

# DIFFUSION WEIGHTED 3D DARK BLOOD SSFP IMAGING OF THE THORACIC AORTA: INITIAL CLINICAL EVALUATION

A. Kirpalani<sup>1</sup>, I. Koktzoglou<sup>1</sup>, K. Dill<sup>1</sup>, T. Carroll<sup>1</sup>, D. Li<sup>1</sup>, J. Carr<sup>1</sup>  
<sup>1</sup>Department of Radiology, Northwestern University, Chicago, IL, United States

**INTRODUCTION:** Dark blood magnetic resonance (MR) imaging is typically implemented as a two dimensional (2D) double inversion–recovery (DIR) turbo spin echo (TSE) [1] and is routinely used in the thoracic aorta to evaluate diseases of the vessel wall, such as atherosclerosis, vasculitis and dissection. Limitations of 2D DIR TSE dark blood include long acquisition time due to the long preparation time associated with the DIR technique, limited coverage due to 2D technique, and reliance on complete inflow of blood into the imaged slice for dark blood effect. A novel imaging sequence using diffusion prepared segmented steady-state free precession (DIFF-SSFP) is proposed in this work for 3D dark blood imaging of the aorta in a long axis oblique (LAO) orientation. This new sequence has several advantages over conventional DIR-prepared 2D TSE dark blood imaging: reliance on motion (i.e. diffusion) of blood (rather than complete inflow) for dark blood image contrast; facilitating imaging of thick 3D slabs in arbitrary orientations; 3D slab imaging where anatomic coverage and spatial resolution can be increased; and faster gradient echo imaging using SSFP. Because of these advantages, 3D DIFF-SSFP may have applicability in both assessment of diseases of the aortic wall, and as a non-contrast enhanced alternative sequence in 3D contrast-enhanced MR angiography (3D CE-MRA) of the aorta.

**PURPOSE:** To evaluate a novel 3D dark blood diffusion-prepared SSFP imaging technique for assessment of thoracic aorta pathology and to compare the technique with ECG-gated 3D CE-MRA.

**METHODS:** Sixteen consecutive patients presenting for 3D CE-MRA of the thoracic aorta were imaged with (a) 3D DIFF-SSFP prior to gadolinium administration, and subsequently with (b) conventional 3D CE-MRA. Both techniques used ECG gating, while only the DIFF-SSFP method was done during free breathing. Imaging was performed with a 1.5 T Siemens Avanto scanner. Imaging parameters for 3D DIFF-SSFP were: TR = 1 R-R interval, FOV = 281×202 mm<sup>2</sup>, matrix = 256×184, iPAT factor of 2, 20 2-mm-thick partitions, 71 segments/TR, BW = 980 Hz/pixel, TA ≈ 90 sec, fat saturation, b-value = 1.91 s/mm<sup>2</sup>. For CE-MRA, gadolinium (0.2 mmol/kg) was administered intravenously at 4 mL/s. Imaging parameters for CE-MRA were: TR/TE = 2.8/1.4; flip angle = 20°; FOV = 380 x 285; matrix = 512 x 310; iPAT factor 2; 6/8 partial fourier; 56 1.6-mm thick partitions; acquisition time 20 secs. Double-oblique multiplanar reformations were performed for both imaging sequences and two orthogonal measurements of aortic diameter were obtained at four locations in the thoracic aorta (sinotubular junction, mid ascending aorta, proximal aortic arch, and proximal descending aorta). Linear regression analysis was performed to determine agreement in aortic diameter measurements between the two imaging sequences. 3D image sets from both methods were assessed by 2 independent observers for image quality (scale 1-5) and presence of pathology.

**RESULTS:** The agreement in orthogonal diameter measurements at all four levels in the thoracic aorta was assessed using linear regression analysis. The linear regression coefficient ( $R^2$ ) was 0.917 (Fig. 1). Using CE-MRA values as predictors of DIFF-SSFP measurements, the slope and y-intercept of the linear regression equation were 0.998 and -0.06, respectively (Fig. 1). Image quality was scored similarly for both techniques ( $p > 0.05$ ). Using CE-MRA as the standard of reference, the DIFF-SSFP method detected all relevant pathology noted on CE-MRA (Fig. 2).

**DISCUSSION:** Diffusion weighted 3D dark blood SSFP imaging has similar accuracy to ECG-gated CE-MRA for measuring orthogonal dimensions and detecting pathology in the thoracic aorta. DIFF-SSFP shows improved depiction of the aortic wall and may be a useful adjunct to CE-MRA thereby providing a more comprehensive assessment of aortic pathology. While potential limitations of 3D DIFF-SSFP as implemented here include respiratory motion, the next iteration of this technique may be combined with navigator gating. This novel method of dark blood imaging holds promise in both vessel and plaque imaging as well as for the purpose of 3D MR angiography.

**REFERENCES:** [1] Fayad et al. Circulation. 2000; 101:2503-9

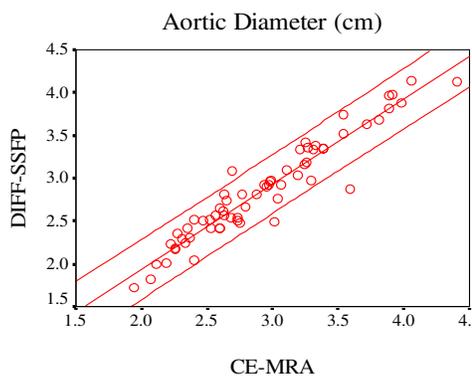


Figure 1: Linear regression analysis showing the relationship of aortic measurements using DIFF-SSFP relative to measurements using CE-MRA. 95% confidence intervals are shown. Excellent correlation was observed:  $R^2 = 0.917$ .

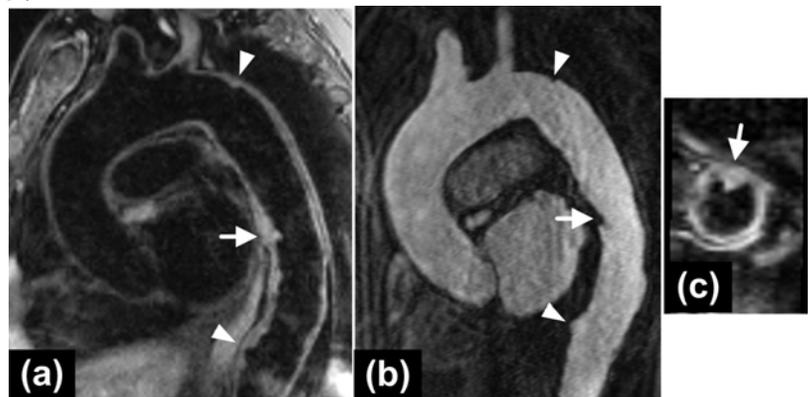


Figure 2: LAO reformations of the thoracic aorta constructed from the 3D DIFF-SSFP (a) and CE-MRA (b) volume sets. An irregular atherosclerotic plaque in the anterior wall of the descending aorta is well depicted with DIFF-SSFP (arrow) and its presence is observed in the CE-MR angiogram. An orthogonal slice through the plaque using DIFF-SSFP is shown in (c). Note the excellent agreement or aortic wall morphology as depicted with CE-MRA and 3D DIFF-SSFP (arrowheads).