High resolution inner ear imaging at 7 Tesla

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Target audience: Clinicians and researchers involved in imaging for cochlear implantation.

Purpose: To optimize high resolution structural imaging of the inner ear at 7 Tesla.

Introduction: High resolution MR imaging of the inner ear is used in patients suffering from a variety of diseases, including tinnitus, hearing loss, or in preoperative screening for cochlear implants (1, 2). The inner ear is comprised of the cochlea, the vestibular system and the endolymphatic duct and sac. The small size of these substructures requires high resolution imaging to detect subtle changes in the fine intralabyrinthine structures. As a result a high magnetic field strength can be beneficial in achieving sufficient spatial resolution in an acceptable scanning time. Spin echo sequences are required due to the large local magnetic field inhomogeneities (B_0), however their use is difficult due to the inhomogeneous B_1^+-field. This abstract describes the steps that have been taken to enable high resolution T_2-weighted imaging of the inner ear anatomy at 7 Tesla.

Methods: High resolution T_2-weighted images have been acquired using the following parameters: TR/TE/TSE factor =3000ms/200ms/69, 0.3mm isotropic voxels, SENSE = 2.5x1.5, 160 slices and scan duration of approximately 10 minutes. A 32 channel receive and quadrature transmit coil (Nova Medical, Wilmington, MA) was used at a Philips Achieva 7 Tesla system (Philips Healthcare, The Netherlands). Two high permittivity pads, consisting of deuterated barium titanate ($\varepsilon_r \approx 290$), were designed using numerical simulations and placed next to the ear to enhance the B_1^+-field at the inner ear (3). Simulations of the B_1^+- have been performed, with and without the placement of dielectric material. In four subjects T_2-weighted images have been acquired. One subject was scanned with and without dielectric pads and one subject was scanned both at 7T and 1.5T for comparison.

Results and Discussion: Figure 1 shows the effect of the dielectric pads on the transmit efficiency and image quality, the top row shows the simulations (the dielectric pads are illustrated in white) and the bottom row shows a transverse thin slice maximum intensity projection (MIP) of the entire region of the inner ear. Without pads the areas of low B_1^+ intensity overlap almost completely with the inner ear (white arrow). The dielectric pads yield a substantial local improvement in the B_1^+-field, which results in much improved signal from the inner ear. Figure 2 shows a single slice through the cochlear nerve and perpendicular to it. There is excellent contrast and spatial resolution to differentiate between the branches of the cochleovestibular nerve and facial nerves, the individual turns of the cochlea, which are separated into 2 scalae by the spiral osseous lamina and part of the semicircular canals. Figure 3 shows a 3D MIP of the cochlear system visualizing the 3D anatomy of the cochleavestibular system. When the high resolution images are compared to those obtained at 1.5T (figure 4), it is clear that the improved spatial resolution results in much clearer delineation of the nerve and intracochlear anatomy, allowing for improved diagnosis and preoperative planning of cochlear implants.

Conclusion: The use of 7T MRI results in very high resolution imaging of the inner ear system. The intrinsic B_1^+ inhomogeneities can be mitigated by placing dielectric pads next to the ear. The high spatial resolution leads to improved visualization of the substructures of the inner ear anatomy. Future patient studies are planned to determine the clinically added value of the improved resolution.

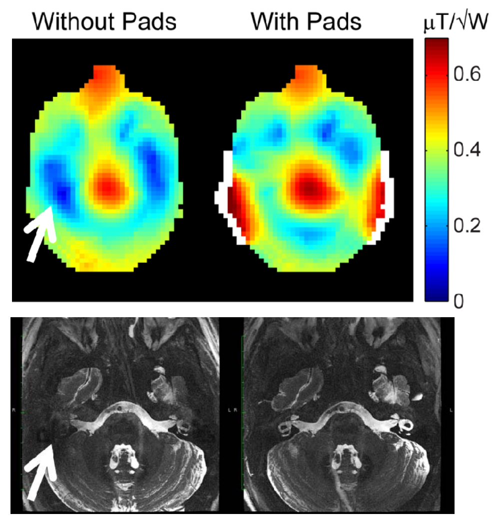

Figure 1: Effect of dielectrics on B_1^+-field. Simulations (top) and 7 Tesla in vivo images (bottom).

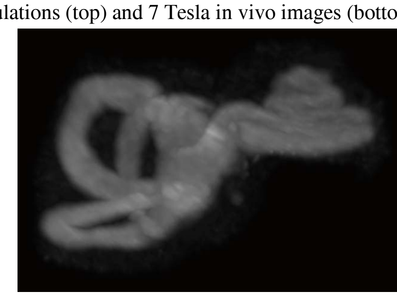

Figure 3: 3D MIP. The image shows the complex 3D structure of the cochlea and semicircular canals.

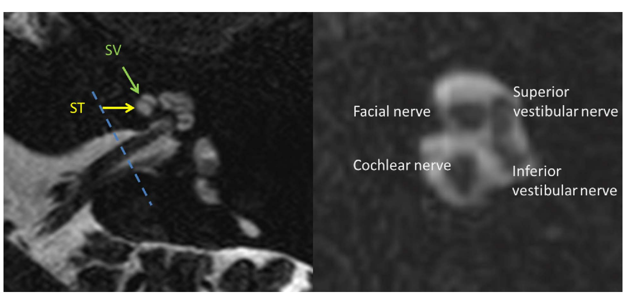

Figure 2: High resolution T_2-weighted images. Individual slice through the cochlear nerve, showing the cochlea and part of the vestibule and posterior semicircular canal (left). Within the cochlear turns there is a clear delineation of the scala vestibuli (SV) and scala tympani (ST) On an oblique multiplanar reconstruction (MPR), perpendicular to the cochlear nerve, the different branches of the cochleovestibular nerve and facial nerve are well seen (right).

References:

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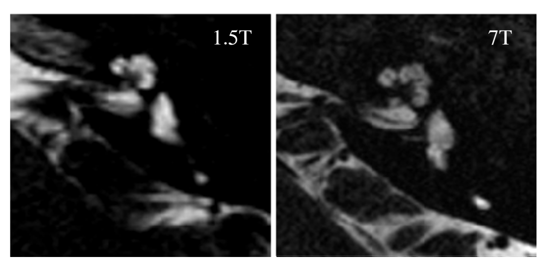

Figure 4: 1.5T vs. 7T Left image shows images acquired at 1.5T at 0.4x.4.1.4mm^3 resolution. Right image obtained at 0.3mm isotropic, revealing much more detail of the fine intrachochlear anatomical structures such as the modiolus, interscalar septum and spiral osseous lamina. Also note the sharper delineation of the inferior vestibular nerve in the internal acoustic meatus .