# Unenhanced 3D Ghost MR Angiography by Toggled Systolic and Diastolic Imaging

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**Introduction:** Ghost magnetic resonance angiography (MRA) is a new method for angiography that suppresses background tissue without subtraction. The method is predicated on the creation of arterial ghost artifacts within a region containing no MR signal (e.g. air), and can be used for both unenhanced and contrast-enhanced MRA. When used for unenhanced MRA, cardiac gating is not required. This can be a substantial advantage compared with previously reported unenhanced MRA methods. However, it is not possible to rotate the ungated MRA from the orientation in which it was acquired.

We report an alternative, ECG-gated approach for ghost MRA that enables the creation of multiple projections and also reduces scan time. We tested the hypothesis that, as a result of better suppression of background signal intensity, gated Ghost MRA improves vessel conspicuity compared with a conventional subtraction-based unenhanced MRA method.

**Subjects and Methods:** For unenhanced 3D Ghost MRA, a segmented 3D pulse sequence sensitive to cardiac-phase-dependent changes in arterial blood flow is used. The sequence is toggled such that even slice-encoding ($k_z$) lines are acquired during systole when arterial flow is fast, and odd $k_z$ lines are acquired during diastole when arterial flow is slow. Fourier transformation of the acquired data to the image domain generates one arterial ghost artifact that is resolved in three dimensions and is displaced one half a field of view from the physical location of the artery. An adequate number of slices are acquired so this ghost artifact is located in air.

The peripheral arteries of 7 volunteers (ages 18-33) and one 70 year old patient with claudication were imaged on a 32-channel 1.5 T scanner (Avanto, Siemens Medical, Erlangen) equipped with peripheral vascular and body coils. A 3D ECG-triggered partial-Fourier turbo spin-echo (TSE) pulse sequence, hereafter referred to as 'Toggled Ghost MRA', was modified to acquire even $k_z$ lines in diastole and odd $k_z$ lines in systole. Even $k_z$ lines were acquired over the first half of the scan, while odd $k_z$ lines were acquired over the second half of the scan. Comparison of the Toggled Ghost MRA sequence was made to a subtractive, ECG-triggered partial-Fourier TSE sequence akin to Fresh Blood Imaging (1). Typical imaging parameters were: TR/TE/flip = 2 cardiac cycles/90 ms/90°, field of view of 35 cm x 50 cm, matrix of 224 x 320, slice thickness of 8 mm, 112 slices (Toggled Ghost MRA) and 56 slices (subtractive PF-TSE), parallel acceleration factor of 4, and scan time of 84 cardiac cycles. Arterial contrast and contrast-to-noise ratio (CNR) relative to background were computed from region of interest measurements. Multiple acquisitions were used to estimate image noise in the parallel-accelerated scans. In some subjects, Toggled Ghost MRA was acquired with thin (1-3 mm) slices to enable rotation of the maximum intensity projections from the coronal plane. Wilcoxon signed-rank tests were used to compare relative contrast and CNR values obtained with the two techniques.

**Results:** Figure 1 shows representative images acquired with Toggled Ghost MRA and subtractive PF-TSE in a volunteer. Visually, the Toggled Ghost MRA method provided better suppression of background signal intensity, better delineation of small vessels, and reduced parallel imaging artifact. Contrast and CNR values were larger for Toggled Ghost MRA than for PF-TSE (66.3±21.2 vs. 25.0±17.1, P = 0.018 for contrast and 47.3±16.2 vs. 7.6±5.4, P = 0.018 for CNR; numbers given as mean ± sd). Figure 2 shows images acquired in a patient with claudication. Ghost MRA depicted the vascular stenoses and collateral vessels similarly to the subtractive contrast-enhanced MRA.

**Conclusions:** Toggled Ghost MRA is a new method for unenhanced angiography predicated on the deliberate creation of ghost artifacts. It provides three-dimensional views of arteries with excellent suppression of background signal intensity. When compared to the conventional subtractive method of PF-TSE, Toggled Ghost MRA provided better image quality with improved contrast and CNR. This superior performance of Toggled Ghost MRA is presumably related to the extreme suppression of background signal intensity and the lack of subtraction artifact.

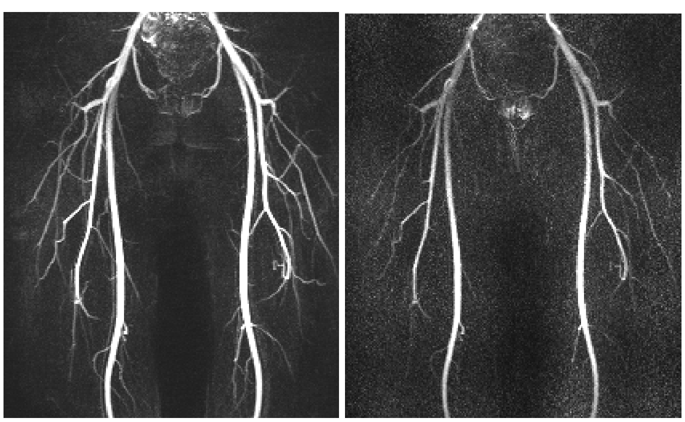

**Figure 1.** Comparison of maximum intensity projection images acquired with Toggled Ghost MRA (left) and the subtraction-based sequence of PF-TSE (right). Improved image quality was seen with Toggled Ghost MRA. Scan times were matched at 68 sec.

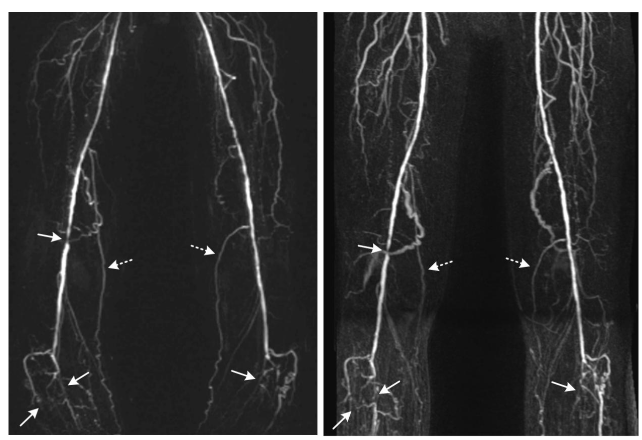

**Figure 2.** Comparison of Toggled Ghost MRA (left) and subtractive contrast-enhanced MRA (right) in a patient with claudication. Stenoses (solid arrows) and small branch vessels (dashed arrows) were well depicted with Toggled Ghost MRA.

**References:** (1) Miyazaki M et al. JMRI 2000;12:776-783.