Cerebral venous thrombosis: direct thrombus imaging with sub-millimeter isotropic resolution dark-blood MRI

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Introduction: Cerebral venous thrombosis (CVT) is a disorder potentially leading to devastating disability and even death if not timely diagnosed and treated [1]. While TOF MRV is most commonly used for diagnosing CVT, the accuracy can be compromised by the flow voids caused by a slow or complex flow pattern and in-plane flow saturation. Several other MRI techniques, relying on characteristic image contrast of CVT, may also involve confusion in image interpretation due to venous flow and other anatomic structures. In addition, given the variation in venous anatomy, it is sometimes impossible to exclude CVT with current non-invasive imaging modalities. We hypothesize that high-spatial-resolution dark-blood MRI, commonly used for vessel wall imaging, may provide a solution. In this work, a fast dark-blood MRI technique was developed and validated in CVT patients.

Methods: *Sequence* SPACE (variable-flip-angle 3D TSE), has increasingly been applied in vessel wall imaging at various arterial vascular beds due to its inherent dark-blood effect and fast imaging speed [2-3]. However, suppressing slower venous blood flow remains a challenge for SPACE. To better detect CVT, particularly in the subacute stage, we combined T1-weighted SPACE with (a) a nonselective saturation preparation to exclude the T2-weighting that resides in the longitudinal magnetization at the end of the long echo train and (b) a DANTE preparation [4] that introduces less T2-weighted contrast than other motion-sensitizing preparation. *Imaging Experiment* Using a 3T system and 32-ch coil, the sequence was first optimized on 5 healthy subjects (2F 3M). Six scans with different DANTE RF pulse train lengths (0, 50, 100, 150, 200, 250) were conducted with all other DANTE parameters held fixed (flip angle 12°, RF gap 1 ms, gradient strength 20 mT/m). Imaging parameters for SPACE included: sagittal whole-brain coverage, isotropic 0.78mm resolution, TR/TE 600/8.8ms, echo train length 37, GRAPPA factor 2, scan time 5min38sec. Contrast-to-noise ratio (CNR) analysis for the residual blood region vs. dark lumen and white matter vs. dark lumen were performed to determine the optimal DANTE pulse train length. The optimized sequence was then tested on 10 prospective CVT patients (**Table**) during their clinical examinations. DANTE-prepared SPACE and TOF MRV images were respectively evaluated in consensus by two radiologists.

Results: Without DANTE, all 5 healthy subjects exhibited residual venous flow signals in at least one venous sinus in SPACE imaging. DANTE with 150-200 pulses appeared to be a suitable preparation to yield sufficiently clean sinus lumens while avoiding further signal loss (**Fig. 1&2**). The sub-millimeter isotropic resolution dark-blood images allowed unambiguous identification of tiny normal structures (e.g. arachnoid granulations in Fig. 2 B.1) in sinuses. In patients, DANTE-SPACE was able to detect CVT (**Fig. 3 A.2**) in sinuses as well as in cortical veins (**Fig. 3 B**). In a total of 10 patients, CVT was diagnosed in 6 patients by DANTE-SPACE and in 9 patients by TOF MRV (**Table**). According to their clinical symptoms, diagnosis in the 3 patients with TOF MRV was false positive. In general, TOF sequence could not display thrombus in the SS ,RCVS, LCVS, RIJV,LIJV, DVS clearly.

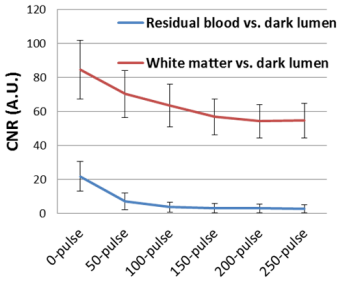

Fig. 1 *150-200 DANTE pulses yields good compromise between blood suppression and signal loss in static tissue.*

Discussion and Conclusion: This work, for the first time, investigated the feasibility of dark-blood MRI for CVT imaging. The proposed T1-weighted DANTE-prepared SPACE technique excludes the influence of blood flow and permits direct visualization of thrombus and surrounding anatomic structures. The preliminary clinical study has demonstrated that the technique may outweigh TOF MRV in diagnosing CVT. A large clinical study is underway to validate the diagnostic value of the technique.

References: [1] Leach JL et al. Radiographics 2006;26:S19-S43; [2] Fan et al. JMRI 2010;31:645-654; [3] Qiao Y et al. JMRI 2011;34:22-30; [4] Li L et al MRM 2012;68:1423-1438.

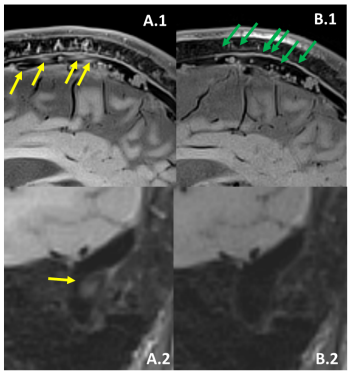

Fig. 2 *DANTE-SPACE (B.1&2) allows better blood signal suppression (yellow arrows) and visualization of fine structures (green arrows) in the sinus than conventional SPACE (A. 1&2).*

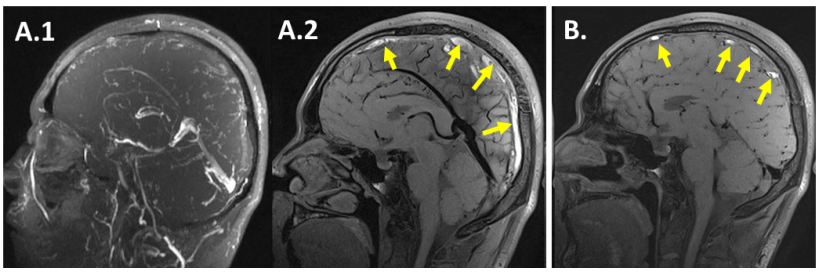

Fig. 3 *A 26 yo man with thrombosis of superior sagittal sinus. Sagittal reconstructed images of TOF MRV(A.1) reveal large isointense filling defect within superior sagittal sinus, and most of the cortical vein thrombus shows isointense signal intensity mimicking flow. Sagittal source images of SPACE (A.2) reveal large hyperintense thrombus in superior sagittal sinus. Thrombus is also clearly depicted in small cortical veins by SPACE (B).*

Patient	Age	Sex	Symptoms	Thrombosed Segments by DANTE-SPACE	Thrombosed Segments by TOF
1	21	F	Headache	RTS	SSS RTS
2	26	M	Headache, Diplopia	SSS RSS RTS RCVS LCVS RIJV	SSS RSS RTS
3	33	F	Headache	Negative	Negative
4	27	M	Headache	Negative	SS(False positive)
5	28	M	Headache	Negative	SS(False positive)
6	41	F	Headache, Diplopia	SSS RSS RTS RIJV DVS	SSS ISS(False positive)
7	48	M	Headache, Diplopia	LSS LTS	LSS LTS
8	27	F	Headache, Blurred vision	SSS RSS RTS RCVS LCVS RIJV	SSS RSS RTS
9	44	F	Headache	SSS	SSS
10	19	F	Headache	Negative	Negative

Table. *Dignosis of thrombosed venous segments by DANTE-SPACE and TOF. Note: superior sagittal sinus (SSS), inferior sagittal sinus (ISS), left transverse sinus (LTS), left sigmoid sinus (LSS),right transverse sinus (RTS), right sigmoid sinus (RSS), straight sinus(SS), deep venous system (DVS; vein of Galen, internal cerebral veins,), right cortical veins (RCVS),left cortical veins (LCVS), left internal jugular vein(LIJV), Right internal jugular vein(RIJV).*