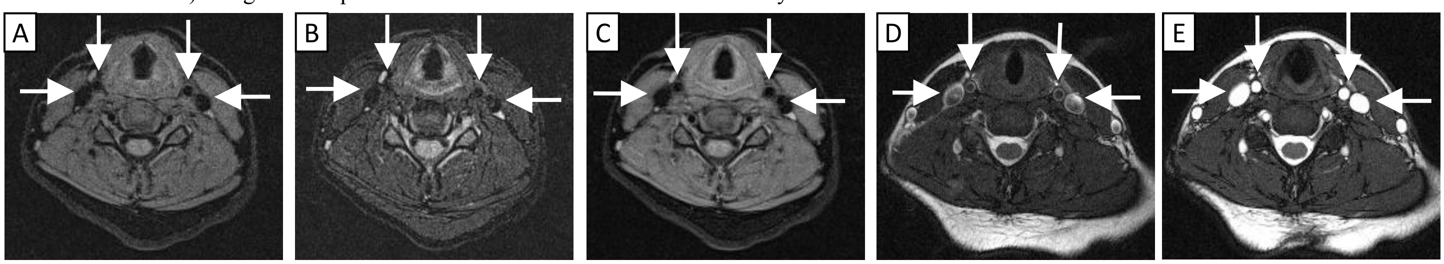
Carotid and Jugular Vessel Wall Imaging - A Study

K. Dara[1,2], D. P. Hsu[2,3], J. J. Derakhshan[1,2], J. A. Jesberger[2], J. L. Duerk[1,2], V. Gulani[2], J. L. Sunshine[2], T. L. Carman[4], and M. A. Griswold[1,2]

[1]Department of Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States, [2]Department of Radiology, University Hospitals of Cleveland, Cleveland, Ohio, United States, [3]Department of Neurosurgery, University Hospitals of Cleveland, Cleveland, Ohio, United States, [4]Department of Vascular Medicine, University Hospitals of Cleveland, Cleveland, Ohio, United States

INTRODUCTION: There is an increasing interest in imaging vessel wall atherosclerotic and stenotic disease as they are major causes of morbidity and mortality. Ultrasound is commonly employed, but there are problems with reliably visualizing atherosclerotic depositions and differentiating between plaque and hemorrhage in echolucent plaques (1). In MRI, atherosclerotic plaque deposition in the outer walls can be visually undistinguishable using bright blood (BB) angiography. However, dark blood (DB) imaging techniques suppress the bright blood signal in the vessel lumen, allowing for better examination of vessel wall depositions and subsequent remodeling. The gold standard for DB imaging is turbo spin echo (TSE) which has long acquisition times as compared to bSSFP sequences. HEFEWEIZEN or 'Halting the effects of flow enhancement with effective intermittent zeugmatographic encoding' eliminates many of the pitfalls of dark blood imaging (2). It is built with an underlying bSSFP framework in which the spatial encoding gradients in some TR blocks are replaced by spatially selective saturation pulses, resulting in directional flow suppression while maintaining the in-slice steady state (2). In this work, we compared the efficacy of the multi-slice 2D HEFEWEIZEN with multi-slice 2D DB prepared TSE as well as axial images from 3D time-of-flight (TOF) sequences for high resolution, high SNR imaging of carotid and jugular vessels.

METHODS: HEFEWEIZEN, T1-w, T2-w and PD-w DB TSE and TOF images were acquired in the necks of 19 asymptomatic volunteers in an IRB approved study using a 1.5T MRI scanner (Siemens Espree, Erlangen, Germany) with standard receiver coils. The sequence parameters were similar to Derakhshan et al (2). In the HEFEWEIZEN sequence, the flowing blood signal was suppressed above and below the imaging slice. The acquired images were subjected to a flow and stationary tissue suppression analysis. Regions-of-interest (ROI) were manually drawn around the carotid and jugular vessels and in the anterior cervical musculature. Flow and stationary tissue suppression values were then calculated from these ROIs as stated in (2). The acquired images were anonymized and provided to a neuroradiologist. The metrics for qualitative analysis by the radiologist included: vessel wall visibility and visible flow suppression scored from -2 through 0 to +2, -2 signifying 'worst visualization' and +2 signifying 'best visualization'; artifacts (affecting vessel wall visibility) scored from -2 through 0, -2 signifying 'severely degraded', -1 signifying 'degraded' and 0 signifying 'no degradation'; perceived image quality scored from -2 through +2, -2 signifying 'very poor SNR' and +2 signifying 'very high SNR' and contrast (between the lumen and vessel wall and between the vessel wall and surrounding tissue) scored from -2 through +2; -2 signifying 'very poor contrast' and +2 signifying 'very good contrast'. The scores were then analyzed using the Minitab statistical software for significance (at a 95% confidence interval) using the non-parametric Kruskal-Wallis and Mann-Whitney tests.



Images from an asymptomatic volunteer (A) T1- (B) T2- (C) PD-w DB TSE (D) HEFEWEIZEN (E) True-FISP. Flow suppression in the carotid and jugular vessels is seen in (A-D). Vertical and horizontal arrows point toward carotid and jugular vessels respectively.

RESULTS: ROI analysis demonstrated 83 ± 2% carotid and 79 ± 3% jugular blood flow signal suppression and 12.8 ± 7% suppression in the stationary tissues using the HEFEWEIZEN sequence. Score analysis from the radiologist is shown in the table. Representative images from an asymptomatic volunteer are shown above.

Factor	HF vs T1-w DB TSE	HF vs T2-w DB TSE	HF vs PD-w DB TSE	HF vs TrueFISP	HF vs TOF
Vessel Wall Visibility	No significance	No significance	No significance	HF > TrueFISP ($p=0.0466$)	HF > TOF ($p<0.0001$)
Visible flow suppression	T1 > HF ($p=0.0001$)	T2 > HF ($p=0.0014$)	PD > HF ($p=0.0001$)	HF > TrueFISP ($p<0.0001$)	HF > TOF ($p<0.0001$)
Artifact	No significance	No significance	No significance	No significance	No significance
Perceived image quality	HF > T1 ($p=0.0003$)	HF > T2 ($p=0.0009$)	HF > PD ($p=0.0004$)	TrueFISP > HF ($p=0.0003$)	TOF > HF ($p=0.044$)
Contrast	HF > T1 ($p=0.0038$)	HF > T2 ($p=0.0125$)	HF > PD ($p=0.0253$)	No significance	No significance

Statistical analysis of HEFEWEIZEN (HF) sequence against T1-w, T2-w, PD-w DB TSE, TrueFISP and TOF at a 95% confidence interval

DISCUSSION: The HEFEWEIZEN sequence provides high resolution, high SNR dark-blood images where the bSSFP contrast is maintained in non-vascular tissues. The arterial and venous vessel flow suppression values and the stationary tissue signal saturation values obtained in this study are in accord with literature values (2). Due to flow suppression, vessel wall visibility and visible flow suppression in HEFEWEIZEN images is significantly better than in TrueFISP and TOF images. However, flow suppression is better in T1-, T2- and PD-w DB TSE images, though it comes with an increase in image acquisition time (not shown). Due to its underlying bSSFP framework, HEFEWEIZEN images have a statistically significant improvement in perceived image quality over DB prepared TSE. The subjective contrast between lumen/vessel wall and vessel wall/surrounding tissue was judged to be better with HEFEWEIZEN than with the dark blood TSE sequences.

ACKNOWLEDGEMENTS: This work was supported by Siemens Medical Solutions. JJD is supported in part by NIH F30HL094002 from the NHLBI.

REFERENCES: (1) Nordestgaard BG, et al.; Curr Opin Lipidol 2003; 14:505-512.
(2) Derakhshan JJ, et al.; JMRI 2009; 29:1163-1174.