Comparison of 3D FSE-XETA with 3D FIESTA-C and 3D FRFSE for Imaging of the Internal Auditory Canal at 3T

H. A. Ward[1], R. F. Busse[2], D. W. Stanley[2], T. J. Kaufmann[1], J. I. Lane[1], and R. J. Witte[1]

[1]Department of Radiology, Mayo Clinic College of Medicine, Rochester, MN, United States, [2]GE Healthcare, United States

Introduction: MR imaging of the Internal Auditory Canal (IAC) is important for the pre-surgical evaluation of cochlear implant candidates. 3D fast recovery fast spin-echo (FRFSE) and 3D steady-state free precession based sequences (3D CISS or 3D FIESTA-C) can both reliably identify pertinent anatomy of the IAC at 3T [1]. While 3D FIESTA-C provides high SNR enabling small FOV imaging, it suffers from residual susceptibility "banding" artifacts within the bony labyrinth (Fig. 1). Pulsatile blood flow within the carotid artery can also obscure anatomy of interest in some patients. 3D FRFSE has much less SNR than 3D FIESTA-C, and the blurring inherent to long echo trains coupled with low SNR makes it less sensitive to signal within the semicircular canals and endolymphatic duct. An MR hydrographic protocol using variable refocusing flip angle 3D fast spin echo [2,3] (3D FSE-XETA) was developed in an effort to better visualize the utricle and semicircular ducts. Here, the three imaging techniques, 3D FRFSE, 3D FIESTA-C, and 3D FSE-XETA are compared directly across 12 volunteers imaged at 3T.

Methods: Twelve volunteers were scanned on a 3T Excite Twinspeed scanner (General Electric, 12.0M4) with an 8-channel brain coil (MRI Devices). All protocols used zoom mode, a 12cm FOV in the axial plane, 512x512 reconstruction matrix, and 0.6 mm slice thickness. The three protocols included: 1) 3D FIESTA-C with 6.7ms/3.3ms/1/±42kHz (TR/TE/NEX/BW), 70° flip angle, no phase-wrap, 256x256x64, scan time=4:22. For this FOV, ±42kHz minimized the TR. 2) 3D FRFSE with 2000ms/102ms/2/±32kHz, 64 ETL, no phase-wrap, 256x192x42, scan time=8:28. Two NEX were required for no phase-wrap, requiring a reduction in phase-matrix to save time. 3) 3D FSE-XETA with 3800-4800ms/712ms/1/±32kHz, 224 ETL, SENSE reconstruction to avoid phase-wrap, 256x224x100, scan time ~7:00. For 3D FSE-XETA, which uses hard refocusing RF, the minimum refocusing flip angle was optimized for hydrography (100°), and crusher gradients set to suppress artifacts from out-of-slice signal. Protocols were acquired in random order to reduce any effect of subject compliance and comfort on image quality.

Regions of interest were drawn on oblique sagittal reformats to measure the mean signal of the facial nerve (S_{FN}), CSF within the IAC (S_{CSF}), and background signal within the temporal bone (S_{BG}). Contrast to noise ratio (CNR) was defined as $(S_{CSF} - S_{FN}) / S_{BG}$. Three radiologists rated the images for several image quality characteristics including perceived CNR, sharpness, artifacts within the labyrinth, and overall image quality on a scale of 1 to 9. The ratings were analyzed using the nonparametric Friedman test for several related samples adjusted for multiple observations.

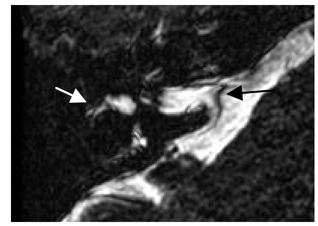

Figure 1: Residual susceptibility artifact (arrows) with FIESTA-C due to minor patient motion.

Results: Example images for each protocol are shown in Fig. 2. Table 1 shows that on average, the CNR of FSE-XETA was much higher than FIESTA-C, which in turn was higher than FRFSE. Median radiologist rankings along with their statistical significance are shown in Table 2. Radiologist ratings indicated a strong preference for either FSE-XETA or FIESTA-C over FRFSE on most categories. FSE-XETA provided less susceptibility artifact within the bony labyrinth, while FIESTA-C provided sharper edges. There was no statistical difference between FIESTA-C and FSE-XETA for perceived CNR or overall image quality.

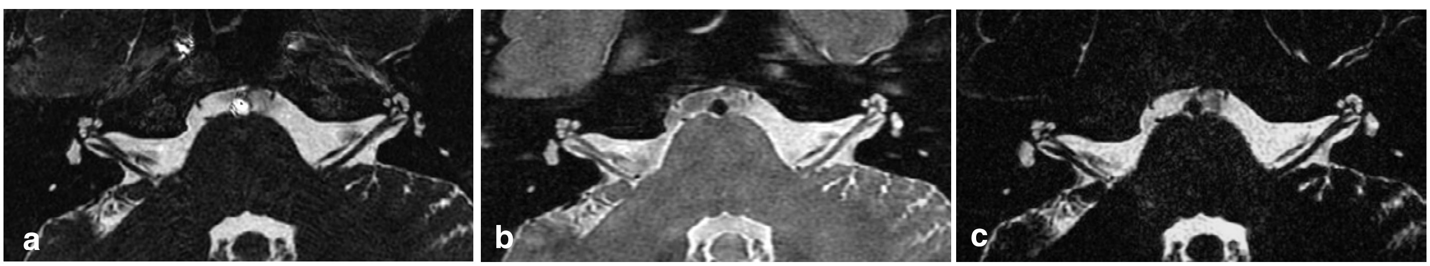

Figure 2: Example images from a single volunteer for 3D FIESTA-C (a), 3D FRFSE (b), and 3D FSE-XETA (c) protocols.

Discussion: Protocols were designed with the minimum number of slices that provided both adequate SNR and anatomical coverage. While not ideal for comparing SNR per unit time, it allows the more realistic evaluation of how subject motion factors into the image quality of the scanning technique. While SNR would be higher if we had scanned more FIESTA-C images, it is possible that any gain in SNR would be degraded by subject motion.

With the long TR necessary for the FSE-XETA, there is the potential to reduce CSF flow artifacts through the use of peripheral gating. It is also conceivable that navigator echoes could be incorporated to correct for head motion in real time. Neither of these options are practical with the steady-state condition required for FIESTA-C. Thus, 3D FSE-XETA shows great promise for imaging of the temporal bone.

References: [1] Lane et al. *AJNR* 25:618, 2003.
[2] Busse *Proc. ISMRM* #2430, 2006.
[3] Busse et al. *MRM* 55:1030, 2006.

Table 1	FIESTA-C	FSE-XETA	FRFSE
Mean CNR ± s.d.	7.6 ± 2.1	11.2 ± 4.7	4.0 ± 1.4
p-value	← 0.001 →	← 0.001 →	
	←	0.001	→

Table 2: Median difference in rating [range]	FIESTA-C minus FSE-XETA	FSE-XETA minus FRFSE	FIESTA-C minus FRFSE
Perceived CNR	1 [-2, 3]	1*** [-1, 6]	2*** [-1, 6]
Sharpness	1.5* [-2, 3]	2*** [-1, 4]	2.5*** [-1, 6]
Artifacts within labyrinth	-2*** [-6, 5]	1* [-1, 4]	-2 [-6, 6]
Overall image quality	0.5 [-6, 4]	1** [-1, 4]	2*** [-3, 5]

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$