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High-resolution MR imaging of the inner ear: findings in Meniere's disease

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Abstract

Symptoms in Meniere's disease are characterized by hydrops of the endolymphatic system with recurrent rupture of the membranous labyrinth. The primary cause of the increased endolymphatic volume appears to be an imbalance between secretion and resorption of the endolymph which may be due to an obstruction of the membranous endolymphatic duct and sac, located in the vestibular aqueduct. The membranous endolymphatic duct and sac are not expected to be visualized using conventional tomography and high-resolution computed tomography (HR-CT), whereas, these are identified with high resolution MRI (HR-MRI). By HR-MRI, we proposed to demonstrate morphological alternation in 12 patients with Meniere's disease, this group was compared with a group of 20 healthy subjects. The degree of visualization on HR-MRI of the membranous endolymphatic duct and sac running through the vestibular aqueduct in the bony canal was assessed. There was a distinct decrease in visualization of the membranous endolymphatic duct and sac in the Meniere's group. The results confirm the value of the HR-MRI technique to identify an anatomical abnormality, which is directly correlated with the lesion in cases of unilateral Meniere's disease.

Introduction

It is well known that the endolymphatic sac plays a major role in the etiology of Meniere's disease; this has been confirmed from findings in temporal bone pathology [1–3] and in animal experiments [4–7]. The endolymphatic hydrops that results from a functional disorder of the endolymphatic sac is the cause of the clinical entity called Meniere's disease.

However, clinical tests of the function of the endolymphatic sac are currently impossible, and the diagnostic tests offering data in this direction are limited to morphological studies using multidirectional tomography and high-resolution CT (HR-CT). It has not been possible by means of these conventional types of radiological examination to visualize more than the bony canal of the vestibular aqueduct. If high-resolution MR images (HR-MRI) are made of the temporal bone region, however, it is possible to visualize the membranous endolymphatic duct and sac [8]. Thus, it has now become a practical proposition to present the condition of these structures in visible images.

In dealing with poorly defined malady, it is useful to evolve a working hypothesis and/or model for the disease state. Within the otologic region, Meniere's disease is suitable for such an approach.

This paper describes such a hypothesis, disease model and presents data obtained on HR-MRI of the membranous endolymphatic duct and sac running through the vestibular aqueduct.

Hypothesis and disease model

The hypothesis and disease model were devised by Austin [9] and modified by the author of this study. The modifications are as follows. Figure 1 illustrates a hypothesis concerning the pathogenesis of Meniere's disease. Stage 1 is a previously normal ear, affected by an etiologic agent. This effect may be on the endolymphatic system, on the perilymphatic system, on the immediate supporting structures, or on the body as a whole. This paper discusses all of these loci as possi-

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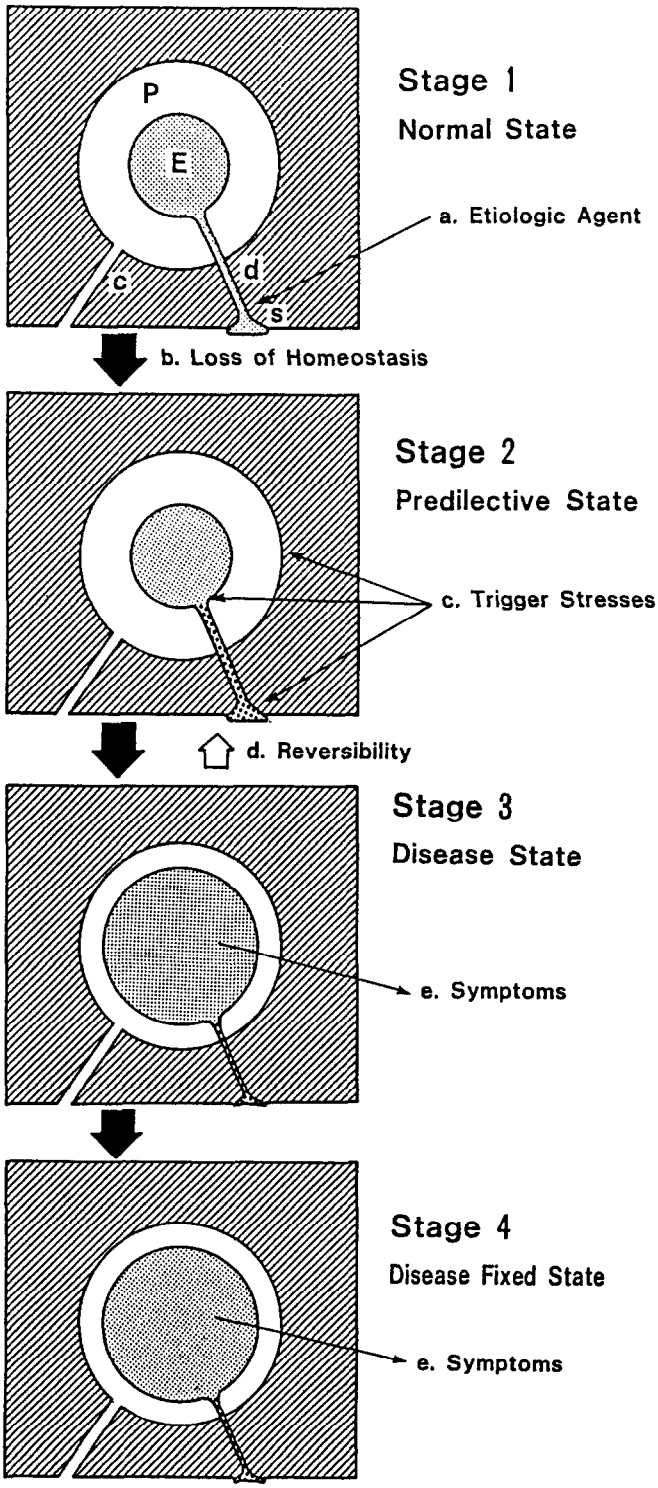

Fig. 1. Disease model: P, perilymph; E, endolymph; c, cochlear aqueduct; d, endolymphatic duct; s, endolymphatic sac.

bilities. As a result of this action, a loss of homeostasis occurs, and the end organ is changed to the predilection state (stage 2).

In stage 2, the inner ear has become susceptible to the effect of stresses because of reduced homeostasis. If uncompensated, such stresses will trigger the end organ into an unstable state, finally causing the appearance of symptoms of the disease (stage 3).

Stage 3 of the disease produces symptoms based on actual physical changes in the endolymphatic system. Fluctuating hydrops must be considered pathogenetic of the symptoms of fluctuating hearing loss, tinnitus, intra-aural pressure, and vertigo. The exact pathophysiologic relation of these symptoms to histopathologic changes remains to be defined. The arrows between stages 2 and 3 indicate that early in the disease process reversibility to quiescent state may occur, but that late in the disease only limited improvement is possible because of irreversible change in the end organ (stage 4).

In the present study, we examined cases of Meniere's disease by imaging the membranous endolymphatic duct and sac. HR-MR images of the membranous endolymphatic duct and sac in the study population will be related to the hypothesis and discussed.

Patients

A total of 32 subjects were examined: 20 healthy subjects (average age: 48 years, ratio of male to female; 3:2) and 12 with unilateral Meniere's disease (average age: 47 years, ratio of male to female; 1:1) as diagnosed by the japanese clinical criteria [10]. Patients underwent MR ear studies within 1 week after symptoms had presented.

Methods

A superconductor-type magnetic resonance (MR) device with a static magnetic field intensity of 1.5 tesla (Siemens Magnetom H15) was used, and imaging was performed with a surface oil of diameter 8 cm. For the pulse sequences, the three-dimensional Fourier transform technique with a Fast Low Angle Shot (3DFT: FLASH) was used.

Imaging conditions were as follows: For 3DFT:FLASH imaging was performed with the flip angle at 24° or 25° with a repetition time (TR) of 100 ms and an echo time (TE) of 10 ms, namely proton density imaging. The matrix size was 256 x 256 x 16, the field of view (FOV) was 15 cm, and averaging was carried out twice. The slice thickness was 1 mm.

Assessments were made by examining the views of the membranous duct and sac running through the vestibular aqueduct, seen in two-dimensional axial images. Evaluations were made by two radiologists and one otorhinolaryngologist; two evaluators (radiologists) were blinded, and did not know the clinical diagnosis. An agreement was reached after discussion. Thus, according to the degree of visibility of the membranous

endolymphatic duct and sac running through the vestibular aqueduct in the images, each case was classified into one of three categories: grades 1 (Fig. 2), 2 (Fig. 3) or 3 (Fig. 4). Grade 1 included those in whom the entire membranous endolymphatic duct and sac was visualized; grade 2 included those in whom the membranous endolympathic duct and sac appeared only partially and without continuity; grade 3 included cases in whom the membranous endolymphatic duct and sac was not visible at all.

Results

With MRI, it was possible to visualize the membranous endolymphatic duct and sac in all healthy subjects in axial images.

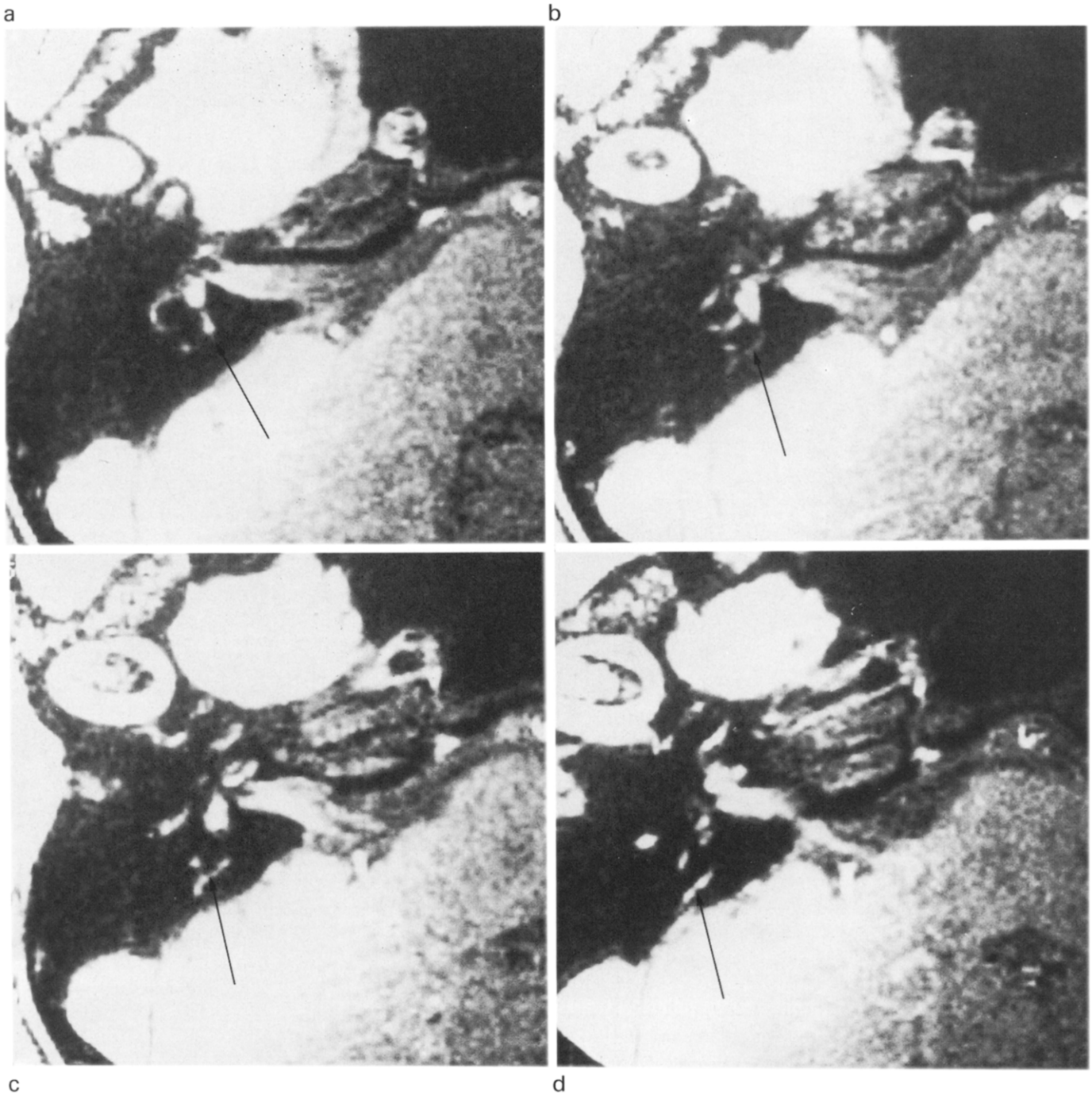

Fig. 2. Grade 1: The membranous endolymphatic duct and sac was visible along its entire range. Two-dimensional axial images are made successively from to the base cranium used by 3DFT: FLASH sequence. The arrow shows the membranous endolymphatic duct and sac running through the vestibular aqueduct.

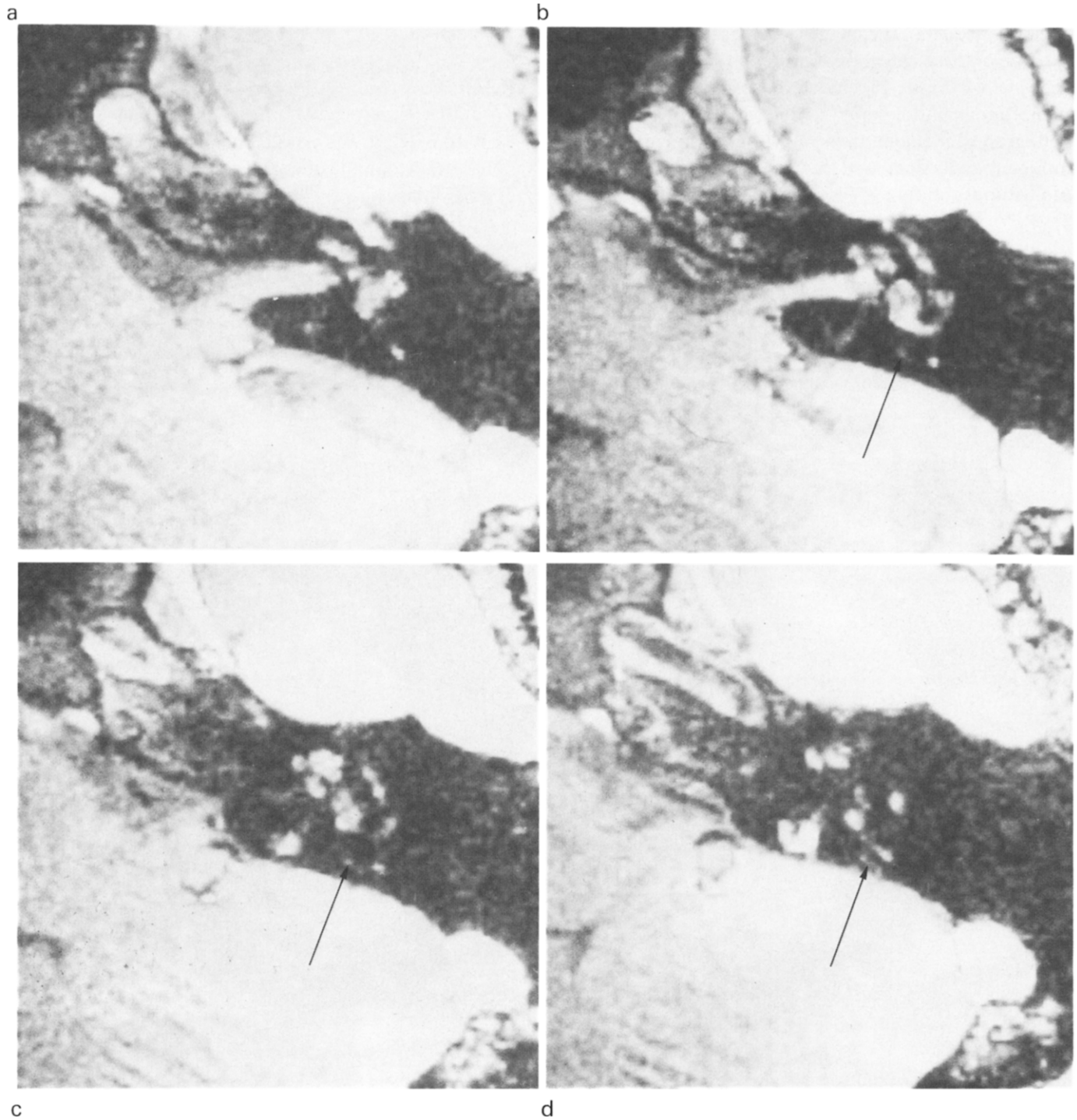

Fig. 3. Grade 2: The membranous endolymphatic duct and sac are only partially visible and without continuity. Two-dimensional axial images are made successively from the temple to the base of the cranium used by 3DFT: FLASH sequence.

Table 1 gives results of patients with unilateral Meniere's disease. On the affected side, 10 ears (83%) were classified as grade 3, 2 ears (17%) as grade 2, none of grade 1; whereas on the non-affected side, none of the ears were classified as grades 2 and 3, but 12 (100%) were grade 1. In healthy normal subjects, no ears were classified as grades 2 or 3.

Discussion

Since Clemis and Valvassori [11], using multidirectional tomography, found that the visualization rate of the vestibular aqueduct in Meniere's disease was low, there have been many reports of morphological studies using radiography [12–18].

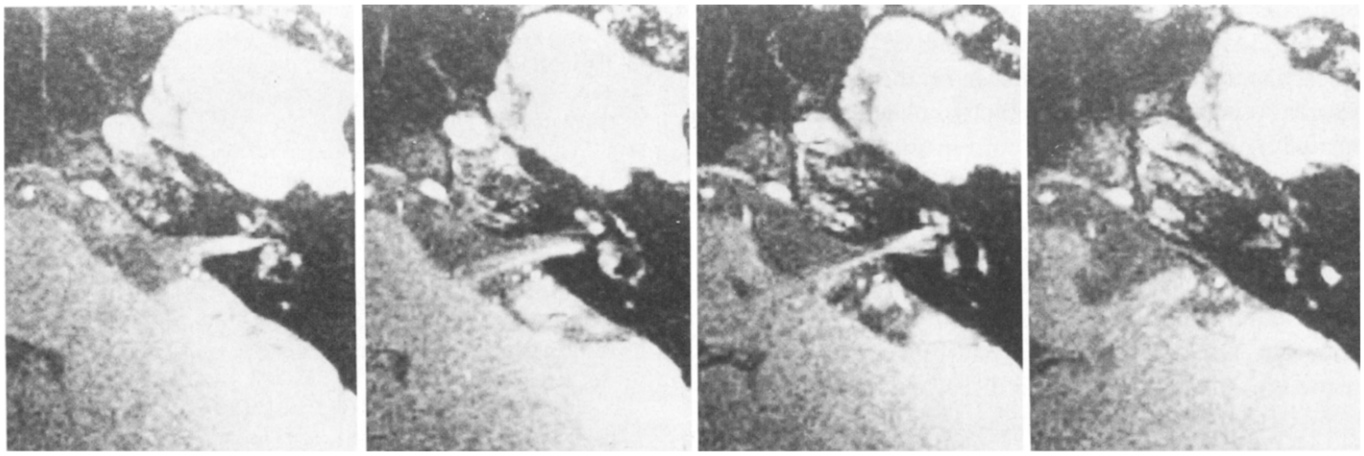

Fig. 4. Grade 3: The membranous endolymphatic duct and sac are not visible. Two-dimensional axial images are made successively from the temple to the base of the cranium used by 3DFT: FLASH sequence.

In addition, recent reports on the pathology of the temporal bone in Meniere's disease have included those of Egami et al. [19], Rizvi and Smith [20], and Yuen and Schuknecht [21]. Egami et al. reported cases in which the vestibular aqueduct and endolymphatic sac of Meniere's disease patients were clearly narrowed and Rizvi and Smith [20], on measuring the vestibular aqueduct at its point of maximum diameter, stated that there was no significant difference in the anteroposterior diameter, but that the aqueduct in Meniere's disease has a significantly smaller side-to-side diameter, at a probability rate of less than 0.5% ($P<0.005$). Yuen and Schuknecht reported as follows. Measurements were made of the widths of the vestibular aqueducts and endolymphatic ducts of the ears of 19 patients with Meniere's disease and an equal number of controls. The data show that the vestibular aqueducts of those with Meniere's disease are not different in caliber from those of unaffected ears. The endolymphatic ducts in Meniere's disease, however, were smaller than those of the control group. It seems probably that this alternation is the result of Meniere's disease, rather than the cause of Meniere's disease. The observation of Clemis and Valvassori [11] of a higher incidence of nonvisualization of vestibular aqueducts in ears with Meniere's disease is inconsistent with their data. Thus, according to findings of recent studies, there is a significant difference between normal subjects and patients with Meniere's disease, and pathological examination of the temporal bone indicates that the vestibular aqueduct (bony canal) and/or the membranous endolymphatic duct and sac are generally hypoplastic.

TABLE 1

Results of patients with unilateral Meniere's disease

Patients	Sex	Age (Yrs)	Visibility grade[1]	
			Right	Left
(1) FK	M	52	1	2*
(2) SS	M	29	3*	1
(3) KI	F	40	3*	1
(4) TI	M	47	1	3*
(5) YF	F	34	1	3*
(6) CK	M	55	1	3*
(7) HH	F	71	3*	1
(8) MT	F	27	3*	1
(9) AI	M	41	1	3*
(10) SK	F	71	3*	1
(11) TH	M	55	1	3*
(12) IK	F	42	2*	1

* Affected side.

[1] Visibility grades are: 1 = entire membranous endolymphatic duct and sac visualized; 2 = entire membranous endolymphatic duct and sac partialy visualized; 3 = entire membranous endolymphatic duct and sac not visible.

Morphological investigations with conventional radiological techniques, however, have examined the vestibular aqueduct as a bony passage, and have not dealt with the membranous endolymphatic duct and sac itself. In contrast, the imaging of the aqueduct with HR-MRI depicts both the membranous endolymphatic duct and sac. This indicates that it is now possible to obtain an understanding of the condition of the membranous endolymphatic duct and sac on MR images.

In this study, patients were selected bearing our hypothesis and disease model in mind; this because between the disease state, stage 3, and the predilective state, stage 2, reversibility is possible.

The number of subjects in the present HR-MRI study was small — only 12 patients with unilateral Meniere's disease. However, visualization of the membranous endolymphatic duct and sac running through the

vestibular aqueduct was not achieved on the affected side in 83% of the diseased patients. In none of these cases was the entire structure seen on the affected side; whereas it was always possible to visualize it (albeit partially) on the healthy side, and in some cases it was totally visible. Thus, there was a marked failure to visualize on the affected side. This finding suggests that the membranous endolymphatic duct and sac collapse, and/or hypoplasia/atresia of the vestibular aqueduct (bony canal) occur in the affected ear in Meniere's disease. The above findings and pathological reports indicate that the hypothesis and disease model presented in this study may help in the diagnosis of Meniere's disease. However, since the number of patients in this study is small, it is necessary to undertake an investigation on a larger population.

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