Title: A novel model of prediction of nerve origin in patients with vestibular schwannoma

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Abstract

Background: Vestibular schwannomas (VSs) typically originate in the superior vestibular nerve or inferior vestibular nerve. Given the potential impact on a patient's hearing and associated surgical risks, preoperative differentiation of a tumor's origin between the inferior and superior vestibular nerves can

influence treatment strategies and optimal therapeutic and counseling approaches.

Methods: 120 patients diagnosed with VS at the Eye and ENT Hospital of Fudan University were enrolled and randomly assigned to a training set or a validation set. T-tests and chi-square tests selected the variables. The variables were further screened using a bidirectional stepwise regression model based on the Akaike information criterion and the Least Absolute Shrinkage and Selection Operator (LASSO) regression. Sensitivity, specificity, predictive values, and likelihood ratios assessed model accuracy. Receiver operating characteristic curve (ROC) analysis maximized the Youden index to determine the optimal cutoff value. Decision curve analysis calculated clinical utility.

Findings: We selected the model obtained by LASSO regression after accuracy testing and external validation. The variables included dural fullness, hearing loss, pure tone audiometry (PTA), and auditory steady-state evoked response (ASSR). The best cutoff value for this model was 0.333, and the area under the ROC curve was 0.839. The sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were 0.800, 0.846, 0.839, 0.809, 5.20, and 0.236, respectively.

Interpretation: In this study, we built a clinical model for predicting VS patients' neural origin. Our model has significant advantages compared to vestibular-evoked myogenic potentials (VEMP), the traditional predictor of neural origin.

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Keywords: Vestibular schwannomas, nerve origin, clinical predictive model, internal auditory canal, cerebellopontine angle

Research in context

Evidence before this study: Prior to this study, the diagnostic evaluation of VS relied primarily on vestibular-evoked myogenic potentials (VEMP) to assess vestibular nerve function. However, previous research has indicated limited accuracy in predicting the origin of the tumor based solely on VEMP results. This underscores the need for an alternative approach to improve diagnostic precision and inform preoperative decision-making.

Added value of this study: This study collected data from 120 patients with vestibular schwannomas and analyzed various demographic and diagnostic indicators. The results revealed that VS originating from the superior vestibular nerve (SVN) exhibited better hearing outcomes compared to those originating from the inferior vestibular nerve (IVN). Moreover, the study constructed a predictive model incorporating variables such as aural fullness, hearing loss, pure tone average, and the auditory steady-state response. This novel model demonstrated superior predictive capabilities compared to previous methods, thus adding significant value to the field.

Implications of all the available evidence: The findings of this study have significant implications for preoperative decision-making in cases of vestibular schwannomas. By establishing a predictive model that incorporates multiple diagnostic variables, clinicians can more accurately determine the neural origin of the tumor, enabling them to tailor surgical interventions accordingly. This personalized treatment approach may

enhance patient outcomes and minimize potential complications.

Introduction

Vestibular schwannomas (VSs) are typically located within the internal auditory canal and can be accompanied or unaccompanied by a cerebellopontine angle (CPA) nerve sheath tumor [1]. Most commonly, they originate from the superior vestibular nerve (SVN) or inferior vestibular nerve (IVN). Reports indicate that patients with tumors originating from the SVN have a better postoperative hearing state than those originating from the IVN [2–4]. This phenomenon is due to the closer anatomical relationship between the IVN, cochlear nerve, and internal auditory artery. Separating the tumor from the IVN may disrupt the surrounding blood supply or damage the cochlear nerve. Therefore, distinguishing the origin of the superior or inferior vestibular nerve before surgery is crucial for therapeutic decision-making and selecting the optimal treatment approach.

Vestibular-evoked myogenic potentials (VEMP) are electromyographic recordings of either the ipsilateral sternocleidomastoid muscle or the contralateral extraocular muscle in response to high-intensity brief tone bursts or clicks. These recordings assessed the inferior and superior vestibular nerve functions, as reflected by cVEMP and oVEMP, respectively. Previous studies have indicated that the nerve origin of VSs can be identified through VEMP and caloric testing [5]. Vestibular testing can predict the nerve of tumor origin and reveal the residual function of the IVN [6]. Additionally, research has confirmed the role of VEMP examination in patients with CPA tumors. Preoperative prediction of nerve origin can help determine the optimal surgical approach. However, postoperatively, a VEMP examination can be used to clarify the nature of the tumor (such as nerve compression or infiltration) and reveal the residual function of the vestibular nerve [7]. However, the use of VEMP for predicting the origin of tumors is not very accurate based on the current evidence.

Identifying the nerve origin before surgery can assist physicians in achieving more effective tumor removal. Although imaging techniques such as MRI are valuable in detecting the presence of a tumor, they cannot reliably determine the neural origin of tumors [8]. Furthermore, while VEMP has been used as a predictive tool for nerve origin, current evidence shows its accuracy is limited [9]. In this study, we collected cases of VS and attempted to construct a prediction model using relevant demographic and diagnostic indicators to achieve better prediction results than traditional prediction methods. The development of such a predictive model holds significant clinical value in the preoperative preparation of relevant cases.

Methods

Patient population

The EYE & ENT Hospital of Fudan University conducted a retrospective review of 120 patients with VS and no concurrent chronic diseases. The ethics committee of the EYE & ENT Hospital of Fudan University approved this study, and all participants signed an informed consent form. The remaining cases were randomly classified into training and test cohorts after excluding six cases with missing detection indicators (Figure 1).

Potential predictive variables and outcomes

Demographic information, clinical characteristics, MRI, pure tone audiometry (PTA), auditory brainstem response (ABR), multiple-frequency auditory steady-state evoked response (ASSR), speed discrimination (SDS), distortion product otoacoustic emission (DPOAE), and VEMP were collected.

Surgery was performed, and the tumor's origin was discovered during surgery. Furthermore, because the predictive value of VEMP for tumor origin remains a topic of debate in the literature, we measured both cVEMP and oVEMP in these cases. We also compared the performance of these two variables with that of the optimal predictive model.

Model development and variable selection

The patients were randomly assigned to a training cohort (n=91) or a test cohort (n=23) in a 4:1 ratio. Analysis of variance, the Mann–Whitney U test, the chi-square test, or Fisher's exact test were used to test whether there was a difference in patient composition between the two cohorts.

A screening program was conducted with 25 variables after considering the correlations among the variables, as previously described. T-tests and chi-square tests were used for the initial selection of variables. Variables that exhibited significant differences in univariate analysis were incorporated into a multifactor logistic regression model (full model). We utilized two for a further selection of variables: a bidirectional stepwise regression model based on the Akaike information criterion (AIC) with a significance level of 0.1 and the Least Absolute Shrinkage and Selection Operator (LASSO) regression. This approach minimized the potential collinearity of variables obtained from the same patient and prevented overfitting. We employed L1-penalized least absolute shrinkage and selection regression for multivariate analysis and utilized 5-fold cross-validation for internal validation. The logistic regression model penalizes the absolute size of the regression coefficients based on the optimal value. The coefficient estimates of the weaker predictors approached zero as the penalty gradually increased, thereby selecting the most powerful predictive variables. The R package "glmnet" statistical software (R Foundation) was used for conducting LASSO regression.

Internal model validation

The Youden index was maximized using receiver operating characteristic curve (ROC) analysis to determine the optimal cutoff value. Model accuracy was assessed using sensitivity, specificity, predictive values, and likelihood ratios. Each variable was used to construct a univariate model to identify the best predictive model. The performance of the univariate models was estimated using the ROC curve and compared with that of a multifactorial model. Decision curve analysis (DCA), used to calculate clinical utility, was employed to estimate the accuracy of the multifactorial and univariate models. The variables selected from the optimal model were used to construct a nomogram, which was further validated in clinical applications.

Results

Baseline information

This study included 114 patients. Regarding baseline characteristics, except for tinnitus and the time sequence of hearing loss and tinnitus, which differed between the two groups, no other significant differences were observed, indicating successful randomization (Table 1). Furthermore, combined with the results of the subsequent univariate analysis (Table 2), no significant association was found between the variables of tinnitus and the timing and origin of VS. Therefore, even though there were differences in the distribution of the two groups, it would not affect the subsequent analysis.

The correlated variables in patients with VS of different neural origins

The results showed that 67 patients had tumors originating from the IVN and 47 from the SVN after

grouping the patients based on the origin of the nerve (Table 1). Compared to patients in the SVN group, those in the IVN group experienced significantly more severe hearing loss (P<0.01). DPOAE provides a measure of cochlear function, specifically the integrity of the outer hair cells. Our findings revealed that patients with VS originating from the SVN exhibited a greater likelihood of DPOAE (P=0.028), showing that the degree of cochlear impairment was less severe in these patients.

Furthermore, hearing characteristic factors, including the average PTA value, ABR value, and average ASSR values, in the IVN group were all significantly higher than those in the SVN group (P=0.001, P=0.01, and P=0.001, respectively). Patients' latent period of the ABR V wave on the affected side was increased (P=0.024). Meanwhile, the inter-peak latency (IPL) of the ABR in the IVN group was significantly higher than that in the SVN group (P=0.025), and the differences in IPL classification between the two groups were found to be statistically significant (P=0.037). Figure 2 illustrates the ROC curves of different univariate models, showing that the course of the disease and some hearing indices had a larger area under the curve (AUC) than other univariate models, indicating their greater explanatory power.

Performance of the prediction model

We found that the regression model selected by LASSO regression (including dural fullness, hearing loss, PTA, and ASSR) seemed to have better predictive performance, with an optimal cutoff value of 0.333, a ROC curve AUC of 0.839, and a Youden index of 0.646 (Table 2), and more clinical benefits (Figure 3B) after performing stepwise regression and LASSO regression to select variables and construct the logistic regression model. The comparison with the single-factor model also demonstrated the

superiority of the selected model, which had a more stable net benefit when the probability threshold was less than 80% (Figure 3A), a larger area under the ROC curve, and better Youden index performance (Figure 2). When the probability threshold was between 20% and 55%, the net benefit value of the regression model selected by LASSO regression was significantly higher compared to the models obtained by stepwise regression based on the AIC and significance level. Moreover, regardless of the probability threshold, the net benefit value of the model was not significantly lower than that of the other models. In addition, other indicators, such as the predicted value and likelihood ratio, showed good performance (Table 3), indicating that this model is effective and beneficial for predicting the origin of VSs in a clinical setting. Finally, Figure 4 presents the nomogram and corresponding ROC curve constructed based on the selected model. We will proceed with clinical validation to evaluate the model's predictive performance.

VEMP's performance in identifying the neural origin is poor

Our findings revealed that out of the 89 patients who underwent relevant vestibular function tests, the use of cVEMP and oVEMP for prediction, based on previous studies, showed significant disadvantages according to all evaluation indicators (Table 3). Additionally, combining the two VEMP tests to predict the neurogenic origin may cause greater confusion, which cannot be fully demonstrated in Table 3. Nine patients exhibited preoperative abnormal oVEMP responses, accurately predicting the neural origin associated with the SVN. Similarly, three patients displayed preoperative abnormal cVEMP responses, successfully predicting the neural origin associated with IVN. Nevertheless, when consolidating the cVEMP and oVEMP results, 54 patients showed either normal or abnormal responses on both tests, thereby hindering the ability to determine the neural origin precisely preoperatively. It is worth noting

that combining the outcomes of multiple vestibular function tests could enhance the predictive accuracy of neural origin.

Discussion

The earliest symptoms of VSs are usually auditory, such as hearing loss and tinnitus (5)[10](11). VSs originate from one of the branches of the vestibular system, and hearing outcomes may be affected by tumor origin [6]. Hearing tests, such as ABR, ASSR, and PTA, can provide much information and may become effective predictors. In our clinical work, we have also found that there seem to be significant differences in hearing test indicators among VS patients with different neural origins. Therefore, hearing indicators were selected as variables for the VS prediction model in this study. We attempted to use indicators such as ABR, ASSR, and PTA for the first time to construct a predictive model for the neural origin of VSs. We compared the "selected model" with a univariate prediction model, showing the stability and effectiveness of the selected model. The validation results show that after including the hearing indicators, our prediction model has a better predictive performance than previous prediction models, thus exhibiting significant advantages.

VEMP is related to vestibular function, and it is generally believed that VEMP testing can help neurosurgeons differentiate neural origins [11]. Although cVEMP and oVEMP have a certain sensitivity and specificity in distinguishing IVN and SVN (as our analysis shows), the predictive value of VEMP for tumor neural origin may be affected when the tumor volume is too large or when the tumor affects both the superior and inferior vestibular nerves. Similarly, our results show that although there is some predictability using separate VEMP indicators, the concordance rate is not high. If both VEMP indicators

are combined, there is a high potential for confusion and conflicting results.

We demonstrated the advantages of the predictive model used in this study. We highlighted the limitations of our experimental design and sample collection through a comparison with the univariate model prediction results. In future studies, we will continue to increase the sample size and apply the model to actual clinical settings to verify its effectiveness. Additionally, we emphasized the clinical significance of this study and its potential impact. In particular, we emphasize that a good predictive model can provide more accurate diagnoses and better patient healthcare services. In our next research plan, we will focus on further enriching the sample size, improving the model to enhance the predictive effects, and incorporating more diverse indicators for research purposes.

VS can lead to symptoms such as hearing loss and tinnitus in patients. Preoperative prediction of the neural origin in patients with vestibular schwannomas can help doctors develop more accurate treatment plans, improve the success rate of surgery, and reduce surgical risks, which are very important for patient recovery [3]. Currently, VEMP indicators are commonly used in clinics to predict neural origins [12]. However, in our clinical work, we found that although VEMP can predict the neural origin of some tumors, it may be affected by conflicting predictive results and cannot fully meet clinical needs. Therefore, we developed and compared a new predictive model with traditional models. Our model has significant advantages that will aid future clinical studies.

Conclusions

The findings of this study showed that the clinical prediction model formulated using aural fullness,

hearing loss, PTA, and ASSR displayed superior predictive performance. A novel model based on hearing parameters may be used to forecast the neural origin of VSs and has demonstrated high consistency with intraoperative outcomes. We contend that the tumor's neural origin profoundly influences a patient's auditory function. Accordingly, implementing this predictive model may augment the accuracy of predicting the origin of tumors and may prove valuable in mitigating the deleterious effects of tumor growth on hearing.

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Declaration of interests

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Consent for publication: All of the authors have consented to publication of this research.

Author Contributions: LYX, WZX and YYB designed the study, wrote the manuscript. ZWD collected the data. YYS, LHW and YHQ conducted critical revisions of the manuscript. All authors read and approved the final manuscript.

Data Availability: The datasets during and/or analyses during the current study available from the corresponding author on reasonable request.

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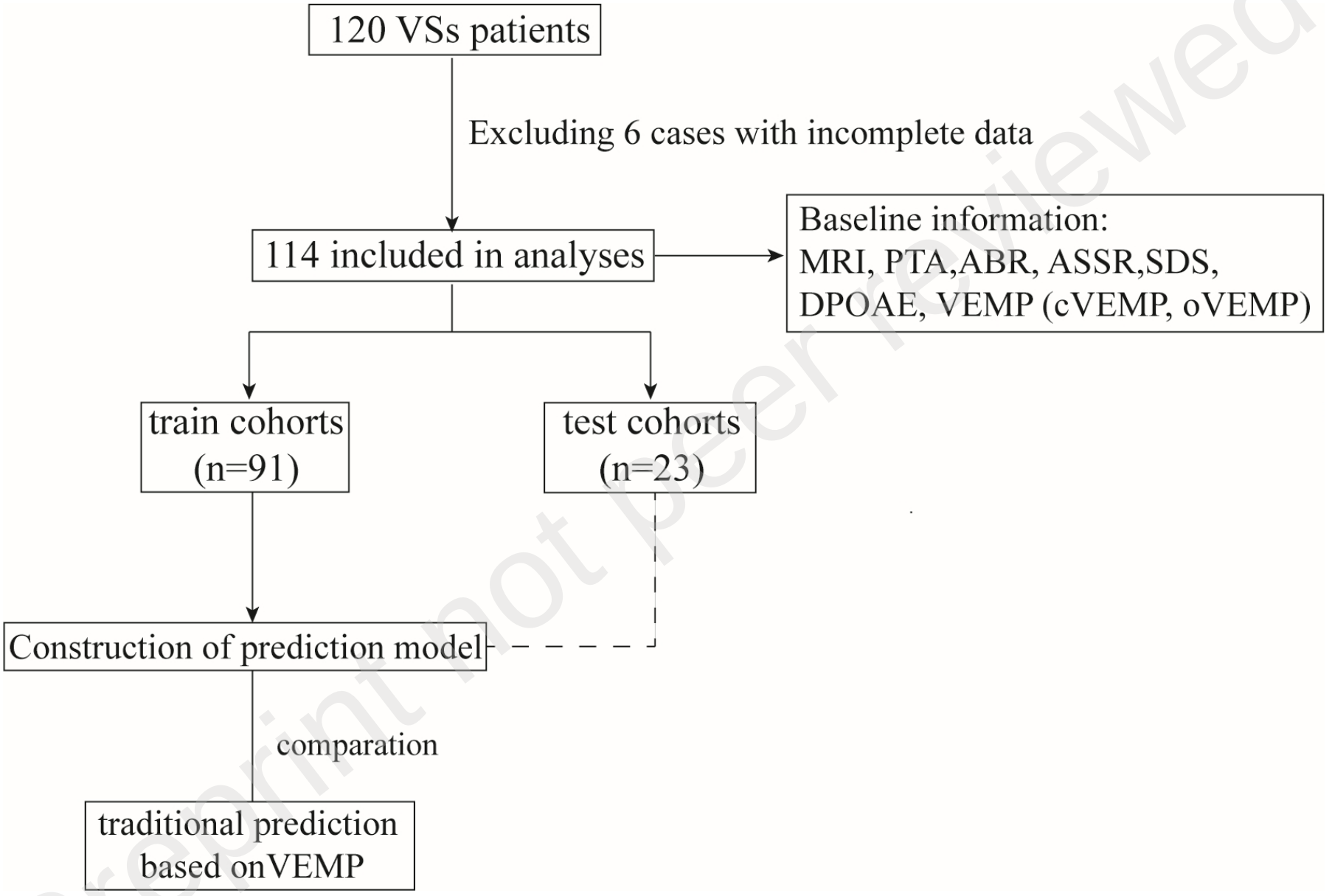
Figure Legend:

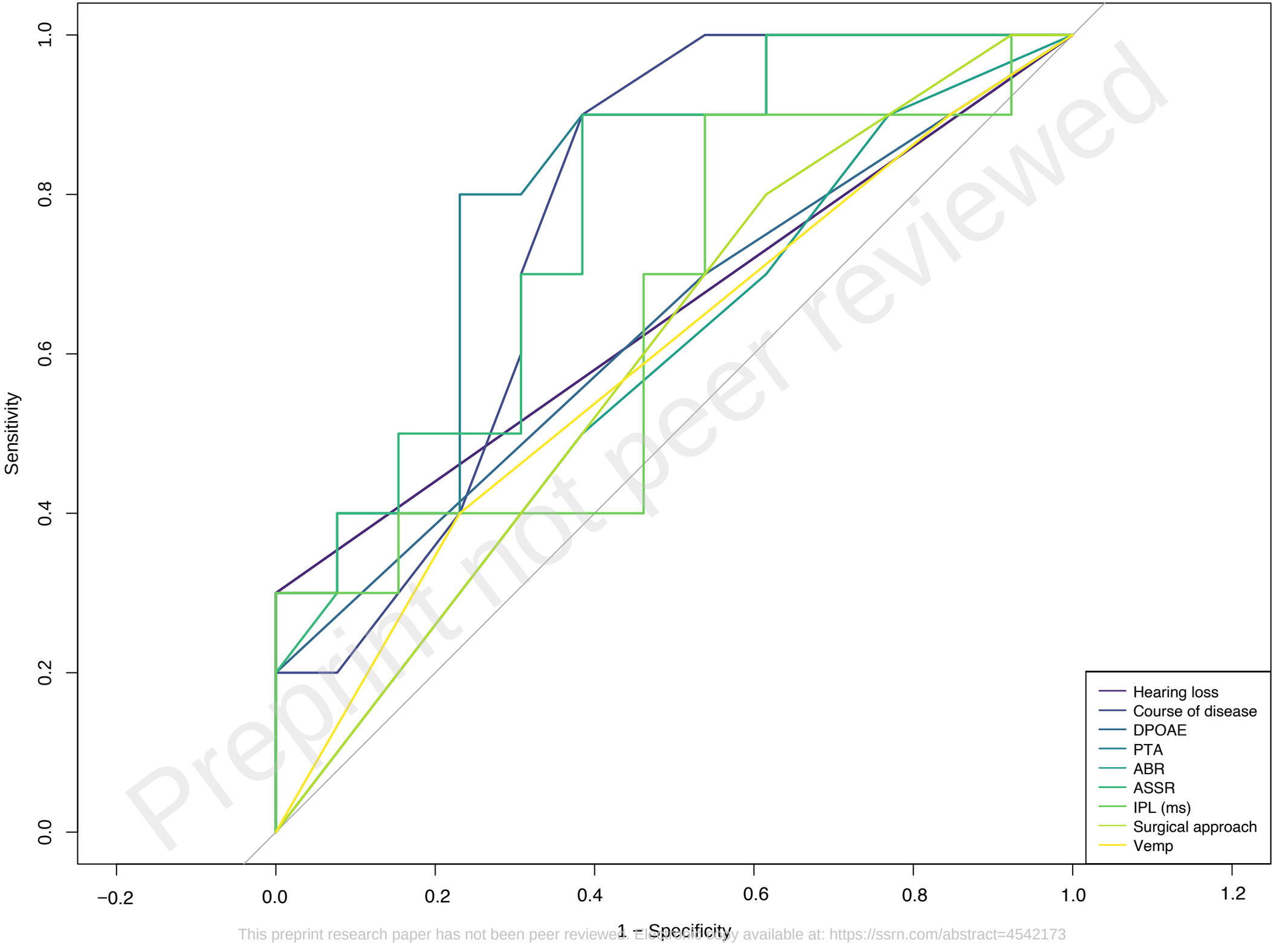
Figure 1. Flow chart of the included, excluded, and analyzed patients, as well as the construction of the model.

Figure 2. ROC curves of different univariate models and the selected model.

Figure 3. Decision curve analysis. (A) DCA of the LASSO selected model and univariate models. (B) DCA of multivariate models.

Figure 4. The nomogram and corresponding ROC curve of the selected model.





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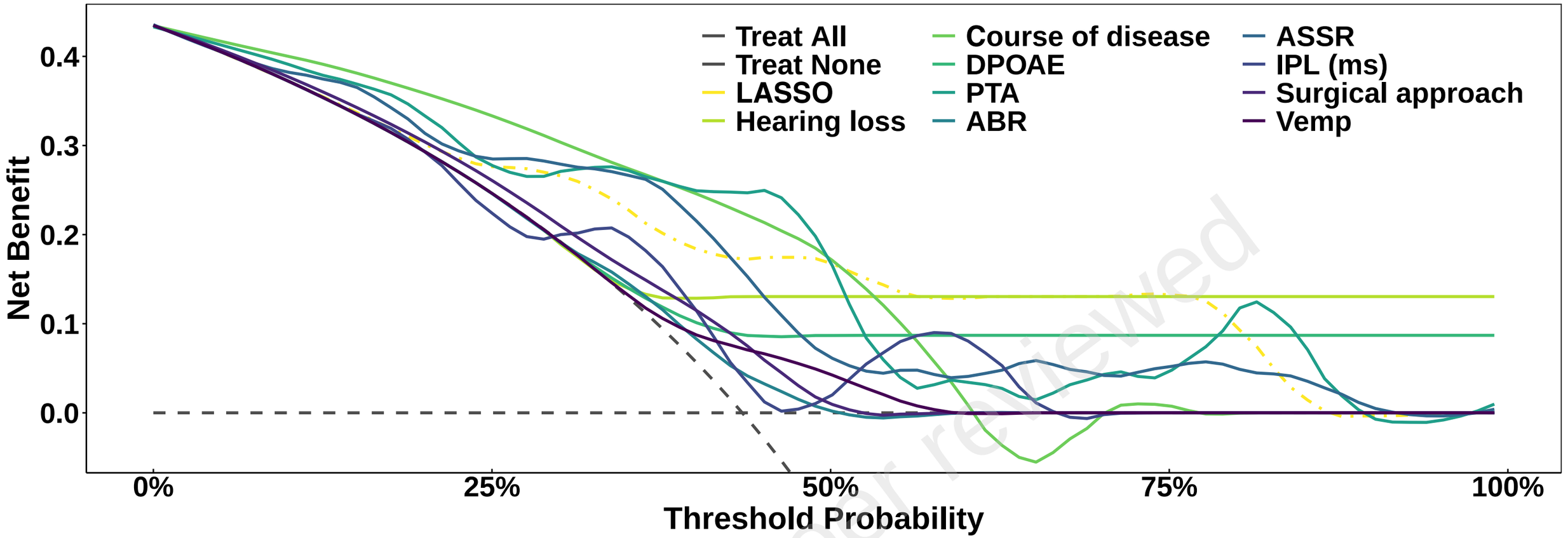

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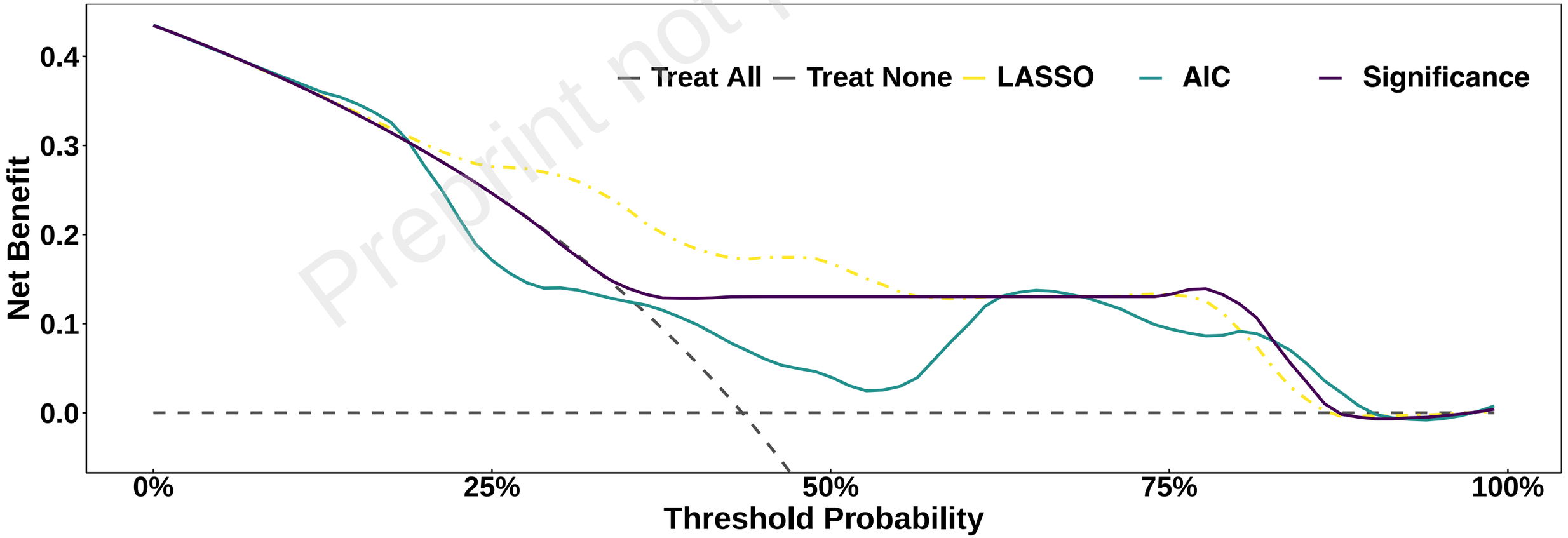

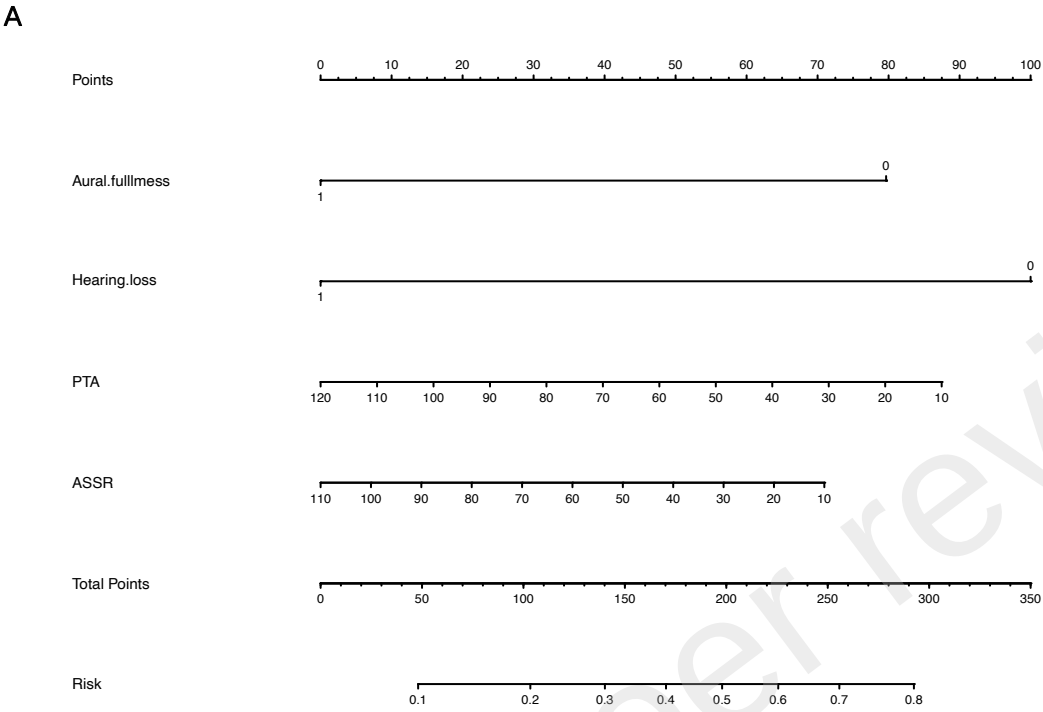

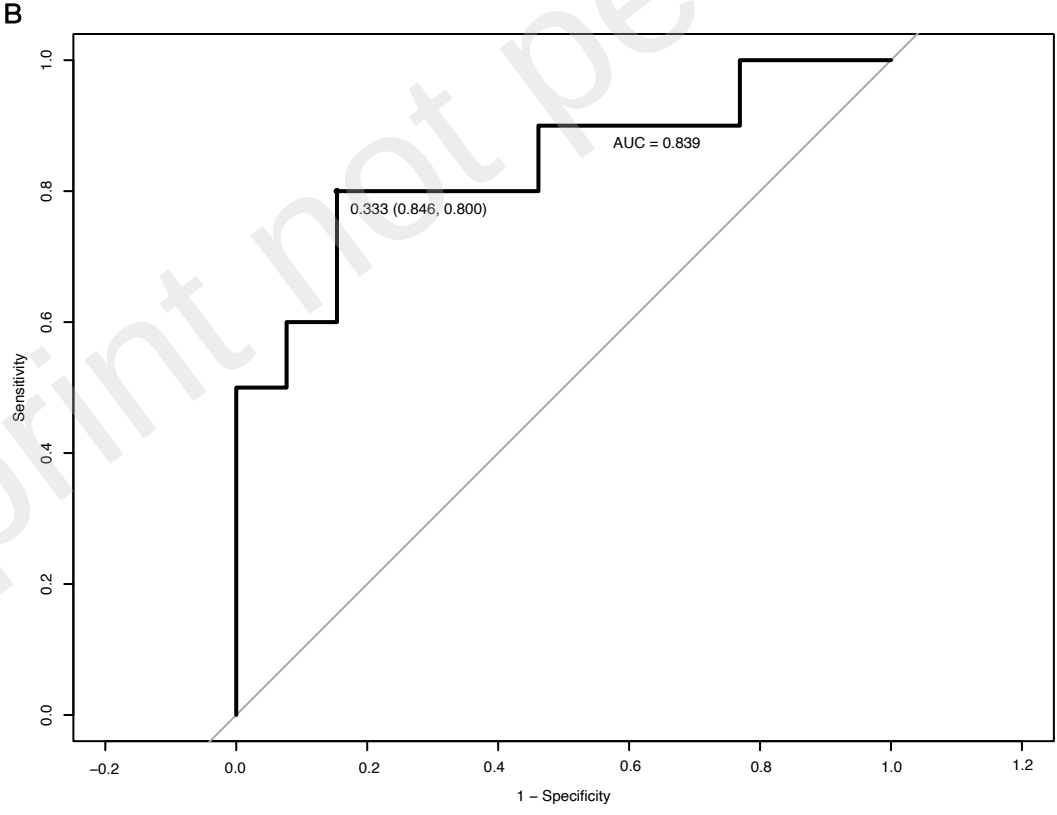

Table.1 Information of test cohort and train cohort

	Overall	Test cohort	Train cohort	*P*-value
n	114	23	91	
Sex (n (%)) (F/M)	61 (53.5)/53 (46.5)	13 (56.5)/10 (43.5)	48 (52.7)/43 (47.3)	0.928
Age (mean (SD))	46.75 (11.44)	50.22 (10.54)	45.87 (11.55)	0.104
Side (n (%)) (L/R)	53 (46.5)/61 (53.5)	10 (43.5)/13 (56.5)	43 (47.3)/48 (52.7)	0.928
Aural fullness (n (%)) (N/Y)	97 (85.1)/17 (14.9)	17 (73.9)/6 (26.1)	80 (87.9)/11 (12.1)	0.175
Facial paralysis (n (%)) (N)	114 (100.0)	23 (100.0)	91 (100.0)	NA
Numbness (n (%)) (N/Y)	108 (94.7)/6 (5.3)	21 (91.3)/2 (8.7)	87 (95.6)/4 (4.4)	0.762
Facial pain (n (%)) (N/Y)	113 (99.1)/1 (0.9)	23 (100.0)/0 (0.0)	90 (98.9)/1 (1.1)	1.000
Headache (n (%)) (N/Y)	89 (78.1)/25 (21.9)	20 (87.0)/3 (13.0)	69 (75.8)/22 (24.2)	0.384
Vertigo (n (%)) (N/Y)	76 (66.7)/38 (33.3)	14 (60.9)/9 (39.1)	62 (68.1)/29 (31.9)	0.680
Tinnitus (n (%)) (N/Y)	19 (16.7)/95 (83.3)	8 (34.8)/15 (65.2)	11 (12.1)/80 (87.9)	0.022
Hearing loss (n (%)) (N/Y)	15 (13.2)/99 (86.8)	3 (13.0)/20 (87.0)	12 (13.2)/79 (86.8)	1.000
Course of disease (mean (SD))	24.31 (39.73)	34.17 (49.28)	21.82 (36.83)	0.184
Time-sequence (n (%))				
Both	84 (73.7)	12 (52.2)	72 (79.1)	<0.001
Hearing loss earlier	18 (15.8)	10 (43.5)	8 (8.8)	
Tinnitus earlier	12 (10.5)	1 (4.3)	11 (12.1)	
Tumor location (n (%))				
IAC	35 (30.7)	7 (30.4)	28 (30.8)	1.000
IAC+CPA	79 (69.3)	16 (69.6)	63 (69.2)	
Max diameter(cm) (mean (SD))	1.60 (0.90)	1.81 (1.12)	1.54 (0.84)	0.209
Tumor grade (n (%))				
0	35 (30.7)	7 (30.4)	28 (30.8)	0.342
1	6 (5.3)	1 (4.3)	5 (5.5)	
2	47 (41.2)	7 (30.4)	40 (44.0)	
3	17 (14.9)	4 (17.4)	13 (14.3)	
4	8 (7.0)	4 (17.4)	4 (4.4)	
5	1 (0.9)	0 (0.0)	1 (1.1)	
DPOAE (n (%))				
Negative	60 (52.6)	9 (39.1)	51 (56.0)	0.231
Positive	12 (10.5)	2 (8.7)	10 (11.0)	
Unknown	42 (36.8)	12 (52.2)	30 (33.0)	
PTA (mean (SD))	56.49 (27.01)	58.53 (27.62)	55.98 (26.99)	0.687
ABR (mean (SD))	70.79 (19.59)	72.39 (16.02)	70.38 (20.46)	0.663
ASSR (mean (SD))	60.81 (22.47)	67.45 (23.48)	59.14 (22.03)	0.114
Hearing loss classification (mean (SD))	3.90 (1.70)	4.00 (1.62)	3.88 (1.72)	0.762
Wave V (Unaffected side) (mean (SD))	5.96 (0.21)	5.97 (0.17)	5.95 (0.22)	0.747
Wave V (Affected side) (mean (SD))	7.22 (0.83)	7.20 (0.90)	7.23 (0.81)	0.880
IPL (ms) (mean (SD))	1.26 (0.80)	1.23 (0.84)	1.27 (0.79)	0.810
IPL classification (mean (SD))	2.02 (1.45)	1.96 (1.43)	2.03 (1.46)	0.822

Origin of nerve (n (%))				
IVN	67 (58.8)	13 (56.5)	54 (59.3)	0.993
SVN	47 (41.2)	10 (43.5)	37 (40.7)	
Surgical approach (n (%))				
MFA	36 (31.6)	6 (26.1)	30 (33.0)	0.719
RSA	75 (65.8)	16 (69.6)	59 (64.8)	
TLA	3 (2.6)	1 (4.3)	2 (2.2)	
Enlarged IAC (n (%))				
Yes	71 (62.3)	15 (65.2)	56 (61.5)	
No	5 (4.4)	0 (0.0)	5 (5.5)	0.516
Unknown	38 (33.3)	8 (34.8)	30 (33.0)	
Blood supply (n (%))				
Exactly abundant	2 (1.8)	0 (0.0)	2 (2.2)	
Abundant	18 (15.8)	5 (21.7)	13 (14.3)	0.253
Moderate	72 (63.2)	11 (47.8)	61 (67.0)	
Unknown	22 (19.3)	7 (30.4)	15 (16.5)	
VEMP (n (%))				
Consistency	68 (59.6)	13 (56.5)	55 (60.4)	0.881
Inconsistency	16 (14.0)	3 (13.0)	13 (14.3)	
Unknown	30 (26.3)	7 (30.4)	23 (25.3)	

Table 2. Univariate analysis of nerve origin in VS patients

Project	Nerve of origin		
	IVN	SVN	P value
n	67	47	
Sex (n (%)) (F/M)	35 (52.2)/32 (47.8)	26 (55.3)/21 (44.7)	0.894
Age (mean (SD))	46.87 (11.73)	46.57 (11.14)	0.894
Side (n (%)) (L/R)	28 (41.8)/ 39 (58.2)	25 (53.2)/ 22 (46.8)	0.312
Aural fullness (n (%)) (N/Y)	54 (80.6)/13 (19.4)	43 (91.5)/4 (8.5)	0.180
Facial paralysis (n (%)) (N)	67 (100.0)	47 (100.0)	NA
Numbness (n (%)) (N/Y)	64 (95.5)/3 (4.5)	44 (93.6)/3 (6.4)	0.982
Facial pain (n (%)) (N/Y)	67 (100.0)/0 (0.0)	46 (97.9)/1 (2.1)	0.858
Headache (n (%)) (N/Y)	51 (76.1)/16 (23.9)	38 (80.9)/9 (19.1)	0.711
Vertigo (n (%)) (N/Y)	43 (64.2)/24 (35.8)	33 (70.2)/14 (29.8)	0.638
Tinnitus (n (%)) (N/Y)	9 (13.4)/58 (86.6)	10 (21.3)/37 (78.7)	0.395
Hearing loss (n (%)) (N/Y)	2 (3.0)/65 (97.0)	13 (27.7)/34 (72.3)	<0.001
Course of disease (mean (SD))	29.75 (46.86)	16.57 (24.93)	0.081
Time-sequence (n (%))			
Both	50 (74.6)	34 (72.3)	0.381
Hearing loss earlier	12 (17.9)	6 (12.8)	
Tinnitus earlier	5 (7.5)	7 (14.9)	
Tumor location (n (%))			
IAC	21 (31.3)	14 (29.8)	1.000
IAC+CPA	46 (68.7)	33 (70.2)	
Max diameter(cm) (mean (SD))	1.57 (0.88)	1.64 (0.94)	0.683
Tumor grade (n (%))			
0	21 (31.3)	14 (29.8)	0.372
1	2 (3.0)	4 (8.5)	
2	30 (44.8)	17 (36.2)	
3	8 (11.9)	9 (19.1)	
4	6 (9.0)	2 (4.3)	
5	0 (0.0)	1 (2.1)	
DPOAE (n (%))			
Negative	35 (52.2)	25 (53.2)	0.024
Positive	3 (4.5)	9 (19.1)	
Unknown	29 (43.3)	13 (27.7)	
PTA (mean (SD))	64.12 (25.87)	45.61 (25.03)	<0.001
ABR (mean (SD))	74.70 (17.49)	65.21 (21.21)	0.010
ASSR (mean (SD))	66.78 (21.73)	52.31 (20.92)	0.001
Hearing loss classification (mean (SD))	4.37 (1.61)	3.23 (1.60)	<0.001
Wave V (Unaffected side) (mean (SD))	5.96 (0.20)	5.95 (0.23)	0.722
Wave V (Affected side) (mean (SD))	7.37 (0.82)	7.01 (0.80)	0.024
IPL (ms) (mean (SD))	1.40 (0.83)	1.07 (0.71)	0.025

IPL classification (mean (SD))	2.25 (1.51)	1.68 (1.29)	0.037
Surgical approach (n (%))			
MFA	25 (37.3)	11 (23.4)	0.074
RSA	39 (58.2)	36 (76.6)	
TLA	3 (4.5)	0 (0.0)	
Enlarged IAC (n (%))			
No	4 (6.0)	1 (2.1)	0.074
Yes	36 (53.7)	35 (74.5)	
Unknown	27 (40.3)	11 (23.4)	
Blood supply (n (%))			
Exactly abundant	2 (3.0)	0 (0.0)	
Abundant	10 (14.9)	8 (17.0)	0.459
Moderate	40 (59.7)	32 (68.1)	
Unknown	15 (22.4)	7 (14.9)	
VEMP (n (%))			
Consistency	40 (59.7)	28 (59.6)	0.323
Inconsistency	7 (10.4)	9 (19.1)	
Unknown	20 (29.9)	10 (21.3)	

Table 3. The comparation between VEMP and Selected model

Variable	Value		
	cVEMP	oVEMP	Selected model
Area under the ROC curve, C index	NA	NA	0.839
Cutoff score	1	1	0.333
Sensitivity, %	57.9	74.5	80.0
Specificity, %	68.6	81.6	84.6
Positive predictive value, %	57.9	84.4	83.9
Negative predictive value, %	68.6	70.4	80.9
Positive likelihood ratio	1.84	4.04	5.20
Negative likelihood ratio	0.614	0.312	0.236