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Detection of endolymphatic hydrops using traditional MR imaging sequences

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ABSTRACT

Purpose: The purpose of this study was to determine whether Meniere's disease (MD) produces endolymphatic cavity size changes that are detectable using unenhanced high-resolution T2-weighted MRI.
Materials & methods: This retrospective case-control study included patients with documented MD who had a high-resolution T2-weighted or steady-state free procession MRI of the temporal bones within one month of diagnosis, between 2002 and 2015. Patients were compared to age- and sex- matched controls. Cross sectional area, length, and width of the vestibule and utricle were measured in both ears along with the width of the basal turn of the cochlea and its endolymphatic space. Absolute measurements and ratios of endolymph to perilymph were compared between affected, contralateral, and control ears using analysis of variance and post-hoc pairwise comparisons.
Results: Eighty-five case-control pairs were enrolled. Mean utricle areas for affected, contralateral, and control ears were 0.038 cm^2, 0.037 cm^2, and 0.033 cm^2. Mean area ratios for affected, contralateral, and control ears were 0.32, 0.32, and 0.29. There was a statistically significant difference between groups for these two variables; post-hoc comparisons revealed no difference between affected and contralateral ears in Meniere's patients, while ears in control patients were different from the ears of patients with MD. All other measurements failed to show significant differences.
Conclusions: Enlargement of the endolymphatic cavity can be detected using non-contrast T2-weighted MRI. MRI, using existing protocols, can be a useful diagnostic tool for the evaluation of MD, and intratympanic or delayed intravenous contrast may be unnecessary for this diagnosis.

1. Introduction

Meniere's disease (MD) is a peripheral vestibular disorder characterized by recurrent attacks of vertigo, fluctuating hearing loss, tinnitus, and a sensation of aural fullness. With a prevalence of 190 per 100,000, it accounts for approximately 5% of all cases of dizziness [1,2]. The pathological hallmark of MD is endolymphatic hydrops (EH), although the precise relationship between EH and MD pathophysiology is incompletely understood. The diagnosis of MD is made clinically, with varying degrees of certainty based on criteria reported by the American Academy of Otolaryngology and Head and Neck Surgery (AAO-HNS) [3]. The guidelines define four diagnostic categories that depend on the nature of the vestibular and auditory symptoms: possible, probable, definite, or certain MD. A diagnosis of "certain" MD can only be achieved with histopathologic confirmation in a patient with clinically "definite" MD. These limitations illustrate the need for a more objective method to identify and diagnose Meniere's disease.

Invasive MRI techniques have shown promise in the visualization of EH in patients with Meniere's disease. Three-dimensional (3D) fluid-attenuated inversion recovery (FLAIR) MRI after intratympanic gadolinium injection has been used to identify EH in patients with MD [4–6]. Alternatively, EH can be identified with delayed imaging using 3D-FLAIR MRI after administration of intravenous gadolinium contrast [7–9]. These studies had small numbers of patients, and although intratympanic contrast injection is a relatively well-tolerated procedure, it is invasive and carries the risk of complications such as tympanic perforation or otitis media. Furthermore, imaging after intratympanic infusion must be performed 24 h after the introduction of gadolinium, which is inconvenient for patients and for medical staff. Intravenous contrast is similarly well-tolerated, but is relatively contraindicated in patients with renal insufficiency. Risk of allergic reaction is also a factor in atopic patients. Detection of EH after IV contrast administration likewise requires delayed imaging – in healthy patients, it has been shown that maximum perilymphatic enhancement occurs 4 h after IV gadolinium administration [10]. Although enhancement at 4 h in patients with

Abbreviations: AAO-HNS, American Academy of Otolaryngology and Head and Neck Surgery; ANOVA, analysis of variance; EH, endolymphatic hydrops; FLAIR, fluid-attenuated inversion recovery; MD, Meniere's disease; SSFP, steady-state free procession.

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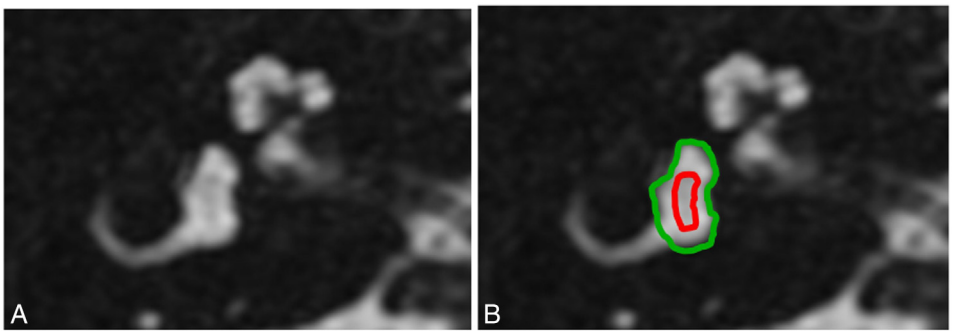

Fig. 1. Measurement of the utricle and vestibule in a healthy 47 year old male. Axial T2-weighted image at the level of the lateral semicircular canal without (A) and with (B) measurement overlay. The green line demarcates the vestibule, and the red line the utricle. The utricular area is less than 1/3 the overall vestibular area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Meniere's disease has been shown in multiple studies, EH could not be detected at the conventional timing of 10 min after contrast administration [11,12]. Although less burdensome than the 24-h delay with intratympanic contrast, this 4-h delay is still an imposition on patients and staff. In addition, for both of these established techniques, adequate detection requires clinical suspicion of the disease prior to imaging, so that imaging protocols can be adjusted.

There remains a need for a less invasive but objective method for the radiologic diagnosis of Meniere's disease. The purpose of this study was to determine whether endolymphatic hydrops in the setting of MD can be detected using non-invasive, traditional MRI sequences, particularly steady-state free procession (SSFP) images and high-resolution T2-weighted images. We hypothesized that the lower-signal region in the center of the labyrinth on SSFP images represents the utricle and would be enlarged in the affected ear of patients with Meniere's disease.

2. Materials and methods

This retrospective case-control study was approved by the institutional review board and waiver of consent was granted. An electronic medical record search was performed to identify patients with probable or definite MD (as defined by AAO-HNS criteria) who had an MRI that included high-resolution T2-weighted or SSFP sequences of the temporal bones within one month of diagnosis. Patients were enrolled from 11 University of Pittsburgh hospitals with MRIs obtained between 2002 and 2015. Patients with age less than 18 years, history of inner ear surgery, or an uncertain diagnosis of Meniere's disease were excluded. Age- and sex-matched controls from the same 11 hospitals were then identified. Control cases were selected from patients who had undergone MRI of the temporal bones but did not have hearing loss or dizziness (reasons for examination included tinnitus and tumor follow-up).

All examinations were performed on General Electric scanners with field strength ranging from 1T to 3T. Our routine examination consists of sagittal T1, axial FLAIR, and axial post-contrast images of the brain, with additional pre- and post-contrast T1-weighted images through the temporal bones. We also perform a high-resolution sequence designed to evaluate the membranous labyrinth, which is usually performed as an SSFP sequence (3D FIESTA HR, with TR 5.9, TE 2.3, flip angle 65, NEX 2, matrix 284 × 256, thickness 0.8 mm, spacing 0.4 mm). On older scanners without the SSFP sequence, a 3-dimensional high-resolution T2-weighted sequence (T2 SPACE with TR 1200, TE 270, flip angle 150, NEX 2, matrix 256 × 260, thickness and spacing 0.8 mm) is substituted.

For each ear, axial cross-sectional area, maximum length, and maximum width of the vestibule and utricle (Figs. 1 and 2) were measured along with the width of the basal turn of the cochlea and its contained endolymphatic space (Fig. 3). Endolymphatic and perilymphatic spaces were distinguished by degree of T2 signal; although both spaces have high T2 signal, perilymphatic spaces have higher signal than endolymphatic spaces. Measurements were made by a 2nd year medical student (JHK) under the guidance of a senior neuroradiology faculty member (BFB). The observers were blinded to the disease status of the patient. Endolymphatic measurements were divided by corresponding measurements of the entire labyrinth to obtain endolymph size ratios for each structure (see Figs. 1–3). Measurements of the vestibule and utricle were made on the axial image that included the posterior crus of the lateral semicircular canal.

Size of endolymphatic spaces, as well as endolymphatic size ratios, were compared between affected, contralateral, and control ears using analysis of variance (ANOVA). When statistically significant differences were found in the ANOVA model, the groups were subsequently compared using post-hoc pairwise analysis. A p value of 0.05 was used as

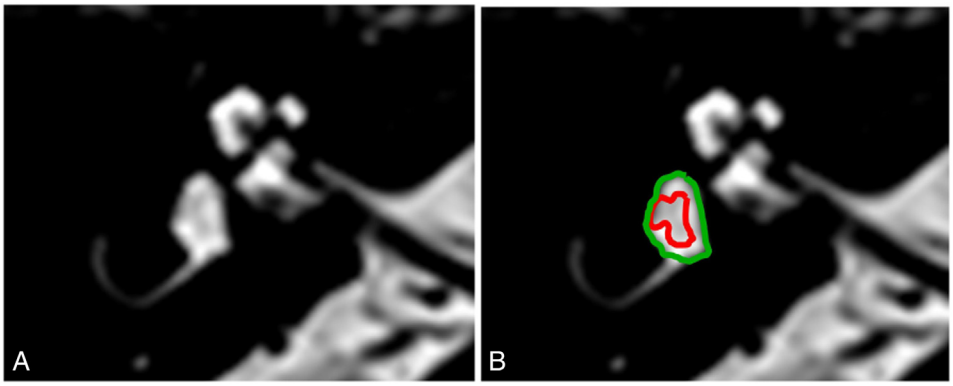

Fig. 2. Measurement of the utricle and vestibule in a 71-year-old man with Meniere's disease. Axial T2-weighted image at the level of the lateral semicircular canal without (A) and with (B) measurement overlay. The green line demarcates the vestibule, and the red line the utricle. Note that the utricle area is approximately half the overall ventricular area. A ratio of more than 1/3 suggests the presence of endolymphatic hydrops. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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