High Resolution 3T MR Imaging of the Cochlea Using Composite Gradients and Intratympanic Gadolinium in an Animal Model

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PURPOSE: High-resolution magnetic resonance (MR) imaging has become a valuable tool for evaluation of the inner ear. Advanced cochlear MR imaging techniques combine cisternographic anatomic imaging via balanced steady state or turbo spin echo T2 weighted sequences with intravenous or intratympanic gadolinium enhanced T1 weighted sequences. On clinical 3T MR scanners, maximum spatial resolution for cochlear imaging reported in the literature has reached 0.3 mm isotropic voxels using a 3D variable flip-angle FSE technique.[1] Our institution has developed a novel MR composite gradient system that operates both whole body and local insert gradients simultaneously, which increases gradient amplitude and slew rates and allows for high spatial resolution while maintaining acceptable signal to noise ratio (SNR) and scan duration.[2] The purpose of this study is to demonstrate improved spatial resolution with 3T MR imaging of the inner ear using this composite gradient system at double the body gradient strength in an animal model.

MATERIALS & METHODS: Sacrificed guinea pigs obtained from an unrelated study group were placed in a custom designed transmit/receive RF coil. MR imaging was performed on a Siemens 3T TIM Trio scanner. 3D constructive interference in steady state (CISS) MR imaging was obtained of both cochleas using the body gradient coil alone and using the composite gradient system with the following parameters: (1) Body gradient at 0.2 mm isotropic voxel size: TR/TE 12.2/6.1 ms, NEX 2, scan time 10 min 11 s; (2) Composite gradient at 0.2 mm isotropic voxel size: TR/TE 6.7/3.4 ms, NEX 2, scan time 5 min 58 sec; and (3) Composite gradient at 0.1 mm isotropic voxel size: TR/TE 10.9/5.5 ms, NEX 2, and scan time 16 min 21 s. After the administration of intratympanic contrast, 3D fast low angle shot (FLASH) MR imaging with the composite gradient at 0.1 mm isotropic voxels was performed continuously for 12 hours with the following parameters: TR/TE 20/3.1 ms, NEX 2, scan time 17 mins. The body gradient operated at 40 mT/m strength and 200 T/m/s slew rate; the composite gradient was set at 80 mT/m and 400 T/m/s.

RESULTS: Composite gradient CISS imaging achieved 8-fold (4-fold in-plane) increase in spatial resolution (0.1 mm isotropic) compared to the body gradients alone (0.2 mm isotropic) with 61% increased scan time (increased number of slices) and acceptable SNR (Figure 1). Equal spatial resolution was obtained with the composite gradient (0.2 mm isotropic) in 41% less scan time than the body gradient alone with no perceptible change in SNR and less banding artifact (Figure 1). FLASH after intratympanic gadolinium administration showed intracochlear enhancement with 0.1 mm isotropic voxel resolution. 12 hour averaged FLASH images demonstrated the vestibular (Reissner's) membrane (a thin membrane which separates the scala media and the scala vestibuli chambers of the cochlea).

DISCUSSION: Increased gradient performance via the composite gradient MR system reduces time to echo (TE) and thus repetition time (TR) in CISS imaging, allowing for decreased imaging time or increased resolution with similar imaging time compared to the body gradient alone. Banding artifact is also reduced by decreasing TR. Post intratympanic contrast FLASH imaging benefits from the composite gradients via decreased TE, which deemphasized the T2* effect of gadolinium and increases SNR.

CONCLUSION: Composite gradient MR imaging of the cochlea can achieve spatial resolution higher than a conventional body gradient system with satisfactory SNR and marginally increased scan time relative to the gain in resolution. Ongoing and future projects include live animal imaging with intratympanic and intravenous contrast to compare resolution, SNR, and conspicuity of the microstructures of the inner ear between gradient systems and routes of gadolinium administration. Potential clinical applications are improved detection of endolymphatic hydrops and cholesteatomas, significantly changing therapy and preserving hearing and inner ear function.

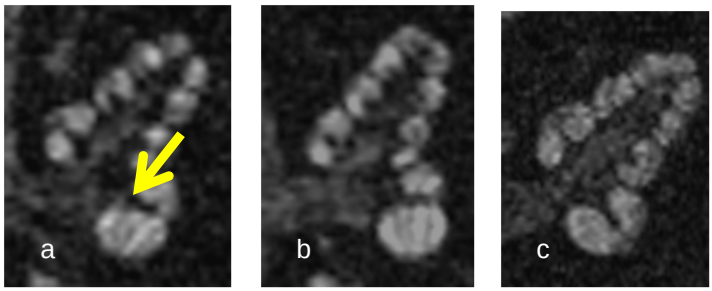

Figure 1. Comparison between noncontrast 3D CISS acquisitions using the body and composite gradients. **a:** 0.2 mm isotropic voxel image using the body gradient alone shows the basilar membrane (arrow) separating the scalar chambers of the cochlea. Hypointense lines coursing perpendicular through the scalar chambers are banding artifact. **b:** 0.2 mm isotropic voxel image using the composite gradient was obtained in 41% less time and with mildly decreased banding artifact. **c:** 0.1 mm isotropic voxel image using the composite gradient demonstrates higher resolution and decreased banding artifact.

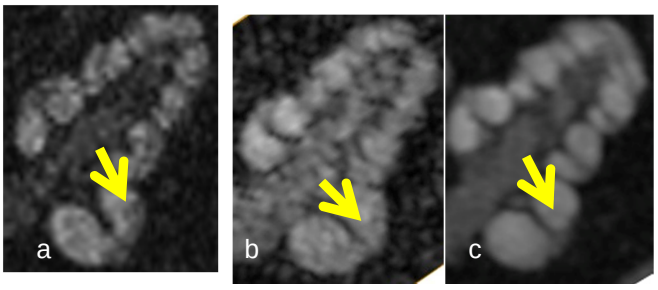

Figure 2. Comparison between noncontrast 3D CISS and post contrast 3D FLASH using the composite gradient. **a:** 0.1 mm isotropic voxel noncontrast CISS image using the composite gradient shows the expected region of the vestibular membrane (arrow). It is difficult to differentiate the vestibular membrane from banding artifact and noise. **b:** 0.1 mm isotropic voxel FLASH image after intratympanic contrast shows a hypointense line (arrow), but low SNR limits evaluation. **c:** 0.1 mm isotropic voxel post intratympanic contrast FLASH image averaged over 12 hours shows clear depiction of the vestibular membrane (arrow) with markedly increased SNR compared to **b**.

References

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