

HR 3 Tesla MRI for the Diagnosis of Endolymphatic Hydrops and Differential Diagnosis of Inner Ear Tumors – Demonstrated by two Cases with Similar Symptoms

HR-3-Tesla-MRT zur Diagnose des endolymphatischen Hydrops und Differentialdiagnose von Innenohrtumoren – demonstriert an zwei Fällen mit ähnlicher Symptomatik

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Key words

- head/neck
- ear
- MR imaging
- hearing loss
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Zusammenfassung

Das gleichzeitige Auftreten von verschiedenen Innenohrpathologien mit ähnlicher Klinik wie dem Morbus Menière und vestibulären Schwannomen ist sehr selten, führt aber bislang aufgrund der reduzierten diagnostischen Möglichkeiten in Bezug auf die der Therapieentscheidung zu einem Dilemma. Die Magnetresonanztomografie ist Goldstandard bei der Detektion und Verlaufskontrolle von intralabyrinthären Tumoren. Ergänzend bieten sich stark T2-gewichtete FLAIR-Sequenzen (4h nach i.v.-Injektion gadoliniumhaltiger Kontrastmittel) zur Diagnostik des Morbus Menière an, welche sowohl den Perilymph- als auch den beim Morbus Menière im Sinne eines endolymphatischen Hydrops distendierten Endolymphraum in vivo abbilden können. Bis heute wurden nur wenige Fälle eines synchronen Vorliegens intralabyrinthiner Schwannome mit einem endolymphatischen Hydrops berichtet, allerdings liegt unseres Wissens keine Studie mit dedizierter Darstellung von Endolymph- und Perilymphraum vor. Ziel dieser Studie war, nicht nur die Koinzidenz des endolymphatischen Hydrops und des vestibulären Schwannoms darzustellen, sondern darüberhinaus erstmalig Tumorgewebe und Endolymphpe voneinander mittels 3-Tesla-MRT zu differenzieren. Dies ist wesentlich für primär dem Morbus Menière zugeordneten Therapien. Mit der vorliegenden Arbeit beschreiben wir den Nutzen und die Anwendbarkeit der MRT auf intralabyrinthäre Tumoren an dem Beispiel einer Patientin mit einem intravestibulären Schwannom. Um die klinische Relevanz und den Einfluss auf die klinische Entscheidungsfindung zu demonstrieren, wird dieser Fall exemplarisch einem typischen Beispiel eines Patienten mit Morbus Menière entgegengestellt.

Abstract

The synchronous appearance of different inner ear pathologies with a nearly equivalent clinical manifestation such as Menière's disease and vestibular schwannoma is very rare but leads to a relevant dilemma concerning therapy options. MRI is the method of choice to detect intralabyrinthine tumors. Since endolymphatic hydrops is considered the morphological equivalent of Menière's disease, magnetic resonance imaging including hT2w-FLAIR sequences 4h after i.v. administration of gadolinium-based contrast agents (GBCA) allows the diagnosis and grading of endolymphatic hydrops in vivo synchronous to diagnosis and monitoring of ILT. To this day, only a few cases of intralabyrinthine schwannoma could be shown to appear simultaneously with endolymphatic hydrops by MRI, but to our knowledge the dedicated distinction of endolymphatic space has not been previously demonstrated. The aim of this work was not only to detect the coincidence of endolymphatic hydrops and vestibular schwannoma, but also to differentiate tumor tissue from endolymphatic space by 3 Tesla MRI. This enables therapy options that are originally indicated for Menière's disease. The aim of this work was to describe the feasibility and usefulness of endolymphatic hydrops MRI on intralabyrinthine tumors in a special case of intravestibular schwannoma to demonstrate the high clinical relevance and impact in therapeutic decision-making for the synchronous appearance of endolymphatic hydrops and intralabyrinthine tumors. Therefore, we present a typical case of Menière's disease in contrast to a patient with an intralabyrinthine schwannoma and Menière-like symptoms.

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Introduction

Schwannoma as a benign neoplasm deriving from the nerve sheath is the most common tumor of the inner auditory canal and the cerebellopontine angle. Less frequently they occur in the labyrinth, where they clinically appear with hearing loss, tinnitus and/or vertigo. Depending on the site of occurrence, a mimicking especially of Menière's disease (MD) and other inner ear-associated disorders is possible.

This synchronous appearance of different inner ear pathologies with nearly equivalent clinical manifestation is rare, but leads to a relevant dilemma concerning therapy options [1]: Especially vertigo as a typical symptom of Menière's disease has been considered as an indication for surgical therapy for intralabyrinthine tumors [2]. In contrast to this, vertigo caused by Menière's disease is commonly well treatable by conservative therapy, so the detection of a coincidentally appearing manifestation of Menière's disease is highly recommendable before initiating therapy.

The endolymphatic hydrops (EH) is considered as the morphological equivalent of Menière's disease. Therefore, new MR imaging techniques including hT2w-FLAIR-weighted sequences 4 h after i. v. administration of gadolinium-based contrast agents (GBCA) allow the in vivo diagnosis and grading of endolymphatic hydrops in nearly 90% of patients [3].

MRI is also the imaging gold standard for tumors in the cerebellopontine angle and the labyrinth [4]. Extralabyrinthine tumor manifestations accompanied by endolymphatic hydrops have been reported before [5]. However, to our knowledge no case of an intralabyrinthine tumor could be shown to appear simultaneously with endolymphatic hydrops. As the reported MR technique allows the differentiation between endolymphatic and perilymphatic space [6], its application for tumorous diseases of the inner ear and cerebellopontine angle seems to be highly recommendable.

The aim of this work was to describe the feasibility and usefulness of endolymphatic hydrops MRI for intralabyrinthine tumors in a special case of intravestibular schwannoma to demonstrate the high clinical relevance and impact in therapeutic decision-making for the synchronous appearance of endolymphatic hydrops and intralabyrinthine tumor manifestations. Therefore, we present a typical case of Menière's disease in contrast to a patient with an intralabyrinthine schwannoma and Menière-like symptoms.

Material and Methods

MRI 4 h after i. v. injection of GBCA has already been stated as a noninvasive tool for in vivo imaging of endolymphatic hydrops [6]. Depending on the MR scanner unit, different techniques and parameters are necessary. In this work we paradigmatically present our system settings on a Philips MR imaging unit. Sequence parameters follow.

During the initial MR scan the intravenous application of a single dose Gadovist®/Gd-DO3A-butrol (0.2 ml/kg or 0.1 mmol/kg body weight) was performed. The second MR scan for the evaluation of the degree of endolymphatic hydrops followed 4 h later.

The imaging was performed on a 3-Tesla MR imaging unit (Philips Achieva, Philips Medical Systems, Best, NL) using a 16-chan-

nel array head and neck coil. The evaluation of endolymphatic hydrops started with a T2DRIVE 3 D MR cisternography for anatomical reference of total lymph fluid. The parameters are: Repetition time (TR) of 2000 ms, echo time (TE) of 200 ms, flip angle of 90° and a refocusing angle of 120°. 1.0-thick axial slices covering the labyrinth were acquired, FOV 100 × 100 × 37.5 mm. The matrix size was 240 × 161, and the scan time was 4.5 minutes.

Afterwards, special sequences for the differentiation of endolymphatic and perilymphatic fluid as proposed by Naganawa et al. [6] were adapted to our scanner unit. The parameters for the positive endolymphatic image (PEI; VISTA-IR-2050) were: VISTA sequence; TR: 9000 ms; TE: 540 ms; inversion time: 2050 ms; SPAIR fat suppression pulse with an inversion delay of 220 ms, refocusing angle of 160°, matrix size: 126 × 163, FOV 150 × 179.2 × 57.6 mm, scan time: 9.5 minutes.

The parameters for the positive perilymphatic image (PPI; VISTA-IR 2350) were: VISTA sequence; TR: 9000 ms; TE: 540 ms; inversion time: 2350 ms; SPAIR fat suppression pulse with an inversion delay of 220 ms, refocusing angle of 160°, matrix size: 126 × 163, FOV 150 × 179.2 × 57.6 mm, scan time: 9.5 minutes.

1.0-thick axial slices were acquired for both PEI and PPI. After acquisition of the images, we acquired HYDROPS images after motion correction by subtracting PEI from PPI as proposed by Naganawa et al. [7]. For subtraction results, a negative signal value was allowed.

The acquired sequences were qualitatively analyzed on an EIZO workstation (EIZO Europe GmbH, Karlsruhe, Germany) using a GE PACS. Endolymphatic hydrops was graded by two different radiologists in a consensus procedure according to the criteria of Nakashima, Naganawa et al. [8].

In a special case of an intralabyrinthine tumor with endolymphatic hydrops, postprocessing by slice-by-slice segmentation of the outer margins of the labyrinth in MR cisternography, the endolymphatic space in the PEI and the schwannoma in contrast-enhanced T1w was performed using Amira 5.4 software (Visualization Sciences Group, Burlington, USA). The segmented volumes were transferred into a 3 D model to illustrate the different inner ear compartments.

Institutional review board approval was obtained for this study.

Results

Endolymphatic hydrops MRI is routinely applied in the case of patients suffering from Menière's disease without intralabyrinthine tumors. The following describes a case of intralabyrinthine schwannoma accompanied by endolymphatic hydrops to illustrate the capabilities of endolymphatic hydrops MRI (Patient 2). To point out the differences with respect to the standard Menière patient – especially regarding image evaluation and grading – a case of isolated endolymphatic hydrops is described (Patient 1).

Patient 1

A 57-year-old woman presented with recurring attack-like vertigo (duration: 1 – 12 h), right-sided hearing loss and vertigo in the right ear. On pure-tone audiometry, the right ear presented with low-tone sensorineural hearing loss, while left side hearing was in the normal range. Caloric testing was not applicable because of an implanted ventilation tube.

Temporal bone MRI was unsuspecting. Endolymphatic hydrops MRI 4 h after i. v. application of GBCA (EH-MRI) was performed. The grade of endolymphatic hydrops was scored separately for

the cochlea and vestibule according to the area ratio of the endolymphatic space on PPI against the total vestibular or cochlear fluid space [8]. EH-MRI revealed a significant combined (cochlear and vestibular) hydrops on the right side and a mild vestibular hydrops on the left side (► Fig. 1).

Patient 2

A 45-year-old woman initially presented two years ago with progressive left-sided hearing loss, ipsilateral ear fullness and initially fluctuating, now constantly active tinnitus in the left ear. Moreover, she reported repetitive staggering vertigo attacks lasting 40–60 minutes. On pure-tone audiometry, right side hearing was in the normal range, while the left ear showed low-tone sensorineural hearing loss. Caloric testing showed a slight hypoexcitability on the left side.

Temporal bone MRI revealed an intravestibular, sharply contoured T2-hypointense mass measuring 3 × 4 mm. On T1-weighted images it showed an intermediate signal intensity with a homogeneously and strongly enhanced signal after i. v. GBCA application.

Initially, wait-and-see management and the daily application of betahistine p.o. were proposed. Serial MRI after 1 year showed no relevant tumor progress. 6 months ago, the patient presented with a provokable vertigo attack, which was diagnosed as BPV and could be managed using the “barbecue maneuver”. Under medication, no non-provokable vertigo attacks occurred.

Serial MRI after 2 years was extended by heavily T2-weighted FLAIR sequences 4 h after the administration of GBCA for the evaluation of endolymphatic hydrops.

Serial MRI revealed a constant size of the initially described, strictly intravestibular localized tumor with homogenous contrast enhancement (► Fig. 2).

Endolymphatic hydrops showed a significant cochlear hydrops on the left side (► Fig. 3). Right-sided inner ear structures showed no hydropic endolymph. As the left-sided vestibular space is nearly filled with the described mass, the application of the proposed grading system in this case is not reasonable. Therefore, we performed slice-by-slice segmentation of the labyrinth in T2 cisternography sequences including the tumor (Amira 5.4 software Visualization Sciences Group, Burlington, USA). The same procedure was performed on the endolymphatic and perilymphatic space as presented in positive endolymph and positive perilymph images.

Volumetric analysis of the several fluid compartments showed a proportion of endolymph to the total vestibular fluid space (including the mass) of 37.0%. Compared to the contralateral vestibule with 3.14%, we stated this as mild vestibular hydrops relative to the aforementioned grading system.

A 3 D model gained by this slice-by-slice segmentation of the different sequences allows demonstration of the different compartments and exemplifies the presence of hydropic endolymphatic space close to the described tumor (► Fig. 4).

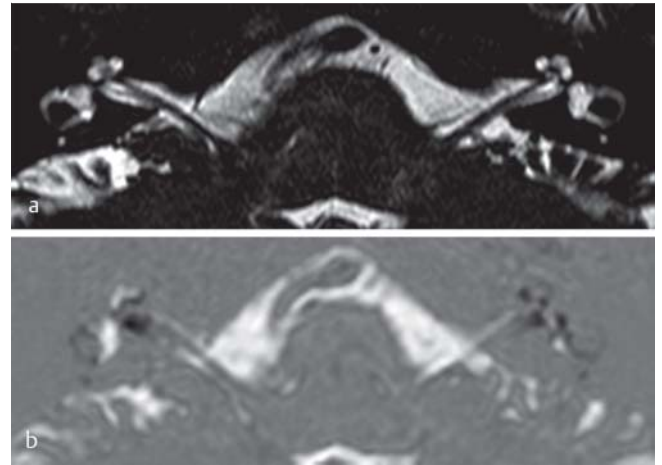


Fig. 1 T2DRIVE cisternography **a** shows a regular labyrinthine configuration without detection of intralabyrinthine tumor manifestations. HYDROPS subtraction (Positive Perilymph Image/PPI – Positive Endolymph Image/PEI, **b** after motion correction allows differentiation of diluted endolymphatic space (dark) in contrast to the perilymphatic space (bright). Qualitative analysis revealed a significant combined (cochlear and vestibular) hydrops on the right side and a mild vestibular hydrops on the left side.

Abb. 1 Die T2DRIVE-Zisternografie **a** zeigt eine reguläre labyrinthäre Konfiguration ohne Nachweis einer intralabyrinthären Tumormanifestation. Die HYDROPS-Subtraktion (Positive Perilymph Image/PPI – Positive Endolymph Image/PEI, **b** nach Bewegungskorrektur erlaubt die Differenzierung von dilatierendem Endolymphraum (Dunkel) vom Perilymphraum (Hell). Die qualitative Analyse führte zur Diagnose eines kombinierten (cochleären und vestibulären) Hydrops rechtsseitig und einem geringgradigen vestibulären Hydrops auf der linken Seite.

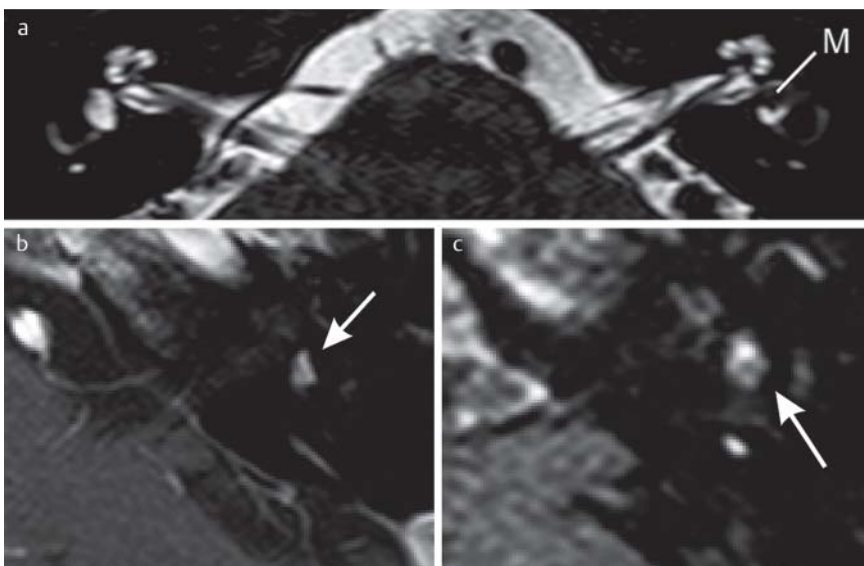


Fig. 2 T2DRIVE cisternography **a** shows a hypointense mass (M) with a diameter of 3 × 4 mm in the left vestibule. Contrast-enhanced T1 **b** and FLAIR **c** show homogenous enhancement of the tumor (arrow).

Abb. 2 Die T2DRIVE-Zisternografie **a** zeigt eine hypointense Raumforderung (M) mit einem Durchmesser von 3 × 4 mm im linken Vestibulum. Die kontrastmittelverstärkte T1 **b** und FLAIR **c** zeigen ein homogenes Enhancement des Tumors (Pfeil).

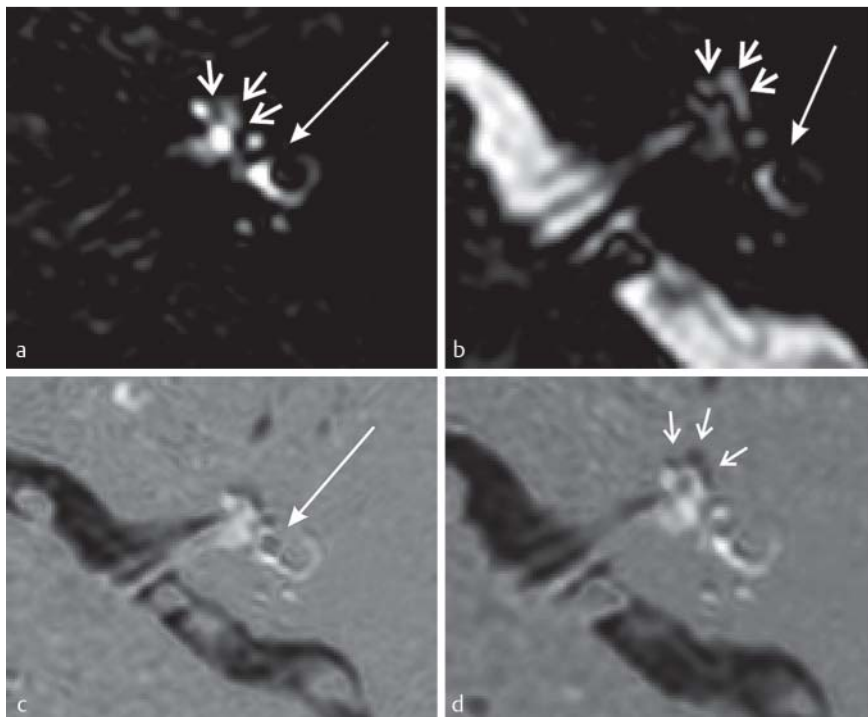


Fig. 3 After acquisition of VISTA heavily T2-weighted images, different inversion times allow the differentiation between endo- and perilymph fluid. With an IR of 2350 ms (Positive Perilymph Image = PPI, **a**) the endolymph is displayed as hypointense, while it appears as hyperintense in the Positive Endolymph Image (PEI, IR 2050 ms, **b**). The left ear shows a significant endolymphatic hydrops of the cochlea (short arrows). Furthermore, PPI and PEI both show a lack of contrast enhancement in the tumor area (long arrow). The HYDROPS subtraction (PPI-PEI) reveals that the tumor area is surrounded by distended endolymphatic space, graded as mild vestibular hydrops (**c**, long arrow). In a different slice of the subtraction images with full recognition, the amount of the significant cochlear hydrops is displayed (**d**, short arrows). Possible motion artifacts in the area of interest of the HYDROPS subtraction have been minimized by manual motion correction before subtraction.

Abb. 3 Nach Akquisition von ht2w VISTA-Bildern ermöglichen unterschiedliche Inversionszeiten die Differenzierung zwischen Endo- und Perilymphe. Mit einer IR von 2350 ms Positive Perilymph Image = PPI; **a** erscheint die Endolympe hypointens, während sie im Positive Endolymph Image PEI, IR 2050 ms, **b** hyperintens imponiert. Das linke Innenohr weist einen signifikanten endolymphatischen Hydrops der Cochlea auf (kurze Pfeile). Darüber hinaus weisen beide Sequenzen ein defizitäres KM-Enhancement im Bereich des beschriebenen vestibulären Tumors auf (langer Pfeil). Die HYDROPS-Subtraktion (PPI-PEI) verdeutlicht, dass der Tumor von distendiertem Endolymphraum im Sinne eines milden endolymphatischen Hydrops umgeben ist (**c**, langer Pfeil). In einer anderen Schicht der Subtraktionsbilder mit voll erfasstem Modiolus zeigt sich die volle Ausprägung des cochleären Hydrops (**d**, kurze Pfeile). Mögliche Bewegungsartefakte in den relevanten Bildabschnitten der HYDROPS-Subtraktionen wurden durch eine manuelle Bewegungskorrektur vor der Subtraktion minimiert.

Discussion

To our knowledge, this is the first description of contrast-enhanced endolymphatic hydrops MRI on an intralabyrinthine tumor manifestation.

The diagnosis of intralabyrinthine schwannoma is still rare. To date, only about 140 cases have been reported [9, 10], but due to the improvement of magnetic resonance imaging techniques the number of detected cases is rising. Depending on the location of the tumor, intralabyrinthine schwannomas can be differentiated into seven categories: Intravestibular, intracochlear, intravestibulo-cochlear, transmodiolar, transmacular, transotic and tympano-labyrinthine [11].

The tumor manifestation has variable presenting symptoms, which are able to mimic other inner ear disorders such as Menière's disease. The coincidence of endolymphatic hydrops and extralabyrinthine tumors has been previously reported [5]. To our knowledge, the reported case is the first one of an intralabyrinthine tumor with endolymphatic hydrops. These reports lead to the hypothesis of a pathophysiologic link between both disorders. Some publications have detected an elevated perilymphatic protein concentration occurring with vestibular schwannoma

[12, 13]. Another hypothesis would be a mechanical stenosis or obstruction of the endolymphatic space leading to altered intralabyrinthine fluid dynamics and maybe endolymphatic pressure elevation. However, we are not able to state a causal relationship between endolymphatic hydrops and intralabyrinthine schwannoma. Further investigations in this research area are needed.

As surgical treatment options of tumors invading the labyrinth lead to a loss of inner ear functions, Kennedy et al. stated that serial MR monitoring is the best method of management due to the low growth rate of intralabyrinthine schwannomas [11]. Nevertheless, the presented case shows that the patient profits from conservative therapy of Menière's disease. Especially under consideration that vertigo has been reported to be one of the risk factors of intralabyrinthine tumor growth [14] and as an indication for surgical removal [2], the in vivo diagnosis and monitoring of Menière's disease is highly desirable before therapeutic decision-making. Probably, several patients with treatable Menière's disease and an intralabyrinthine tumor may be spared post-surgical hearing loss by early MR evaluation of endolymphatic hydrops before indication of surgery. This emphasizes the tremendous relevance of endolymphatic hydrops MRI not only for the assessment of Menière's disease, but also for other disorders which may occur with vertigo

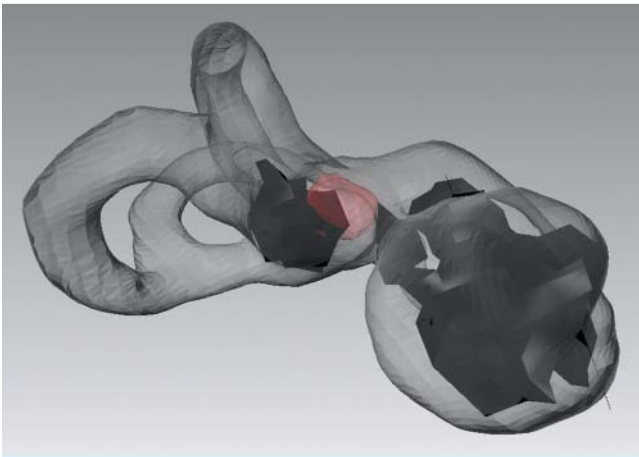


Fig. 4 3D model of the left inner ear gained by slice-by-slice segmentation of the different compartments. Hyropic endolymphatic structures are illustrated as black structures, and the intralabyrinthine tumor in the vestibule is colored red. 3D slice-by-slice volumetry revealed an amount of endolymph of 37.0%. Due to 3D postprocessing effects, single voxels are not represented in this graphic.

Abb. 4 3D-Modell des linken Innenohrs nach Slice-by-slice-Segmentation der verschiedenen Kompartimente. Die hydropischen endolymphatischen Strukturen sind schwarz dargestellt, der intralabyrinthine vestibuläre Tumor rot. Die durchgeführte 3D-Slice-by-slice-Volumetrie ergab einen Anteil der Endolymphe von 37,0%. Aufgrund von 3D-Nachbearbeitungseffekten sind einzelne Voxel in der Grafik nicht abgebildet.

or are associated with vestibular tumors. Concerning this, further investigations, especially in the research of the pathophysiology of endolymphatic hydrops are strongly needed.

In contrast to recent publications on intralabyrinthine tumors using non-enhanced MRI [5], the i.v. application of GBCA not only allows the diagnosis of endolymphatic hydrops, but also is able to differentiate between endolymphatic and perilymphatic space. In this case, we could show the absence of endolymphatic and perilymphatic fluid in the tumor and therefore we could differentiate the different tissues not only by contrast enhancement characteristics for the first time. As a matter of course, in this context the preexisting quantitative and qualitative grading systems are inaccurate. In this regard, the proposed 3D volumetry of the inner ear's fluid compartment seems to be the most exact method of measurement and grading.

Pragmatically, intravenous GBCA application methods with MRI measurement 4 hours after injection are easily integratable into the standard imaging routine and serial MRI. In contrast to intratympanic GBCA application occurring with a 24 h latency between Gadolinium application including special patient positioning after injection [15], only the standard i.v. dose as routinely applied for serial MRI is necessary. Therefore, we recommend this procedure as the method of choice.

Obviously there are some limitations for this study: Still, the histological proof for endolymphatic hydrops is not possible in vivo without destruction of the labyrinth and consecutive loss of inner ear function. Moreover, the diagnosis of vestibular Schwannoma has not been verified histologically yet, but with regard to the MR-morphologic picture aspect and the growth characteristics it seems to be the most probable explanation.

Prospectively, there is good cause to believe that the sensitivity of hT2w-FLAIR to detect very small intralabyrinthine tumors

is higher than standard contrast-enhanced MRI. Especially for screening purposes in hereditary diseases such as neurofibromatosis type 2, the utility of these sequences should be evaluated prospectively.

Disclosure

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