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Hearing impairment is associated with impaired glymphatic function in middle- and older-aged adults: evidence from DTI-ALPS imaging

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Abstract

Hearing impairment is a common age-related sensory disorder and has been increasingly linked to central nervous system changes beyond peripheral auditory dysfunction. This study aimed to investigate the relationship between hearing impairment and glymphatic system function using the diffusion tensor imaging along the perivascular space (DTI-ALPS) index, and to explore its potential as an imaging biomarker in middle- and older-aged adults. A total of 131 participants aged 45–80 years were enrolled, including 71 individuals with normal hearing and 60 with hearing impairment defined by pure-tone average thresholds ≥ 25 dB HL. All participants underwent brain MRI with diffusion tensor imaging, and glymphatic function was evaluated using the DTI-ALPS index. Cognitive function was assessed using the Mini-Mental State Examination and Montreal Cognitive Assessment. Associations between pure-tone average and DTI-ALPS indices were examined using Spearman correlation analysis. Logistic regression models were applied to identify independent factors associated with hearing impairment, and receiver operating characteristic analysis was used to evaluate diagnostic performance. Participants with hearing impairment were older, more frequently male, and exhibited lower MoCA scores compared with controls. Global and regional DTI-ALPS indices were significantly reduced in the hearing impairment group and were inversely correlated with hearing thresholds. In multivariate analysis, both older age and lower DTI-ALPS index remained independently associated with hearing impairment. The combined model incorporating age and DTI-ALPS achieved the best discriminative performance. These findings suggest that hearing impairment is independently associated with reduced glymphatic system function, and that the DTI-ALPS index, particularly when combined with age, may serve as a promising imaging biomarker for age-related hearing decline.

1 Introduction

Hearing impairment is a common sensory disorder among middle- and older-aged adults and has been shown not only to affect quality of life but also to independently increase the risk of cognitive decline, social isolation, and reduced functional capacity [1, 2]. Traditionally, it has been attributed primarily to peripheral cochlear degeneration and vascular factors. However, growing evidence suggests that hearing impairment is not limited to peripheral auditory system damage but may also be associated with more widespread central nervous system alterations, including white matter microstructural abnormalities and brain network reorganization, indicating that it may reflect disturbances in overall brain homeostatic regulation [3, 4].

The glymphatic system is a widespread perivascular network within the brain that enables exchange between cerebrospinal fluid and interstitial fluid, thereby contributing to the removal of metabolic waste and the regulation of neural homeostasis [5, 6]. Diffusion tensor imaging along the perivascular space (DTI-ALPS) provides a non-invasive MRI approach for in vivo assessment of this clearance pathway and serves as an indirect marker of glymphatic activity [7–9]. Impairment of glymphatic function has been associated with several neurological conditions, such as cerebral small vessel disease and Alzheimer's disease [10–12].

In recent years, several studies have explored the relationship between hearing impairment and glymphatic system function, reporting decreased DTI-ALPS indices in cases of congenital and noise-induced hearing loss [13, 14]. In addition, some studies have observed increased brain free water and enlargement of perivascular spaces, suggesting that abnormal interstitial fluid dynamics may contribute to shared pathological processes across different types of auditory pathway damage [15]. However, most existing research has primarily focused on specific subtypes of hearing loss, and systematic evidence in the general middle- and older-aged population remains limited. Furthermore, the independent association of DTI-ALPS with hearing impairment and its potential value as an imaging biomarker have not yet been fully evaluated.

Therefore, this study aims to investigate whether the DTI-ALPS index is an independent factor associated with hearing impairment and to further assess its diagnostic performance in identifying hearing loss, with the goal of providing systematic imaging evidence for the central mechanisms underlying age-related auditory decline.

2 Materials and Methods

2.1 Study subjects

Approval for this study was obtained from the Ethics Committee of Tongren People's Hospital (No. 202502). All methods were performed in accordance with the Declaration of Helsinki and relevant guidelines and regulations. All participants signed written informed consent forms prior to study enrollment.

A total of 131 participants were consecutively recruited from the Departments of Neurology and Otorhinolaryngology at Tongren People's Hospital between August 2023 and December 2025. All participants underwent pure-tone audiometry, cognitive assessments, and MRI. Based on pure-tone average (PTA) thresholds, participants were classified into a normal hearing group (n = 71) and a hearing impairment group (n = 60).

The inclusion criteria were as follows: (1) age between 45 and 80 years; (2) right-handedness; and (3) completion of audiological assessment, cognitive evaluation, and MRI examination. The exclusion criteria included: (1) intracranial space-occupying lesions, congenital brain malformations, hydrocephalus, or other neurological disorders that could affect MRI assessment; (2) large cortical or subcortical infarctions; (3) severe psychiatric disorders, impaired consciousness, or a history of malignant tumors; (4) severe cardiac, hepatic, or renal dysfunction; and (5) inability to complete audiological, cognitive, or MRI examinations.

2.2 Cognitive assessment

Demographic and clinical data, including age, sex, and years of education, were collected for all subjects. Cognitive function was assessed using the Beijing version of the Montreal Cognitive Assessment

(MoCA) and the Mini-Mental State Examination (MMSE). MoCA scores were adjusted for years of education [19]. The diagnostic thresholds for mild cognitive impairment determined by the MoCA were as follows: (1) ≤ 13 for illiterate individuals; (2) ≤ 19 for individuals with 1–6 years of education; and (3) ≤ 24 for individuals with more than 6 years of education.

2.3 Hearing assessment

Hearing function was evaluated using pure-tone audiometry in accordance with the national standard GB/T 7341.1–2010. Air-conduction thresholds were measured separately for the left and right ears at frequencies of 0.5, 1, 2, and 4 kHz using a clinical audiometer with ear-covering headphones in a sound-attenuated environment. The PTA for each ear was calculated as the mean threshold across the four frequencies (0.5, 1, 2, and 4 kHz). Hearing impairment was defined as a PTA ≥ 25 dB hearing level (dB HL), based on the World Health Organization criteria (1997). Participants were classified as having hearing impairment if the PTA of either ear met or exceeded this threshold; otherwise, they were classified as normal hearing. For statistical analysis, the average PTA of both ears was used as a continuous variable.

2.4 MRI scanning

All participants underwent MRI examination using a 3.0T scanner (Ingenia CX, Philips Healthcare, The Netherlands), with data acquisition performed using a 32-channel head–neck coil. The detailed imaging sequences and parameters are summarized in Table 1.

Table 1
MRI scanning sequences and imaging parameters

Sequence	3D-T1WI	T2-FLAIR	T2WI	DTI (SE-EPI)
TR (ms)	6.6	9000	45.4	2495
TE (ms)	3	119. 84	2354	75
Flip angle (°)	8	160	20	90
FOV (mm × mm)	256 ×256	225 ×225	240 × 240	224 ×224
Matrix	256 ×256	512 × 512	512 × 512	224 × 228
Slice thickness (mm)	1.0	7	1.0	2.0
Other parameters				64 diffusion directions

3D-T1WI: three-dimensional T1-weighted imaging; T2-FLAIR: T2-weighted fluid-attenuated inversion recovery imaging; T2WI: T2-weighted imaging; DTI: diffusion tensor imaging; SE-EPI: spin-echo echo-planar imaging; TR: repetition time; TE: echo time; FOV: field of view.

2.5 Measuring the DTI-ALPS Index

Diffusion tensor imaging (DTI) datasets were processed using a standard diffusion MRI preprocessing pipeline, including skull stripping, head motion correction, and eddy current distortion correction,

implemented using established software such as FSL or comparable platforms. Following preprocessing, fractional anisotropy (FA) maps and corresponding color-encoded FA images were reconstructed for subsequent analysis. The DTI-ALPS index was derived according to the previously described approach by Taoka et al [8]. For region-of-interest (ROI) analysis, the FA color maps were imported into ITK-SNAP software (version 3.8.0; https://www.itksnap.org), which was used solely for manual ROI delineation. ROI placement was independently performed by two experienced neuroradiologists (each with more than 3 years of experience in neuroimaging), who were blinded to all clinical and grouping information. ROIs were positioned at the level of the lateral ventricular body, a region in which medullary veins course at right angles to the ventricular wall, consistent with the standard anatomical landmark for ALPS evaluation. On the FA color maps, two spherical ROIs (8 mm in diameter) were symmetrically placed in each hemisphere, including one located in the projection fiber region (predominantly aligned with the z-axis) and another in the association fiber region (predominantly aligned with the y-axis) (Fig. 1).

Within each ROI, diffusion tensor components along the x-, y-, and z-axes (Dx, Dy, Dz) were extracted. The x-axis, which is orthogonal to the dominant fiber orientation in this region, is considered to reflect diffusivity along the perivascular space. The DTI-ALPS index was then calculated using the formula below:

$$\text{DTI - ALPS index} = \frac{\text{mean (Dxx projection, Dxx association)}}{\text{mean (Dyy projection, Dzz association)}}$$

The global DTI-ALPS index, as well as hemisphere-specific indices (DTI-ALPS-L and DTI-ALPS-R), were calculated for further analysis.

2.6 Statistical analysis

All statistical analyses were carried out with SPSS version 25.0 (IBM Corp., Armonk, NY, USA) and MedCalc version 22.0 (MedCalc Software Ltd, Ostend, Belgium). The Shapiro–Wilk test was applied to examine data normality. Continuous variables with a normal distribution were reported as mean ± standard deviation and analyzed using independent-samples t-tests, whereas skewed data were expressed as median (interquartile range) and compared using the Mann–Whitney U test. Categorical data were presented as numbers and percentages, and group differences were assessed using chi-square or Fisher’s exact tests depending on expected frequencies. Associations between the DTI-ALPS index and PTA were examined using Spearman’s rank correlation analysis. In logistic regression modeling, the DTI-ALPS index was converted into standardized z-scores to enhance model interpretability, with effect estimates expressed as odds ratios corresponding to one standard deviation increase in the index. Variables showing statistical significance in univariate analyses ($P < 0.05$) were

subsequently included in multivariate logistic regression to identify independent predictors of hearing impairment. Receiver operating characteristic (ROC) curve analysis was performed based on the original (non-standardized) DTI-ALPS values together with age, and the area under the curve (AUC) was calculated to assess diagnostic performance. A two-sided P value < 0.05 was defined as statistically significant.

3 Results

3.1 Participant Characteristics

A total of 131 participants were enrolled in the present study, including 71 individuals with normal hearing and 60 with hearing impairment. Table 2 presents the baseline demographic and clinical characteristics of both groups. The hearing impairment group was significantly older than the normal hearing group [66 (61–72) vs. 59 (54–65) years, P < 0.001] and showed a higher proportion of males (50.0% vs. 22.5%, P = 0.001). In contrast, the two groups did not differ significantly in height, weight, body mass index, smoking status, alcohol consumption, hypertension, or diabetes mellitus (all P > 0.05). Regarding cognitive function, the hearing impairment group exhibited significantly lower MoCA scores than the normal hearing group (20 [16.25–23] vs. 23 [19–27], P < 0.001), whereas MMSE scores did not differ significantly between groups (P = 0.063). For imaging parameters, the hearing impairment group demonstrated significantly lower DTI-ALPS indices, including overall ALPS (1.50 ± 0.14 vs. 1.61 ± 0.12, P < 0.001), left DTI-ALPS (1.56 ± 0.17 vs. 1.65 ± 0.14, P < 0.001), and right DTI-ALPS (1.44 ± 0.15 vs. 1.57 ± 0.15, P < 0.001). Consistently, PTA values and unilateral hearing thresholds were significantly higher in the hearing impairment group (all P < 0.001) .

Table 2
The Baseline characteristics of Normal hearing and Hearing impairment groups

Groups	**Normal hearing (n = 71)**	**Hearing impairment (n = 60)**	***P* value**
Sex			0.001
Male	16	30	
Female	55	30	
Age (years)	59 (54, 65)	66 (61, 72)	<0.001
Height (cm)	158 (155, 161)	159 (153, 163)	0.74
Weight (kg)	60.58 ± 8.93	62.56 ± 10.09	0.24
BMI	24.19 ± 3.05	24.88 ± 3.39	0.22
Smoking history			0.51
Yes	15	19	
No	56	41	
Alcohol consumption history			0.29
Yes	15	22	
No	58	38	
Hypertension history			0.35
Yes	18	12	
No	53	49	
Diabetes history			0.55
Yes	11	8	
No	60	52	
MMSE	27 (24, 29)	26 (22, 28)	0.06
MoCA	23 (19, 27)	20 (16.25, 23)	<0.001
DTI-ALPS	1.61 ± 0.12	1.50 ± 0.14	<0.001
DTI-ALPS-L	1.65 ± 0.14	1.56 ± 0.17	<0.001

DTI-ALPS, diffusion tensor imaging analysis along the perivascular space index; DTI-ALPS-L, left hemisphere diffusion tensor imaging analysis along the perivascular space index; DTI-ALPS-R, right hemisphere diffusion tensor imaging analysis along the perivascular space index; BMI, body mass index; MMSE, mini-mental state examination; MoCA, montreal cognitive assessment; PTA, pure-tone average; PTA-L, pure-tone average of the left ear; PTA-R, pure-tone average of the right ear.

Groups	Normal hearing (n = 71)	Hearing impairment (n = 60)	*P* value
DTI-ALPS-R	1.57 ± 0.15	1.44 ± 0.15	<0.001
PTA	11.50 (9.00, 17.50)	30.25 (26.50, 42.38)	<0.001
PTA-L	11.00 (8.00, 16.00)	32.00 (26.00, 44.00)	<0.001
PTA-R	12.00 (9.00, 18.00)	29.50 (26.00, 41.00)	<0.001

DTI-ALPS, diffusion tensor imaging analysis along the perivascular space index; DTI-ALPS-L, left hemisphere diffusion tensor imaging analysis along the perivascular space index; DTI-ALPS-R, right hemisphere diffusion tensor imaging analysis along the perivascular space index; BMI, body mass index; MMSE, mini-mental state examination; MoCA, montreal cognitive assessment; PTA, pure-tone average; PTA-L, pure-tone average of the left ear; PTA-R, pure-tone average of the right ear.

3.2 Correlations Between Hearing Thresholds and DTI-ALPS Indices

Correlation analysis demonstrated inverse relationships between hearing thresholds and DTI-ALPS measurements. Overall PTA showed a significant negative correlation with the global DTI-ALPS index ($r = -0.337$, $P < 0.001$) (Fig. 2). At the hemispheric level, PTA-L was inversely correlated with DTI-ALPS-L ($r = -0.254$, $P = 0.003$), while a similar association was identified between PTA-R and DTI-ALPS-R ($r = -0.280$, $P = 0.001$). Collectively, these results suggest that reduced glymphatic activity, as reflected by lower DTI-ALPS values, is associated with worse auditory function.

3.3 Univariate Logistic Regression Analysis

Univariate logistic regression analysis was conducted to explore potential predictors of hearing impairment (Table 3). Increasing age showed a significant positive association with hearing impairment (OR = 1.137, 95% CI: 1.077–1.202, $P < 0.001$), corresponding to an approximately 13.7% increase in risk per additional year. In contrast, higher MoCA scores were associated with lower odds of hearing impairment (OR = 0.888, 95% CI: 0.828–0.951, $P = 0.001$). The standardized DTI-ALPS index (z-score) demonstrated a strong inverse association with hearing impairment (OR = 0.385, 95% CI: 0.248–0.597, $P < 0.001$). Smoking history (OR = 2.528, 95% CI: 1.088–5.870, $P = 0.031$) and alcohol consumption (OR = 2.583, 95% CI: 1.163–5.737, $P = 0.020$) were also linked to higher odds of hearing impairment. No significant associations were observed for MMSE score, hypertension, or diabetes mellitus.

Table 3
Univariate logistic regression analysis for hearing impairment.

Variable	β	SE	Wald	OR (95% CI)	*P* value
Age (years)	0.129	0.028	21.545	1.137 (1.077–1.202)	< 0.001
MMSE	-0.073	0.038	3.685	0.929 (0.863–1.002)	0.055
MoCA	-0.118	0.035	11.242	0.888 (0.828–0.951)	0.001
DTI-ALPS-Z	-0.954	0.224	18.160	0.385 (0.248–0.597)	< 0.001
Hypertension history	-0.414	0.431	0.923	0.661 (0.284–1.537)	0.337
Diabetes history	-0.175	0.502	0.122	0.839 (0.314–2.246)	0.727
Smoking history	0.927	0.430	4.658	2.528 (1.088–5.870)	0.031
Alcohol consumption history	0.949	0.407	5.427	2.583 (1.163–5.737)	0.020

DTI-ALPS-Z, standardized z-score of diffusion tensor imaging analysis along the perivascular space index; β, regression coefficient; CI, confidence interval; MMSE, mini-mental state examination; MoCA, montreal cognitive assessment; OR, odds ratio; SE, standard error; Wald, Wald chi-square statistic.

3.4 Multivariate Logistic Regression Analysis

To control for confounding effects, variables with potential significance in univariate analysis were incorporated into a multivariate logistic regression model (Table 4). After adjustment, both age and the standardized DTI-ALPS index (z-score) retained independent associations with hearing impairment. Specifically, older age remained an independent risk factor (OR = 1.098, 95% CI: 1.031–1.169, P = 0.004), whereas a lower DTI-ALPS index was independently linked to increased odds of hearing impairment (OR = 0.532, 95% CI: 0.319–0.888, P = 0.016). By contrast, MoCA score, smoking history, and alcohol consumption were not independently associated with the outcome in the multivariate model (all P > 0.05). These results indicate that impaired glymphatic function, reflected by reduced DTI-ALPS values, is independently associated with hearing impairment, even after accounting for demographic and cognitive variables.

Table 4
Multivariate logistic regression analysis for hearing impairment.

Variable	β	SE	Wald	OR (95% CI)	*P* value
Age (years)	0.093	0.032	8.491	1.098 (1.031–1.169)	0.004
MoCA	-0.062	0.042	2.176	0.939 (0.865–1.021)	0.140
DTI-ALPS-Z	-0.631	0.261	5.840	0.532 (0.319–0.888)	0.016
Smoking history	0.266	0.632	0.177	1.304 (0.378–4.498)	0.674
Alcohol consumption history	0.620	0.574	1.166	1.859 (0.603–5.728)	0.280

DTI-ALPS, diffusion tensor imaging analysis along the perivascular space index; β, regression coefficient; CI, confidence interval; MoCA, montreal cognitive assessment; OR, odds ratio; SE, standard error.

3.5 Diagnostic Value of the DTI-ALPS Index in Hearing Impairment

The diagnostic value of the DTI-ALPS index, age, and their combination was evaluated using ROC curve analysis for the discrimination of hearing impairment (Fig. 3, Table 5). Among the individual predictors, age demonstrated the highest discriminative ability, yielding an AUC of 0.752 (95% CI: 0.669–0.823), followed by the DTI-ALPS index (AUC = 0.709, 95% CI: 0.624–0.785). For the DTI-ALPS index, the optimal cutoff value was 1.46, corresponding to a sensitivity of 92.96% and a specificity of 41.67%. For age, the optimal threshold was 58 years, with a sensitivity of 47.89% and a specificity of 88.33%. When combined, the integrated model incorporating both DTI-ALPS and age achieved improved diagnostic performance, with an AUC of 0.802 (95% CI: 0.732–0.866), sensitivity of 66.2%, and specificity of 83.33%. DeLong test analysis indicated that the combined model performed significantly better than either DTI-ALPS alone (P = 0.009) or age alone (P = 0.045). In contrast, no statistically significant difference was detected between the DTI-ALPS index and age (P = 0.436). Overall, while both variables provide moderate discriminatory power individually, their combination offers superior classification performance for identifying hearing impairment.

Table 5
Diagnostic accuracy of single-parameter and multiparametric models in predicting hearing impairment.

Indices	AUC	95%CI	Cut off	Sensitivity	Specificity	*P* value
DTI-ALPS	0.709	0.624 ~ 0.785	1.46	92.96	41.67	0.436a
Age	0.752	0.669 ~ 0.823	58	47.89	88.33	0.045b
DTI-ALPS + Age	0.802	0.732 ~ 0.866	--	66.2	83.33	0.009c

AUC: area under curve; DTI-ALPS, diffusion tensor imaging analysis along the perivascular space index; CI, confidence interval; a standard for the comparison between DTI-ALPS and Age. b standard for the comparison between Age and DTI-ALPS + Age. c standard for the comparison between DTI-ALPS and DTI-ALPS + Age.

4 Discussion

Hearing impairment is among the most prevalent sensory disorders in middle-aged and older populations. It not only adversely affects quality of life but is also closely linked to cognitive decline and a range of negative health outcomes. Therefore, identifying neuroimaging biomarkers that reflect the underlying central mechanisms of hearing impairment is of great importance for improving early detection and understanding auditory aging. In the present study, we investigated the association between glymphatic system function and hearing impairment in middle-aged and older adults using the DTI-ALPS index. Our results demonstrated that patients with hearing impairment exhibited significantly reduced DTI-ALPS values compared with controls. Furthermore, lower DTI-ALPS indices were correlated with worse hearing thresholds. Importantly, after adjustment for potential confounders, the DTI-ALPS index remained independently associated with hearing impairment. In addition, a combined model incorporating DTI-ALPS and age showed superior diagnostic performance compared with either variable alone, suggesting that DTI-ALPS may serve as a promising neuroimaging biomarker for age-related auditory dysfunction.

Firstly, our study showed that compared with individuals with normal hearing, patients with hearing impairment had significantly lower DTI-ALPS indices, consistent with previous studies [16]. This phenomenon may be related to multiple factors: on one hand, hearing loss is accompanied by central nervous system plasticity changes and white matter microstructural damage [4], which may affect the integrity of perivascular pathways; on the other hand, the chronic metabolic burden induced by hearing decline, along with accelerated brain aging, may further impair the clearance of metabolic waste in the brain [17]. In addition, microvascular dysfunction and impaired interstitial fluid flow may also contribute to this process, ultimately leading to a reduction in the ALPS index.

Secondly, previous multivariate analyses of hearing impairment have mainly focused on brain gray and white matter structural metrics [18] and DTI parameters, such as FA and mean diffusivity [19], whereas

less attention has been given to the functional status of the brain's glymphatic system. In the present study, we further incorporated the DTI-ALPS index into a multivariate model and found that it was independently associated with hearing impairment. This finding suggests that hearing loss may not only be related to traditional structural and white matter microstructural changes, but also involve alterations in the brain's metabolic waste clearance system [20]. In our model, the DTI-ALPS index remained significant after adjusting for age and other basic confounding factors, indicating that its association with hearing impairment is not entirely driven by physiological aging, but may reflect a relatively independent central nervous system process. Compared with conventional structural and DTI metrics, the DTI-ALPS index provides a novel imaging dimension for understanding the central mechanisms underlying hearing loss.

Finally, our ROC analysis showed that the DTI-ALPS index alone showed moderate diagnostic performance in identifying hearing impairment, indicating that it has value as a neuroimaging marker reflecting glymphatic system function in the brain, although certain limitations remain. Building on this, a combined model incorporating the DTI-ALPS index and age yielded a significantly higher AUC than either predictor alone, demonstrating superior diagnostic discrimination. The improvement in performance may be attributed to the complementary information provided by the two variables: age primarily reflects overall physiological aging, whereas the DTI-ALPS index mechanistically reflects the functional status of the brain's glymphatic system and its capacity for metabolic waste clearance [21]. Together, they capture two distinct dimensions of hearing impairment pathology—systemic aging burden and central clearance function. By including both types of information in the model, it not only accounts for major risk factors associated with auditory decline but also captures central nervous system variations that cannot be explained by age alone, thereby providing a more comprehensive characterization of the heterogeneity of hearing impairment and enhancing overall predictive performance.

This study has several limitations. First, due to its cross-sectional design, causal inference between the DTI-ALPS index and hearing impairment cannot be established, and the temporal relationship remains unclear. Second, the single-center small-sample design may introduce selection bias and limit the generalizability of the findings to broader or multicenter populations. Third, inter-rater and test–retest reliability were not assessed using intraclass correlation coefficients (ICC), which limits evaluation of measurement reproducibility and robustness. In addition, although the DTI-ALPS index is considered a promising indirect marker of glymphatic system activity, it only partially reflects glymphatic function and does not directly measure cerebrospinal fluid–interstitial fluid exchange or waste clearance, thereby limiting its physiological interpretability. Finally, hearing assessment relied primarily on PTA and did not include measures such as speech recognition or central auditory processing, which may limit comprehensive evaluation of auditory function.

5 Conclusion

Hearing impairment in middle- and older-aged adults is independently associated with a reduced DTI-ALPS index after adjustment for potential confounders. These findings suggest that glymphatic system

dysfunction may be involved in the pathophysiology of auditory aging and support the potential of the DTI-ALPS index as a non-invasive imaging biomarker for age-related hearing decline.

Declarations

Ethics Statement

This study was approved by Tongren People's Hospital (Approval No. 202502), Guizhou Province, China

Consent

All participants gave their written informed consent.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Author Contribution

All authors contributed to the study conception and design. Conceptualization: Chao Huang; Methodology: Chao Huang, Min Wu, Bo Wu, Minggui Long, Jin Yang, Guangxian Kuang, Lin Wang; Formal analysis and investigation: Yonghua An, Jiancheng Zhang, Peng Jiang; Writing - original draft preparation: Chao Huang,Chongshuang Yang; Writing - review and editing: Chongshuang Yang; Resources: Chao Huang; Supervision: Chongshuang Yang, Tianliang Shi, Zhihong Qin, Yinbin Luo.

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Not applicable

Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

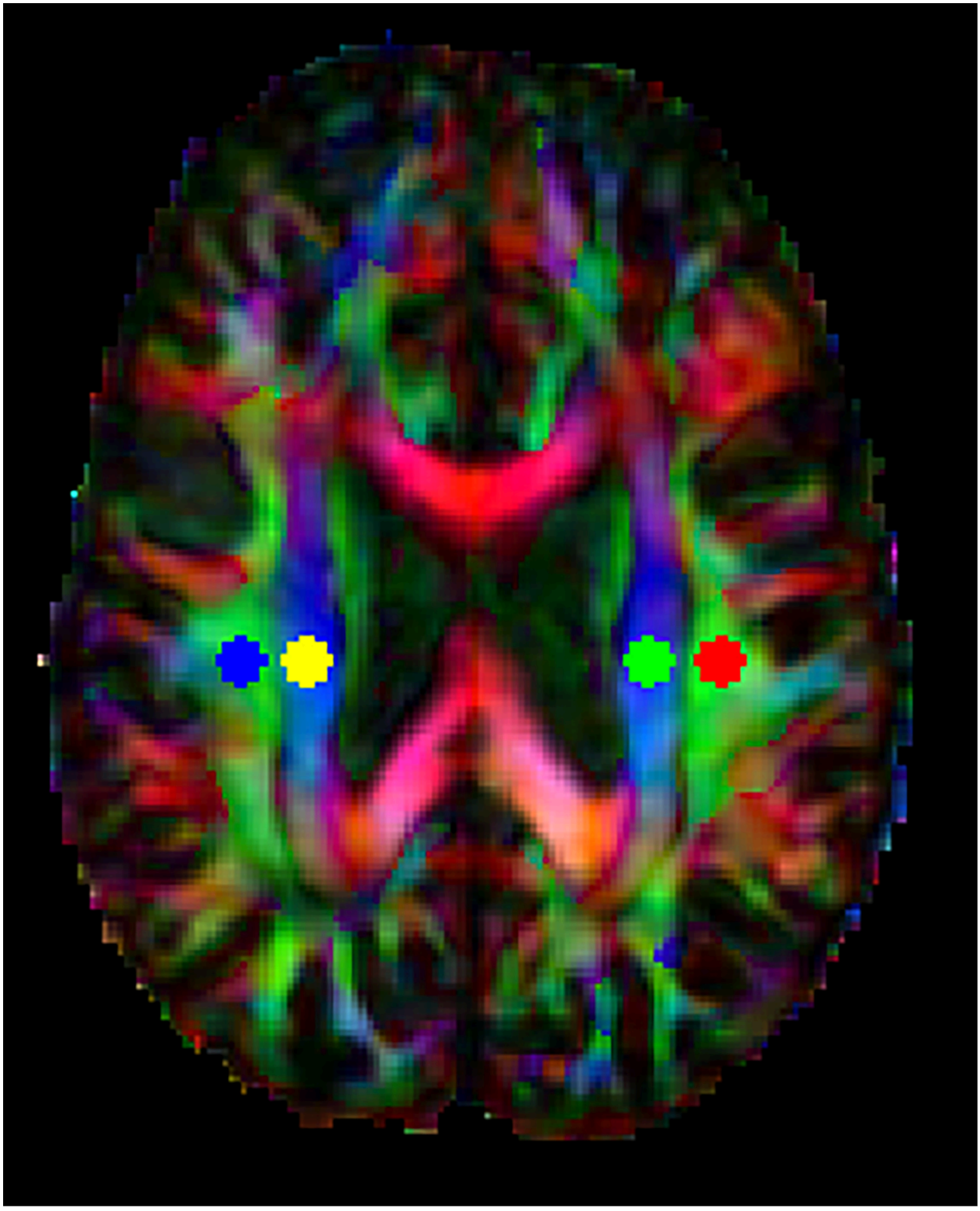


Figure 1

Placement of spherical ROIs (8 mm) for DTI-ALPS calculation. Two ROIs were symmetrically placed in each hemisphere at the level of the lateral ventricular body: one in the projection fiber region (z-axis) and one in the association fiber region (y-axis), as shown on FA color-coded maps.

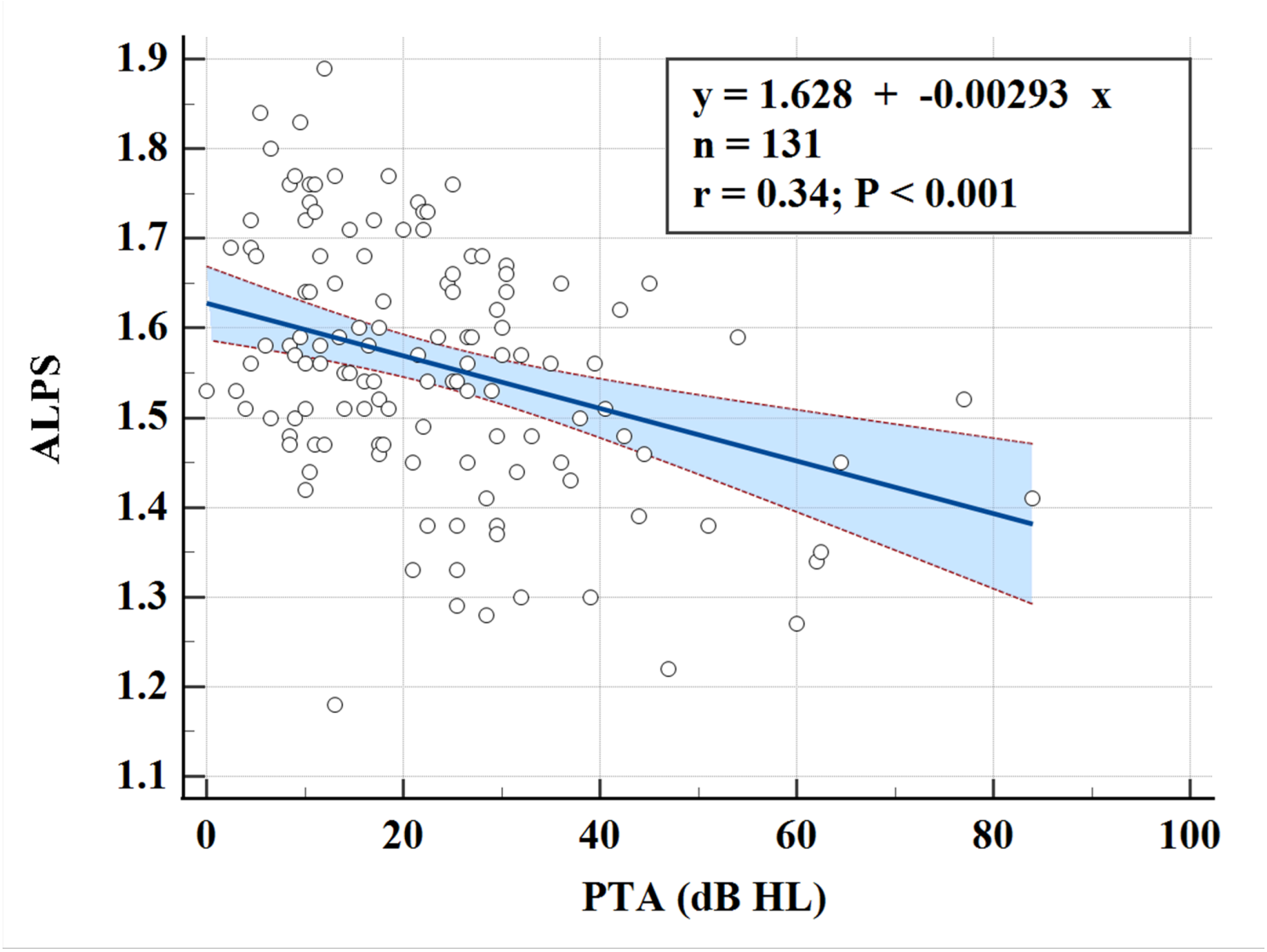


Figure 2

Correlation between PTA and DTI-ALPS index.

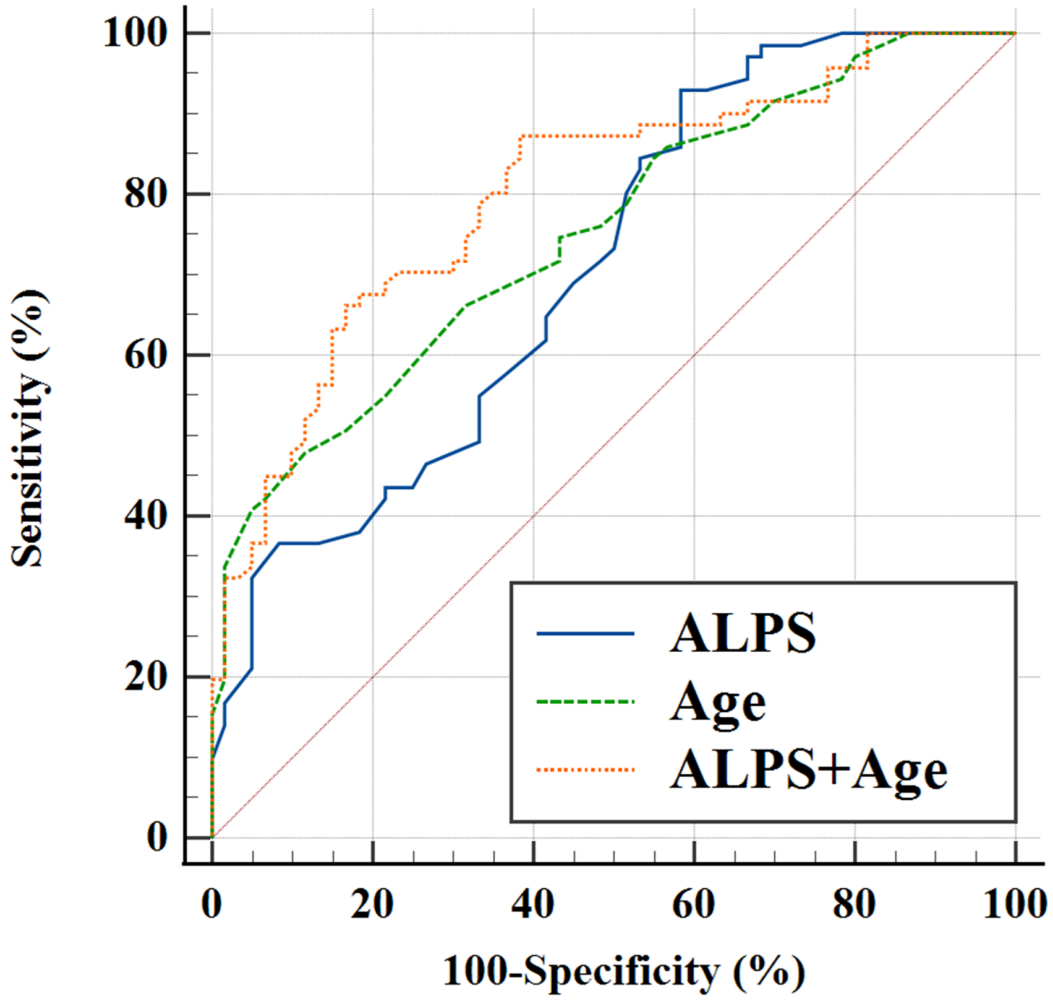


Figure 3

ROC curves of DTI-ALPS index and age for hearing impairment.