Imaging of Abdominal Aortic Aneurysm Morphology and Inflammation using 3D Isotropic Black Blood MRI

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Target audience: Radiologists and MR physicists who are interested in aortic aneurysm imaging and risk stratification.

Purpose: Abdominal Aortic Aneurysm (AAA) disease is a common condition with high morbidity and mortality. Current clinical management based on diameter alone has poor ability to predict AAA progression or rupture. Recent MRI studies demonstrated that AAAs with fresh thrombus [1] or inflammation [2] grew 2-3 times faster than AAAs without. However, these studies were limited by coarse through plane resolution (~5mm). 3D MRI studies of the abdominal aorta have been reported in volunteers, but were limited by long scan times (~22 minutes), which are poorly tolerated by patients [3]. Those techniques are also sensitive to flow artifacts, especially in AAAs with complex flow. This study aims to develop a 3D MRI technique which can achieve high isotropic resolution and good blood suppression within a clinically acceptable scan time. A fast spin echo sequence using long variable refocusing flip angle trains (SPACE, Siemens) was used to provide high scan efficiency. In order to optimize blood suppression, a delay alternating with nutation for tailored excitation (DANTE) [4] preparation module was used. The technique was first optimized in volunteers and then evaluated in a group of patients pre and post USPIO administration to assess AAA morphology and inflammation.

Methods: (a) Study population: 5 volunteers and 8 patients with AAA disease (>3cm in diameter as identified on either ultrasound or CT) underwent T_1 weighted SPACE and DANTE-SPACE. Patients were also imaged 3-5 days after USPIO contrast agent injection using DANTE-SPACE. **(b) MRI Protocol:** All examinations were performed on a 3T Siemens Skyra scanner using a 32 channel body coil. *T_1w SPACE*: TR/TE = 800-1000ms/20ms; echo train length 60; 44-60 coronal slices with 1.3mm slice thickness; 32cm×32cm FOV and 256×256 matrix; 3.4 averages; 7-10 minutes scan time; 1.3mm isotropic resolution. *DANTE parameters:* train length 100, RF gap 1ms; gradient amplitude 22mT/m; gradient duration 700µs; RF flip angle 15°. **(c) Image and Data Analysis**: In volunteers, reformatted axial slices were selected below the renal bifurcation and above the iliac bifurcation; in patients, axial slices were reformatted through the aneurysm at 5.2mm intervals (every 5 slices). In total,10 slices in the volunteer study and 49 slices in the patient study were included. Lumen and wall SNR/areas were quantified and compared between methods. In patients, thrombus age was identified by signal intensity: hyper-intense/iso-intense regions were assigned as fresh/old thrombus. Inflammation within the wall was identified by areas of signal drop between pre- and delayed post-contrast images.

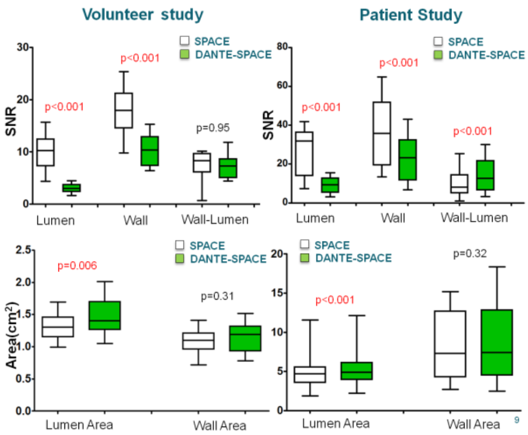

Figure 1. Quantitative comparison of wall and lumen SNR/areas using SPACE and DANTE-SPACE.

Results: The addition of DANTE substantially reduced flow artifacts (Fig 1-3). Thrombus age (Fig 2) and inflammation (Fig 3) were clearly identified. Fresh thrombus and inflammation was found in 3/8 and 2/8 patients, respectively. Even though DANTE decreased the wall SNR, the wall-lumen CNR was increased in patients and remained equivalent in volunteers. Wall area measurements were similar on DANTE-SPACE and SPACE, and the lumen area was slightly larger with DANTE-SPACE.

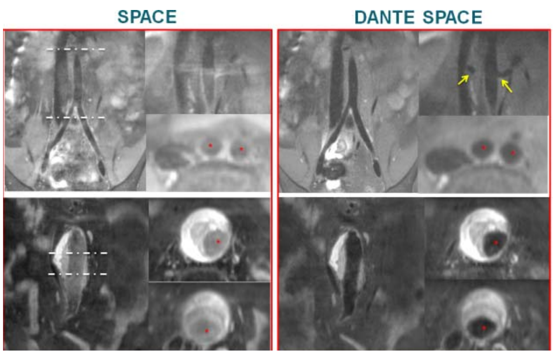

Figure 2. SPACE and DANTE-SPACE images in a volunteer (Top row) and in a patient with AAA (Bottom row). Yellow arrows show renal arteries and red asterisks show aorta/iliac lumen. Two layers of thrombus with different age were clearly shown in patient.

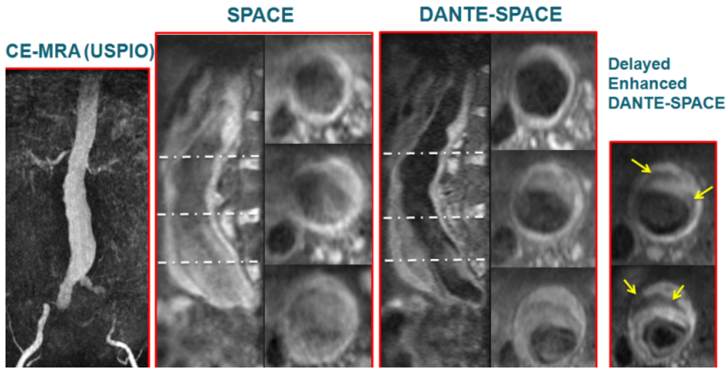

Figure 3. Baseline and delayed SPACE / DANTE-SPACE images of AAA in a patient. Yellow arrows show areas with inflammation identified by signal drop (USPIO uptake).

Discussion: DANTE substantially improved blood suppression with a penalty of SNR loss. However, the wall to lumen CNR was increased in patients and the boundaries of AAAs became clear. DANTE can be of particular use in patients with AAA disease, where complex flow is common. In 1/8 patients (Fig 3), some residual flow artefacts were still evident, however they could still be distinguished from wall boundary. Further optimization of the DANTE module is needed. DANTE-SPACE led to slightly larger lumen area measurements, possibly due to better blood suppression.

Conclusion: DANTE substantially reduces the flow artifacts in SPACE, and increases the wall to lumen CNR in patients. DANTE-SPACE is a good non-invasive tool for accurate AAA size measurement. The feasibility of using DANTE-SPACE to differentiate thrombus components and the ability to identify inflammation with USPIO contrast agents was demonstrated. These methods can potentially improve patient risk stratification.

Reference: 1. Nguyen VL. Eur J Vasc Endovasc Surg 2014 **2.** Richards JMJ. Circulation 2011 **3.** Mihai G et al. JMRI 2010 **4.** Li L et al. MRM 2012