A voxel-wise comparison of global BOLD changes during breath-hold with CBV maps derived from bolus-injected Gd-DTPA

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Introduction:

Bolus-injected Gd-DTPA is the most commonly used method for mapping blood volume and perfusion. This method, however, is invasive, and gives virtually no information about vascular reserve and hemodynamic response properties. Arterial spin labeling (ASL) is emerging as a non-invasive clinically used technique that is able to map perfusion, but it is limited by poor signal to noise, limited brain coverage, and again, limited information about hemodynamic response properties. More recently, breath-holding has been used both with ASL and blood oxygenation level dependent (BOLD) MRI to assess global blood flow increases to the brain (1). In this study we compare time series BOLD contrast imaging during brief breath-holds to signal changes induced by a bolus injection of Gd-DTPA.

There are number of key differences between the breath-hold induced and contrast agent induced signal changes. First, the Gd-DTPA induced signal change reflects blood volume in both arteries and veins whereas the BOLD signal changes from a breath hold challenge reflect primarily oxygenation changes in veins. The difference of the maps created from the breath hold and the Gd-DTPA bolus may therefore highlight voxel-wise differences in the contribution from arterial and venous sources. Secondly, breath holding relies on an active blood flow response to a stressor, and may therefore highlight pathologies in the vascular response that are not as easily detected from a bolus of Gd-DTPA that is passively transported through the vasculature. A critical first step is to understand the differences between the breath hold response and the Gd-DTPA response in normal individuals.

Methods:

Several series of images were acquired using gradient-echo echo-planar sequence. (3T, TE: 30ms, TR: 500ms, voxel size: 3.75x3.75x5mm3, 5 slices, 300 image volumes/run) In 2 runs, subjects were at rest and received a bolus injection of Gd-DTPA after 1 min of scanning. In another 2 runs, subject were given a visual cue to hold their breath for a period of 20s, and a cue to resume normal breathing (for a period of 40s). Subject were instructed to hold their breath at the end of expiration. In addition, a high resolution T2*-weighted image was acquired to localize the vessels (2).

Relative magnitudes of Gd-DTPA induced signal changes across the brain were computed by first averaging the signal response for all brain voxels, normalizing this averaged response, then fitting this response to each voxel. The relative magnitude of the breath-holding response was computed in the same manner. Difference maps between Gd induced and breath hold induced changes were computed by converting the signal response magnitude to Z-scores, and subtracting the Z-score maps.

Results:

Breath holding for a period of 20s resulted in an average signal increase of 4.7%. A bolus injection of Gd-DTPA resulted in an average signal decrease of 42%. These changes were generally the largest in gray matter for both breath holding and Gd-DTPA bolus. However, a number of key differences emerged. Some regions of the brain showed large signal increases upon breath-holding but no correspondingly large changes with Gd-DTPA. In contrast, other areas showed a large blood volume change measured by Gd-DTPA, but relatively small changes with breath holding. These differences are highlighted in Figure 1d. A voxel-wise correlation of the relative magnitudes are shown in Figure 2.

Discussion:

Both breath holding and bolus injection of Gd-DTPA highlight regions in the brain that correspond to higher blood flow, most notably the gray matter. The differences between these measures likely reflect differences in the venous and arterial contributions. This is particularly evident in one of the inferior slices (slice 1 in Figure 1) in a region indicated to have a large vessel on the susceptibility-weighted venogram. Hypothesized differences are also in regions of different vascular responses to the hemodynamic stress. It is hypothesized that this technique may complement Gd-DTPA bolus injection studies clinically in that patients showing flow deficits or susceptibility to stroke may reveal regions of poor responsivity or vascular reserve that do not show significant signal changes yet show a normal blood volume.

References:

1. A. Kastrup, et al. *NeuroImage* 10 (1999)
2. J.R. Reichenbach, et al., *Radiology* 204 (1997)

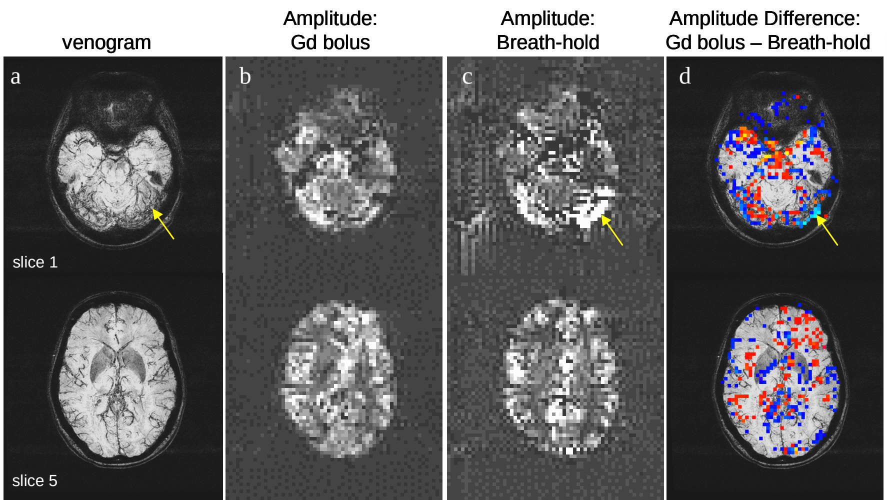

Figure 1: 2 slices of a) susceptibility weighted venogram, b) amplitude of signal changes in response to a bolus of Gd-DTPA, c) amplitude of signal changes in response to 20s breath-holding d) difference in normalized amplitudes of signal responses to breath-holding compared to Gd bolus. Blue = stronger response to breath-holding; Red = stronger response to Gd bolus.

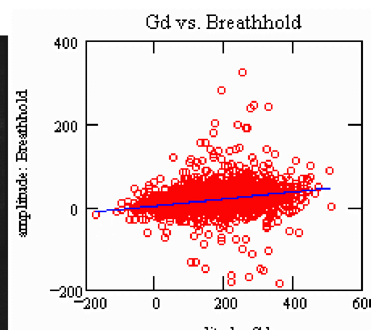

Figure 2: voxel-wise comparison of the signal intensity changes in response to 20s breath-holding and in response to a bolus injection of Gd-DTPA.