A Method for Removing Fluid-Bearing Voxels from STARBURST MR Angiographic Images

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Introduction: STARBURST (Selectively Targeted Angiographic Rendering using Blood's Unique Relaxation properties and Subtraction Technique) is a newly described method for creating high quality flow-independent MR angiograms. An optimal implementation of STARBURST involves the use of a balanced steady-state free precession (bSSFP) image acquisition. In this setup, bSSFP-based STARBURST enhances blood signal while concomitantly suppressing signal from background tissues such as fat and muscle. Although fat and muscle signals are suppressed, fluid tissues with long T_1 and high T_2/T_1 (e.g. joint effusions, cerebrospinal fluid) appear bright with bSSFP STARBURST and may degrade the appearance of the angiogram. Herein a method is presented for identifying and automatically removing fluid-bearing voxels from bSSFP STARBURST angiographic images.

Methods: STARBURST requires the acquisition of two image sets (with one set being tagged by a radiofrequency (RF) pulse and the other not) that are subtracted to render an angiogram (Fig. 1). To reduce sensitivity of the sequence to motion artifacts, STARBURST is typically acquired in an interleaved manner (see Fig. 1). For the purpose of fluid removal, we propose the use of sequential (non-interleaved) STARBURST acquisition that seeks to null fluid signal on the RF tagged image set. We hypothesize such an acquisition will: (1) yield high signal from fluids on the untagged image set; and (2) allow for removal of fluid voxels in the subtracted STARBURST angiographic image based on the relation $R = S_U^{\,2} / [S_T \cdot \max(S_U)]$ where S_U and S_T denote voxel intensities in the untagged and tagged images, and $\max(S_U)$ denotes the maximum voxel intensity in the untagged image.

The neck of a volunteer was imaged on a 32-channel 1.5 T Siemens Avanto system equipped with a 6-channel head and neck coil. Segmented 3D bSSFP STARBURST imaging was performed with parameters: RF tag = 180 degree spatially non-selective adiabatic inversion pulse, RF tagging mode = sequential, FOV = 24 cm x 24 cm, matrix = 256 x 256, imaging slab = 64 0.8 mm-thick slices, TR = 2500 ms, TI = 1200 ms, flip angle = 90 degrees, bSSFP TR/TE = 3.6/1.8 ms, receiver bandwidth = 975 Hz/pixel, one shot per partition, GRAPPA acceleration factor = 2, slice oversampling = 25%, slice partial Fourier = 6/8th, acquisition time = 5 min. An axial slab orientation was chosen to visualize the carotid vasculature and cerebrospinal fluid (CSF). A water vial was placed next to the volunteer to further validate the technique's capability for fluid removal.

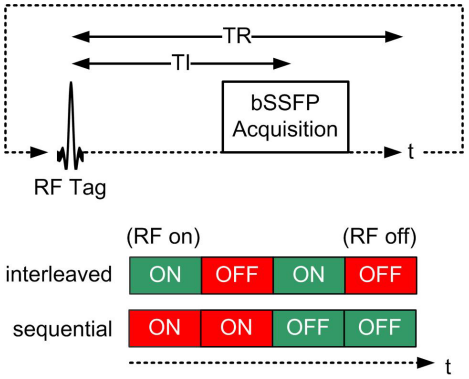

Figure 1. *Top*, Diagram of STARBURST imaging sequence. A non-selective RF pulse tag is applied. *Bottom*, interleaved and sequential acquisition modes for STARBURST. A single block represents one TR interval and indicates the presence or absence of a RF tag.

Results: Figure 2 shows tagged (a), untagged (b), and subtracted angiographic (c) image sets generated from a bSSFP STARBURST acquisition. The STARBURST angiographic image (Fig. 2c) clearly depicts the cervical vasculature (red arrows) and suppresses background muscle and fat. CSF and the water vial, however, appear undesirably hyperintense in the same image (yellow arrows). As shown in Fig. 2d, the value of R is especially large for CSF and for water voxels. Mean R values for the water vial, CSF, blood, muscle, and fat were 12.7 ± 0.4, 21.5 ± 1.9, 1.8 ± 0.4 ($\mu_{BLOOD} \pm \sigma_{BLOOD}$), 0.1 ± 0.1, and 0.5 ± 0.1, respectively. Fig. 2e shows the fluid-removed STARBURST image constructed by removing voxels from Fig. 2c with R values greater than 3.4 ($\mu_{BLOOD} \pm 4\sigma_{BLOOD}$).

Conclusion: Distracting fluid-bearing voxels appearing bright in bSSFP STARBURST angiograms may be identified and automatically removed based on their signal characteristics in untagged and RF tagged image sets.

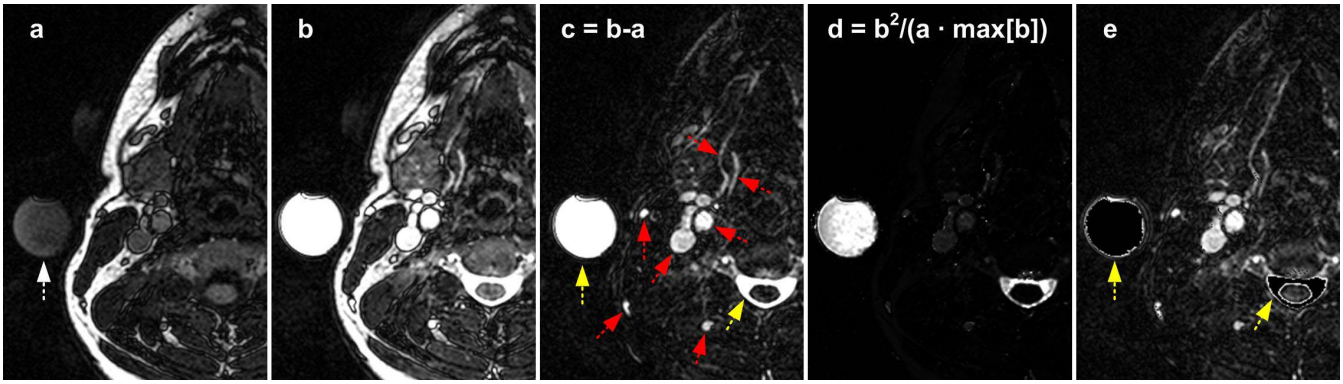

Figure 2. Transverse images through the neck of a volunteer illustrating the method for fluid removal. The water vial is indicated by the arrow in (a). Left to right: (a) tagged image (water vial indicated by arrow); (b) untagged image; (c) subtracted angiographic image; (d) R image; (e) fluid-removed angiographic image.