Facial nerve elongation as predictive factors of facial nerve outcome after the vestibular schwannoma resection

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Research Article

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Abstract

Background: To analyze risk factors affecting the long-term facial nerve functional outcomes in patients receiving vestibular schwannoma surgery.

Method: A total of 89 cases receiving vestibular schwannoma surgery via retrosigmoid sinus approach were analyzed retrospectively. The facial nerve functional outcomes of all enrolled patients were evaluated 6 months after the operation according to House-Brackmann grading scale. The relationships between facial nerve injury and its potential risk factors were analyzed.

Results: Postoperative facial nerve injury was found in 53 patients (59.6%) 6 months after the operation. The results of univariate logistic regression analysis indicated that the tumor volume, the maximum tumor diameter, the facial nerve elongation, the enlargement of internal auditory canal (IAC), the IAC size on the affected side, and the facial nerve adhesion to tumor were significantly correlated with the occurrence of facial nerve injury. The multivariate logistic regression analysis revealed that the facial nerve elongation, the facial nerve adhesion to tumor, the tumor volume, and the enlargement of IAC were the independent risk factors of facial nerve injury 6 months after vestibular schwannoma surgery. The ROC curve showed that the cut-off points of the facial nerve elongation, tumor volume and enlargement of IAC were 2.925cm,10.965 cm^3 and 1.818 respectively. When the cut-off points were exceeded, the possibility of facial nerve injury would largely increase.

Conclusion: With the growth of the facial nerve elongation, the tumor volume, the facial nerve adhesion to tumor, and the enlargement of IAC, the possibility of facial nerve injury after the vestibular schwannoma surgery would accordingly increase.

1. Background

Vestibular schwannoma (VS) is a benign intracranial tumor growing in the internal auditory canal (IAC) and the cerebellopontine angle. It easily compresses the peripheral nerve leading to tinnitus, hearing loss, and facial paralysis. The surgical procedure is the main mode of treatment for VS. Facial nerve injury is one of the most serious postoperative complications of VS, which brings about paralytic eyelids and disfiguring facial palsy. Previous studies have confirmed that postoperative facial nerve injury significantly decreases the quality of life in VS patients [1, 2]. Therefore, identifying risk factors for postoperative facial nerve injury is extremely urgent to help to improve facial nerve function after VS resection.

Accumulated studies have recognized the tumor size as an independent risk factor for postoperative facial nerve injury [3-8]. However, discrepancy on the other associated risk factors still exists, for example, the facial nerve adhesion to tumor and facial nerve location. Through evaluating published researches, we can carry out further research on the basis of previous research. For instance, Walz, et al calculated tumor size using the maximum tumor diameter, which was not consistent with the actual tumor size [9]. Due to the difference in the internal auditory canal (IAC) size among individuals, it is difficult to demarcate the enlargement of IAC. Also, the degree of tumor compression to the facial nerve was not included adequately in the research analysis. Moreover, although the size is important, also important is the location of epicenter of the tumor, thus some discrepancies in some of the studies in the literature. Compared to other studies, this study innovative introduced the concept of the facial nerve elongation to measure the location of epicenter of the tumor.

In order to solve these problems, we conducted this study to explore accurate associations of the potential risk factors including the facial nerve elongation, the enlargement of IAC, and the tumor volume with the postoperative long-term facial nerve function.

2. Methods

2.1 Object

A total of 89 VS patients treated in the Neurosurgery Department from January 2010 to December 2020 were analyzed retrospectively. Vestibular schwannoma surgery via retrosigmoid sinus approach was conducted in all patients. The electrophysiological technique was used to monitor the facial nerve function intraoperatively. The exclusion criteria were as follows: preoperative facial nerve injury, the unprotected facial nerve in operation, residual VS found in postoperative follow up recurrent VS.

2.2 Clinical data

Patients' gender, age, preoperative duration of symptoms (time from the initial onset of clinical symptoms to the surgery), duration of operation, intraoperative bleeding volume, and postoperative pathological results were collected through the electronic medical record system (Table 1).

The radiologic parameters of enrolled patients were collected by craniocerebral MRI and/or CT, including maximum tumor diameter (the maximum diameter of the tumor outside the IAC measured by T1-weighted MRI, Figure 1), side of tumor (left or right), tumor properties, IAC enlargement or not (>6mm was recognized as enlarged), maximum IAC diameter on the affected side and normal side, facial nerve elongation , tumor volume, and tumor grade (KOOS grade) (Table 1).

VS was divided into cystic (non-enhanced MRI), solid-cystic (heterogeneous enhanced MRI), and solid (homogeneous enhanced MRI) VS according to the tumor properties [10].

Three-dimensional reconstruction of the tumor was performed using Mimics19.0 software to obtain the tumor volume data (Figure 2). As shown in Figure 3, The maximum IAC diameters on the affected side and normal side were measured. The enlarged degree of the IAC was defined as the ratio of the maximum IAC diameter on the affected side to the maximum IAC diameter on the normal side.

The deformation of facial nerve compressed by the tumor was frequently observed in vestibular schwannoma surgery. However, the compressional deformation degree of facial nerve has rarely been analyzed. In this study, the facial nerve elongation was introduced to evaluate the compressional deformation degree based on the axial MRI or coronal MRI (Figure 4). The facial nerve elongation was defined as the length of the tumor edge from the opening of IAC to the intersection of the facial nerve (long axis) with the brainstem.

The degree of facial nerve adhesion to tumor was determined and recorded by the chief surgeon during the operation. Facial nerve adhesion to tumor could be divided into three degrees, including no adhesion (the anatomical structure between the tumor and the facial nerve is clearly visible and easily separated), mild adhesion (the anatomical structure between the tumor and the facial nerve can be distinguished and separated with a few difficulties), and severe adhesion (the anatomical structure between the tumor and the facial nerve is unrecognizable and hard to be separated).

The positions of facial nerve relative to the tumor (anterior type, posterior type, superior type, and inferior type) were evaluated and recorded by the chief surgeon during the operation.

2.3 Evaluation of facial nerve outcomes

The facial nerve functions of all patients were evaluated preoperatively and 6 months after the operation. According to the House-Brackmann scale, the postoperative facial nerve functional outcomes of grade 1 and grade 2 were defined as normal, while grade 3 to 6 were defined as facial nerve injury.

2.4 Statistical analysis

SPSS version 23.0 was used for statistical analysis. Qualitative data were represented by the number of cases (percentage) while quantitative data were represented by the average ± standard deviation (maximum-minimum). The correlation between potential risk factors and facial nerve injury 6 months postoperatively was statistically analyzed by binary univariate logistic regression analysis. The significant risk factors in univariate analysis were then included in multivariate logistic regression analysis by using the forward stepwise regression method based on maximum likelihood estimation. A significant difference was achieved when $p < 0.05$. The R Studio 3.6.3 and the pROC packages were used to draw the ROC graph.

3. Results

3.1 General data

A total of 45 males (50.6%) and 44 females (49.4%), aged from 24 to 70 years old (mean 51 years old) were enrolled. The average duration of operation was 4.9 hours and the average intraoperative bleeding volume was 481.9 ml. There were 11 cases of the cystic tumor (12.4%), 44 cases of solid tumor (49.4%), and 34 cases of solid-cystic tumor (38.2%). As for the facial nerve adhesion to tumor, there were 14 no adhesion cases (15.7%), 21 mild adhesion cases, and 54 severe adhesion cases (60.7%). The average IAC size on the affected side was 1.1 cm. The average facial nerve elongation, average tumor volume, and average maximum tumor diameter were2.8 cm, 19.6cm³, and 3.6 cm respectively (Table 1).

3.2 Risk factors for facial nerve injury 6 months after operation

The facial nerve function was evaluated 6 months after operation. A total of 36 patients (40.4%) had normal facial nerve function (HB Ⅰ-Ⅱ), while 53 patients (59.6%) suffered from facial nerve injury (HB III-VI) (Table 1). The results of binary univariate logistic regression analysis showed that the tumor volume (p <0.001), the maximum tumor diameter (p <0.001), the facial nerve elongation (p <0.001), the enlargement of IAC (p <0.001), the IAC size on the affected side (p =0.002), and the facial nerve adhesion to tumor (p <0.001) were significantly correlated with the functional lesion of facial nerve 6 months postoperatively (Table 2). The multivariate logistic regression analysis identified the facial nerve elongation(p=0.036) , the facial nerve adhesion to tumor (p=0.016), the tumor volume (p =0.049), and the enlargement of IAC (p =0.048) as independent risk factors affecting facial nerve function 6 months postoperatively (Table 3).

3.3 The predictive effects of facial nerve elongation tumor size and enlargement of IAC

The ROC curve showed that the enlargement of IAC (AUC= 0.798, Figure 5) , tumor volume (AUC= 0.791, Figure 6) and facial nerve elongation(AUC=0.769,Figure7) possessed the potential to predict the facial nerve injury of patients 6 months after the operation. The cut-off point of the enlargement of IAC was 1.818, at which the specificity and sensitivity were 83.3% and 71.7% respectively (Figure 5). The cut-off point of the tumor volume was 10.965 cm^3 with the specificity and sensitivity of 69.4% and 92.5% respectively (Figure 6). The cut-off point of the facial nerve elongation was 2.925 cm with the specificity and sensitivity of 91.7% and 62.3% respectively (Figure 7). When exceeding the cut-off point, the risk of facial nerve injury 6 months after operation would increase.

4. Discussion

A variety of therapeutic approaches including follow-up observations, surgical treatments, and stereotactic radiotherapy could be recommended for VS patients. Vestibular schwannoma surgery is the first choice for symptomatic patients. Although the microsurgical and imaging technology have made much progress in recent years, the postoperative facial nerve injury in patients receiving vestibular schwannoma surgery is still inevitable, which greatly reduces the quality of life [1, 2]. To intraoperatively improve the protection of facial nerve, we identified the factors that might affect the long-term facial nerve function of patients receiving vestibular schwannoma surgery.

Previous studies have shown that the intraoperative anatomical retention rate of facial nerve in VS patients is about 86.9%-98.1% [3, 11-13] while the incidence of long-term facial paralysis was 26% to 67.1% (HB Ⅲ-Ⅵ) [3, 5, 11]. In this study, 53 patients (59.6%) suffered from facial nerve injury (HB Ⅲ-VI) 6 months after operation, which is consistent with previous reports.

During the surgery, we found that due to the difference growth pattern and locations of epicenter of the tumor, the facial nerve location and deformation degree were differences. Despite some tumors volume were small, but due to their growth direction facing the face nerve which could cause severe pushing of the facial nerve, and some tumors were large, but their growth direction is opposite to the facial nerve, which makes the facial nerve receive lighter pushing. Therefore, this study innovative used the concept of the facial nerve elongation in order to explore the relationship between the facial nerve deformation degree and post-operative facial nerve function. The results of logistic regression analysis showed that facial nerve elongation was an independent risk factor and positively correlated to facial nerve injury 6 months after operation, whichresults were not founded in the past . Besides, the ROC curve analysis showed that the possibility of facial nerve injury increases largely when the facial nerve elongation is larger than 2.925cm.

The fact that tumor size affects the postoperative facial nerve functional outcomes has been widely recognized [6, 14, 15]. Most of previous studies evaluated the tumor size by calculating the maximum tumor diameter. However, a big deviation exists when the maximum diameter is used to represent the actual tumor size [9]. Here, we used the tumor volume to measure the tumor size. The results of logistic regression analysis showed that tumor volume was an independent risk factor and positively correlated to facial nerve injury 6 months after operation, which is consistent with published studies [4, 16]. Besides, the ROC curve analysis showed that the possibility of facial nerve injury increases largely when the tumor volume is larger than 10.965cm^3.

The relationship between the enlargement of IAC and the postoperative facial nerve injury remains controversial [4, 17]. In previous study, the IAC was mostly divided into enlarged or not even though the IAC sizes in patients differ greatly. Distinguishing whether the IAC enlarges or not according to one standard is not suitable. In this study, the enlarged degree of IAC was used to evaluate IAC size to reduce the potential error. The results showed that the possibility of long-term postoperative facial nerve injury increased as the enlarged degree of IAC grew. When enlarged degree of IAC exceeded the cut-off point of 1.88, the risk of facial nerve injury 6 months after the operation would largely increase.

The compressional deformation of facial nerve has rarely been included as a risk factor to be analyzed in previous studies. In clinical practice, we found that the postoperative facial nerve injury was prone to appear when the facial nerve was compressed and deformed seriously. Thus, the facial nerve elongation was introduced and statistically analyzed in this study. The univariate logistic regression analysis showed that the facial nerve elongation was significantly correlated with facial nerve injury after vestibular schwannoma surgery, while multivariate logistic regression analysis revealed that facial nerve elongation was not an independent risk factor for facial nerve injury. These suggest that facial nerve elongation could be used as a potential predictive factor for postoperative facial nerve injury in patients receiving vestibular schwannoma surgery. However, the distributional course of facial nerve was not limited to the aforementioned four types. Using the MRI to evaluate the facial nerve elongation was not precise, which lead to potential error. Diffusion tensor image-based three-dimensional reconstruction could be used to reconstruct the distribution of facial nerve [18-20] and to accurately evaluate the facial nerve elongation in the future.

In addition, this study showed that the facial nerve adhesion to tumor was an independent risk factor for facial nerve injury, which was consistent with the findings of Renato Torres et al. [3, 21]and with the clinical experience of surgeons.There are still some defects in this study. First, the number of patients enrolled in this study is not sufficient to get a precise conclusion. Second, several potential confounding risk factor, such as the blood pressure, blood glucose and so on, are not included to be analyzed.

5. Conclusion

In summary, with the growth of the facial nerve elongation, the tumor volume, the facial nerve adhesion to tumor, and the enlargement of IAC, the possibility of facial nerve injury after the vestibular schwannoma surgery would accordingly increase.

6. Abbreviations

internal auditory canal (IAC)，Vestibular schwannoma (VS)，area under the curve(AUC)

7. Declarations

Ethics approval and consent to participate: This study was approved by the Research Ethics Committee of The First Affiliated Hospital of Xiamen University and all patients signed informed consents. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for publication: Written informed consent for publication was obtained from all participants.

Availability of data and material: The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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Authors' contributions: Zhi Zhu and Ningning Song analyzed and interpreted the patient data, and were major contributors in writing the manuscript. Weichao Jiang, Xi Chen, Sifang Chen recorded and collected patients’ information, and also participated in writing the manuscript. Guowei Tan performed surgeries for most of cases and designed this study. All authors read and approved the final manuscript.

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Tables

Table 1. The general and clinical characteristics of enrolled patients

Characteristics	Number (percentage)
Gender	
Male	45(50.6)
Female	44(49.4)
Age, year	51±10.3(24-70)
Side of tumor	
Left	49(55.1)
Right	40(44.9)
Duration of symptoms, year	2.8±3.1(0-20)
Tumor properties	
Cystic	11(12.4)
Solid	44(49.4)
Cystic-solid	34(38.2)
Facial nerve adhesion to tumor	
No adhesion	14(15.7)
Mild adhesion	21(23.6)
Severe adhesion	54(60.7)
Duration of operation, hours	4.9±2(2-12)
Intraoperative bleeding volume, ml	481.9±380(100-2500)
Pathological type	
A	18(20.2)
B	33(37.1)
A+B	38(42.7)
Maximal tumor diameter, cm	3.6±1.1(0.79-6.2)
Tumor volume, cm^3	19.6±12.2(1.34-61.10)
Enlargement of IAC	
Enlarged	3(3.4)
Not Enlarged	86(96.6)
IAC size, cm	1.1±0.3(0.5-2.1)
Enlarged degree of IAC	1.8±0.5(1-3.2)
Facial nerve elongation, cm	2.8±1.1(1.03-5.78)
Facial nerve outcomes 6 months after operation	
[illegible]	15(16.9)
[illegible]	21(23.6)

□	23□25.8□
□	16□18.0□
□	12□13.5□
□	2□2.2□
KOOS grade	
□	0□0□
□	2□2.2□
□	22□24.7□
□	65□73□
Positions of facial nerve relative to the tumor	
Anterior	72□80.9□
Posterior	7□7.9□
Superior	4□4.5□
Inferior	6□6.7□

Table 2. The univariate logistic analysis revealing potential risk factors for facial nerve injury

Variables	*B*	*S.E.*	*Wald*	*df*	*P*	*OR*	95% *C.I.*
Age	-0.008	0.021	0.160	1.000	0.689	0.992	0.951-1.034
Gender	-0.225	0.433	0.269	1.000	0.604	0.799	0.342-1.865
Side of tumor	-0.154	0.434	0.127	1.000	0.722	0.857	0.366-2.006
Symptomatic duration	0.003	0.071	0.001	1.000	0.971	1.003	0.872-1.152
Tumor properties	-0.074	0.327	0.052	1.000	0.820	0.928	0.489-1.762
Duration of operation	0.138	0.115	1.441	1.000	0.230	1.148	0.916-1.438
Intraoperative bleeding volume	0.001	0.001	1.207	1.000	0.272	1.001	0.999-1.002
Positions of facial nerve relative to the tumor	0.312	0.417	0.559	1.000	0.455	1.365	0.603-3.091
Pathology	-0.074	0.285	0.067	1.000	0.796	0.929	0.532-1.623
Tumor volume	0.154	0.33	21.433	1.000	0.000	1.166	1.093-1.244
Maximal tumor diameter	0.982	0.255	14.787	1.000	0.000	2.670	1.618-4.404
Facial nerve elongation	1.217	0.323	14.199	1.000	0.000	3.376	1.793-6.537
Enlarged degree of IAC	2.846	0.753	14.301	1.000	0.000	17.219	3.939-75.267
IAC size on the affected side	2.649	0.874	9.193	1.000	0.002	14.136	2.551-78.336
Enlarged IAC or Not	1.118	1.244	0.807	1.000	0.369	3.059	0.267-35.061
Facial nerve adhesion to tumor	1.528	0.367	17.350	1.000	0.000	4.610	2.246-9.462

Table 3. The multivariate logistic analysis revealing independent risk factors for facial nerve injury

Variables	*B*	*S.E.*	*Wald*	*df*	*P*	*OR*	95% *C.I.*
Tumor volume	0.075	0.038	3.867	1	0.049	1.078	1.000-1.163
Enlarged degree of IAC	1.697	0.857	3.923	1	0.048	5.458	1.018-29.263
Facial nerve adhesion to tumor	1.229	0.511	5.798	1	0.016	3.419	1.257-9.303
Facial nerve elongation	0.889	0.425	4.382	1	0.036	2.433	1.058-5.595
Maximal tumor diameter					0.226		
IAC size on the affected side					0.176		
Tumor properties					0.442		

Figures

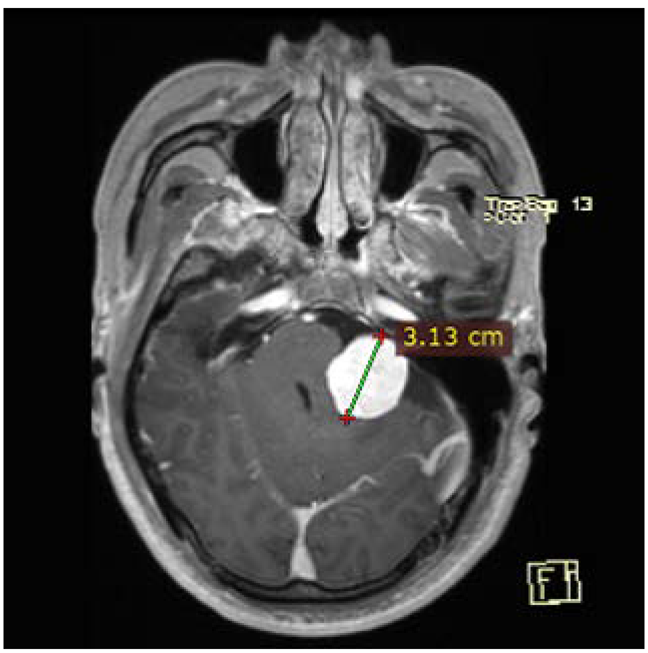

Figure 1

The maximum tumor diameter outside IAC

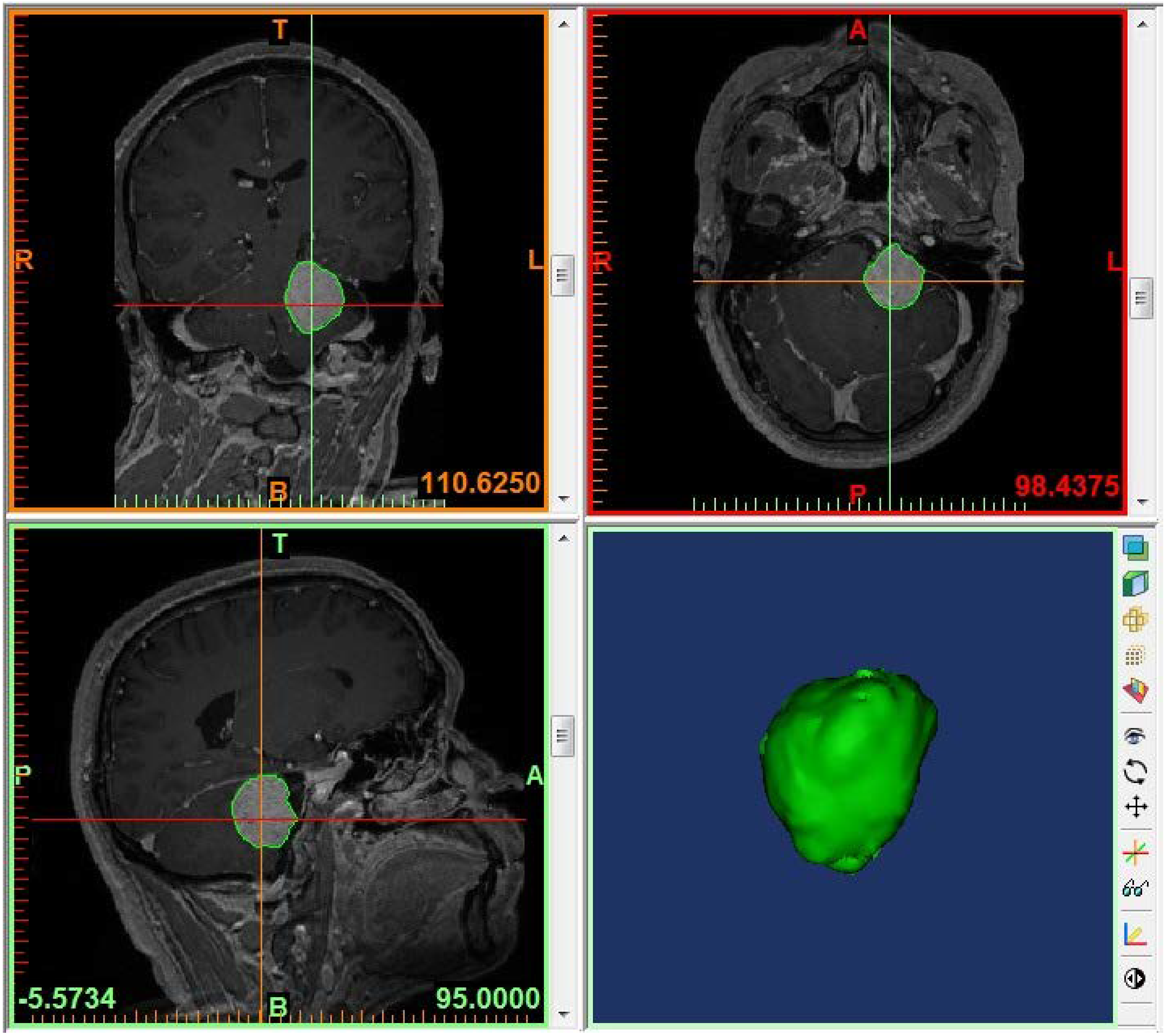

Figure 2

Three-dimensional reconstruction of the tumor through Mimics19.0 software to measure the tumor volume

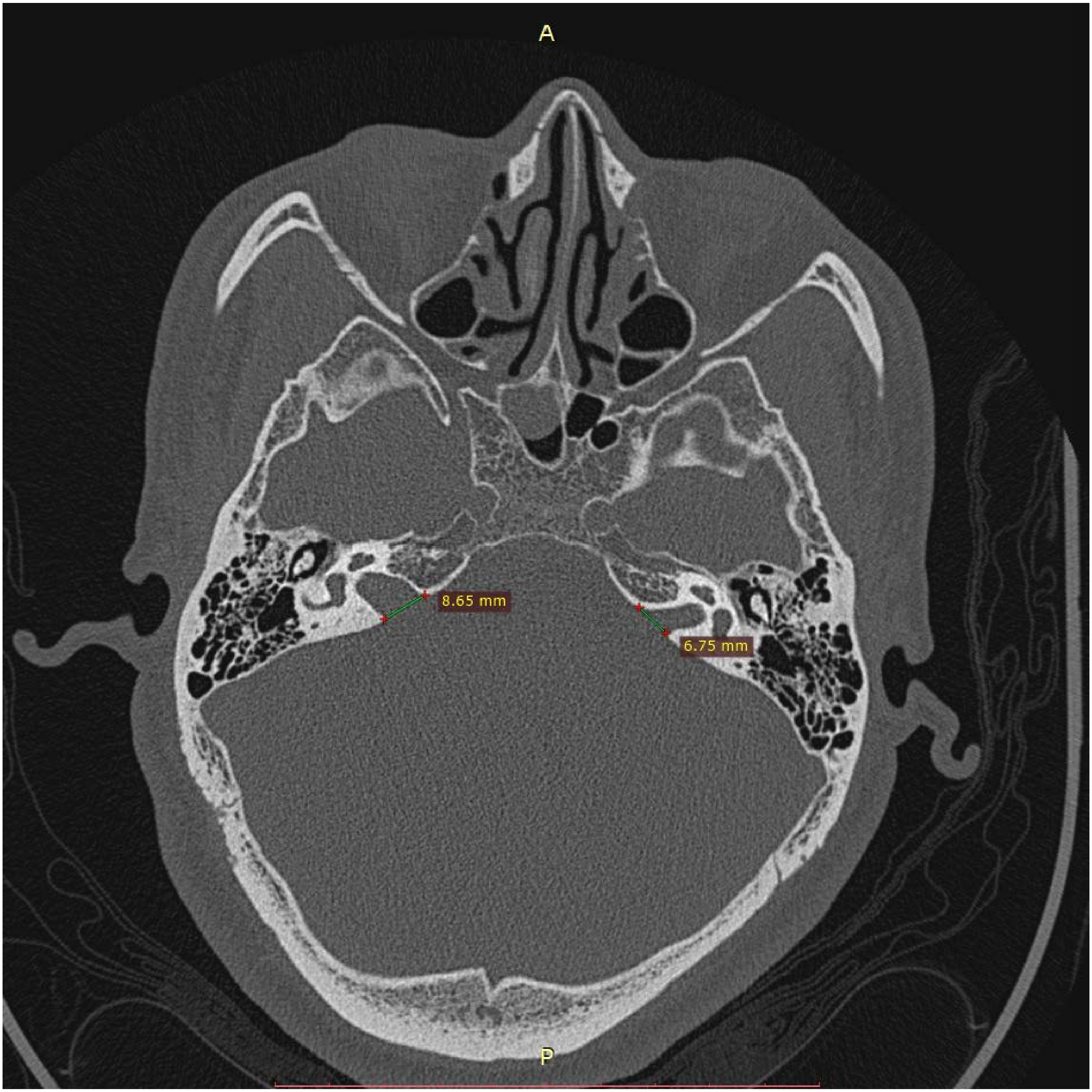

Figure 3

The measurement of the maximum IAC diameter on the affected side and normal side

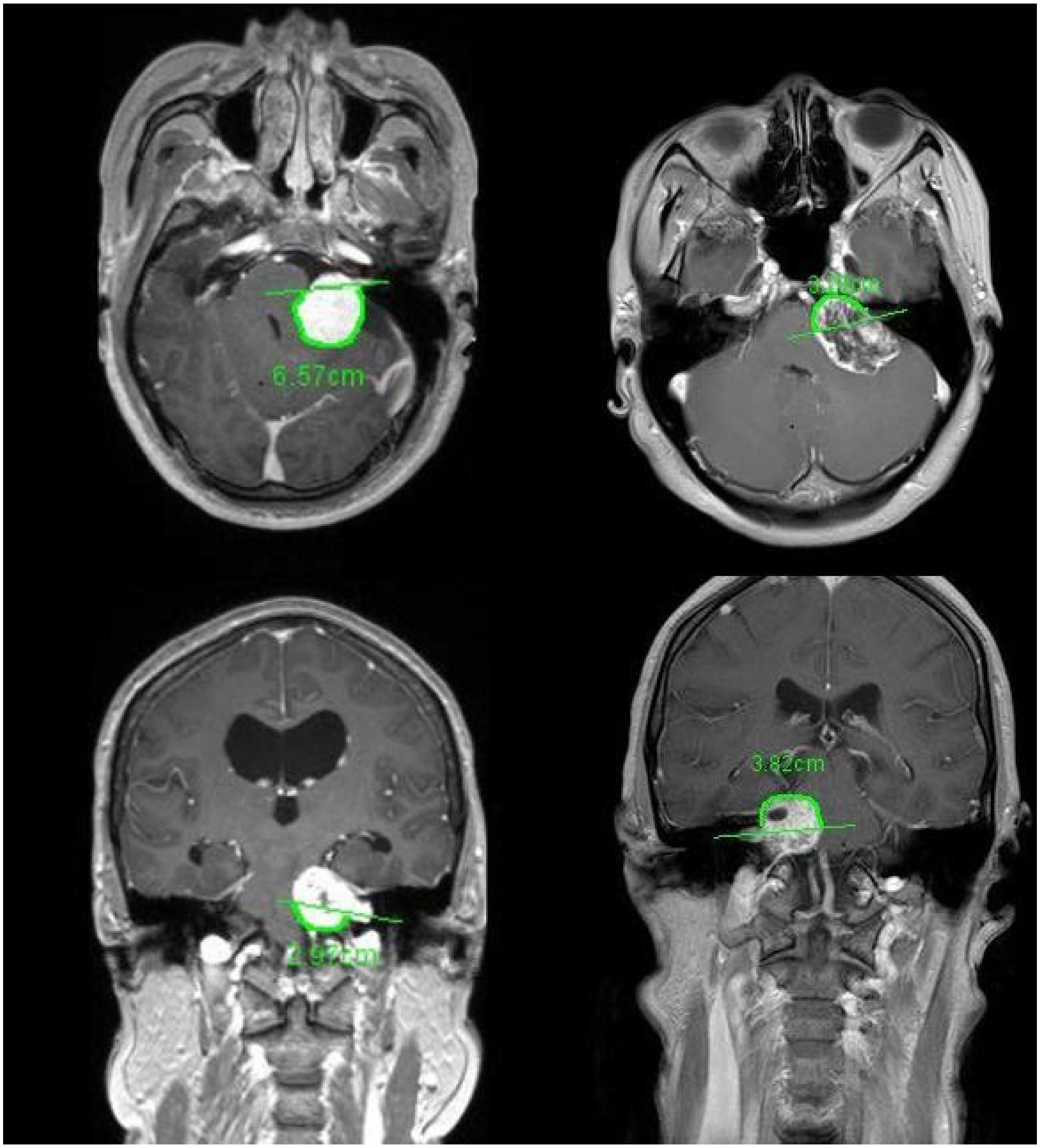

Figure 4

Measuring the facial nerve elongation: posterior type ((Top left 4a), anterior type (Top right 4b), inferior type (Bottom left 4c), and superior type (Bottom right 4d).

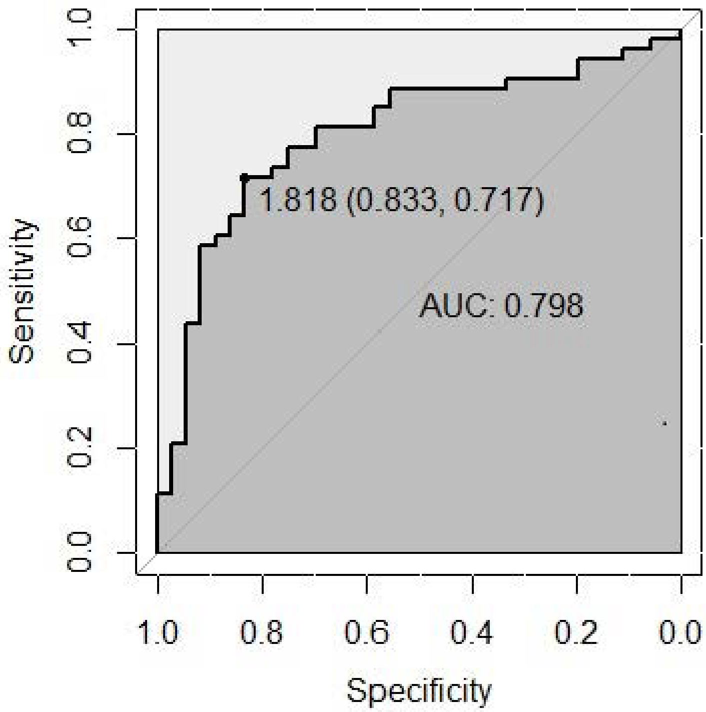

Figure 5

The ROC curve of the enlargement of IAC and the cut-off point.

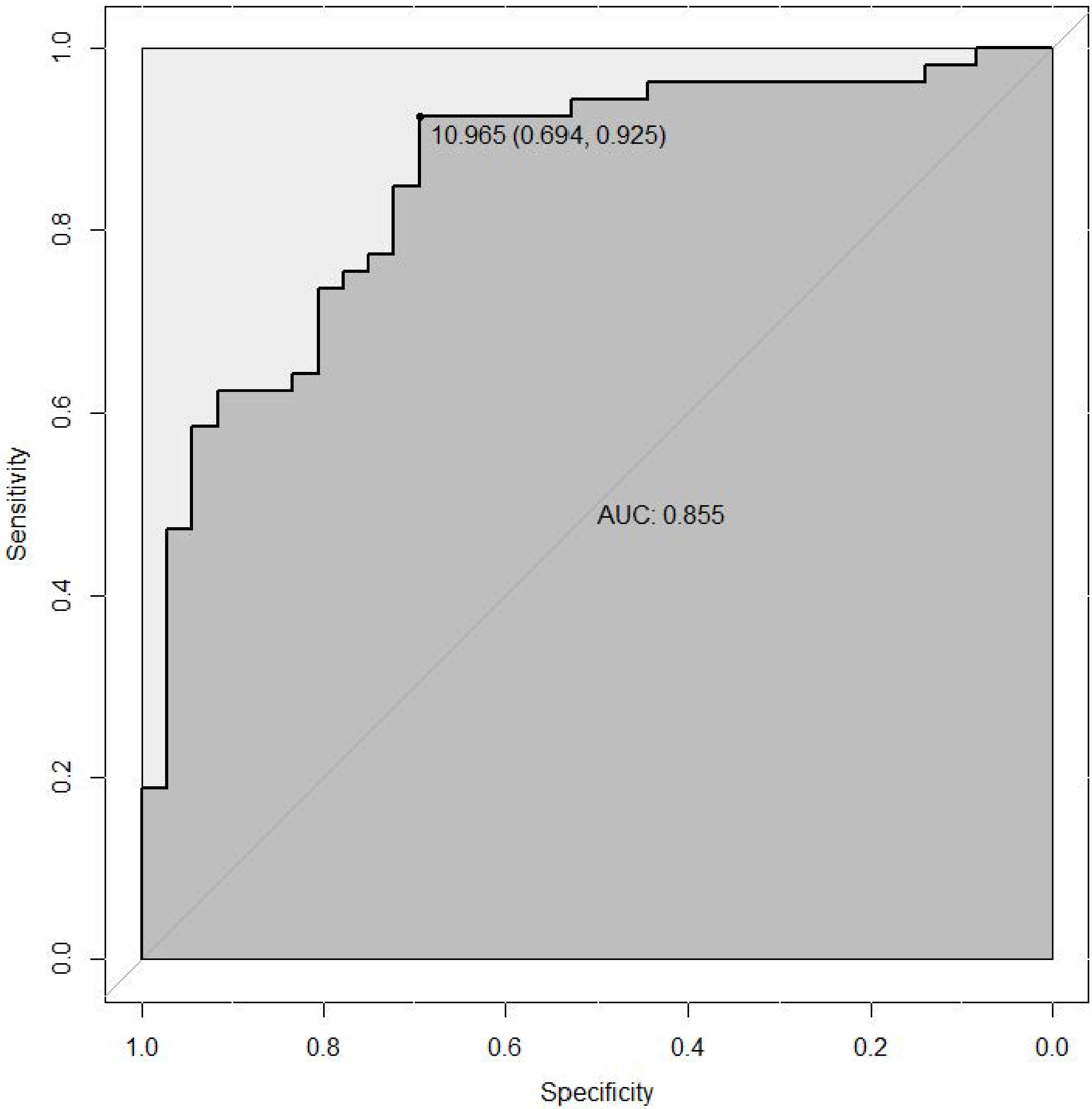

Figure 6

The ROC curve of the tumor size and the cut-off point.

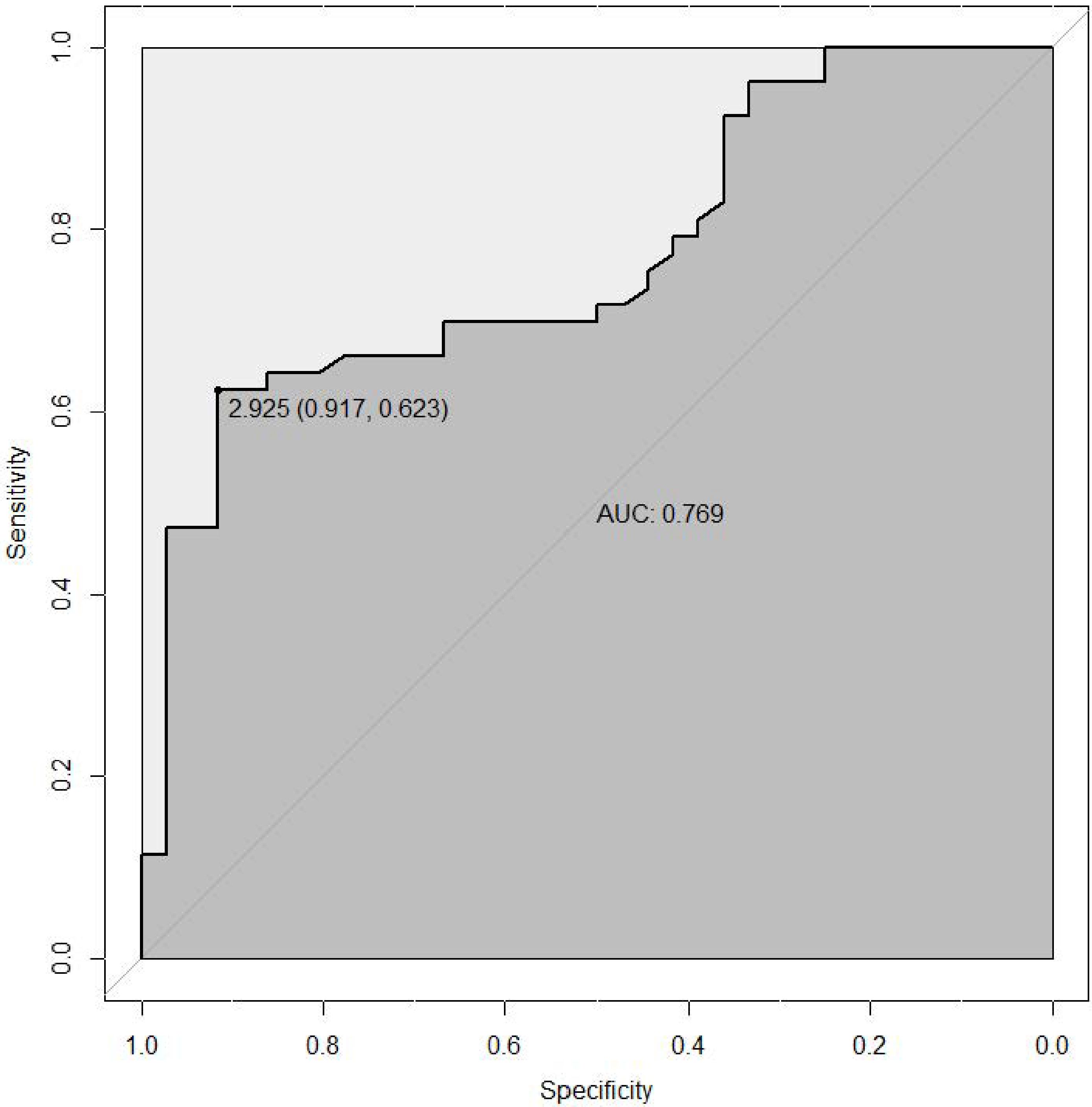

Figure 7

The ROC curve of the facial nerve elongation and the cut-off point.