

## Original Article

# Predictive value of inflammatory biomarkers in individuals with sensorineural hearing loss and type 2 diabetes mellitus

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**Abstract:** Objectives: To evaluate the predictive value of inflammatory markers (neutrophil-to-lymphocyte ratio [NLR] and platelet-to-lymphocyte ratio [PLR]) combined with clinical characteristics for hearing prognosis in patients with sudden sensorineural hearing loss (SSNHL) and type 2 diabetes mellitus (T2DM). Methods: A retrospective cohort of 188 SSNHL patients with T2DM treated between 2018 and 2025 was analyzed. Patients were randomly divided into a training cohort (n=132) and a test cohort (n=56). Least absolute shrinkage and selection operator (LASSO) regression combined with multivariate logistic regression was used to identify independent predictors for poor hearing recovery. A combined predictive model and a visual nomogram were built. Model performance was measured using the area under the curve (AUC), with internal validation. Results: Six independent predictors were identified: age, time from onset to treatment, vertigo, initial pure-tone average (PTA), PLR, and NLR. The combined model achieved an AUC of 0.899 in the training cohort and 0.892 in the test cohort, significantly outperforming the model based on clinical features alone (AUC=0.820). The nomogram demonstrated good discrimination and calibration. Conclusions: Incorporating NLR and PLR into a clinical risk model substantially improves prediction of poor hearing prognosis in SSNHL patients with T2DM. The nomogram furnishes a user-friendly, bedside-ready means for personalized risk appraisal.

**Keywords:** Sudden sensorineural hearing loss, type 2 diabetes mellitus, neutrophil-to-lymphocyte ratio, platelet-to-lymphocyte ratio, inflammatory markers

## Introduction

Sudden sensorineural hearing loss (SSNHL) is considered an otologic urgency. It is defined by the sudden onset of hearing impairment within 72 hours, with a decline of at least 20 dB HL across two or more contiguous frequencies [1, 2]. This condition typically affects one ear and is often accompanied by tinnitus, aural fullness, and vertigo [3]. Currently, the main treatments used in clinical practice include glucocorticoids, which can be administered orally or through injections into the eardrum, as well as vasoactive drugs and hyperbaric oxygen therapy. In some cases, fibrinogen-lowering medications are also employed [4, 5]. However, even with these treatments, the recovery rates vary considerably among individuals, and only a

subset of patients experience a satisfactory improvement in their hearing [6]. The coexistence of diabetes mellitus (T2DM) further complicates clinical management. Diabetes is a common comorbidity of SSNHL, and evidence suggests that patients typically experience poorer hearing recovery than those without diabetes [7]. Therefore, there is growing interest in identifying reliable predictors to facilitate early risk stratification and guide treatment decisions in this population.

The adverse interaction between T2DM and SSNHL is underpinned by multiple mechanisms, including microvascular damage, endothelial dysfunction, and enhanced oxidative stress [8, 9], all of which compromise cochlear perfusion and exacerbate ischemic injury.

Recent evidence has highlighted systemic inflammation as a common pathway linking metabolic disorders to inner ear injury [10]. Among the available inflammatory markers, the neutrophil-to-lymphocyte ratio (NLR) and platelet-to-lymphocyte ratio (PLR) have drawn particular research attention [11, 12]. Both are inexpensive, routinely available laboratory parameters that indicate the balance between pro-inflammatory and regulatory immune responses. Elevated NLR and PLR have been associated with worse clinical outcomes across diverse cardiovascular, metabolic, and infectious diseases [13]. However, their specific prognostic value in SSNHL patients with concurrent T2DM has not been systematically investigated, nor has their incremental utility beyond conventional clinical variables been established.

This study aimed to evaluate the predictive role of NLR and PLR, together with other readily accessible clinical factors, in patients with SSNHL and T2DM. We sought to identify independent predictors of poor hearing recovery and to develop a simple, practical tool for individualized risk assessment. This tool enables doctors to identify high-risk patients more quickly, allowing them to develop more targeted treatment plans for each individual and more efficiently allocate resources.

## Subjects and methods

### Research subjects

This retrospective study included 188 patients diagnosed with SSNHL and T2DM who were admitted to Yichang Central People's Hospital between December 2018 and December 2025. Inclusion criteria: (1) Conforming to the diagnostic standards for SSNHL outlined in the "Guidelines for Diagnosis and Treatment of Sudden Deafness (2015)" [14]: sudden, unexplained sensorineural hearing loss occurring within 72 hours, with a decrease of at least 20 dB HL at two consecutive frequencies; (2) Fulfilling the diagnostic criteria for T2DM according to the "Standards of medical care for type 2 diabetes in China 2019" [15]; (3) First-onset and unilateral SSNHL; (4) Aged  $\geq 18$  years; (5) Received standardized treatment after admission, with a complete course of treatment; (6) Having complete clinical and follow-up audiological data. Exclusion criteria: (1) Having received treatment for SSNHL prior

to admission; (2) Congenital or hereditary hearing disorders; (3) Conductive hearing loss due to external ear and middle ear diseases; (4) History of exposure to ototoxic drugs; (5) History of head trauma or ear surgery; (6) Coexisting with malignant tumors, severe infectious diseases, hematologic diseases, or autoimmune diseases; (7) Combined with severe dysfunction of important organs such as heart, liver, and kidney; (8) Accompanied by mental and behavioral abnormalities, unable to cooperate with treatment and examinations; (9) During pregnancy or lactation.

This retrospective study was approved by the Ethics Committee of Yichang Central People's Hospital. No informed consent was required because the study involved retrospective analysis of anonymized existing medical records, and patient identities could not be ascertained. All activities complied with the committee's ethical policies, the Helsinki Declaration (1964) as amended, and comparable ethical frameworks.

### Treatment

After admission, patients underwent routine pure-tone audiometry using an audiometer (Orbiter 922, Madsen Audio, Denmark) to assess the pure-tone average (PTA), calculated as the mean of the hearing thresholds at 500, 1,000, 2,000, and 4,000 Hz. All patients received standardized treatment: (1) Glucocorticoids: intravenously dexamethasone injection (10 mg) diluted in 100 mL of normal saline was administered once daily for 5 days, followed by 5 mg/d for another 5 days; (2) Microcirculation-improving agents: Ginkgo biloba extract (105 mg) diluted in 250 mL of normal saline was administered intravenously once daily for 10 days; (3) Hyperbaric oxygen therapy: Inhalation of pure oxygen for 60 minutes once daily, for a total of 10 sessions; (4) Fibrinogen-lowering treatment: For patients experiencing total deafness or a flat-type audiogram, Batroxobin injection was added, with an initial dose of 10 BU diluted in 250 mL of normal saline administered intravenously, followed by 5 BU diluted in 100 mL of normal saline every other day for a total of 3 to 5 times. Fibrinogen levels were checked before each administration, and the medication was withheld until fibrinogen levels recovered to  $>1$  g/L.

For patients with T2DM, endocrinologists were consulted upon admission for glycemic management. Patients with high blood glucose received hypoglycemic treatment, with regular monitoring during glucocorticoid therapy. In cases of severe or uncontrolled hyperglycemia, systemic steroids were discontinued and switched to intratympanic glucocorticoid injections. During hospitalization, all patients received diabetes management education, including instructions on self-monitoring of blood glucose.

#### *Prognostic evaluation*

One month post-treatment, hearing recovery was evaluated using the Siegel criteria [16]: (1) Complete recovery: final hearing level better than 25 dB HL; (2) Partial recovery: hearing gain exceeding 15 dB, with a final hearing level between 25 and 45 dB HL; (3) Slight improvement: hearing gain exceeding 15 dB HL improvement with final hearing >45 dB HL; (4) No improvement: hearing gain less than 15 dB HL. Good prognosis = complete recovery + partial recovery. Based on the efficacy assessment, the 188 SSNHL patients with T2DM were categorized into two groups: a good prognosis group (n=61) and a poor prognosis group (n=127).

#### *Observation indicators*

Clinical data collected at admission included age, sex, body mass index (BMI), comorbidities (hypertension, hyperlipidemia), duration of diabetes, time from onset to treatment, affected side, symptoms (tinnitus, aural fullness, vertigo), initial PTA, audiogram patterns (low-, high-frequency descending type, flat descending type, total deafness type), and laboratory indicators. Glycated hemoglobin (HbA1c), fasting blood glucose (FBG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels were measured using an automated biochemical analyzer (AU5800, Beckman Coulter, USA). Prothrombin time (PT) and activated partial thromboplastin time (APTT) were measured using an automated coagulation analyzer (ACL TOP750, Werfen, USA). Red blood cell distribution width (RDW), platelet count (PLT), neutrophil count (NEU), and lymphocyte count (LYM) were detected using an automated hematology analyzer (BC-

6800, Mindray, China). PLR and NLR were calculated accordingly.

#### *Statistical analysis*

Statistical analyses were performed using SPSS 27.0 and R 4.3.1. Continuous variables were reported as means  $\pm$  standard deviations ( $M \pm SD$ ), and independent samples t-tests were used for group comparisons. Categorical variables were presented as frequencies and percentages [ $n$  (%)], with chi-square tests applied for between-group contrasts. Patients were randomly assigned to a training set and a testing set in a 7:3 ratio. For variable selection, Least Absolute Shrinkage and Selection Operator (LASSO) regression was employed, with  $\lambda$  selected through cross-validation. Candidate predictors for LASSO encompassed all clinically relevant variables listed in **Tables 1-3**, including demographic, disease-related, and laboratory indicators. The lambda.1se criterion was deliberately adopted to favor a parsimonious model with improved generalizability and reduced risk of overfitting. Variables shrunk to zero coefficients were interpreted as providing no independent incremental predictive value beyond the selected predictors. Those with non-zero regression weights at lambda.1se were then analyzed in the multivariate logistic regression to ascertain which factors independently forecast poor prognosis in SSNHL and T2DM patients. There were no missing data in the analytic cohort, obviating the need for imputation. Receiver operating characteristic (ROC) analyses were utilized to assess the predictive power of both single and combined independent risk factors for poor prognosis in these patients. Furthermore, we created a nomogram from the multivariable logistic regression model as a graphical aid for estimating individualized risk. Its internal reliability was checked through 1,000 bootstrap resamples to generate a calibration plot. A  $P$  value <0.05 was considered statistically significant.

## **Results**

#### *Clinical data in the training set*

Baseline demographic characteristics of the two groups are compared in **Table 1**. Patients in the poor prognosis group were significantly older than those in the good prognosis group ( $P=0.028$ ), and the time from symptom onset

**Table 1.** Comparison of demographics characteristics between the two groups in the training set

| Indicator                        | Good prognosis group<br>(n=42) | Poor prognosis group<br>(n=90) | t/ $\chi^2$ value | P value |
|----------------------------------|--------------------------------|--------------------------------|-------------------|---------|
| Age (years)                      | 57.23 $\pm$ 11.46              | 61.74 $\pm$ 10.61              | 2.216             | 0.028   |
| Gender [n (%)]                   |                                |                                | 1.633             | 0.201   |
| Male                             | 26 (61.90%)                    | 45 (50.00%)                    |                   |         |
| Female                           | 16 (38.10%)                    | 45 (50.00%)                    |                   |         |
| BMI (kg/m <sup>2</sup> )         | 24.15 $\pm$ 3.12               | 24.52 $\pm$ 3.08               | 0.649             | 0.517   |
| Hypertension [n (%)]             |                                |                                | 2.514             | 0.113   |
| Yes                              | 10 (23.81%)                    | 34 (37.78%)                    |                   |         |
| No                               | 32 (76.19%)                    | 56 (62.22%)                    |                   |         |
| Dyslipidemia [n (%)]             |                                |                                | 0.422             | 0.516   |
| Yes                              | 6 (14.29%)                     | 17 (18.89%)                    |                   |         |
| No                               | 36 (85.71%)                    | 73 (81.11%)                    |                   |         |
| Duration of diabetes (years)     | 8.51 $\pm$ 4.34                | 10.13 $\pm$ 5.02               | 1.798             | 0.075   |
| Time from onset to treatment (d) | 4.57 $\pm$ 2.26                | 5.82 $\pm$ 2.34                | 2.885             | 0.005   |

Note: BMI, body mass index.

**Table 2.** Comparison of disease characteristics between the two groups in the training set

| Indicator                   | Good prognosis group<br>(n=42) | Poor prognosis group<br>(n=90) | t/ $\chi^2$ value | P value |
|-----------------------------|--------------------------------|--------------------------------|-------------------|---------|
| Affected side [n (%)]       |                                |                                | 0.036             | 0.850   |
| Left                        | 24 (57.14%)                    | 53 (58.89%)                    |                   |         |
| Right                       | 18 (42.86%)                    | 37 (41.11%)                    |                   |         |
| Tinnitus [n (%)]            |                                |                                | 0.003             | 0.958   |
| Yes                         | 37 (88.10%)                    | 79 (87.78%)                    |                   |         |
| No                          | 5 (11.90%)                     | 11 (12.22%)                    |                   |         |
| Aural fullness [n (%)]      |                                |                                | 0.028             | 0.867   |
| Yes                         | 12 (28.57%)                    | 27 (30.00%)                    |                   |         |
| No                          | 30 (71.43%)                    | 63 (70.00%)                    |                   |         |
| Vertigo [n (%)]             |                                |                                | 8.327             | 0.004   |
| Yes                         | 9 (21.43%)                     | 43 (47.78%)                    |                   |         |
| No                          | 33 (78.57%)                    | 47 (52.22%)                    |                   |         |
| Initial PTA (dB HL)         | 76.89 $\pm$ 15.74              | 93.56 $\pm$ 16.23              | 5.551             | <0.001  |
| Total deafness type [n (%)] |                                |                                | 5.584             | 0.018   |
| Yes                         | 3 (7.14%)                      | 22 (24.44%)                    |                   |         |
| No                          | 39 (92.86%)                    | 68 (75.56%)                    |                   |         |

Note: PTA, pure-tone average.

to treatment initiation was also markedly longer in the poor prognosis group ( $P=0.005$ ). No significant differences were observed between the two groups regarding gender distribution, BMI, prevalence of hypertension, dyslipidemia, or duration of diabetes (all  $P>0.05$ ). Overall, the two groups were comparable in most baseline characteristics except for age and time to treatment.

Comparison of disease-related characteristics between the two groups is presented in **Table 2**. No notable differences were observed in affected side, presence of tinnitus, or aural fullness (all  $P>0.05$ ). The poor prognosis group had a markedly higher proportion of patients presenting with vertigo ( $P=0.004$ ), a markedly higher mean initial pure-tone average ( $P<0.001$ ), and a markedly greater prevalence of

**Table 3.** Comparison of laboratory indicators between the two groups in the training set

| Indicator      | Good prognosis group<br>(n=42) | Poor prognosis group<br>(n=90) | t value | P value |
|----------------|--------------------------------|--------------------------------|---------|---------|
| HbA1c (%)      | 7.82 ± 1.55                    | 8.15 ± 1.72                    | 1.051   | 0.295   |
| FBG (mmol/L)   | 9.58 ± 2.71                    | 10.23 ± 2.84                   | 1.233   | 0.220   |
| HDL-C (mmol/L) | 1.46 ± 0.36                    | 1.38 ± 0.41                    | 1.045   | 0.298   |
| LDL-C (mmol/L) | 3.28 ± 1.02                    | 3.19 ± 0.98                    | 0.482   | 0.631   |
| PT (s)         | 13.85 ± 1.69                   | 14.52 ± 2.35                   | 1.868   | 0.064   |
| APTT (s)       | 33.42 ± 4.18                   | 31.76 ± 4.51                   | 2.014   | 0.046   |
| PLR            | 129.78 ± 43.96                 | 159.94 ± 57.89                 | 2.995   | 0.003   |
| NLR            | 4.14 ± 1.37                    | 5.78 ± 2.22                    | 5.222   | <0.001  |

Notes: HbA1c, glycated hemoglobin; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; PT, prothrombin time; APTT, activated partial thromboplastin time; PLR, platelet-to-lymphocyte ratio; NLR, neutrophil-to-lymphocyte ratio.

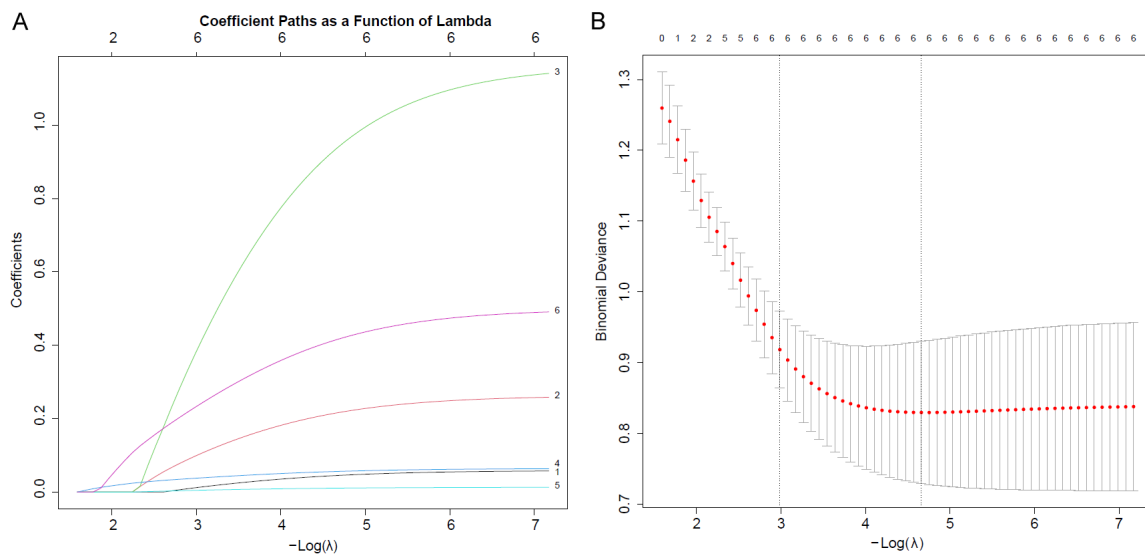


**Figure 1.** Prognostic indicators selection through LASSO regression. A. Coefficient path as a function of lambda; B. Cross validation. LASSO, least absolute shrinkage and selection operator.

total deafness type audiogram ( $P=0.018$ ) compared to the good prognosis group. Overall, the two groups differed significantly in vertigo prevalence, baseline hearing severity, and the proportion of total deafness pattern, while other disease characteristics were comparable between groups.

**Table 3** presents the comparison of laboratory indicators between the two groups. No notable differences were observed in HbA1c, FBG, HDL-C, LDL-C, or PT (all  $P>0.05$ ). The poor prognosis group showed a markedly shorter APTT ( $P=0.046$ ), as well as significantly higher PLR ( $P=0.003$ ) and NLR ( $P<0.001$ ) compared with the good prognosis group. Overall, the two

groups differed significantly in coagulation activity (APTT) and inflammatory markers (PLR and NLR), while glycemic and lipid profiles remained comparable between groups.

#### Logistic regression analysis

**Figure 1** presents the results of LASSO regression for predictor selection. **Figure 1A** displays the coefficient paths against  $\log(\lambda)$ . As  $\lambda$  increases, coefficients progressively shrink toward zero, with only a subset retaining non-zero values at the final selected  $\lambda$ . **Figure 1B** shows the 10-fold cross-validation curve, where the vertical dashed line indicates the optimal  $\lambda$  chosen by the one-standard-error

**Table 4.** Multivariate logistic regression analysis of factors influencing poor prognosis in patients with SSNHL and T2DM

| Indicator                    | Coefficient | Std Error | Wald Stat | OR    | 95% CI       | P value |
|------------------------------|-------------|-----------|-----------|-------|--------------|---------|
| Age                          | 0.060       | 0.027     | 2.237     | 1.062 | 1.007-1.119  | 0.025   |
| Time from onset to treatment | 0.246       | 0.116     | 2.118     | 1.279 | 1.018-1.606  | 0.034   |
| Vertigo                      | 1.184       | 0.577     | 2.052     | 3.266 | 1.054-10.119 | 0.040   |
| Initial PTA                  | 0.066       | 0.018     | 3.741     | 1.069 | 1.032-1.107  | <0.001  |
| PLR                          | 0.013       | 0.005     | 2.640     | 1.014 | 1.003-1.024  | 0.008   |
| NLR                          | 0.519       | 0.161     | 3.217     | 1.681 | 1.225-2.306  | 0.001   |

Notes: SSNHL, sudden sensorineural hearing loss; T2DM, type 2 diabetes mellitus; OR, odds ratio; CI, confidence interval; PTA, pure-tone average; PLR, platelet-to-lymphocyte ratio; NLR, neutrophil-to-lymphocyte ratio.

**Table 5.** ROC analysis of independent factors influencing poor prognosis in patients with SSNHL and T2DM

| Indicator                    | Best_threshold | Sensitivity | Specificity | AUC   | Youden_index | F1_score |
|------------------------------|----------------|-------------|-------------|-------|--------------|----------|
| Age                          | 59.990         | 0.622       | 0.619       | 0.623 | 0.241        | 0.691    |
| Time from onset to treatment | 4.505          | 0.700       | 0.548       | 0.646 | 0.248        | 0.733    |
| Vertigo                      | 0.500          | 0.478       | 0.786       | 0.632 | 0.264        | 0.606    |
| Initial PTA                  | 79.605         | 0.822       | 0.667       | 0.776 | 0.489        | 0.831    |
| PLR                          | 145.315        | 0.611       | 0.714       | 0.668 | 0.325        | 0.701    |
| NLR                          | 5.010          | 0.622       | 0.833       | 0.737 | 0.455        | 0.732    |

Notes: SSNHL, sudden sensorineural hearing loss; T2DM, type 2 diabetes mellitus; AUC, area under the curve; PTA, pure-tone average; PLR, platelet-to-lymphocyte ratio; NLR, neutrophil-to-lymphocyte ratio.

(lambda.1se) criterion. This procedure selected six predictors with non-zero coefficients: age, time from onset to treatment, vertigo, initial PTA, PLR, and NLR. These six variables were subsequently entered into the multivariate logistic regression analysis.

**Table 4** presents the multivariate logistic regression analysis for factors independently associated with poor prognosis. All six variables entered into the model remained significant predictors. Increasing age (OR=1.062, P=0.025), longer time from onset to treatment (OR=1.279, P=0.034), presence of vertigo (OR=3.266, P=0.040), higher initial PTA (OR=1.069, P<0.001), elevated PLR (OR=1.014, P=0.008), and increased NLR (OR=1.681, P=0.001) were all independently associated with an increased risk of poor hearing recovery. Among these, vertigo showed the largest effect size, followed by NLR. Overall, both clinical and inflammatory markers contributed independently to the prognostic model.

Several clinically relevant variables that were initially considered as candidates - including diabetes duration, hypertension, dyslipidemia, HbA1c, FBG, HDL-C, LDL-C, and PT - did not

reach statistical significance in univariate comparisons between the two prognosis groups (**Tables 1** and **3**; all P>0.05) and were consequently assigned zero coefficients by LASSO regression. Their lack of independent association with prognosis in this cohort suggests that these factors do not independently drive hearing outcomes in SSNHL patients with T2DM, or that their predictive information is subsumed by the six selected variables (particularly initial PTA and NLR).

#### Prognostic value analysis

**Table 5** presents the ROC analysis of each independent predictor for predicting poor prognosis. Among the six indicators, initial PTA yielded the highest AUC of 0.776, with a sensitivity of 0.822 and specificity of 0.667 at the optimal cutoff of 79.605 dB HL. NLR also demonstrated good predictive performance with an AUC of 0.737, sensitivity of 0.622, and specificity of 0.833 at a cutoff of 5.010. PLR showed moderate discriminatory ability (AUC=0.668, cutoff = 145.315), while time from onset to treatment (AUC=0.646, cutoff = 4.505 days), vertigo (AUC=0.632), and age (AUC=0.623, cutoff = 59.990 years) exhibited rela-

## NLR/PLR for prognosis in diabetic SSNHL

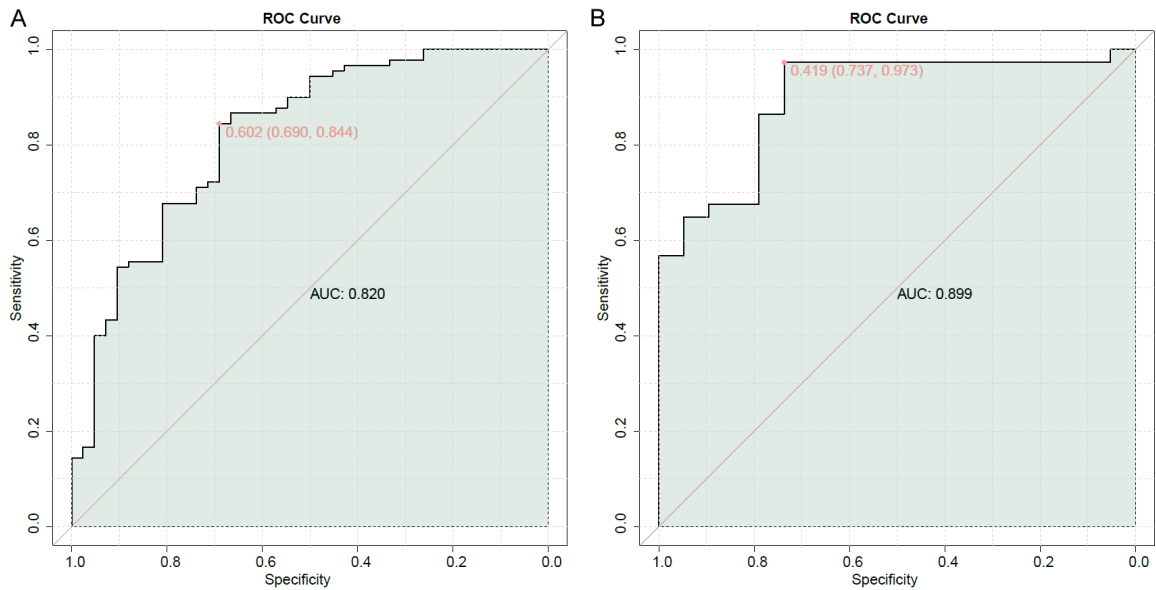


**Figure 2.** Different combined prediction models for poor prognosis in patients with SSNHL and T2DM. A. Clinical features; B. Clinical features + inflammatory markers. SSNHL, sudden sensorineural hearing loss; T2DM, type 2 diabetes mellitus; ROC, receiver operator characteristic; AUC, area under the curve.

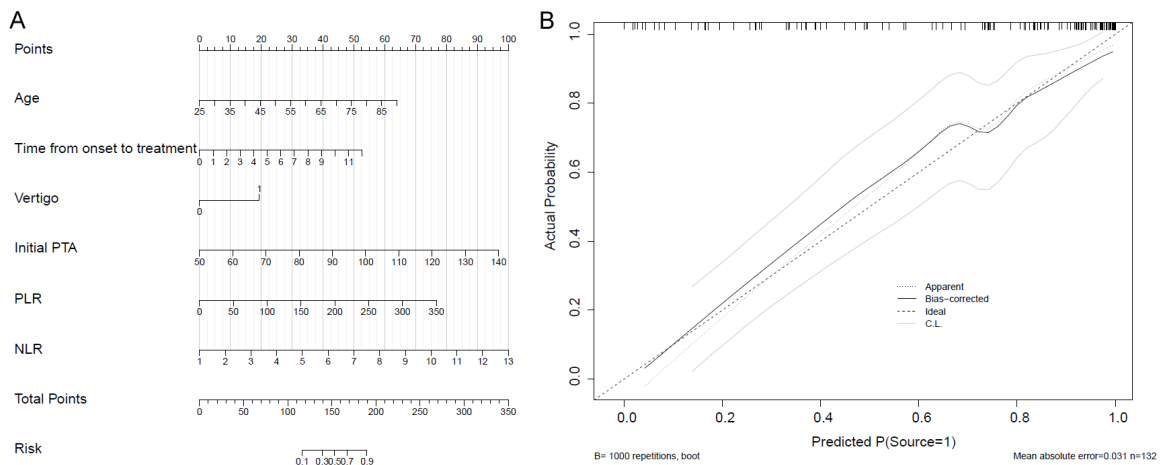


**Figure 3.** Nomogram for predicting poor prognosis in patients with SSNHL and T2DM. A. Nomogram; B. Calibration plot. SSNHL, sudden sensorineural hearing loss; T2DM, type 2 diabetes mellitus; PTA, pure-tone average; PLR, platelet-to-lymphocyte ratio; NLR, neutrophil-to-lymphocyte ratio.

tively lower predictive accuracy. Overall, initial PTA and NLR were the most powerful single predictors, whereas the remaining indicators showed modest to limited prognostic value.

### Combined predictive model

**Figure 2** displays the ROC curves of different combined prediction models for poor prognosis. **Figure 2A** shows the model based on clinical features alone (age, time from onset to treatment, vertigo, and initial PTA), which ac-

hieved an AUC of 0.820. **Figure 2B** presents the model incorporating both clinical features and inflammatory markers (PLR and NLR), yielding a substantially higher AUC of 0.899. The addition of inflammatory markers to the clinical model significantly improved the discriminatory ability, indicating that the combined model possesses superior predictive performance for identifying patients at risk of poor prognosis.

A nomogram was constructed based on the six independent predictors to facilitate individual-

**Table 6.** Comparison of prognostic indicators between the two groups in the test set

| Indicator                    | Good prognosis group<br>(n=19) | Poor prognosis group<br>(n=37) | t/ $\chi^2$ value | P value |
|------------------------------|--------------------------------|--------------------------------|-------------------|---------|
| Age (years)                  | 56.12 $\pm$ 10.89              | 62.43 $\pm$ 10.21              | 2.142             | 0.037   |
| Time from onset to treatment | 4.58 $\pm$ 2.03                | 6.21 $\pm$ 2.28                | 2.612             | 0.012   |
| Vertigo [n (%)]              | 5 (26.32%)                     | 20 (54.05%)                    | 3.908             | 0.048   |
| Initial PTA                  | 77.42 $\pm$ 14.29              | 94.18 $\pm$ 14.02              | 4.211             | <0.001  |
| PLR                          | 126.45 $\pm$ 42.10             | 162.76 $\pm$ 56.34             | 2.473             | 0.017   |
| NLR                          | 4.21 $\pm$ 1.32                | 5.83 $\pm$ 2.17                | 3.461             | 0.001   |

Notes: PTA, pure-tone average; PLR, platelet-to-lymphocyte ratio; NLR, neutrophil-to-lymphocyte ratio.

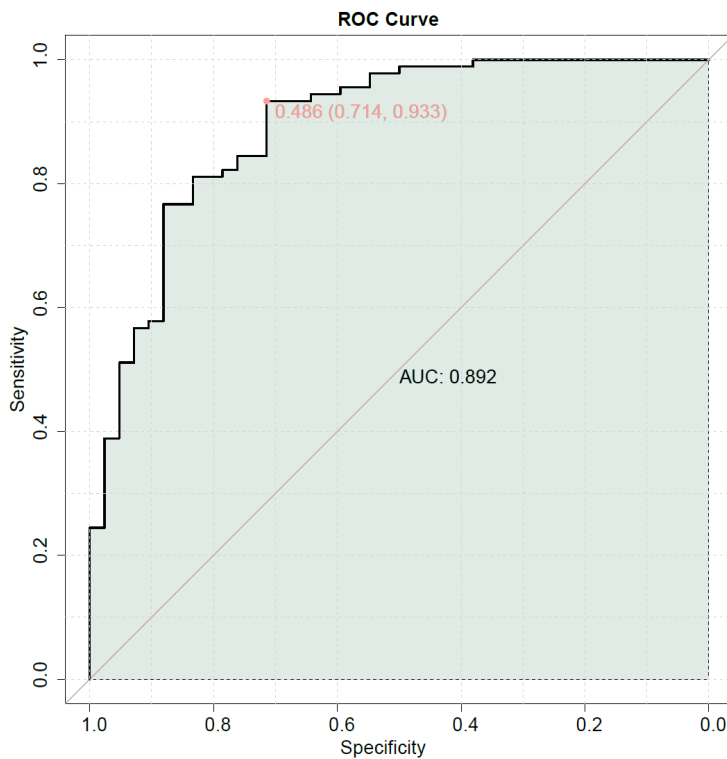


**Figure 4.** Validation of the combined prediction model for poor prognosis in patients with SSNHL and T2DM based on clinical features and inflammatory markers. SSNHL, sudden sensorineural hearing loss; T2DM, type 2 diabetes mellitus; ROC, receiver operator characteristic; AUC, area under the curve.

ized prediction of poor prognosis (**Figure 3**). Each predictor in **Figure 3A** was assigned a point scale on the upper axis, and total points were obtained by summing individual scores. The corresponding predicted probability of poor prognosis could be read directly from the total points axis. **Figure 3B** demonstrated excellent agreement between predicted probabilities and observed outcomes, with the bootstrap-corrected curve lying close to the ideal diagonal line across the full probability spectrum.

#### Prognostic indicators in test set

**Table 6** compares the prognostic indicators between the two groups in the test set, confirming the findings from the training set. Patients in the poor prognosis group were significantly older than those in the good prognosis group ( $P=0.037$ ), and the time from symptom onset to treatment initiation was markedly longer in the poor prognosis group ( $P=0.012$ ). The proportion of patients presenting with vertigo was significantly higher in the poor prognosis group ( $P=0.048$ ). Additionally, the poor prognosis group exhibited markedly higher initial PTA ( $P<0.001$ ), elevated PLR ( $P=0.017$ ), and increased NLR ( $P=0.001$ ) compared with the good prognosis group. Overall, all six independent predictors identified in the training set were successfully validated in the test set, demonstrating the consistency and robustness of the prognostic model across both cohorts.

#### Prediction model validation

**Figure 4** presents the ROC curve of the combined prediction model in the test set, validating its prognostic performance. The model achieved an AUC of 0.892, indicating excellent discriminatory ability. This validation result confirms the robustness and generalizability of the combined model, as the performance in the test set closely matched that observed in the training set (AUC=0.899), demonstrating con-

sistent predictive accuracy across independent samples.

## Discussion

Both clinical factors and inflammatory markers independently predicted hearing recovery in patients with SSNHL and T2DM. When combined into a comprehensive model, the predictive performance was superior to that of clinical characteristics alone. This supports the conclusion that conventional inflammatory markers can indeed provide additional predictive value for this high-risk population.

Age was a significant predictor of poor hearing recovery, consistent with the well-established decline in cochlear elasticity and regenerative capacity with advancing age. This is attributable to age-related microvascular degeneration, cumulative oxidative damage, and diminished physiological reserves, all of which collectively render the aging inner ear more vulnerable to ischemia and inflammation [17, 18]. In diabetic patients, who experience accelerated vascular aging, this effect is exacerbated, posing significant challenges for cochlear recovery. A recent study of diabetic SSNHL patients receiving intratympanic steroids confirmed that increasing age is an independent negative prognostic factor [19]. Additionally, the response to glucocorticoids diminishes with age, and comorbidities may further impair treatment outcomes.

The time from symptom onset to treatment initiation was also an independent predictor. The longer treatment is delayed, the poorer the prognosis tends to be. This aligns with the well-established principle that timely treatment is crucial, as the therapeutic window for cochlear salvage is narrow [20]. The cochlea has limited anaerobic capacity, rendering it particularly susceptible to ischemic injury. Damage can sometimes occur within a matter of hours, and it is difficult to reverse [21]. This time sensitivity is further accentuated in diabetic patients. Diabetic patients have pre-existing microvascular pathology, which further reduces cochlear tolerance to ischemia and accelerates cellular damage. Previous studies have noted that treatment delay beyond one week often increases the risk of poor recovery [22]. Our findings extend this conclusion to diabetic popula-

tion, emphasizing the importance of minimizing both patient-related and system-related delays.

Among clinical predictors, vertigo had the strongest association with poor prognosis. The presence of vertigo during treatment often indicates a more challenging recovery course. Vertigo typically suggests more extensive inner ear involvement, particularly when the vestibular apparatus is affected [23]. Because the vestibular and cochlear end organs share the same labyrinthine arterial supply, severe ischemic injury often affects both systems [24]. In diabetic patients, pre-existing microvascular instability may result in more extensive damage when vascular compromise occurs. Previous studies have already identified vertigo as a negative prognostic indicator for SSNHL, and our study confirms this association in diabetic patients [25]. Mechanistically, this may reflect greater initial injury severity and persistent vestibular dysfunction, both of which impede recovery.

Initial PTA remained one of the strongest single predictors of prognosis. The higher the threshold, the worse the prognosis. This finding is consistent across various SSNHL populations. The severity of hearing loss reflects the extent of cochlear damage, regardless of its underlying etiology (viral, vascular, or inflammatory) [26]. In diabetic patients, higher initial PTA may indicate more advanced microvascular disease or more severe ischemic events [27]. Initial PTA demonstrates strong predictive ability and plays a central role in prognosis assessment. However, adding inflammatory markers to models already containing initial PTA still provided additional predictive value. This indicates that systemic inflammatory status provides information not fully captured by hearing loss severity alone.

Elevated NLR and PLR were associated with poor prognosis. NLR has been extensively studied in the context of SSNHL. A previous meta-analysis demonstrated that higher NLR levels often correlate with poorer patient outcomes [28]. Mechanistically, neutrophils are the first responders to acute inflammation, releasing reactive oxygen species and proteolytic enzymes that can damage cochlear tissue [29]. Lymphocytes play a primarily regulatory role in

the inflammatory response. A relative decrease in lymphocyte count may indicate stress-induced immune suppression [30]. Therefore, elevated NLR reflects a pro-inflammatory state that may exacerbate cochlear damage and make recovery more challenging.

The prognostic value of PLR in SSNHL remains controversial. Some studies have reported a significant association, whereas others have not [31, 32]. However, in our study, PLR emerged as an independent predictor in diabetic patients. This suggests that platelets may play a more important role in diabetic patients. Beyond hemostasis, platelets also actively participate in inflammatory responses and thrombosis. In diabetic patients, hyperglycemia and advanced glycation end-products promote platelet activation and cytokine release [33]. Therefore, elevated PLR may reflect a hypercoagulable state that could compromise cochlear microcirculation. The discrepancy between studies may be attributable to differences in the metabolic characteristics of the study populations.

However, NLR and PLR are indirect surrogates of systemic inflammation. Direct measurement of pro-inflammatory cytokines (e.g., interleukin-6 [IL-6], tumor necrosis factor- $\alpha$  [TNF- $\alpha$ ], or C-reactive protein [CRP]) would be needed to determine whether elevated R/PLR reflects chronic low-grade inflammation inherent to T2DM or acute inflammation triggered by cochlear ischemia. Nevertheless, comparable HbA1c and FBG levels between the good- and poor-prognosis groups suggest similar baseline chronic inflammatory burden. Therefore, the significant inter-group difference in NLR and PLR more likely reflects an acute-on-chronic inflammatory response secondary to inner ear injury, rather than merely mirroring pre-existing diabetic inflammation. Future prospective studies incorporating direct cytokine profiling are warranted to clarify this causal pathway.

The combined model demonstrated superior performance, highlighting the complementary roles of clinical indicators and inflammatory markers. Clinical features reflect localized injury, whereas inflammatory markers capture the systemic host response. In diabetic patients with chronic inflammation, this systemic effect is particularly relevant. Combining both pro-

vides a more comprehensive assessment, which in turn confirms that SSNHL prognosis is determined by both local and systemic factors. To facilitate clinical translation, we further developed a nomogram that allows rapid individualized risk estimation by summing variable-specific scores, without the need for computational tools.

This study has several limitations. First, selection bias is inherent to its retrospective design. Although we applied strict criteria, the single-center nature of the study may limit generalizability. Second, follow-up was limited to one month; long-term hearing stability and recurrence risk were not assessed. Third, as indirect surrogates, NLR and PLR cannot establish causality, and we lacked direct measurements of inflammatory cytokines. Thus, it remains unclear whether elevated NLR/PLR reflects chronic diabetic inflammation or acute injury-induced inflammation. However, we note that HbA1c and FBG were comparable between the two prognosis groups, arguing against a purely diabetes-driven chronic inflammatory basis for the observed difference. Additionally, NLR and PLR are not specific and may be concurrent infections or medications. Fourth, all cases were retrospectively collected from a single tertiary hospital between 2018 and 2025. While this ensured protocol homogeneity and reduced confounding, it limits external generalizability. Variations in clinical practice across different hospital tiers or geographic regions may influence inflammatory marker distributions and hearing outcomes. External validation in independent multi-center cohorts is therefore needed before broad clinical application. Fifth, some potential prognostic factors were not included in the final model. Diabetes duration, baseline HbA1c, and hypertension/dyslipidemia status were excluded by LASSO, consistent with their non-significant univariate associations. However, stratified analyses (e.g., by HbA1c categories or hypertension severity) were not performed and may have revealed subgroup effects. Types of hypoglycemic agents and preoperative cochlear imaging findings (e.g., MRI) were not systematically recorded and could not be evaluated. Regarding steroid administration route, switching from systemic to intratympanic delivery was based on glycemic control during hospitaliza-

tion and was not a fixed baseline characteristic; including it as a baseline variable would introduce indication bias. These unmeasured or unstratified variables may introduce residual confounding. Future prospective studies should include detailed medication histories, imaging data, and treatment-modality tracking. Sixth, the requirement for complete baseline data eliminated missing values but may limit generalizability to real-world clinical settings where incomplete records are common. Future studies with larger, less strictly screened populations should consider employing multiple imputation to handle potential missing data.

Several priorities for future research should be noted. First, although we performed rigorous internal validation, external validation in multicenter cohorts is needed to confirm generalizability across varied treatment protocols, testing equipment, and diabetes management standards. Second, a prospective study design with long-term follow-up is needed to assess hearing stability over time and validate the cut-off values identified here. Third, incorporating additional inflammatory biomarkers (e.g., systemic immune-inflammation index, CRP) and cytokine profiling would help clarify the causal pathways discussed above. Fourth, intervention trials targeting systemic inflammation or glycemic control are warranted to determine whether modulation of these pathways improves hearing outcomes. Finally, the nomogram developed in this study requires calibration and validation in an independent external dataset before it can be recommended for routine clinical use.

In conclusion, NLR, PLR, and several clinical factors independently predict hearing recovery in patients with SSNHL and T2DM. Combining inflammatory markers with clinical characteristics enables more accurate risk stratification. Therefore, incorporating these readily available routine blood markers into daily risk assessment for this high-risk population is practical and clinically useful.

#### Disclosure of conflict of interest

None.

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#### References

- [1] Cavallaro G, Pantaleo A, Pontillo V, Barbara F, Murri A and Quaranta N. Endothelial dysfunction and metabolic disorders in patients with sudden sensorineural hearing loss. *Medicina (Kaunas)* 2023; 59: 1718.
- [2] Kim JM, Rim HS, Kim SS, Kim SH, Byun JY and Yeo SG. Comparative study of SSNHL with and without tinnitus: audiologic and hematologic differences. *Acta Otolaryngol* 2023; 143: 589-595.
- [3] Skarzynski PH, Kolodziejek A, Gos E, Skarzynska MB, Czajka N and Skarzynski H. Hyperbaric oxygen therapy as an adjunct to corticosteroid treatment in sudden sensorineural hearing loss: a retrospective study. *Front Neurol* 2023; 14: 1225135.
- [4] Zhang X, Wang Y, Yan Q, Zhang W, Chen L, Wang M and Guan B. Prognostic correlation of immune-inflammatory markers in sudden sensorineural hearing loss: a retrospective study. *Ear Nose Throat J* 2026; 105: 308-314.
- [5] Gioacchini FM, Pisani D, Viola P, Astorina A, Scarpa A, Libonati FA, Tulli M, Re M and Chiarella G. Diabetes mellitus and hearing loss: a complex relationship. *Medicina (Kaunas)* 2023; 59: 269.
- [6] Niknazar S, Bazgir N, Shafaei V, Abbaszadeh HA, Zali A and Asghar Peyvandi A. Assessment of prognostic biomarkers in sudden sensorineural hearing loss: a systematic review and meta-analysis. *Clin Biochem* 2023; 121-122: 110684.
- [7] Xu Y, Zhang Y, Yan Q, Chen C, Zhu B and Wang Y. Association of metabolic syndrome or weather conditions with the severity and prognosis of sudden sensorineural hearing loss. *J Int Adv Otol* 2024; 20: 203-209.
- [8] Deng Y, Chen S and Hu J. Diabetes mellitus and hearing loss. *Mol Med* 2023; 29: 141.
- [9] Gedawy A, Al-Salami H and Dass CR. Biochemical changes to the inner ear contributing to diabetes-induced hearing loss: possible pharmacological targets for therapy. *J Pharm Pharmacol* 2024; 76: 295-306.
- [10] Parekh S and Kaur T. Cochlear inflammaging: cellular and molecular players of the innate and adaptive immune system in age-related hearing loss. *Front Neurol* 2023; 14: 1308823.
- [11] Liu Y, Ma G, Li Y and Wu Y. The predictive value of NLR, PLR and SII for SSNHL in children and young adults. *Indian J Otolaryngol Head Neck Surg* 2024; 76: 5393-5399.

- [12] Huang X, Ni X, Shen J, Chen L, Xu L and Tang X. Associations between neutrophil-to-lymphocyte/platelet-to-lymphocyte and recovery in sudden sensorineural hearing loss. *Biomark Med* 2024; 18: 115-122.
- [13] Thottuvelil SR, Chacko M, Warriar AR, Nair MP and Rajappan AK. Comparison of neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and systemic immune-inflammation index (SII) as marker of adverse prognosis in patients with infective endocarditis. *Indian Heart J* 2023; 75: 465-468.
- [14] Editorial Board of Chinese Journal of Otorhinolaryngology Head and Neck Surgery; Society of Otorhinolaryngology Head and Neck Surgery, Chinese Medical Association. Guideline of diagnosis and treatment of sudden deafness (2015). *Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi* 2015; 50: 443-447.
- [15] Jia W, Weng J, Zhu D, Ji L, Lu J, Zhou Z, Zou D, Guo L, Ji Q, Chen L, Chen L, Dou J, Guo X, Kuang H, Li L, Li Q, Li X, Liu J, Ran X, Shi L, Song G, Xiao X, Yang L and Zhao Z. Standards of medical care for type 2 diabetes in China 2019. *Diabetes Metab Res Rev* 2019; 35: e3158.
- [16] Siegel LG. The treatment of idiopathic sudden sensorineural hearing loss. *Otolaryngol Clin North Am* 1975; 8: 467-473.
- [17] Zhang Z, Yu C, Wang X, Ge S, Zhai G, Si S, Ma T, Li F, Cui Z, Jin X and Jin Y. The construction and validation of prognostic prediction model for sudden sensorineural hearing loss in middle-aged and elderly people. *Auris Nasus Larynx* 2024; 51: 276-285.
- [18] Lang H, Noble KV, Barth JL, Rumschlag JA, Jenkins TR, Storm SL, Eckert MA, Dubno JR and Schulte BA. The stria vascularis in mice and humans is an early site of age-related cochlear degeneration, macrophage dysfunction, and inflammation. *J Neurosci* 2023; 43: 5057-5075.
- [19] Chen SL, Ho CY, Chin SC, Chan KC and Wang YC. Sudden sensorineural hearing loss in diabetes mellitus patients receiving intra-tympanic steroid injections. *Am J Otolaryngol* 2025; 46: 104576.
- [20] Dong A, Peng J and Lin R. Predictive model for prognosis of sudden sensorineural hearing loss by nomogram. *Ear Nose Throat J* 2025; 104: 244-253.
- [21] Olivetto E, Simoni E, Guaran V, Astolfi L and Martini A. Sensorineural hearing loss and ischemic injury: development of animal models to assess vascular and oxidative effects. *Hear Res* 2015; 327: 58-68.
- [22] Askar AA, Ghonim MR and Shabana YK. Discriminant analysis of the prognostic factors for hearing outcomes in patients with idiopathic sudden sensorineural hearing loss. *J Int Adv Otol* 2023; 19: 162-168.
- [23] Castellucci A, Botti C, Delmonte S, Bettini M, Lusetti F, Brizzi P, Ruberto R, Gamberini L, Martellucci S, Malara P, Armato E, Renna L, Ghidini A and Bianchin G. Vestibular assessment in sudden sensorineural hearing loss: role in the prediction of hearing outcome and in the early detection of vascular and hydropic pathomechanisms. *Front Neurol* 2023; 14: 1127008.
- [24] Chen K, Sun J, Huang B, Liang Y, Liu M and Wu X. Labyrinthine lesions in presumed inner ear hemorrhage-related sudden deafness. *Am J Otolaryngol* 2022; 43: 103331.
- [25] Deng G, Jiang X and Wang M. Analysis of prognostic factors in patients with sudden sensorineural hearing loss. *Ear Nose Throat J* 2024; [Epub ahead of print].
- [26] Wu Z, Zhang P, Sun J and Diao M. Prognostic factors for pediatric sudden sensorineural hearing loss: a systematic review and meta-analysis. *Front Pediatr* 2026; 14: 1808182.
- [27] Huang H, Fan Y, Yan F, Hu Y, He H, Xu T, Zhu X, Zhu Y, Diao W, Xia X, Tu J, Li A, Lin B, Liu Q, Lu Z, Xi T, Wang W, Xu D, Chen Z, Wang Z, Chen X and Shan G. Diabetes and long duration leading to speech-, low/mid-, and high- frequency hearing loss: current evidence from the China National Health Survey 2023. *J Endocrinol Invest* 2025; 48: 233-243.
- [28] Chen L, Wang M, Zhang W, Zhang X, Jiao C, Yu Y, Guan B and Zhong Z. The value of inflammatory biomarkers in the occurrence and prognosis of sudden sensorineural hearing loss: a meta-analysis. *Eur Arch Otorhinolaryngol* 2023; 280: 3119-3129.
- [29] Zhou Y, Fang C, Yuan L, Guo M, Xu X, Shao A, Zhang A and Zhou D. Redox homeostasis dysregulation in noise-induced hearing loss: oxidative stress and antioxidant treatment. *J Otolaryngol Head Neck Surg* 2023; 52: 78.
- [30] Li Y, Zhou X, Dou Z, Deng D and Bing D. Clinical features and prognosis of pediatric idiopathic sudden sensorineural hearing loss: a bi-center retrospective study. *Front Neurol* 2023; 14: 1121656.
- [31] Zhang X, Weng Y, Xu Y, Xiong H, Liang M, Zheng Y and Ou Y. Selected blood inflammatory and metabolic parameters predicted successive bilateral sudden sensorineural hearing loss. *Dis Markers* 2019; 2019: 7165257.
- [32] Tsuzuki N and Wasano K. Idiopathic sudden sensorineural hearing loss: a review focused on the contribution of vascular pathologies. *Auris Nasus Larynx* 2024; 51: 747-754.
- [33] Dharmarajan S, Carrillo C, Qi Z, Wilson JM, Baucum AJ 2nd, Sorenson CM, Sheibani N and Belecky-Adams TL. Retinal inflammation in murine models of type 1 and type 2 diabetes with diabetic retinopathy. *Diabetologia* 2023; 66: 2170-2185.