Micro-MR of the Cochlea on a Conventional 1.5T Scanner with Small Single-Channel Surface Coils

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Introduction

Imaging microscopy of the temporal bone is a useful tool in the creation of morphologic models that include the internal structures of the cochlea [1]. Information obtained from MR images is shown to be useful in the assessment of cochlear implant candidates [2]. CT Microscopy has been demonstrated to produce fine bone detail, allowing for 3D reconstruction of the bony labyrinth [3], but internal structure is not well visualized. 3D linear-combination steady-state free-precession (LC-SSFP, also called CISS, SIMCAST, FIESTA-C) produces in-vivo images of the cochlea with superior SNR to that of 3D fast-spin echo (FSE) at 3T [4-6] with 80-mm and 100x60-mm/60x45-mm coil phased arrays [7-8]. Although SNR scales linearly with field strength in the body-noise dominated regime and by a factor of $B_0^{(7/4)}$ in the coil-noise dominated regime [9], susceptibility banding artifacts inherent to LC-SSFP will also increase, as will the need for more phase cycles. We present MR microscopy of a temporal bone sample using LC-SSFP with 3 different surface coil sizes at 1.5 T. Images of the sample acquired using micro-CT are provided for comparison.

Methods

A previously frozen and thawed human cadaver temporal bone sample was immersed in saline prior to scanning with a GE Excite 1.5 T MR scanner equipped with 40 mT/m amplitude and 150 T/m/s slew rate gradients. A 6 x 6 x 3 cm^3 volume was scanned using 3 different size surface coils: a GE 3-inch (76-mm) coil, and 2 Doty coils of 38-mm and 32-mm diameter. The Doty coils were modified with a home-built Q-spoiling cable designed for our system. The body coil was used for transmit. An LC-SSFP sequence with TR/TE of 13.1/6.3 ms, 2 phase cycles, and a receive bandwidth of 25 kHz was used to acquire the volume with 187 μm resolution in-plane, and 600 μm resolution in the slab direction. Scan time was 7 min, 32 s using partial *k*-space acquisition in the phase-encoding direction. After images were reconstructed using homodyne then maximum-intensity projection (MIP) functions, image masks were made with which to calculate the SNR of the cochlea. The sample was then imaged using a Scanco Medical VivaCT 40 micro-CT scanner. The entire specimen was imaged using 2320 slices at 19 μm isotropic resolution. The scan time was 3 hours.

Results

SNR was measured in the cochlea to be 4, 9, and 10 using the 76-mm, 38-mm, and 32-mm coils, respectively. Figure 1 shows a 3x2 cm portion of an oblique slice through the cochlea, with clear visualization of the scala vestibuli, scala tympani, and osseous spiral lamina of the middle turn, along with the apical turn. Although a cross-section of the vestibule is located within the slice, an air bubble likely caused by a fracture caused a small area of signal dropout in that structure. Figure 2 shows 2 of the micro-CT slices through the cochlea. Although thin bone separating the cochlear turns can be seen, the osseous spiral lamina are not visible as distinct structures. The cochlea was also located at the center of the image, and affected by a ring-shaped aliasing artifact from CT projection rays. In Figure 3, similar slices to the CT images (with the bone rotated with respect to Figure 1,) containing a cross-section of the cochlea with all 3 turns is shown for each of the 3 coils. Air signal dropout affects visualization of the vestibule, but the cochlea and connection to the IAC is well visualized.

Conclusion

We demonstrate that MR microscopy of the temporal bone can be performed at 1.5 T using a single receive surface coil, with fewer phase cycles than needed at 3T. Despite excellent bone detail with 19-μm isotropic resolution, micro-CT does not give contrast of structures internal to the cochlea such as the scalar laminae. With a scan time of only 24 minutes, an MR 3D data set could be acquired with 200 μm isotropic resolution, enough to render a 3D surface that includes inner cochlear structure. We suspect that the combination of bone detail available with micro-CT and the detail of fluid-filled internal structures with micro-MR can be used to create a high-quality volume dataset.

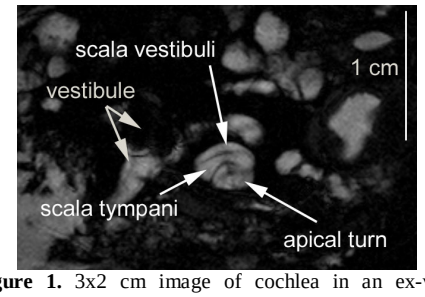

Figure 1. 3x2 cm image of cochlea in an ex-vivo temporal bone, imaged using the 32-mm surface coil and 3D LC-SSFP. Resolution is 187 μm in-plane, and 600 μm in the slab-direction. The scala vestibuli and scala tympani are well visualized.

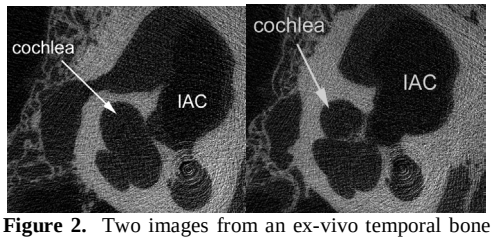

Figure 2. Two images from an ex-vivo temporal bone sample using micro-CT, with 19-μm isotropic resolution. Scan time for the image set was 3 hours.

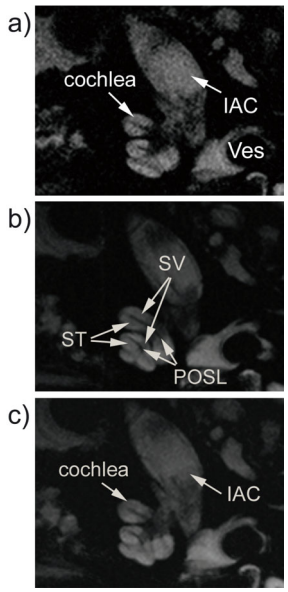

Figure 3. Images of the same ex-vivo temporal bone (different scan, bone rotated) using 3D LC-SSFP with 187 μm in-plane and 600 μm slab-direction resolution. Abbreviations: *IAC*: internal auditory canal, *Ves*: vestibule, *SV*: scala vestibuli, *ST*: scala tympani, and *POSL*: primary osseous spiral lamina. Scan time: 7 min, 32 s for a 6x6x3 cm^3 volume. Primary osseous spiral lamina, separating the two scalae, is seen in basal and mid cochlea turns. Images were acquired using an a) 76-mm surface coil, b) 38-mm surface coil, and c) 32-mm surface coil.

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