High Resolution Cochlear Imaging with Dual Gradients

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Introduction: The diagnosis of inner ear pathology has been historically subjective. High resolution MRI of the temporal bone enables the diagnosis of certain diseases such as acoustic neuroma and cochlear fibrosis. Resolution of the fine ultrastructure of the cochlea remains elusive given the limits of standard MRI gradient systems. Endolymphatic hydrops, the pathologic inner ear state associated with Meniere's disease, has only been seen in histopathologic preparation in humans [1]. Clinical diagnosis remains subjective, based on history and audiometric evaluation [2]. Although early studies using high resolution MRI in high field small bore MRI scanners have allowed detection of hydrops in animal models, current human MRI systems do not allow for the objective diagnosis of hydrops in humans [3,4,5,6,].

Ultra high resolution MRI capable of resolving cochlear infrastructure has been performed in small bore MRI scanners which have increased field strength and higher gradient performance. We hypothesize that improved images of the cochlear infrastructure may also be obtained on high field human MRI scanners which have increased gradient performance. To test this hypothesis a head and neck insert gradient has been developed for simultaneous use with the whole body gradients of our 3T research MRI scanner. The use of dual gradients will allow double or triple resolution without increasing repetition time or bandwidth. This should decrease artifact and noise, allowing for improved cochlear imaging. To test the utility of this dual gradient system we scanned the temporal bone of guinea pigs with the whole body gradients alone and then with the dual gradients and compared image quality.

Methods: Deceased guinea pigs obtained from a previous study group were placed in a RF transmitting/receiving wrist coil. Imaging was performed on the Siemens 3T TIM Trio scanner (Siemens Healthcare AG, Erlangen Germany). The standard system was augmented with three additional gradient amplifiers and master/slave configured computers capable of controlling extra RF and gradient channels. The control hardware and software were developed and provided by Siemens. A separate pulse sequence was used to control each gradient set. For these experiments, the master computer served four purposes: 1) to maintain the first-order gradient shims using the standard system gradients, 2) to control RF excitation and reception 3),to control the standard system gradients for imaging and 4) trigger the slave computer. The slave computer executed a pulse sequence controlling the head gradient insert coil [7].

Table 1 Varied acquisition parameters

	Body	Dual
FOV(mm)	50x100	37.5x50
Matrix	160x320	240x320
Acquisition Time (min)	6:33	9:50
Inplane Resolution (mm)	0.3x0.3	0.15x0.15

Results: The T2 weighted images of a guinea pig cochlea in Figure 1 were obtained using constructive interference in steady state (CISS) with TE/TR 6.38/12.76 ms, bandwidth=130 Hz/pixel, with slice thickness = 0.3mm. Other parameters summarized in Table 1. The increased acquisition time does recover some of the SNR lost in the higher resolution images.

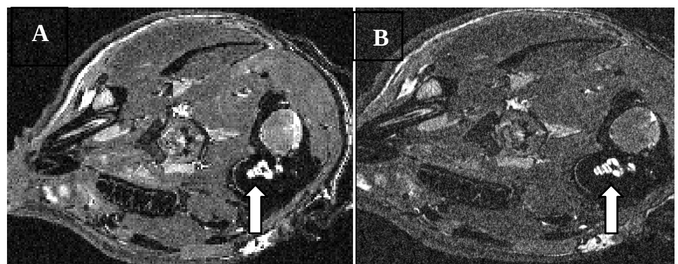

Figure 1: Axial T2 weighted CISS images of normal guinea pig cochlea (arrow) using a) body gradients alone and b) whole body + insert gradient.

Discussion: Results from this early work in animals are promising in that the improved resolution seen with the composite gradient system not only demonstrates better visualization of the cochlea, but may actually allow for differentiation of the cochlear fluid compartments. High resolution imaging of the inner ear in humans is but one potential utility of this novel system which allows for the simultaneous use of insert gradients and body gradients. This system would be particularly useful clinically in that in addition to the improved imaging obtained with the composite system over insert gradient coils alone, it would allow for the use of body gradients alone for conventional clinical studies without the need for removing the insert gradients. Our hope is to develop imaging protocols for human temporal bone studies using a high field (3T) human whole body scanner with a head and neck insert gradient coil operating simultaneously in a dual gradient mode. These early comparisons showing improved visualization of cochlear infrastructure in animals are evidence of the potential of this system to resolve the fine detail of the human cochlea in a way in which there may at last be an objective test for the diagnosis of inner ear pathology.

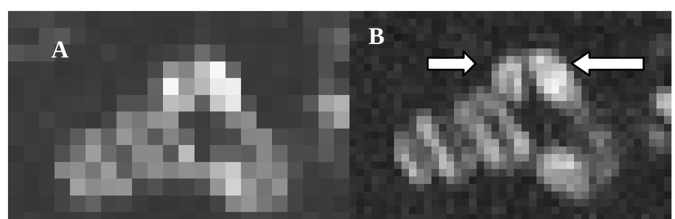

Figure 2: Enlargement of cochlea demonstrating 3 of the 4 cochlear turns in a) body gradients alone it is possible to see the apical 3 turns, in b) composite gradient system, in addition to the turns it is possible to visualize the cochlear chambers scala vestibuli (large arrow) and scala tympani (small arrow) in the basilar turn.

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