Imaging with Full Static Tissue Suppression for 3D Volume Rendered (VR) Intracranial Angiography: Application of DANTE-Prepared FLASH (3D-DASH) to Magnetic Resonance Angiography

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Background: In cerebral MR angiography (MRA), volume rendering (VR) has several advantages over maximum intensity projection (MIP) [1]. Compared to MIP reconstruction, which does not provide a good perception of depth of the original data, the application of VR 3D imaging may improve delineation of intracranial arteries and, consequently, may yield more accurate and robust detection and characterization of intracranial disease [1]. However, in the case of 3D TOF intracranial angiography, MIP is much more routinely used than the VR reconstruction. The main reason is that MIP reconstruction is less affected by residual static tissue signal, which is present in TOF MRA. Also, there may be subjective variability between clinicians in the selection of a threshold during creation of VR images, which may influence final diagnosis [1].

In this study, we propose the use of an additional black blood (BB) dataset, obtained using DANTE-Prepared FLASH (denoted 3D-DASH), that is digitally subtracted from a conventional TOF dataset to create a static tissue suppressed angiogram. Unlike other background subtraction methods used in non-contrast imaging [2] which match the background signal intensity, the static tissue signal in the 3D-DASH method may be arranged to be significantly larger than the static tissue signal in the TOF bright blood dataset. The purpose of two imaging subtraction (TOF-DASH, denoted as T-D image) is to allow automatic assignment of zero as a justified threshold for VR reconstruction, which we call as "full background suppression". In such cases the final T-D image should exhibit only background-free bright blood signal. Note that spatial resolution must be sufficiently high to avoid partial volume effects between static tissue and vessel signal. Here, we demonstrate a high-resolution 0.5 mm isotropic VR dataset created from T-D images, showing significant improvement in revealing small arteries. In addition, the visualization quality of the MIP images generated from a T-D dataset is greatly improved in comparisons to its original TOF version.

Theory: As demonstrated in Bloch simulations (Fig. 1a and 1b), when using DANTE pulse trains [3] as a preparation module prior to a FLASH imaging readout, the longitudinal magnetization of flowing spins is substantially attenuated, whereas the longitudinal magnetization of static tissue/fluid gradually settles to a higher signal intensity than that of a standard (TOF) FLASH readout. This is because the DANTE-FLASH steady state saturation level is higher than the previous TOF-FLASH readout. Use of a centric k-space readout scheme for 3D-DASH will result in a higher static tissue intensity in the final 3D-DASH image than the corresponding 3D-TOF image. Another important factor that causes static signal reduction in TOF images is the magnetization transfer effect from any pre-saturation pulses used for venous blood saturation. Finally, in post processing any static tissue in the final subtraction between 3D-TOF and 3D-DASH will have negative values, which can be assigned to zero as a threshold, shown in Fig 1.

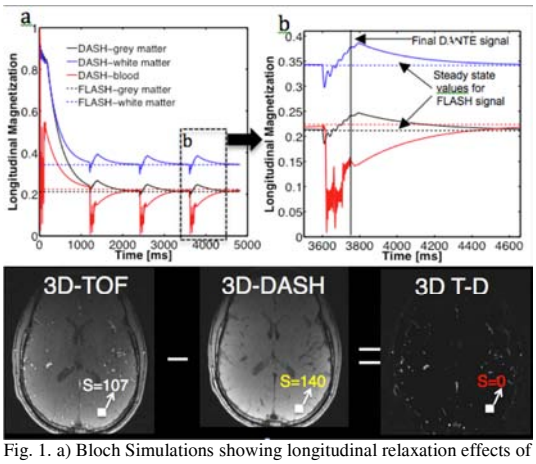

Fig. 1. a) Bloch Simulations showing longitudinal relaxation effects of 3D-FLASH, 3D-DASH on grey and white matter. b) Magnified portion from (b) showing that 3D-DASH will have higher signal for all static tissues compared with 3D-TOF. S, signal intensity at the marked pixel.

Materials and Methods: *Subjects*: 3 healthy volunteers (males, 24 to 35 years) underwent 3D-TOF and 3D-DASH imaging. Written informed consent was obtained from all subjects. *Protocol*: All scans were acquired using a 3T Siemens Verio scanner and a 32-channel head coil. TOF: axial imaging acquisition, 3 slab sequential acquisition, slab distance -20%, slab over sampling 20%, FOV=200×180×52 mm, matrix size 384 × 365, interpolated to 512 × 512, partition thickness = 0.5mm, NEX =1, GRAPPA = 2, slices = 104, FLASH flip angle α = 18°, slice resolution = 67%, phase and slice partial FT = 6/8, Fat suppression = off, TR=21ms, BW = 186 Hz/pixel, resolution=0.5mm isotropic, spatial presaturation pulse gap=10mm, thickness=40mm on upper side of imaging slab. Acquisition time=4min. The parameters for the FLASH readout of the 3D-DASH sequence are identical to 3D-TOF, except that no spatial presaturation pulses were applied and a centric k-space scheme was used after each DANTE pulse train. FLASH readout duration between DANTE trains≈500ms, Acquisition time=5min. Parameters for the DANTE module: flip angle (FA) α_{DANTE} = 12°; Number of pulses N_p=150; time duration between DANTE pulses, t_D=1 ms; $G_{x,y,z}$=18 mT/m; gradient duration≈1 ms.

Results: Fig. 2 shows a significant improvement in visualizing arteries in VR images reconstructed from T-D images. Fig. 3 shows that the visualization quality of MIP images generated from T-D images is also greatly improved over TOF images.

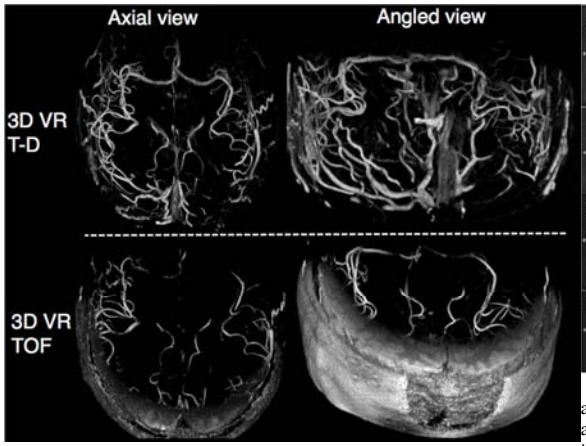

Fig. 2. Intracranial angiography comparisons between T-D and TOF 3D VR images in axial view and coronal view with a slightly tilted angle. The imaging location is shown in Fig. 3d.

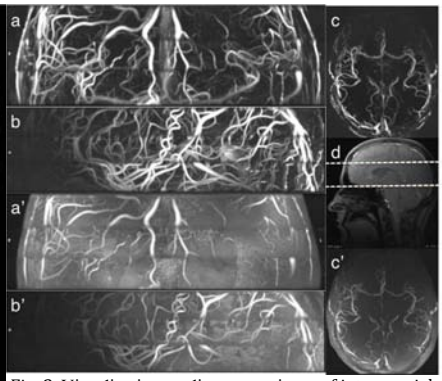

Fig. 3. Visualization quality comparisons of intracranial angiography between T-D and TOF MIP images. a), b) and c) are coronal, sagittal and axial views of T-D MIP images, respectively. a'), b') and c') are coronal, sagittal and axial views of TOF MIP images, respectively. d) localizer shows the location of imaging acquisition.

Conclusions: Subtraction images of 3D-DASH images from conventional 3D-TOF images yields angiograms with full background suppression for 3D Volume Rendering (VR) intracranial MRA.

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References: [1] Mallouhi A et al. Am J Roentgenol. 2003 180:55-64. [2] Koktzoglou I et al. Magn Reson Med. 2009 61:117-24. [3] Li L et al. Magn Reson Med. 2012, 68:1423-1438.