Flow sensitivity analysis of variable refocusing angle 3D FSE

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Introduction: FSE sequences can be adapted either to maintain brightness or to suppress the signal of moving blood. Subtraction methods with FSE can generate angiographic images without injection of contrast agents [1]. 3D FSE variants with variable refocusing angle (VRA) of the echo train are naturally suitable for high scanning efficiency and SAR reduction [2]. We analyze sequence parameter modifications to adapt 3D VRA FSE sequences for Fresh Blood Imaging (FBI) angiography.

Methods: Bloch equations simulations were performed with uniform velocity, 3T blood relaxation parameters, and actual VRA RF pulse trains. Flow was assumed to have constant velocity nominally along the unrefocused readout gradient. For several sets of sequence parameters, we calculated signal suppression as a function of velocity relative to static signal. We identified a "critical velocity", above which the sequence exhibited a "black blood" appearance. We determined the approximate sensitivity of the critical velocity to IES (interecho spacing), TE, gradient readout and spoiler size, and lowest refocusing angle.

Healthy human volunteer scans under IRB control were performed at the trifurcation of the legs on a Toshiba 3T research system. An FSE VRA sequence was generated which acquired 3D scans at both systolic and diastolic delays using PPG cardiac gating. Magnitude subtraction of the volumes and maximum intensity projection yielded angiographic images.

Results: Simulation showed that critical velocity depends approximately inversely upon IES (with echo number held constant, TE scaling as IES, and VRA train reoptimized for each IES)[Fig 1]. Critical velocity depended inversely upon gradient first moment including spoiling (i.e. linearly upon readout plus spoiling resolution) [Fig 2]. Critical velocity decreased as the lowest refocusing angle of the sequence decreased, but no simple functional relationship for this dependence could be discerned. Critical velocity exhibits different relationships to TE for two refocusing pulse regimes. In the first regime, in which the VRA scheme was reoptimized for maximum echo strength as a function of the echo number (at fixed IES), the critical velocity was inversely related to the echo number and TE (at the kspace center) [Fig 3]. In the second regime, in which the refocusing pulse was held constant across different choices of the TE (but fixed ISE), the critical velocity was almost constant and independent of TE and echo number.

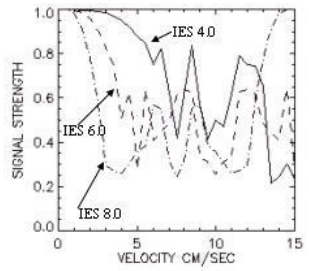


Fig. 1

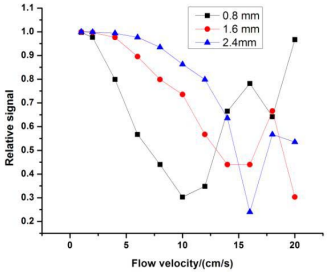
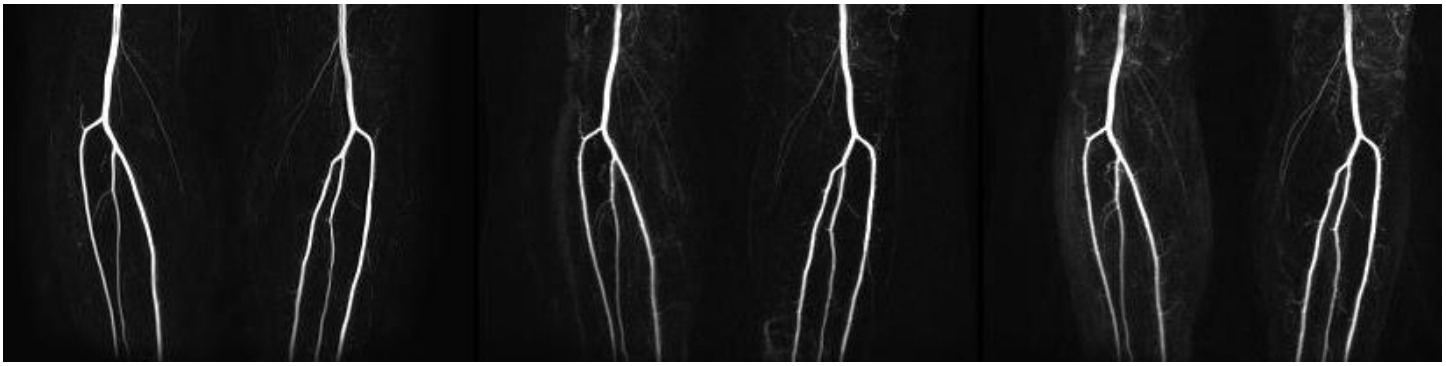


Fig. 2

Main Echo Number (IES=4.0)	Approx. Critical Velocity
32	3 cm/sec
24	4 cm/sec
16	6 cm/sec
12	10 cm/sec
10	10 cm/sec

Fig. 3

Human images demonstrated the ability to reduce SAR while maintaining comparable artery appearance. In the VRA sequences, background suppression was not controlled for, and was somewhat degraded. Left image: conventional FSE sequence, refocusing pulses 150°, TE80, 84 echoes, SAR reduction to 68% (relative to 180° pulses, 84 echoes), IES 5msec. Middle image: VRA pulses ranging from 50.9° to 130°, TE 40, 74 echoes, refocusing SAR reduced to 35.1%. Right image: VRA train ranging from 46.4° to 130°, TE 60, 79 echoes, refocusing SAR reduced to 35.3%. FBI VRA sequences needed lower IES (4 msec) and shorter TE to maintain equivalent flow contrast, compensating for the higher flow sensitivity caused by lower RF angles. Scan times were about 3:30.



D**iscussion:** VRA 3D FSE methods show promise for management of SAR in 3T non-contrast angiography. Vessel contrast can be maintained using the velocity sensitivity tradeoffs described above. Clinical performance may also depend upon other metrics such as background suppression, which may be a subject for further development by simulation, or by empirical assessment of prepulses.
References: [1] M. Miyazaki et al, Radiology, 2007 v227 pp 890-896. [2] R. Busse, Magn Reson Med 2004 v51 pp 1031-1037.