High Resolution Imaging of the Membranous Labyrinth: a comparison of 3D CISS and 3D SPACE at 1.5T

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Introduction

Recent advances in MR imaging of the inner ear yields spatial resolution that extends its use beyond traditional roles to permit visualization of the more prominent sub-structures of the membranous labyrinth[1]. This high resolution information can be useful in the clinical evaluation of cochleovestibular symptoms such as tinnitus, vertigo and hearing loss, and could potentially be employed to diagnose endolymphatic hydrops (Meniere's disease). Two T2-weighted 3D techniques, CISS (trueFISP-based) and SPACE (TSE-based), are commonly used in this capacity[2] and have been demonstrated to produce high resolution isotropic images of the membranous labyrinth. The purpose of this study is to determine which of these pulse sequences performs better for imaging labyrinthine sub-structures.

Methods

Nineteen (19) ears of fifteen (15) healthy volunteers were scanned on a 1.5T Avanto MR scanner (Siemens Healthcare, Erlangen, DE). High resolution, isotropic volumes through the IAC were acquired unilaterally with both the 3D CISS and 3D SPACE pulse sequences in an oblique sagittal plane coplanar with the superior semi-circular canal (Poschl's plane) using a two-channel flexible surface coil (Carotids Coil, Machnet, Eelde, NL), placed over the external auditory canal. The imaging protocol, matched between the two sequences in terms of imaging volume, resolution, and imaging time, used an 80mm FOV with a 192x192 acquisition matrix to produce 0.4 mm isotropic resolution. For CISS, the acquisition parameters (TR/TE/#signal averages/BW/flip) were 6.3 ms/2.68 ms/3/310 $Hz \cdot px^{-1}$/80°. For SPACE they were 1400 ms/130 ms/2/300 $Hz \cdot px^{-1}$/180°. The acquisition time for each sequence was 10 min for the first 5 volunteers, but was reduced to 7 min for the latter 10 volunteers to improve subject compliance. The coverage and number of partitions in the slice direction was decreased to obtain this reduction along with a 100 ms decrease in the TR of the SPACE acquisition. Further, the order of acquisition of SPACE and CISS was randomized to reduce potential bias in the results due to patient fatigue.

Cases were reviewed and scored by three radiologists with respect to general image quality, perceived CNR, sharpness, lack of artifacts impacting the region of interest and the conspicuity of several prominent substructures within the labyrinth. The two techniques for each case were presented side by side. The scoring was a direct comparison for each case on an integer scale of -3 to +3, where -3 indicated a strong preference for the technique presented on the left and +3 a strong preference for the right. The side on which each technique was presented was randomized from case to case throughout the review process. The ratings were analyzed using a nonparametric Friedman test for several related samples adjusted for multiple observers[3]. An estimate of the CNR between the utricle and the macula was also measured in each case.

Results

Radiologists' scores for general image quality, perceived CNR, sharpness and absence of artifacts demonstrated a preference for T2 SPACE over CISS ($p<0.001$). Conspicuity of the utricular membrane, utricular macula (*see Fig 1*) and the cochlear nerve hiatus were also perceived to be better with SPACE ($p<0.001$) as was the christa ampularis (*Fig 1*) ($p<0.005$). SPACE was also favored for detection of the basilar membrane in all 3 turns of the cochlea (basal, $p<0.001$, medial & apical, $p<0.005$). Measured CNR was slightly higher for CISS (67 vs. 53) ($p<0.05$).

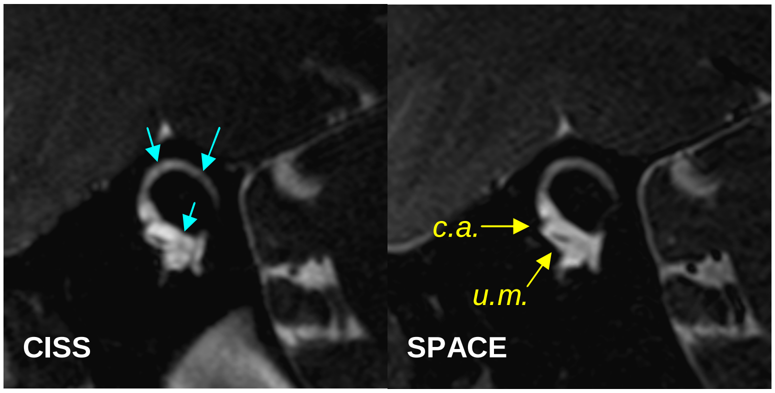

Figure 1: Sample images from one subject showing typical results from the two techniques. Blue arrows show CISS banding artifacts. Yellow arrows identify the christa ampularis (*c.a.*) and the utricular macula (*u.m.*).

Discussion

Due to the summation step in the CISS acquisition, it is more sensitive to motion induced blurring than SPACE. Because CISS is trueFISP-based, it is also prone to residual banding artifacts in regions of rapid spatial variation of susceptibility (see blue arrows in Figure 1). In general, these artifacts are minor in the CISS acquisition compared to trueFISP, but still they frequently overlap features of interest. Reviewers consistently perceived the CNR of SPACE to be higher than that of CISS, even when measurements of CNR suggest the opposite. This is most likely due to an increased sharpness in the SPACE images which was perceived as higher contrast. Susceptibility changes also induced "blooming" in the CISS images, which was perceived as a fuzzier appearance making it more difficult to accurately delineate labyrinthine substructures. We speculate that this could potentially have a negative impact on the accuracy of quantitative measures of these substructures.

Conclusion:

T2 SPACE more reliably depicts the structures of the membranous labyrinth that are detectable at the current limits of resolution. Further studies using this technique are warranted to determine the normal size and position of these structures in an effort to establish imaging criteria for labyrinthine disease.

References: 1)Lane JI et.al. Am J Neuroradiol. 29:1436-40. 2008. 2)Ward HA. et.al. ISMRM #1819, 2007. 3)Conover WJ. Practical Nonparametric Statistics: 3rd Edition. 1999; 383-385.