

Quiescent Interval Single Shot MR Angiography

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Introduction

Given the frequency of renal functional impairment in patients with peripheral vascular disease (PVD) and concerns about nephrogenic systemic fibrosis, there is growing interest in unenhanced MRA (1,2). While promising, existing unenhanced MRA methods suffer from limitations that preclude robust clinical application for PVD. An ideal unenhanced method should be fast, easy to use, and insensitive to patient motion, heart rate, and flow patterns. For this purpose, we have implemented *quiescent interval single shot* (QISS) MRA, which acquires data using a modified single shot two-dimensional (2D) balanced steady-state free precession (bSSFP) pulse sequence. Technical optimization of QISS MRA was followed by a pilot clinical study in PVD.

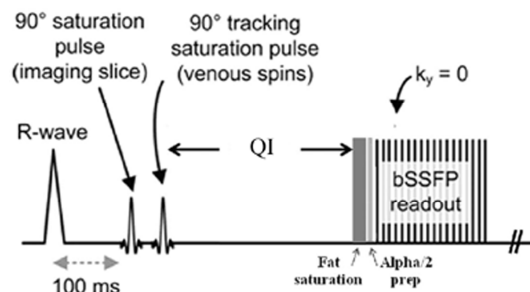


Figure 1. QISS MRA pulse sequence.

Subjects and Methods

The pulse sequence is illustrated in Figure 1. The study was approved by the IRB and written informed consent was obtained from all subjects. A series of healthy subjects and 8 patients (8 male, ages 56-90) with documented PVD were studied using a 1.5T MAGNETOM Avanto (Siemens Healthcare, Erlangen, Germany). Technical comparisons made during the optimization process included the following: (a) ECG gating vs. pulse gating; (b) linear vs. alpha/2 RF catalyzed; (c) 5/8th partial Fourier using center-to-out trajectory vs. out-to-center trajectory; (d) full Fourier; (e) flip angle of 0 degrees, 90 degrees, and 180 degrees for the preparatory slice-selective RF pulse. QISS and 2D TOF MRA were compared in healthy subjects and using a programmable pulsatile flow phantom (CompuFlow 1000 MR, Shelley Medical Imaging Technologies, London, Ontario) with a blood-mimicking fluid (T1 = 850 ms, T2 = 170 ms). For the pilot clinical study, QISS MRA was compared with a hybrid protocol consisting of a time-resolved CE-MRA through the calf and stepping table CE-MRA for the remainder of the peripheral vascular system.

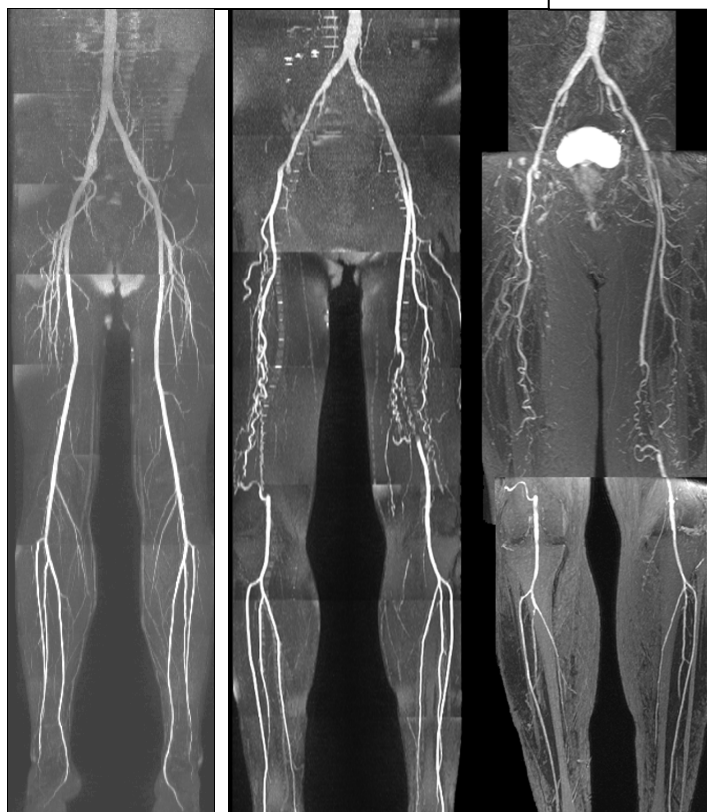


Figure 2. QISS

Figure 3a. QISS

3b. CE-MRA

Results

An example of a normal whole leg QISS MRA is given in Figure 2 and in a patient with PVD in Figure 3. Main and branch arterial conspicuity was excellent and there was uniform background signal as well as near-total venous suppression. ECG gating was superior to pulse gating. A center-to-out partial Fourier trajectory showed much better fat suppression than an out-to-center trajectory due to the reduced number of RF pulses between the application of fat saturation and the center of k-space. Use of a 180 degree flip angle increased muscle suppression but made the technique more sensitive to variations in heart rate compared with a 90 degree flip angle. Compared with 2D TOF, QISS MRA quality was superior, motion artifacts were reduced, and scan time was much shorter. Initial evaluation of QISS MRA in a pulsatile flow phantom demonstrated excellent flow contrast over a wide range of velocities. Compared with 2D TOF, maximal signal was reached at substantially lower peak velocities using QISS MRA. For instance, at a 3 mm slice thickness, QISS signal was maximal at about 10 cm/sec whereas 2D TOF signal was maximal at about 34 cm/sec.

For the pilot clinical study, all of the 112 arterial segments deemed assessable by CE-MRA in the four volunteers were assessable by QISS, while 225 out of 231 arterial segments considered to be assessable by CE-MRA in patients with PVD were assessable by QISS. Four of the six unassessable segments were due to stents. Excluding stented segments, sensitivity, specificity, PPV, and NPV values of QISS for arterial narrowing greater than 50% or occlusion were 92.2%, 94.9%, 83.9% and 97.7% respectively. There was excellent agreement between stenosis scores obtained with QISS MRA and CE-MRA ($\kappa = 0.79$).

Conclusions

QISS MRA is a fast, easy-to-use unenhanced MRA method for evaluating the peripheral arteries. It is robust to a wide range of flow patterns and velocities. This property is due to the fact that unsaturated arterial spins translate only a short distance (3mm or less) to enter the slice and QI is timed to coincide with the period of rapid systolic arterial inflow. The relatively long duration of the QI (228ms) provides sufficient leeway that there is no need to individually calibrate the sequence timing for each subject. Flow artifacts are minimized by acquiring data during slow diastolic flow. In a small group of patients, this technique accurately identified and characterized PVD and proved insensitive to respiratory and bowel motion in the pelvis. Moreover, image quality was consistent irrespective of the disease severity or location. A multi-center trial is now underway to evaluate the accuracy and utility of the method in a large cohort of patients. The method also shows promise in other vascular areas including the carotid and renal arteries.

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References: 1. Guerrero A, et al. *Nephrol Dial Transplant*. 2006;21:3525-31. 2. Kuo PH, et al. *Radiology*. 2007;242:647-649.