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ORIGINAL RESEARCH

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Improvement of vertigo symptoms and acoustic power absorbance in cases with endolymphatic hydrops

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Abstract

Objective: The pathophysiology and symptoms underlying Meniere's disease (MD) manifest as endolymphatic hydrops (EH), potentially impacting acoustic power absorbance in vestibular EH. The longitudinal effects of middle ear pressure therapy (MEPT) and conservative therapies for EH by magnetic resonance imaging (MRI) and on acoustic power absorbance on wideband acoustic immittance (WAI) were evaluated, and their changes were compared with clinical symptoms.

Methods: Eleven patients with definite MD or delayed endolymphatic hydrops (DEH), resistant to conservative therapies and who continued MEPT for 1 year, were included. Vertigo scores, hearing levels, acoustic power absorbance on WAI, and degrees of EH on 3-T MRI were evaluated and compared before and after the treatments.

Results: One year after the start of MEPT, all cases showed symptomatic improvement in vertigo score; however, the degrees of EH showed no improvements except in one case. In the affected ears with EH, their absorbances on WAI improved, particularly at 1580–1905 or 2400–2953 Hz ($p < .05$).

Conclusion: Alleviation of vestibular symptoms with the therapy of MD was not necessarily associated with improved EH. Vestibular symptoms could be related to the change in the impedance of inner ear pressure, which was proven by the normalization of acoustic power absorbance. Assessments of acoustic power absorbance may provide useful information for physiological conditions and causative factors of vertigo in ears with EH.

Level of evidence: 4

KEYWORDS
acoustic power absorbance, endolymphatic hydrops, middle ear pressure therapy, wideband acoustic immittance

1 | INTRODUCTION

The pathophysiology underlying Meniere's disease (MD) is endolymphatic hydrops (EH), which can cause hearing or balance disorders. Various therapies have been attempted to alleviate the symptoms of MD, including diuretics, oral or intratympanic steroids, and pressure pulse treatment, or more invasive surgical treatments. Since the risk–benefit ratios of these various treatments remain debatable, treatments that are both effective and less invasive are needed. Since 2018, a novel middle ear pressure therapy (MEPT) with a transtympanic membrane massage (TMM) device, named the EFET device (Daiichi Medical Co., Ltd., Tokyo, Japan), has become available in Japan for cases with recurrent vertigo attacks resistant to conservative treatment due to MD and delayed endolymphatic hydrops (DEH).[1] The advantages of positive pressure therapy include the increased outflow of endolymphatic fluid into the endolymphatic sac,[2] dissipated debris retained in the vestibular aqueduct,[3] and its effect on the endolymphatic fluid production mechanism.[4,5] The EFET device was as effective as the conventional Meniett device,[6] while obviating the need for tubing, though its benefits were controversial according to clinical practice guidelines proposed by the American Academy of Otolaryngology–Head and Neck Surgery in 2020.[7]

Visualization of EH using 3 T magnetic resonance imaging (MRI) performed 24 h after intratympanic or 4 h after intravenous administration of gadolinium-based contrast agents (GBCAs)[8,9] has become an epoch-making invention for precise diagnosis of EH. In a previous study using wideband acoustic immittance (WAI), we reported for the first time that significant vestibular EH affected acoustic power absorbance to the inner ear.[10] Acoustic power absorbance on WAI measures the acoustic energy presented from the outer ear and the acoustic energy reflected by the eardrum.

The purpose of this study is to investigate the longitudinal effects of MEPT using the EFET device and conservative therapies for cases with MD or DEH by evaluating the degrees of EH on MRI or acoustic power absorbance on WAI and comparing them with their clinical symptoms. The results may provide useful information for evaluating physiological conditions and causing factors of vertigo in ears with EH.

2 | MATERIALS AND METHODS

The study recruited 11 patients (8 males, 3 females; 28–72 years old) with advanced stages based on the degree of hearing and balance disability of definite MD and DEH, resistant to conservative therapies, who were recruited from 2020 to 2022 in our hospital. The diagnostic and staging criteria of MD and DEH were according to the criteria proposed by the Japan Society for Equilibrium Research (JSER) were applied.[11] Patients were treated with the EFET device to the affected ear for more than 1 year, and they continued to take conservative therapies. There were no abnormal findings in the middle ear on eardrum examination and MRI. Vertigo score, the data of pure tone audiometry (PTA), WAI using a Titan wideband tympanometry (WBT) (Interacoustics; Assens, Denmark), and 3-T MRI with gadolinium were measured and compared before and after treatments for 1 year.

2.1 | Vertigo score

Each patient reported the severity as a vertigo score using a five-point scale each day, as presented in a previous study.[6] Patients visited the hospital every 4 weeks, and the number of definitive vertigo days with a vertigo score of >2 per month was counted while using the EFET device according to the JSER guideline.[12]

2.2 | Hearing level

Hearing thresholds on PTA, at frequencies ranging from 125 to 8000 Hz, were measured using an audiometer (AA-79, Rion, Tokyo, Japan), and the average values of thresholds at 250, 500, 1000, 2000, and 4000 Hz in each ear of the subjects were calculated.

2.3 | WAI

Power absorbance (PA) is the ratio of acoustic energy power that is absorbed by the middle ear to an incident acoustic energy power presented in the ear canal on WAI.[13] First, the PA difference at each frequency between each case and the 50th percentiles of normal adults before and after treatment were calculated. Next, the total PA differences of all frequencies were calculated as the sum of the differences at each frequency, which were presented in a previous study.[10] Then, the total PA differences of all frequencies between the affected and contralateral sides were compared to evaluate how much the PA changed before and after treatment and approached the average value for normal adults, and further analyzed by frequency.

2.4 | MRI

Ears were evaluated by MRI performed 4 h after intravenous injection of a standard dose (0.1 mL/kg body weight) of gadolinium hydrate. All scans were performed using a 3-T MRI scanner (Trio or Verio; Siemens, Erlangen, Germany or Vantage Centurian; Canon Medical Systems, Tochigi, Japan) equipped with a receive-only, 32-channel, phased-array coil. HYDROPS (hybrid of the reversed image of positive endolymph signal and native image of positive perilymph signal) was used to detect EH.[14] At least two radiologists blinded to the patient's clinical courses classified the degree of EH using 3 grades (none, mild, and significant) according to the criteria described previously.[15]

Statistical analyses were conducted using SPSS IBM Statistics version 28 (IBM Corporation, Armonk, NY). The Mann–Whitney *U* test was used to compare the absorbance at each frequency. The significance level was set at 5%. Informed consent has been obtained from all individuals included in this study. This study was approved

by the ethics review committee of Nagoya University School of Medicine, Nagoya, Japan (approval number 2022-0475).

3 | RESULTS

Table 1 shows a summary of the clinical data and imaging results of the 11 subjects before and after treatment. The median age of the patients was 61 years old. Ten cases had definite MD, of which 9 were unilateral, and 1 was bilateral. The remaining case had DEH. The duration of diseases ranged from 1 to 20 years, with a median of 3 years. Except for one case, all ears had significant cochlear and vestibular EH on the affected sides.

After the treatment with the EFET device for 1 year, all cases showed improvement in the vertigo score; five cases had no vertigo attacks per month, and two cases required no other therapy thereafter. Changes in hearing levels of the affected ear varied from a 10 dB improvement to a 20 dB deterioration, with a median change of 5 dB deterioration. No improvements of vestibular EH of the affected ear were observed, except 1 ear. Cochlear EH remained significant in all affected ears.

A representative case is shown in Figure 1. Case 4, diagnosed with left MD, had a left PA far from the normal adult mainly around 2000 Hz before treatment (B1); MRI showed mild EH in the vestibule (C1). After 1 year of MEPT on the left side, vertigo attacks were improved to 0, and PA improved to within the normal range (B2). However, MRI findings worsened, with significant EH in the vestibule (C2).

Figures 2 and 3 show the summary of the result of PA on WAI. The total PA differences between each case and the normal adult at all frequencies were measured before and after the treatment to show the degree of improvement. A positive value was a value closer to the normal adult in 1 year, and a negative value was a value further from the normal. The total PA differences on ear-affected sides approached closer to the normal ranges of PA after treatment, significantly different from those on the contralateral sides ($p = .011$) (Figure 2). In Figure 3, PA difference changes between each case and the normal adult for each frequency are shown on the affected and contralateral

TABLE 1 Encapsulated the attributes of individual cases, as well as the alterations in vertigo symptoms, the degree of endolymphatic hydrops on the vestibule and cochlear, and the average hearing threshold on air-conduction from 250 to 4000 Hz in 1 year. One year after the application of middle ear pressure therapy, all cases showed symptomatic improvement on vertigo score, however, EH in the vestibule revealed no improvements in degrees of endolymphatic hydrops (EH) except in one case.

						Vertigo score	Hearing levels (dB)	Vestibular EH	Cochlear EH
Case	Age (y.o.)	Sex	Disease	Side	Duration (year)	Before → After	Before → After	Before → After	Before → After
1	59	M	dMD	Left	2	8 → 3	72 → 82	Significant → Significant	Significant → Significant
2	68	F	dMD	Left	4	6 → 1	64 → 68	Significant → Significant	Significant → Significant
3	61	M	DEH	Right	5	6 → 2	58 → 71	Significant → Significant	Significant → Significant
4	28	M	dMD	Left	1	7 → 0	44 → 61	Mild → Significant	Significant → Significant
5	61	M	dMD	Left	11	11 → 2	55 → 51	Significant → Significant	Significant → Significant
			dMD	Right	11		59 → 61	Significant → Significant	Significant → Significant
6	47	M	dMD	Left	2	3 → 0	53 → 43	Significant → Significant	Significant → Significant
7	65	F	dMD	Left	2	4 → 2	52 → 47	Significant → Significant	Significant → Significant
8	67	M	dMD	Right	2	31 → 1	71 → 76	Significant → Significant	Significant → Significant
9	67	M	dMD	Right	2	5 → 0	43 → 63	Significant → Significant	Significant → Significant
10	72	F	dMD	Right	10	4 → 0	32 → 48	Significant → None	Significant → Significant
11	41	M	dMD	Right	20	2 → 0	56 → 62	Significant → Significant	Significant → Significant

Abbreviations: DEH, delayed endolymphatic hydrops; dMD, definite Meniere's disease; F, female; M, Male; y.o., years old.

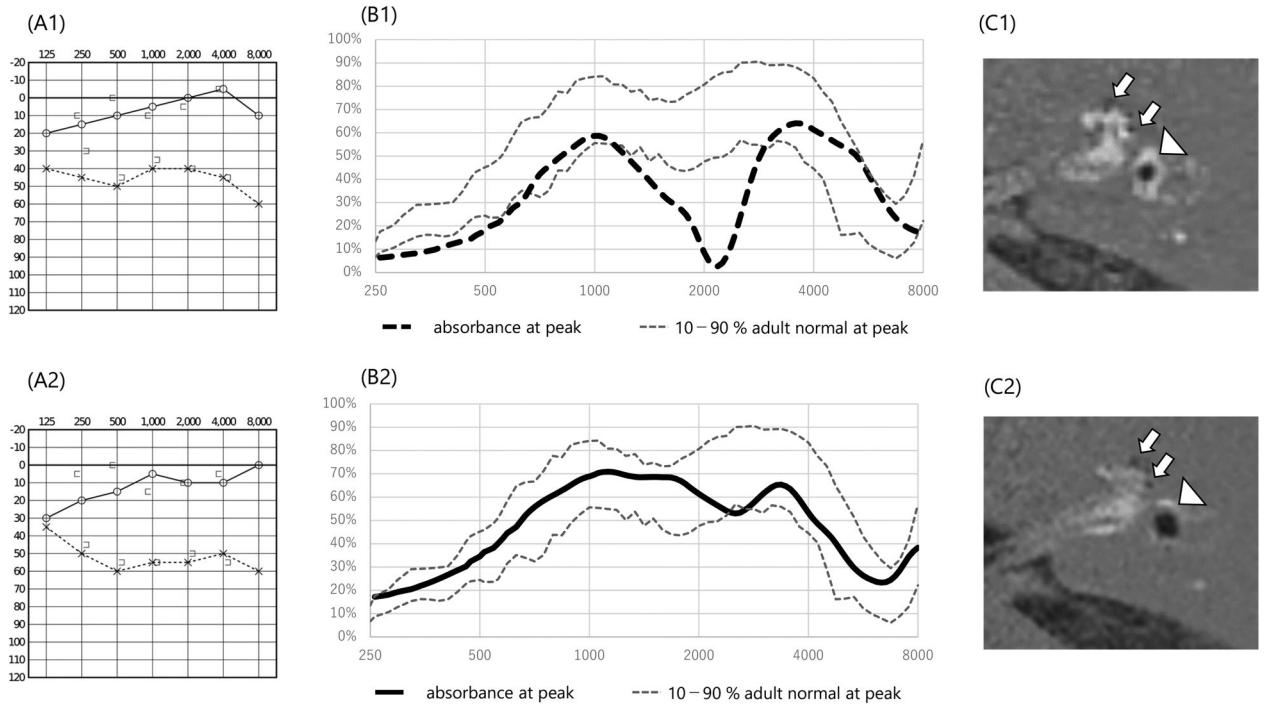

FIGURE 1 Representative case: A 28-year-old patient with recurrent vertigo and left sensorineural hearing loss (SNHL) resistant to conservative treatment for 1 year was diagnosed as left Meniere's disease. Middle ear pressure therapy (MEPT) was applied to his left ear using the EFET device. He had left SNHL (A1) and 7 times vertigo symptoms per month. Acoustic power absorbance on wideband acoustic immittance was far from the normal range mainly around 2000 Hz. (B1) HYDROPS (hybrid of the reversed image of positive endolymph signal and native image of positive perilymph signal) was used to identify endolymphatic hydrops (EH) on magnetic resonance imaging (MRI). The presence of vestibular EH (arrowhead) can be visualized as black areas surrounded by gadolinium-filled perilymph. (C1, C2) Arrows show cochlear EH. (C1, C2) MRI revealed mild EH in the left vestibule and significant EH in the cochlea before MEPT. (C1) After 1 year of MEPT, he did not have hearing improvement (A2), but vertigo attacks were improved to 0 per month. Acoustic power absorbance improved to within normal range. (B2) However, MRI findings worsening, with significant EH in the vestibule and cochlea. (C2).

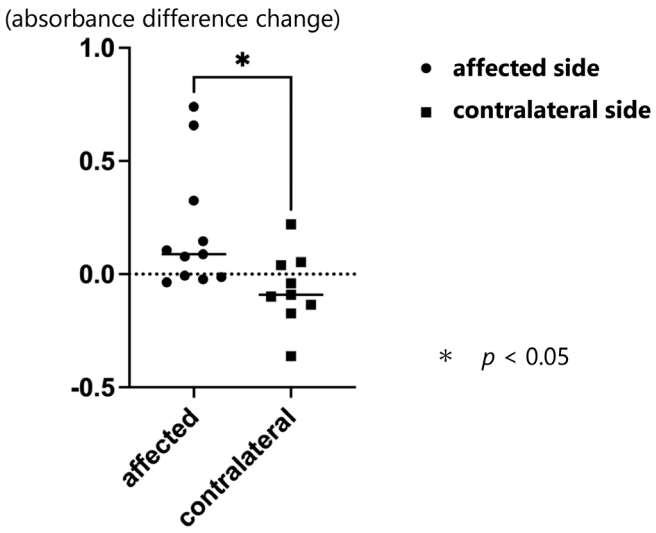

FIGURE 2 The total absorbance differences between each case and the normal adult at all frequencies were measured before and after middle ear pressure therapy (MEPT) to show the degree of improvement in Figure 2. The *y*-axis was the absorbance difference change of each case. A positive value indicates to approach closer to the normal adult in 1 year, and a negative value away from the normal. Absorbance at the affected ear significantly approached normal after 1 year of MEPT compared to the contralateral ear.

sides, indicating at which frequencies PA improved after treatment. PA difference changes on the affected sides were especially significant at 1580–1905 Hz and 2400–2953 Hz. ($p < .05$) (Figure 3).

4 | DISCUSSION

We attempted to comprehend unsolved physiological mechanisms causing clinical symptoms in cases of EH by means of measurement of acoustic PA and imaging analysis of EH. Vestibular symptoms improved in all cases after treatment, however, the degrees of EH on MRI remained unchanged in all affected ears, except one. In our previous study observing changes in EH of patients with MD treated conservatively for more than 1 year, the relationship between improvements in vestibular symptoms with degrees of EH on MRI was considered controversial.[16] Another report also reported no correlation between the decrease in vestibule EH and the improvement in vertigo attacks after endolymphatic sac surgery.[17] A case study was reported in which a decrease in EH on MRI was correlated with improvement in vestibular symptoms after treatment with MEPT.[18] In the present study, a similar finding was observed in only one of 11 ears. The effects of MEPT are considered to include the promotion of excretion of endolymph fluid into the endolymphatic sac and

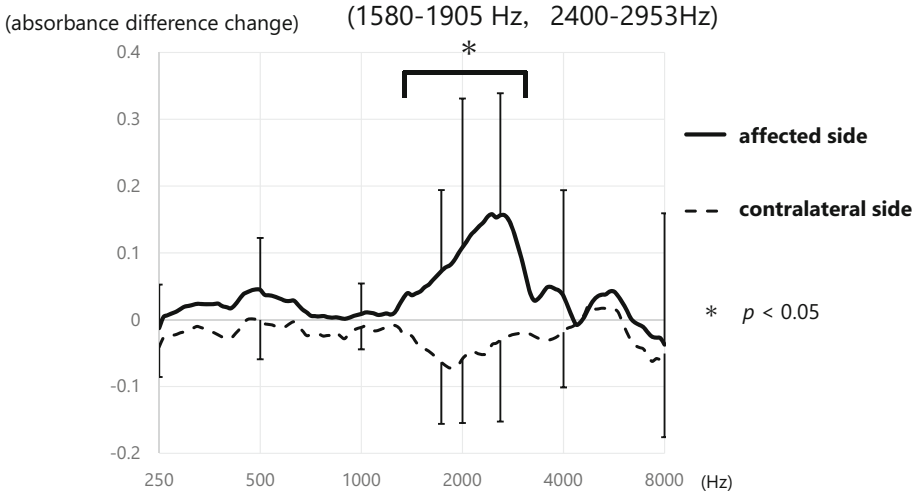

FIGURE 3 The absorbance differences between each case and the normal adult at each frequency were measured before and after middle ear pressure therapy (MEPT) to show the degree of improvement in Figure 3. The x-axis was the frequency, and the y-axis was the average absorbance difference change at the affected ear and contralateral ear. Absorbance at the affected ear significantly approached normal after 1 year of MEPT compared to the contralateral ear at 1580–1905, 2400–2953 Hz.

dissipated debris retained in the vestibular aqueduct. A drainage hypothesis has been proposed in which debris is retained in the vestibular aqueduct, resulting in EH, and pressure changes cause vertigo attacks in MD.[19] The results in the present study indicate that a decrease in vestibular symptoms is not necessarily accompanied by an improvement in EH. The decrease of vestibular symptoms after treatment would correlate with pressure changes rather than the degree of endolymphatic space, and such changes appeared on PA, but not on MRI.

Previously, we have reported that significant vestibular EH would affect acoustic PA.[10] Acoustic PA was high at low frequencies in ears with significant vestibular EH, which might cause air-bone gaps on PTA. Higher PA and air-bone gaps are considered to be energy-transmitted impairments to the cochlea, including some loss mechanisms within the middle ear or elsewhere. Glycerol drips could change low PA in the middle frequencies in ears with significant vestibular EH. In the present study, acoustic PA in the affected ear moved to normal ranges with the recovery of symptoms, especially at similar middle frequencies. Interestingly, previous investigations have shown the relationship between middle ear pressure and EH using multifrequency tympanometry (MFT) at 2 kHz clinically.[20] Experimentally induced changes in inner ear pressure caused changes in the tympanogram curves at 2 kHz.[21] We have reported imaging findings taken during a vertigo attack of MD, in which the attacks occurred without large ruptures in the Reissner's membrane.[22] Considering a theory that vertigo attacks in MD are not due to disruption of the Reissner's membrane but elevated endolymphatic pressure,[23] the decreased of vestibular symptoms and improvement of PA observed in the present study may suggest that the suppression of impedance changes in inner ear pressure and concomitant improvement in vestibular symptoms.

In the present study, ears with significant EH treated with MEPT were compared with non-MEPT ears, and vertigo attacks, inner ear pressure, and the degree of vestibular EH were analyzed. The limitations of the present study include a small number of cases involved. It was difficult to select appropriate control cases which were stage 4 severe MD and used no oral treatment and MEPT for 1 year ethically. Therefore, it was difficult to conclude that the changes in PA were not due to the natural history of the disease. Considering the above points, we discussed the degree of EH evaluated by MRI and changes in WAI associated with treatment. We are planning a large-scale study with longer observation periods.

5 | CONCLUSIONS

Improvement in vestibular symptoms in cases undergoing MEPT with an EFET device for 1 year, and medication was not necessarily associated with improved EH. Vestibular symptom relief may be related to changes in inner ear pressure impedance, which was correlated by the normalization of acoustic power absorbance, but not to changes in the degree of EH. Assessments of PA on WAI may provide useful information for physiological conditions and causative factors of vertigo attacks in ears with EH.

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CONFLICT OF INTEREST STATEMENT

The authors have no sources of funding, financial relationships, or conflicts of interest to disclose.

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