Ungated Ghost MR Angiography

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Introduction: Traditional methods for magnetic resonance angiography (MRA) involve the excitation of vascular spins within a region of tissue, followed by localization and imaging of those spins within that same region. Signals that unfaithfully localize within the imaging volume, such as so-called "ghost artifacts", are considered to be undesirable and every effort is made to suppress them. To the contrary, we hypothesized that these ghost artifacts could be manipulated to create detailed angiograms of the human body. In this initial demonstration of the method, which we call "Ghost MRA", we show that the human arterial system can be depicted with exquisite anatomic detail and near total suppression of background signal. Moreover, unlike alternative unenhanced methods, Ghost MRA can be acquired without the need for cardiac synchronization or image subtraction.

Theory: With a segmented 3D sequence, there is often a long time delay (~1 s or longer) between one slice-encoding step and the next, whereas the time delay between successive phase-encoding steps is short (<10 ms). The considerable time delay between slice-encodes, in combination with the variation of vascular signal over the duration of pulse sequence, causes ghost artifacts to emanate from blood vessels. These artifacts propagate along the slice-encoding direction (1). With Ghost MRA, a sufficient number of slices are acquired so that some slices are located outside of the body and so that ghost artifacts propagate outside of the body and into surrounding air. A projected or summed image is then created along the slice-encoding direction, including only the ghost artifacts within the air and excluding other signals from tissues in the body. This process is shown in Fig. 1.

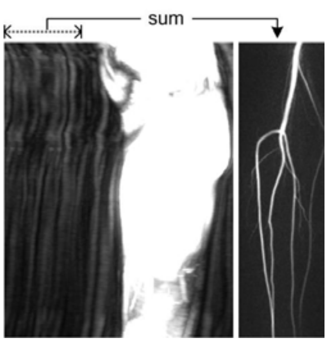

Fig. 1. Ghost artifacts outside the body are summed to create a Ghost angiogram.

Methods: The peripheral arteries of 9 volunteers and 1 patient with claudication were imaged on a 32-channel 1.5 T scanner (Avanto, Siemens). Segmented 3D balanced steady-state free precession (bSSFP) and partial-Fourier turbo spin-echo (PF-TSE) pulse sequences were used to create Ghost MRAs. Modulation of arterial signal was performed by either applying a flow-encoding preparation (2) prior to the bSSFP readout or by exploiting the inherent flow sensitivity of TSE imaging (3). Segmented bSSFP Ghost MRA of the calf was performed in 4 volunteers to examine the effects of parameters such as segment repetition time (TR), GRAPPA factor and velocity encoding sensitivity (VENC). Multiple-station PF-TSE Ghost MRA of the entire leg was performed in 5 volunteers. PF-TSE-based Ghost MRA and contrast-enhanced MRA were performed in the patient. Apparent CNR (aCNR) and relative contrast between arterial and background signals (S_a and S_b, respectively) were computed as: $(S_a-S_b)/\sigma_b$ and (S_a/S_b-1). Typical imaging parameters were: TR = 1-3 s, field of view = 35-40 cm x 40-50 cm, matrix = 224-320 x 320, slice thickness = 4-8 mm, 80-192 slices, flip = 90, GRAPPA factor = 1-4, venc = 12.5-100 cm/s.

Results: During bSSFP-based Ghost MRA of the calf (example shown in Fig. 1), relative contrast and aCNR increased with lengthening of the segment TR and with increased parallel acceleration. Relative contrast and aCNR demonstrated a modest dependence on VENC, with optimal VENC occurring at ~25 cm/s.

Figure 2 shows a whole-leg Ghost MRA acquired with a PF-TSE sequence. The entire arterial system from the pelvis down to the feet was seen with excellent clarity, with little background signal. Mean relative contrast and aCNR values for the iliac, femoral, popliteal, and anterior tibial arteries exceeded 5 and 30 units, respectively. In the patient with claudication (Fig. 3), Ghost MRA depicted the same stenoses seen with contrast-enhanced MRA.

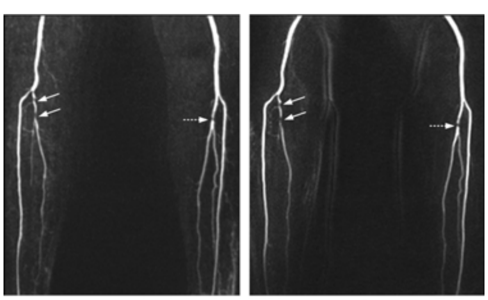

Fig. 3. Contrast-enhanced MRA (left) and ungated Ghost MRA (right) of a patient with claudication and left foot ulcer.

Conclusions: Ghost MRA offers a new contrast mechanism for the creation of MR angiograms. The method enables the formation of fully resolved arteriograms without cardiac synchronization and with little or no background signal contamination. Image subtraction is not required to suppress the appearance of unwanted and potentially confounding background tissue. Further study will be needed to evaluate the usefulness of the method and to determine additional applications.

Fig 2. Four-station ungated PF-TSE-based Ghost MRA acquired in 9 minutes.

References: **(1)** Frank LR et al. MRM 1993;30:296-304. **(2)** Korosec FR et al. MRM 1993;30:704-714. **(3)** Jara H et al. MRM 1999;41:575-590.