin responses are as follows: The first pulse consisted of four train stimuli, which enhanced stimulation penetration to allow current to traverse the high-impedance skull and cerebrospinal fluid, reaching the deep cortical motor areas and activating the target pathway (cortex $\rightarrow$ corticobulbar tract $\rightarrow$ facial nucleus). The second pulse was used to verify peripheral nerve excitation via the refractory period effect: if no waveform was elicited by the second pulse, the response was attributed to the central conduction pathway rather than direct peripheral nerve excitation. In the present study, a response was classified as central-origin if the second pulse failed to elicit a waveform or only induced a single-phase waveform. Conversely, if the second pulse still evoked a waveform identical to that of the first pulse, the response was deemed to involve peripheral nerve excitation or a mixed response and was therefore excluded.

Facial Nerve Function Evaluation and Grouping Method

Facial nerve function was evaluated using the House-Brackmann (HB) grading system. Observations and recordings were conducted at 3 days, 1 month, 3 months, and 1 year postoperatively, and facial nerve function was assessed via telephone, WeChat, and outpatient visits. Patients with postoperative HB grades I–II were assigned to the good prognosis group, while those with HB grades III–IV were assigned to the poor prognosis group. Differences in general clinical data, tumor conditions, and intraoperative neuroelectrophysiological monitoring results were compared between the two groups.

Statistical Methods

Statistical analysis was performed using R 4.3.2 software. Continuous variables conforming to a normal distribution were expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$), and comparisons between the two groups were conducted using the independent samples t-test. Continuous variables not conforming to a normal distribution were expressed as median (interquartile range) [M (Q1, Q3)], and comparisons between the two groups were performed using the Mann-Whitney U test. Categorical variables were described by frequency, percentage, or composition ratio; comparisons between the two groups were made using the chi-square (χ^2) test or Fisher's exact test. Comparisons of ordinal data were carried out using the Mann-Whitney U test. Indicators with statistically significant differences between the two groups were included in a multivariate logistic regression model for analysis. A two-tailed test with $P < 0.05$ was considered to indicate a statistically significant difference.

Results

Total tumor resection was achieved in all 176 patients (100%), and the anatomical preservation rate of the facial nerve after surgery was 100%. No severe complications or deaths occurred in any patient during the perioperative period, and no tumor recurrence was observed in all patients during the 1-year follow-up period.

Postoperative Facial Nerve Function Status

Among the 176 patients, at 3 days postoperatively, 128 cases (72.73%) had a good prognosis and 48 cases (27.27%) had a poor prognosis; among them, 62 cases were classified as HB Grade I, 66 cases as HB Grade II, 30 cases as HB Grade III, 7 cases as HB Grade IV, and 1 case as HB Grade V (Table 1). At the 1-month postoperative follow-up, 124 cases (70.45%) had a favorable prognosis, and 52 cases (29.55%) had a poor prognosis; among these, 58 cases were HB Grade I, 66 cases were HB Grade II, 34 cases were HB Grade III, 17 cases were HB Grade IV, and 1 case was HB Grade V (Table 1). At the 3-month postoperative follow-up, 140 cases (79.55%) had a favorable prognosis, and 36 cases (20.45%) had a poor prognosis; among them, 74 cases were HB Grade I, 66 cases were HB Grade II, 26 cases were HB Grade III, and 10 cases were HB Grade IV (Table 2). At the 1-year postoperative follow-up, 151 cases (85.80%) had a favorable prognosis, and 25 cases (14.20%) had a poor prognosis; among these, 86 cases were HB Grade I, 65 cases were HB Grade II, 22 cases were HB Grade III, and 3 cases were HB Grade IV (Table 2).

Comparison Results between the Favorable and Poor Prognosis Groups for Postoperative Facial Nerve Function: The evaluation at 3 days postoperatively showed that compared with the poor prognosis group, the favorable prognosis group had a higher proportion of patients with a $\leq 50\%$ decrease in FNMEP amplitude of the orbicularis oris muscle, a $\leq 50\%$ decrease in FNMEP amplitude of the mentalis muscle, and microcurrent ≤ 0.05 mA; additionally, there was a statistically significant difference in age (all $P < 0.05$) (Table 1 and Fig. 3). However, there were no statistically significant differences in gender, tumor side, Samii classification, tumor size, or tumor texture between the two groups ($P > 0.05$) (Table 1 and Fig. 3). Multivariate logistic regression analysis revealed that a $\geq 50\%$ decrease in FNMEP amplitude of the mentalis muscle and microcurrent > 0.05 mA were independent risk factors for postoperative facial paralysis in patients ($P < 0.05$) (Table 3 and Fig. 3).

The evaluation at 1 month postoperatively showed that compared with the poor prognosis group, the favorable prognosis group had a higher proportion of patients with a $< 50\%$ decrease in FNMEP amplitude of the orbicularis oris muscle, a $< 50\%$ decrease in FNMEP amplitude of the mentalis muscle, and microcurrent ≤ 0.05 mA, with statistically significant differences ($P < 0.05$) (Table 1 and Fig. 3); while there were no statistically significant differences in age, gender, tumor side, Samii classification, tumor size, or tumor texture between the two groups ($P > 0.05$) (Table 1 and Fig. 3). Multivariate logistic regression analysis indicated that a $\geq 50\%$ decrease in FNMEP amplitude of the mentalis muscle and microcurrent > 0.05 mA were independent risk factors for postoperative facial paralysis in patients ($P < 0.05$) (Table 3 and Fig. 3).

The evaluation at 3 months postoperatively showed that compared with the poor prognosis group, the favorable prognosis group had a higher proportion of patients with a $< 50\%$ decrease in FNMEP amplitude of the orbicularis oris muscle, a $< 50\%$ decrease in FNMEP amplitude of the mentalis muscle, and microcurrent ≤ 0.05 mA, as well as a statistically significant difference in age ($P < 0.05$) (Table 2 and Fig. 3); however, there were no statistically significant differences in gender, tumor side, Samii classification, tumor size, or tumor texture between the two groups ($P > 0.05$) (Table 2 and Fig. 3). Multivariate logistic regression analysis demonstrated that a $\geq 50\%$ decrease in FNMEP amplitude of the mentalis muscle and microcurrent > 0.05 mA were independent risk factors for postoperative facial paralysis in patients ($P < 0.05$) (Table 3 and Fig. 3).

The evaluation at 1 year postoperatively showed that compared with the poor prognosis group, the favorable prognosis group had a higher proportion of patients with a $< 50\%$ decrease in FNMEP amplitude of the orbicularis oris muscle, a $< 50\%$ decrease in FNMEP

amplitude of the mentalis muscle, and microcurrent ≤ 0.05 mA, along with a statistically significant difference in age ($P < 0.05$) (Table 2 and Fig. 3); whereas there were no statistically significant differences in gender, tumor side, Samii classification, tumor size, or tumor texture between the two groups ($P > 0.05$) (Table 2 and Fig. 3). Multivariate logistic regression analysis showed that a $\geq 50\%$ decrease in FNMEP amplitude of the orbicularis oris muscle, microcurrent > 0.05 mA, and age were independent risk factors for postoperative facial paralysis in patients ($P < 0.05$) (Table 3 and Fig. 3). Further comparative analysis of the ROC curves of the facial paralysis prediction models at the four time points was conducted. The ROC curves of all prediction models were located above the diagonal, indicating that all prediction models had good discriminative ability. Among them, the prediction model at 1 year postoperatively had the largest area under the ROC curve, showing the best predictive ability (Figure2).

Table 1

Comparison Results between the Good and the Poor outcome Group of House - Brackmann Grading in Patients after Surgery(3 days and 1month)

Variables	3days					1month				
	Total (n = 176)	Good outcome	Poor outcome	Statistic	P	Total (n = 176)	Good outcome	Poor outcome	Statistic	P
Age (years), Mean $\pm$ SD	48.38 $\pm$ 12.52	47.09 $\pm$ 12.10	51.81 $\pm$ 13.09	t=-2.26	0.025	48.38 $\pm$ 12.52	47.30 $\pm$ 12.01	50.94 $\pm$ 13.42	t=-1.77	0.078
Oris CR $\geq$ 50%, M (Q₁,Q₃)	-0.13 (-0.82, 0.19)	-0.05 (-0.59, 0.22)	-0.44 (-2.39, 0.03)	Z=-3.13	0.002	-0.13 (-0.82, 0.19)	-0.04 (-0.59, 0.24)	-0.41 (-2.38, 0.03)	Z=-3.13	0.002
Mentalis CR $\geq$ 50%, M (Q₁, Q₃)	-0.06 (-0.58, 0.13)	-0.01 (-0.25, 0.20)	-0.54 (-1.93, -0.01)	Z=-4.49	< .001	-0.06 (-0.58, 0.13)	-0.01 (-0.35, 0.23)	-0.40 (-1.78, 0.02)	Z=-4.06	< .001
Samii scale, n(%)				-	0.231					0.236
2	6 (3.41)	6 (4.69)	0 (0.00)			6 (3.41)	6 (4.84)	0 (0.00)		
3	80 (45.45)	60 (46.88)	20 (41.67)			80 (45.45)	58 (46.77)	22 (42.31)		
4	90 (51.14)	62 (48.44)	28 (58.33)			90 (51.14)	60 (48.39)	30 (57.69)		
Sex, n(%)				$\chi^2=0.01$	0.926					0.516
Male	78 (44.32)	57 (44.53)	21 (43.75)			78 (44.32)	53 (42.74)	25 (48.08)		
Female	98 (55.68)	71 (55.47)	27 (56.25)			98 (55.68)	71 (57.26)	27 (51.92)		
Tumor Side, n(%)				-	1.000					0.817
Right	92 (52.27)	67 (52.34)	25 (52.08)			92 (52.27)	66 (53.23)	26 (50.00)		
Left	83 (47.16)	60 (46.88)	23 (47.92)			83 (47.16)	57 (45.97)	26 (50.00)		
Tumor size (cm), n(%)				$\chi^2=0.28$	0.597					0.539
<3cm	101 (57.39)	75 (58.59)	26 (54.17)			101 (57.39)	73 (58.87)	28 (53.85)		
$\geq$3cm	75 (42.61)	53 (41.41)	22 (45.83)			75 (42.61)	51 (41.13)	24 (46.15)		
Characteristics of tumor, n(%)				$\chi^2=4.54$	0.103					0.250
Solid, no. (%)	70 (39.77)	55 (42.97)	15 (31.25)			70 (39.77)	52 (41.94)	18 (34.62)		
Cystic, no. (%)	37 (21.02)	22 (17.19)	15 (31.25)			37 (21.02)	22 (17.74)	15 (28.85)		
Cystic-solid, no. (%)	69 (39.20)	51 (39.84)	18 (37.50)			69 (39.20)	50 (40.32)	19 (36.54)		
Low current, n(%)				$\chi^2=22.34$	< .001					< .001
$\leq$0.05ma	150 (85.23)	119 (92.97)	31 (64.58)			150 (85.23)	116 (93.55)	34 (65.38)		
>0.05ma	26 (14.77)	9 (7.03)	17 (35.42)			26 (14.77)	8 (6.45)	18 (34.62)		

Table 2

Comparison Results between the Good and the Poor outcome Group of House - Brackmann Grading in Patients after Surgery(3 months and 1year)

Variables	3 months					1 year				
	Total (n = 176)	Good outcome	Poor outcome	Statistic	P	Total (n = 176)	Good outcome	Poor outcome	Statistic	P
Age (years), Mean $\pm$ SD	48.38 $\pm$ 12.52	46.93 $\pm$ 12.59	54.00 $\pm$ 10.63	t=-3.42	0.001	48.38 $\pm$ 12.52	47.07 $\pm$ 12.44	56.28 $\pm$ 10.00	t=-3.52	< .001
Oris CR $\geq$ 50%, M (Q₁,Q₃)	-0.13 (-0.82, 0.19)	-0.05 (-0.59, 0.22)	-0.58 (-3.02, -0.10)	Z=-3.65	< .001	-0.13 (-0.82, 0.19)	-0.05 (-0.59, 0.21)	-1.00 (-3.55, -0.30)	Z=-4.26	< .001
Mentalis CR $\geq$ 50%, M (Q₁, Q₃)	-0.06 (-0.58, 0.13)	-0.00 (-0.33, 0.23)	-0.67 (-2.46, -0.29)	Z=-5.24	< .001	-0.06 (-0.58, 0.13)	-0.04 (-0.42, 0.17)	-1.44 (-2.62, -0.29)	Z=-4.42	< .001
Samii scale, n(%)				-	0.324				$\chi^2=3.77$	0.151
2	6 (3.41)	6 (4.29)	0 (0.00)			6 (3.41)	6 (3.97)	0 (0.00)		
3	80 (45.45)	66 (47.14)	14 (38.89)			80 (45.45)	72 (47.68)	8 (32.00)		
4	90 (51.14)	68 (48.57)	22 (61.11)			90 (51.14)	73 (48.34)	17 (68.00)		
Sex, n(%)				$\chi^2=0.59$	0.442				$\chi^2=0.16$	0.689
Male	78 (44.32)	60 (42.86)	18 (50.00)			78 (44.32)	66 (43.71)	12 (48.00)		
Female	98 (55.68)	80 (57.14)	18 (50.00)			98 (55.68)	85 (56.29)	13 (52.00)		
Tumor Side, n(%)					0.482				-	0.313
Right	92 (52.27)	76 (54.29)	16 (44.44)			92 (52.27)	82 (54.30)	10 (40.00)		
Left	83 (47.16)	63 (45.00)	20 (55.56)			83 (47.16)	68 (45.03)	15 (60.00)		
Tumor size (cm), n(%)				$\chi^2=0.39$	0.531				$\chi^2=0.35$	0.557
<3cm	101 (57.39)	82 (58.57)	19 (52.78)			101 (57.39)	88 (58.28)	13 (52.00)		
$\geq$3cm	75 (42.61)	58 (41.43)	17 (47.22)			75 (42.61)	63 (41.72)	12 (48.00)		
Characteristics of tumor, n(%)				$\chi^2=6.27$	0.044				$\chi^2=6.37$	0.041
Solid, no. (%)	70 (39.77)	59 (42.14)	11 (30.56)			70 (39.77)	62 (41.06)	8 (32.00)		
Cystic, no. (%)	37 (21.02)	24 (17.14)	13 (36.11)			37 (21.02)	27 (17.88)	10 (40.00)		
Cystic-solid, no. (%)	69 (39.20)	57 (40.71)	12 (33.33)			69 (39.20)	62 (41.06)	7 (28.00)		
Low current, n(%)				$\chi^2=26.00$	< .001				$\chi^2=35.61$	< .001
$\leq$0.05ma	150 (85.23)	129 (92.14)	21 (58.33)			150 (85.23)	139 (92.05)	11 (44.00)		

Variables	3 months					1 year				
	Total (n = 176)	Good outcome	Poor outcome	Statistic	P	Total (n = 176)	Good outcome	Poor outcome	Statistic	P
>0.05ma	26 (14.77)	11 (7.86)	15 (41.67)			26 (14.77)	12 (7.95)	14 (56.00)		

Table 3
Analysis of Single - factor and Multi - factor Influencing Factors Occurring after Surgery

Variables	Single - factor 3 days					Multi - factor 3 days				
	β	S.E	Z	P	OR (95%CI)	β	S.E	Z	P	OR (95%CI)
Low current										
≤0.05ma					1.00 (Reference)					1.00 (Reference)
>0.05ma	1.98	0.46	4.32	< .001	7.25 (2.95 ~ 17.82)	1.78	0.51	3.48	< .001	5.93 (2.18 ~ 16.13)
Oris CR ≥ 50%	-0.26	0.10	-2.67	0.008	0.77 (0.63 ~ 0.93)	-0.01	0.13	-0.11	0.914	0.99 (0.76 ~ 1.28)
Mentalis CR ≥ 50%	-0.88	0.21	-4.12	< .001	0.41 (0.27 ~ 0.63)	-0.74	0.23	-3.27	0.001	0.48 (0.30 ~ 0.74)
Age (years), Mean ± SD	0.03	0.01	2.21	0.027	1.03 (1.01 ~ 1.06)	0.02	0.02	1.26	0.207	1.02 (0.99 ~ 1.05)
Variables	Single - factor 1 month					Multi - factor 1 month				
	β	S.E	Z	P	OR (95%CI)	β	S.E	Z	P	OR (95%CI)
Low current										
≤0.05ma					1.00 (Reference)					1.00 (Reference)
>0.05ma	2.04	0.47	4.36	< .001	7.68 (3.07 ~ 19.19)	1.92	0.50	3.81	< .001	6.79 (2.53 ~ 18.19)
Oris CR ≥ 50%	-0.26	0.10	-2.61	0.009	0.77 (0.64 ~ 0.94)	-0.01	0.12	-0.06	0.956	0.99 (0.78 ~ 1.27)
Mentalis CR ≥ 50%	-0.76	0.20	-3.75	< .001	0.47 (0.32 ~ 0.70)	-0.63	0.21	-2.99	0.003	0.53 (0.35 ~ 0.80)

Variables	Single - factor 3months					Multi - factor 3 months				
	β	S.E	Z	P	OR (95%CI)	β	S.E	Z	P	OR (95%CI)
Low current										
≤0.05ma					1.00 (Reference)					1.00 (Reference)
>0.05ma	2.13	0.46	4.61	< .001	8.38 (3.39 ~ 20.70)	1.89	0.54	3.50	< .001	6.65 (2.30 ~ 19.22)
Oris CR ≥ 50%	-0.34	0.10	-3.22	0.001	0.72 (0.58 ~ 0.88)	-0.16	0.13	-1.18	0.238	0.85 (0.66 ~ 1.11)
Mentalis CR ≥ 50%	-0.75	0.20	-3.76	< .001	0.47 (0.32 ~ 0.70)	-0.54	0.22	-2.47	0.014	0.58 (0.38 ~ 0.89)
Age (years), Mean ± SD	0.05	0.02	2.95	0.003	1.05 (1.02 ~ 1.09)	0.05	0.02	2.18	0.029	1.05 (1.01 ~ 1.09)
Characteristics of tumor, n(%)										
Solid, no. (%)					1.00 (Reference)					1.00 (Reference)
Cystic, no. (%)	1.07	0.48	2.24	0.025	2.91 (1.14 ~ 7.38)	0.42	0.61	0.68	0.495	1.52 (0.46 ~ 5.05)
Cystic-solid, no. (%)	0.12	0.46	0.27	0.790	1.13 (0.46 ~ 2.76)	-0.35	0.58	-0.60	0.550	0.71 (0.23 ~ 2.21)

Variables	Single - factor 1 year					Multi - factor 1 year				
	β	S.E	Z	P	OR (95%CI)	β	S.E	Z	P	OR (95%CI)
Low current										
$\leq 0.05\text{ma}$					1.00 (Reference)					1.00 (Reference)
$> 0.05\text{ma}$	2.69	0.50	5.35	$< .001$	14.74 (5.50 ~ 39.50)	2.86	0.68	4.21	$< .001$	17.47 (4.62 ~ 66.10)
Oris CR $\geq 50\%$	-0.41	0.11	-3.65	$< .001$	0.67 (0.53 ~ 0.83)	-0.38	0.14	-2.63	0.009	0.68 (0.52 ~ 0.91)
Mentalis CR $\geq 50\%$	-0.36	0.13	-2.65	0.008	0.70 (0.54 ~ 0.91)	-0.17	0.12	-1.49	0.137	0.84 (0.67 ~ 1.06)
Age (years), Mean $\pm$ SD	0.07	0.02	3.26	0.001	1.07 (1.03 ~ 1.12)	0.10	0.03	3.06	0.002	1.10 (1.04 ~ 1.17)
Characteristics of tumor, n(%)										
Solid, no. (%)					1.00 (Reference)					1.00 (Reference)
Cystic, no. (%)	1.05	0.53	2.00	0.046	2.87 (1.02 ~ 8.07)	0.42	0.73	0.58	0.563	1.53 (0.36 ~ 6.43)
Cystic-solid, no. (%)	-0.13	0.55	-0.24	0.807	0.88 (0.30 ~ 2.56)	-1.02	0.82	-1.25	0.212	0.36 (0.07 ~ 1.79)

Discussion

The first article describing that FNMEP can predict postoperative facial nerve function was published in 2005[10], However, there is currently no unified standard to define the percentage of FNMEP decrease as a criterion for judging the impact on facial nerve function. Most scholars believe that a 50% decrease in FNMEP will impair facial nerve function[13], while some scholars argue that the threshold is an 80% decrease [14]. Additionally, some scholars suggest that an increase in the stimulation threshold by 20 mA compared with the baseline indicates damage to facial nerve function[15]. In this study, a 50% decrease in FNMEP of the orbicularis oris muscle and mentalis muscle was used as the cutoff for evaluating facial nerve function.

In addition, regarding which can more accurately reflect the function of the facial nerve, there are different viewpoints on the changes in the action potentials of the orbicularis oris muscle[16] orbicularis oculi[13] or mentalis[13] more precisely indicate facial nerve function. It was found that a 50% decrease in FNMEP of the orbicularis oris muscle and mentalis muscle could serve as an independent indicator for predicting postoperative facial nerve function and combining it with microcurrent could significantly improve the prediction rate of facial nerve function. Furthermore, when considering the time points of 3 days, 1 month, 3 months, and 1 year postoperatively, the prediction rate of the combination of FNMEP and microcurrent gradually increased with the extension of time. Therefore, both FNMEP and electromyography (EMG) are indispensable for intraoperative electrophysiological monitoring during vestibular schwannoma surgery. Combining these two methods can enable more accurate prediction of postoperative facial nerve function.

This study also explored the relationships between tumor properties, tumor size, tumor classification, patient gender, age, and postoperative facial nerve function. It was found that facial nerve function at the 1-year postoperative follow-up was only correlated with patient age, and there were no significant statistical relationships with other factors. Can we interpret this as indicating that the older the patient, the weaker the nerve recovery ability?

Currently, the treatment options for patients with facial paralysis after vestibular schwannoma surgery include facial nerve rehabilitation therapy and nerve transplantation surgery. However, there is currently no definite conclusion on whether facial paralysis in such patients can recover or when to perform transplantation surgery, and effective predictive indicators are lacking. Through the postoperative facial nerve function prediction model established in this study, we found that if the patient is young, with intraoperative microcurrent ≤ 0.05 mA and FNMEP amplitude decrease $< 50\%$, the probability of postoperative facial paralysis is very low. If facial paralysis occurs in the short term after surgery, further observation is feasible, as there is a high probability of recovery within 1 year. If the patient has intraoperative microcurrent > 0.05 mA and FNMEP amplitude decrease $\geq 50\%$, and the patient is elderly, early nerve transplantation surgery is recommended if facial paralysis occurs after surgery.

Conclusion

Intraoperative electrophysiological monitoring has now become an indispensable part of acoustic neuroma surgery. Through this study, it is demonstrated that the combination of microcurrent and FNMEP can significantly improve the prediction rate of postoperative facial paralysis and provide more accurate guidance for subsequent treatment.

Abbreviations

EMG
electromyography
FNMEP
facial nerve motor evoked potential
HB
House-Brackmann
CT
Computed Tomography
MRI
Magnetic Resonance Imaging
CPA
cerebellopontine angle
ROC
Receiver Operating Characteristic

Declarations

Competing interests

The authors declare no competing interests

Ethics approval

All procedures performed were in accordance with the ethical standards of the Huashan Hospital Institutional Review Board (HIRB: KY2020-065) and with the 1964 Helsinki declaration and its later amendments.

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Author Contribution

Ying Wang is the first author and took the lead in writing the manuscript. Nainai Ma is co-first author and took the lead in writing the manuscript. Yining Wang, Jianfei Long and Ping Zhong contributed substantially to writing the main text. All authors contributed to reviewing the manuscript and have read and approved the final version.

Data availability

The authors confirm that the data supporting the findings of this study are available within the article.

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Figures

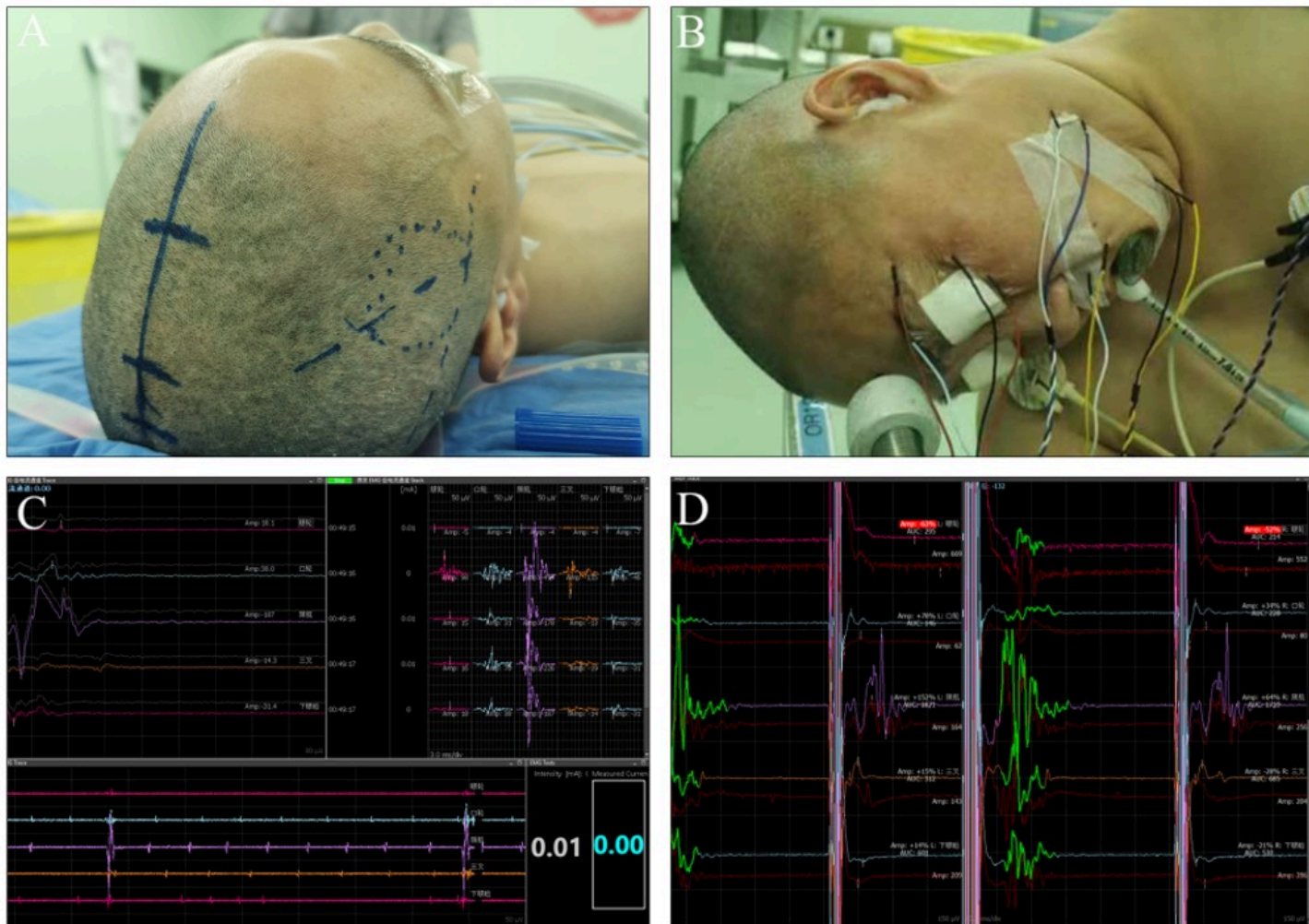


Figure 1

intraoperative neuroelectrophysiological monitoring methods A.mark the surface projections of facial movement regions
B.neuroelectrophysiological probe position C.intraoperative EMG picture D.intraoperative FNMEP picture

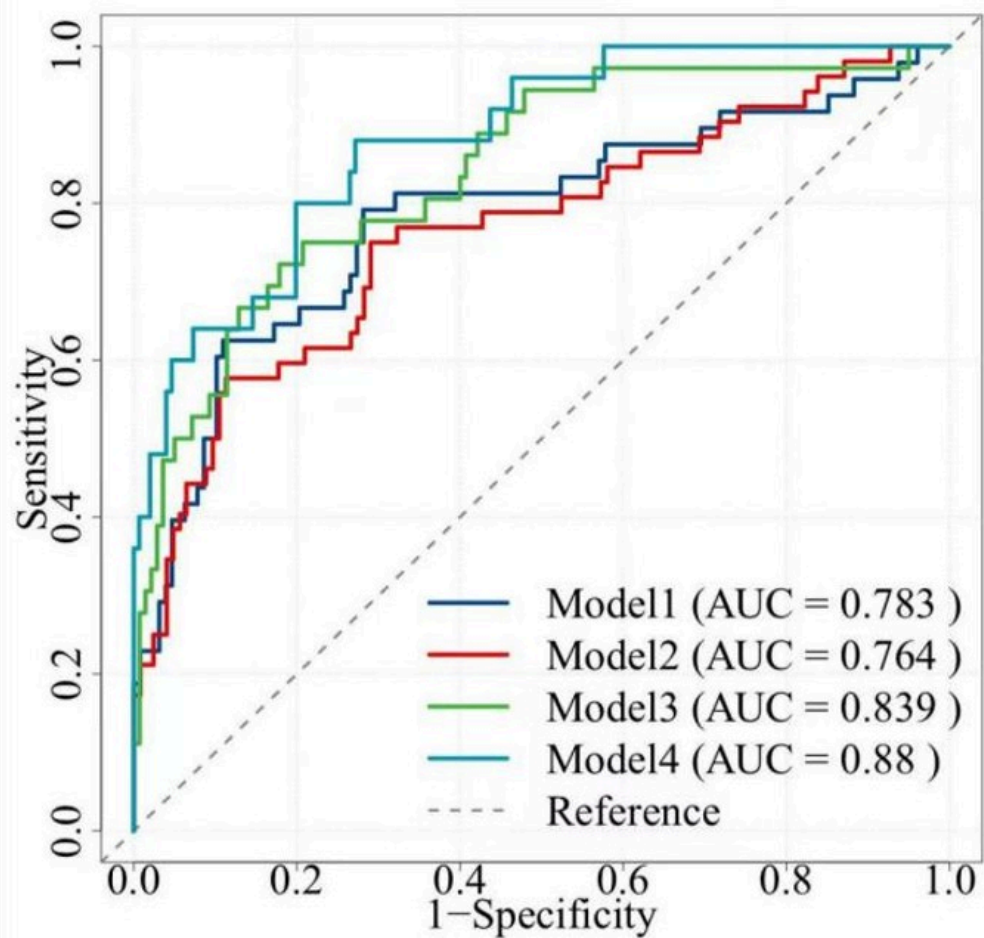


Figure 2

Analysis of Receiver Operating Characteristic (ROC) Curves of Predictive Models at 3 Days Model 1, 1 Month Model 2, 3 Months Model 3, and 1 Year Model 4 Post-Surgery

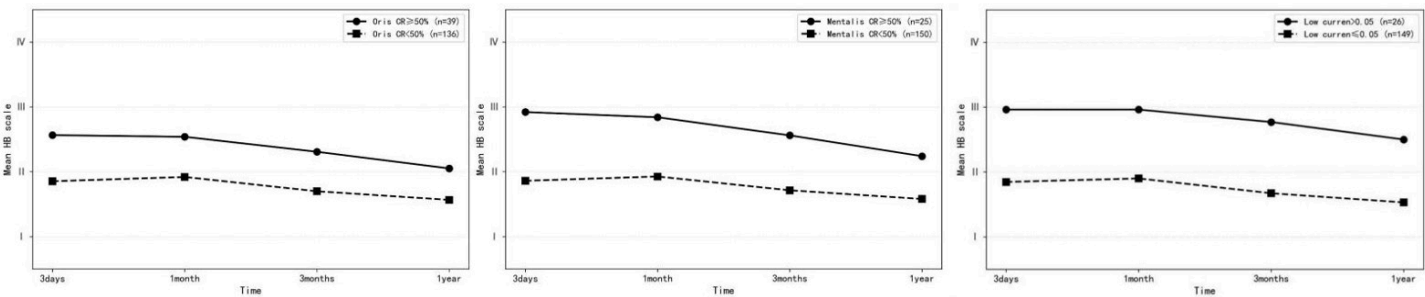


Figure 3

Mean postoperative recovery rates of facial nerve function for patients with intraoperative stimulation