Prospective Self-Gated Nonenhanced Magnetic Resonance Angiography

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INTRODUCTION: Most nonenhanced magnetic resonance angiography (MRA) techniques require cardiac synchronization through physiological gating. Electrocardiogram (ECG) gating is frequently used however setup of ECG leads adds to the overall scan time and interference with gradient switching and radiofrequency pulses can cause misgating (1). To circumvent these problems we have developed a self-gating method that provides cardiac synchronization without the use of an ECG. MRA imaging is prospectively triggered by detecting flow acceleration during systole using a reference-less phase contrast (PC) navigator sequence. The effectiveness of self-gating was evaluated in non-subtractive Quiescent Interval Single Shot (QISS) MRA (2). Feasibility in a subtractive sequence (NATIVE SPACE) (3) was also demonstrated.

METHODS: Prior to each imaging readout, a non-phase-encoded (i.e. projective) axial slice with cranial-caudad velocity encoding was repeatedly acquired 10mm cephalad to the QISS FOV. The phase difference between the n^{th} and $(n-1)^{th}$ navigator readout was computed yielding acceleration. Imaging was triggered if this value surpassed a pre-calculated threshold. Self-, ECG-, and pulse-gated QISS MRA was performed in the lower peripheral arteries (foot to thigh) of eight healthy subjects using a 1.5T scanner (MAGNETOM Avanto, Siemens Healthcare). Contrast and CNR were measured at three vessel locations and averaged over subjects. Image quality was assessed on a 0-4 Likert scale for diagnostic display by a licensed radiologist. Self-gated NATIVE SPACE was performed in a single subject. Navigator parameters: VENC 20 cm/s, FA 30°, TR 16ms. QISS parameters: FOV 400x260mm, matrix 400x260, FA 90°, 48 3mm axial slices, TR/TE 1 R-R/1.43ms, BW 658 Hz/Px. NATIVE SPACE parameters: FOV 430x355mm, matrix 320x329, FA 90°, TR/TE 1 R-R /20ms, BW 1042 Hz/Px, TD (systole/diastole) 280/0 ms. Navigator VENC and FA were optimized prior to the study.

RESULTS: The reference-less PC navigator triggered the QISS sequence with 99% accuracy. ECG-, navigator, and pulse signal traces are displayed in Fig 1. ECG-, self- and pulse-gated QISS MR angiograms in a single subject are displayed in Fig 2a. ECG- and self-gated QISS images appeared similar however areas of vasculature in the self-gated image showed slight signal loss. The pulse-gated QISS image showed complete signal loss at multiple locations due to frequent misgating. Quantitative results comparing ECG-, self- and pulse-gated QISS are shown in Table 1. Diagnostic display of ECG-, self-, and pulse-gated QISS was 4.00 ± 0.00, 3.38 ± 0.74, and 0.57 ± 0.79 respectively. All results found no significant difference between self- and ECG-gated QISS ($p > 0.05$). Figure 2b shows ECG-, self- and non-gated NATIVE SPACE angiograms in a single subject.

DISCUSSION: An acceleration-based PC navigator was found capable of triggering a QISS sequence and a NATIVE SPACE sequence without the need for ECG gating. An acceleration-based PC method may be advantageous over velocity-based methods because it enables earlier flow detection by triggering on the systolic flow velocity upslope. This benefits QISS MRA by maximizing arterial inflow after in-plane saturation. Furthermore, the use of a reference-less PC scheme is advantageous because temporal resolution is doubled and every navigator TR employs identical flow-sensitizing gradients; with subtraction, the latter eliminates gradient-induced eddy current effects (4). Saturation of blood by the navigator excitation can lead to signal loss in the images. This effect was minimized by reducing the navigator FA to 30°, and may be reduced further by placing the navigator slice below the imaging slice. Other limitations include mistriggering due to low navigator SNR, which has been seen in patients where occlusion leads to slow blood flow with low pulsatility.

REFERENCES: 1. Felblinger, et al. MRM 1994. 2. Edelman, et al. MRM 2010. 3. Miyazaki, et al. JMRI 2000. 4. Bernstein, et al. MRM 1998.

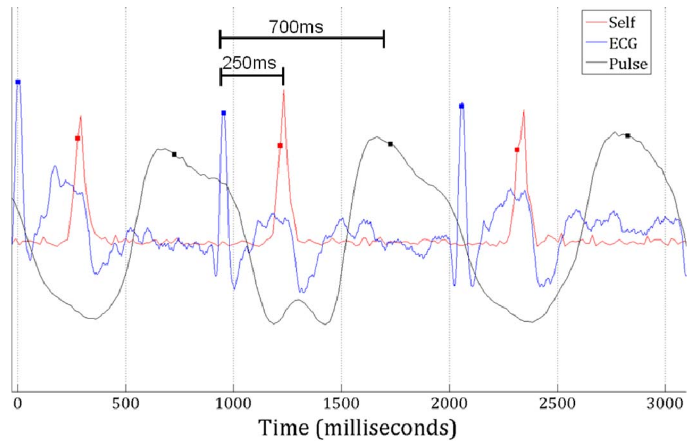

Fig 1. Trace of ECG, navigator, and pulse signals in time. Colored squares indicate trigger points. ECG-navigator and ECG-pulse delay times are shown.

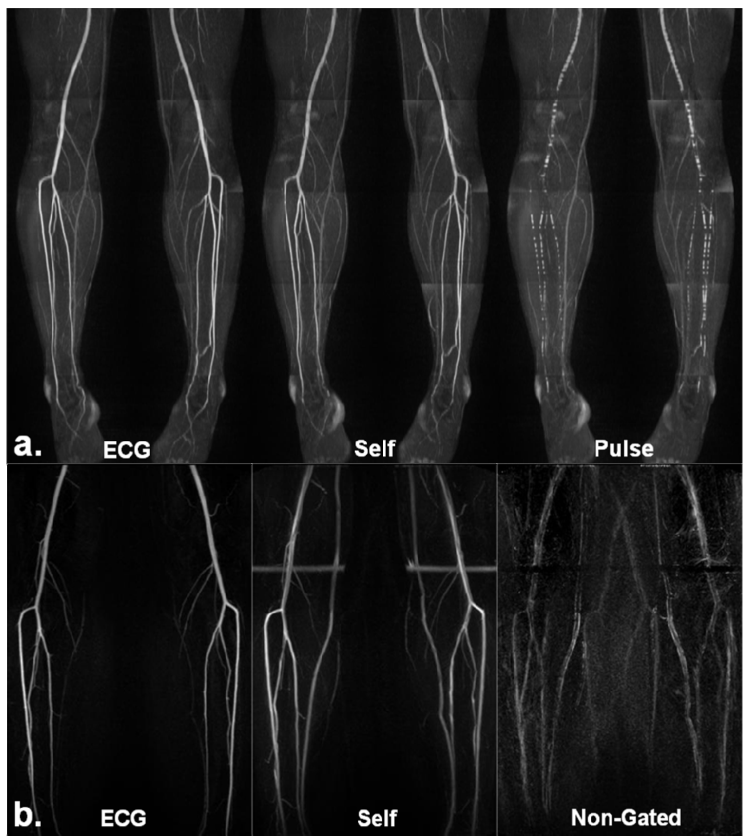

Fig 2. (a) ECG-, self-, and pulse-gated QISS angiograms in a healthy subject and **(b)** ECG-, self-, and non-gated NATIVE SPACE angiograms in a healthy subject.

Table 1. Quantitative Results

	CNR Popliteal	CNR Anterior Tibial	CNR Posterior Tibial	Contrast Popliteal	Contrast Anterior Tibial	Contrast Posterior Tibial
ECG[a]	17.1 ± 2.2	18.2 ± 1.7	18.5 ± 2.3	6.4 ± 1.2	5.6 ± 0.6	5.6 ± 0.5
Self[a]	15.4 ± 3.0	17.0 ± 1.4	16.4 ± 1.4	5.7 ± 1.1	5.1 ± 0.6	4.9 ± 0.4
Pulse	8.1 ± 3.9	10.0 ± 8.2	10.0 ± 7.0	3.5 ± 1.5	2.9 ± 2.4	3.1 ± 2.3

[a]No significant difference was found between these methods at all locations ($p > 0.05$).