Imaging of the Inner Ear at 7T: Initial Results

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Introduction

Until recently, visualization of the membrane structures of the inner ear has been limited to the detection of normal fluid signal intensity within the bony labyrinth. New developments in 3D sequences based on constructive interference in the steady state (CISS) or fast spin-echo (FSE) techniques have shown to provide excellent depiction of the nerves within the internal auditory canal as well as the fluid within the labyrinth at 1.5T and 3.0T [1,2]. At the same time, ultra-high field MR imaging at 7T has emerged as a high-resolution and high-contrast imaging technique for the brain. Unfortunately, with standard technology diagnostic imaging of the inner ear is severely hampered by substantial signal loss at the interface between the inner ear and its surroundings due to severe inhomogeneities both in B_0 and B_1. This study clarifies how to overcome these challenges and resulted in diagnostic high-resolution T2-weighted imaging of the inner ear structures at 7T.

Subjects and Methods

Four healthy volunteers (3 women; mean age, 19.0 years [age range, 18-21 years]) underwent MR imaging at a 7 Tesla scanner (Philips Achieva, Best, the Netherlands) using a T/R volume coil in combination with a 16-channel receive coil (Nova Medical). The sequence parameter were as follows: VISTA (Volumetic ISotripic Turbo spin-echo Acquisition), TR/TE of 4844/278 ms, excitation flip angle of 150 degrees, no refocusing pulse angle sweep, FOV of 160×160×20mm, acquired voxel size of 0.4×0.4×0.5mm^3, reconstructed voxel size of 0.25×0.25×0.25mm^3, 80 partitions, SENSE factor of 2.5, slice phase encoding oversample factor of 1.8, 4 start-up echoes, scan time of 16m43s. Prior to the VISTA scan, a B_0 map was acquired at the location of the inner ear, which was used for 3rd order image based shimming after brain extraction using the FSL brain extraction tool (BET) [3]. B_1 maps were performed using the double TR map according to Yarnykh et al [4]. One radiologist specialized in inner ear imaging evaluated the images. A total of 9 anatomical parts of the inner ear (cochlear aqueduct (CA), four nerve bundles in internal auditory canal (NB), cochlear modiolus (CM), interscalar septum (IS), macula utriculi (MU), macula sacculi (MS), crista ampullaris (CA), singular canal (SC), and osseous spiral lamina (OSL)) were assessed using a 4-point-grading scale (3: clearly demonstrated, 2: demonstrated, 1:demonstrated but nuclear, 0: not demonstrated).

Results

Reliable B_1 mapping in the area of the petrous bone in the presence of inhomogeneous B_1 and B_0 fields is quite challenging The actual flip angle achieved in the petrous bone was estimated to be 50% of the flip angle that was set in the protocol, requiring overcompensation (150 degrees) of the applied excitation flip angle. The results of the image evaluation are summarized in Table 1. Large objects (CA, NB, CM, IS) were visualized perfectly. MU, SC, and OSL were moderately visualized; i.e. image quality was nearly equivalent to that achieved at 3T. Small objects such as MS and CA were not sufficiently well visualized. Figure 1 shows representative images.

Table 1. *Scores (mean ± SD) regarding the visual evaluation of the anatomical parts of the inner ear.*

cochlear aqueduct	3.00±0.00
four nerve bundles	3.00±0.00
cochlear modiolus	3.00±0.00
interscalar septum	3.00±0.00
macula utriculi	2.17±0.75
macula sacculi	0.83±0.98
crista ampullaris	0.50±0.55
singular canal	2.67±0.52
osseous spiral lamina	2.83±0.41

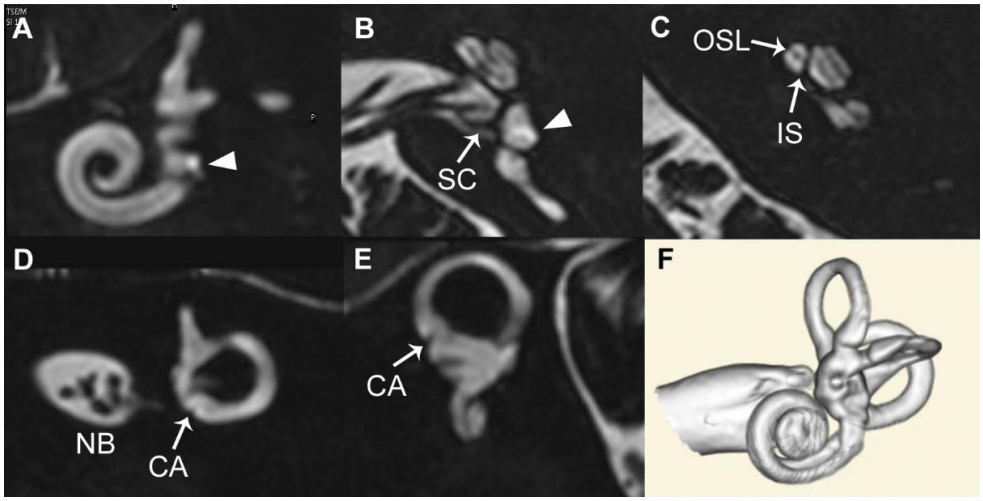

Figure 1. *High-resolution inner ear images obtained in a healthy volunteer. Coronal oblique image through cochlea (A), axial source images (B,C), sagittal oblique images through posterior (D) and superior (E) semicircular canals, and volume rendering image (F) show fine inner ear structures. Susceptibility artifact is noted at the vestibulum (arrowheads).* ***SC****: singular canal,* ***OSL****: osseous spiral lamina,* ***IS****: interscalar septum,* ***NB****: nerve bundles in internal auditory canal,* ***CA****: crista ampularis*

Conclusions

To our knowledge, this is the first time the inner ear was imaged at 7T using a 3D-turbo spin echo sequence. Although not all parts of the inner ear could be visualized well due to inhomogeneities, our results are promising and may have a positive impact for future (MR) studies of cochlear implants. Improvement in B1 shimming and dedicated RF pulses are expected to further improve image quality.

References

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