Peripheral vascular disease (PVD) has an age-adjusted prevalence of 12% in the United States, causes significant morbidity and is associated with excess cardiovascular mortality.\textsuperscript{1,2} Contrast-enhanced magnetic resonance angiography (CE-MRA) often substitutes for the more invasive “gold standard” procedure of digital subtraction angiography (DSA).\textsuperscript{3} Given the frequency of renal functional impairment in patients with PVD and concerns about nephrogenic systemic fibrosis (NSF), there is growing interest in unenhanced MRA.\textsuperscript{4,5}

Two-dimensional time of flight (2DTOF) has been extensively evaluated for unenhanced MRA of the lower extremities.\textsuperscript{6,7,8} However, the method is too slow for many patients to tolerate, is sensitive to patient motion, and suffers from flow artifacts within horizontally-oriented vessel segments. Over the last few years, several “next generation” unenhanced MRA techniques such as fresh blood imaging (FBI)\textsuperscript{9} and flow-sensitive dephasing (FSD)\textsuperscript{10} have been introduced with promising clinical results. However, a fundamental challenge is the need to calibrate the trigger delay and flow-dephasing gradients for individual patients and vessel segments. This can be problematic in patients with significant vascular disease. For instance, the onset of peak flow is delayed in distal arterial segments compared with proximal ones and the timing is altered by the presence of stenotic lesions. Moreover, such techniques require image subtraction, which can be problematic when there is bowel or respiratory motion.

An ideal methodology for unenhanced MRA 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 2D balanced steady-state free precession (bSSFP) pulse sequence.\textsuperscript{11} Unlike subtractive unenhanced 3D MRA methods, the imaging parameters for QISS MRA do not need to be tailored for the patient.

QISS MRA can be summarized as follows:

1. Following a user-selected time delay (TD) after the R-wave, a slice-selective saturation radiofrequency (RF) pulse is applied to the imaging slice to set the longitudinal magnetization of tissues within the slice to zero.
2. A tracking saturation RF pulse is applied caudally.
3. Next there is a quiescent interval (QI), roughly coinciding with the period of rapid systolic arterial flow, during which no RF pulses are applied.
4. A chemical shift-selective fat saturation RF pulse is followed by an RF catalyzation sequence to force the magnetization of in-plane spins towards the steady-state value.
A single shot 2D bSSFP pulse sequence is used to image arterial spins within the slice during diastole, when flow is slow or absent.

The entire process is repeated for the next slice, with the acquisition order being sequential from bottom to top.

QISS is acquired as the first scan without the need for a separate scout acquisition. The resultant full-length unenhanced MRA is of diagnostic quality and also serves as a detailed scout if a subsequent contrast-enhanced MRA is required. The imaging procedure is very efficient, with typical scan time less than 6.5 minutes to image the entire length of the peripheral arteries from the aorta through the feet.

In an initial study (MRM, in press), the sensitivity, specificity, positive and negative predictive values of QISS MRA for arterial narrowing greater than 50% or occlusion were 92.2%, 94.9%, 83.9% and 97.7% respectively. These results have subsequently borne out in a multi-institutional trial of 50 patients. In addition to its utility for the peripheral arteries, QISS also has shown promise for evaluation of the renal and carotid arteries.

Ghost MRA is an alternative unenhanced imaging strategy that eliminates the need for ECG gating. Using either a fast spin-echo or bSSFP readout, Ghost acquires data at regular intervals, typically around one to three seconds. Variations in intravascular signal intensity due to pulsatility cause ghost artifacts to propagate along the phase-encoding direction. If these ghost artifacts are collapsed using a maximum intensity projection or summation algorithm, then highly detailed angiographic images can be created. Although promising, there has been only limited clinical validation of this method to date.

Unlike the previous two methods, signal targeting using alternative radiofrequency and flow-independent relaxation enhancement (STARFIRE) produces fully flow-independent unenhanced MRA. The method involves the subtraction of two 3D bSSFP acquisitions, in one of which a spatially non-selective inversion pulse suppresses the signal intensity of blood. The subtracted images depict both arteries and veins, although additional techniques such as presaturation or T2prep can be used to improve vessel selectivity. To date, the technique has shown promise for imaging of deep venous thrombosis. Arterial applications are also feasible.
References


