

Development and Evaluation of a Clinical Model to Predict High-Frequency Hearing

Prognosis in Menière's Disease

Model development and internal validation

For the model development for high-frequency hearing levels on the affected side during the 1–2-year period after the initial visit (HFH-Prognosis), we used the same procedure as that of the low-frequency hearing model ($n = 92$). The model incorporating age and high-frequency hearing level at the initial visit (HFH-Initial) yielded the smallest average root mean square error (RMSE). On the affected side, high correlation was observed between HFH-Initial and age; however, no multicollinearity was detected (variance inflation factor < 3). The predictive model is expressed as follows:

“Predicted value for HFH-Prognosis = $a + b1 \times \text{age} + b2 \times \text{HFH-Initial}$ ”

TABLE 1 presents the intercept (a) and regression coefficients ($b1$, $b2$) for each of the four predictive models (Models 1–4). By substituting age and high-frequency hearing level at the initial visit into the predictive model, predicted high-frequency hearing levels 1 year later were calculated.

FIGURE 1A shows plots of the predicted versus measured values for internal validation of the predictive models, along with the accuracy metrics for each model. RMSE ranged from 7.6

to 11.6, and R^2 ranged from 0.74 to 0.90, suggesting reliable predictive performance with no evidence of overfitting.

External validation

External validation was conducted to assess the generalisability of the predictive model to new cases. Patient data from the external validation cohort ($n = 32$) were applied to Models 1–4, and the average of the four predicted values was used as the final HFH-Prognosis estimate.

FIGURE 1B shows plot of predicted versus the measured values for external validation. RMSE was 12.6, and R^2 was 0.71, demonstrating that the proposed model can be applied to unseen datasets.

Prediction of HFH-Prognosis on the healthy side

When the predictive model was validated using hearing test results from the healthy side, the model also produced accurate predictions (**FIGURE 2**). This suggests that the model cannot specifically predict high-frequency hearing prognosis on the affected side in patients with Menière’s Disease.

TABLE 1: Regression coefficients of the predictive models for HFH-Prognosis

Model	a	$b1$ (95% CI)	$b2$ (95% CI)
Model 1	-8.84	0.30 (0.12–0.48)	0.82 (0.71–0.93)
Model 2	-12.43	0.35 (0.18–0.53)	0.83 (0.70–0.96)
Model 3	-9.94	0.32 (0.12–0.52)	0.83 (0.70–0.96)
Model 4	-10.12	0.34 (0.16–0.52)	0.82 (0.70–0.95)

a indicates the intercept. $b1$ represents the regression coefficient for age. $b2$ represents the regression coefficient for HFH-initial. A 95% CI was also provided for the regression coefficients. HFH-Prognosis, high-frequency hearing level measured during the 1–2-year period after the initial visit; HFH-initial, high-frequency hearing level at the initial visit; CI, confidence interval.

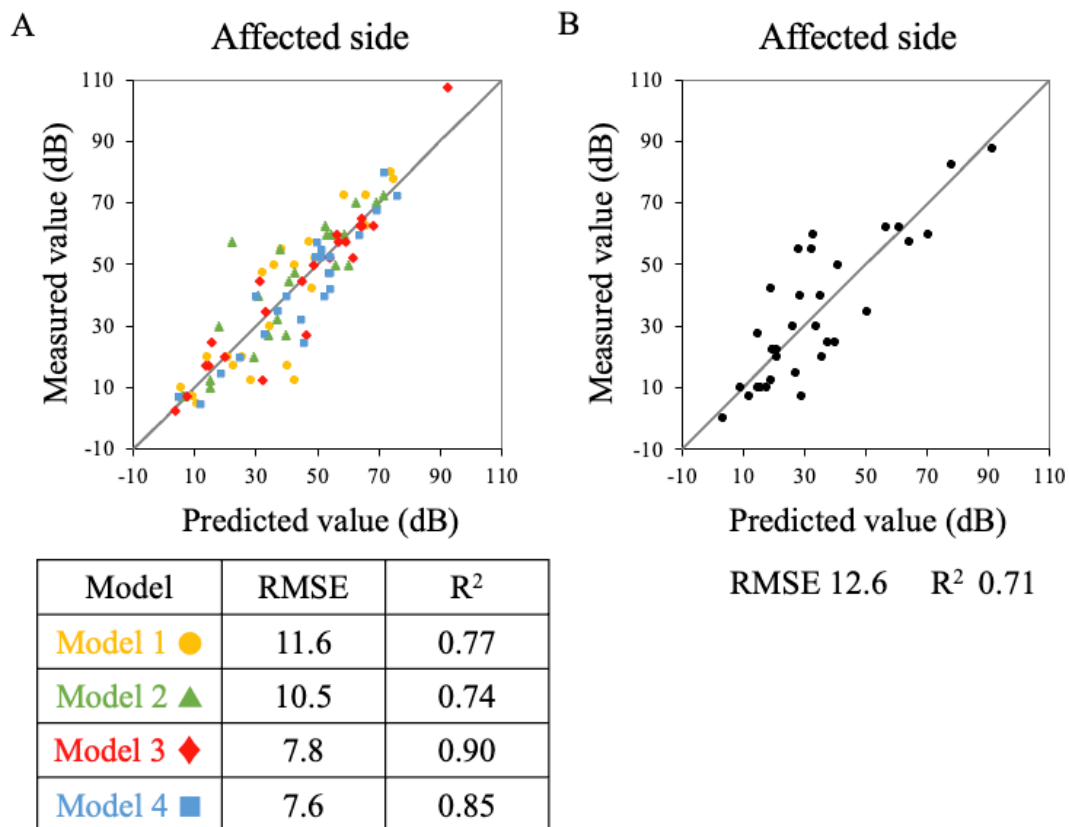


FIGURE 1: Performance of the predictive model for HFH-Prognosis.

Plots of predicted versus measured HFH-Prognosis values and the linear fit when predicted and measured values match (grey), along with RMSE and correlation coefficient (R^2). **(A)** Internal validation. Verification results for each model ($n = 23$; Model 1–4) are shown. **(B)** External

validation. Results of the external validation cohort ($n = 32$) are shown. RMSE, root mean square error; HFH-Prognosis, high-frequency hearing level measured during the 1–2-year period after the initial visit.

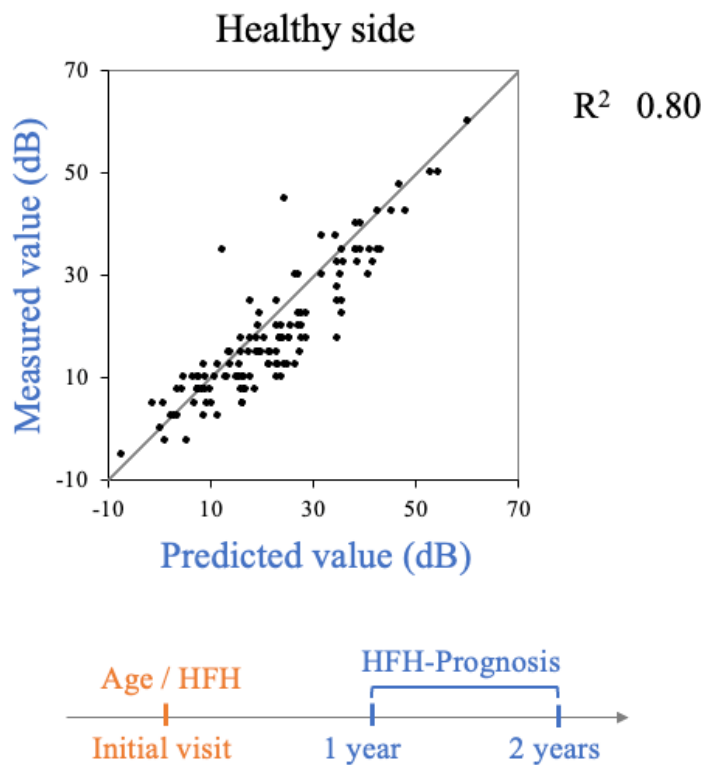


FIGURE 2: Predictive performance of HFH-Prognosis on the healthy side using the affected-side predictive model.

Plot of predicted versus measured HFH-Prognosis values on the healthy side ($n = 124$) and regression line (grey), along with correlation coefficient (R^2). HFH-Prognosis, high-frequency hearing level measured during the 1–2-year period after the initial visit.