Free-Breathing Dynamic Contrast-Enhanced Abdominal Imaging using Navigator Gating and Adaptive Navigator Correction

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Introduction: Dynamic contrast-enhanced (DCE) 3D T1w MRI is routinely used in abdominal imaging. Each contrast-enhanced phase is acquired within a ~20s breath-hold to minimize motion artifacts [1]. However, this multi-breath-hold requirement faces many drawbacks: 1) compromised image quality in uncooperative patients, 2) disruption of temporal continuity between enhancement phases, 3) slice misregistration between phases, and 4) limited spatial resolution due to finite breath-hold duration. A navigated free-breathing technique may address many of these shortcomings.

Recently, a navigator gating method for free-breathing 3D T1w liver imaging was reported in which data was accepted/rejected based on diaphragm position [2]. Here we extend the navigator gating method to include prospective adaptive navigator correction [3-5] (aka "slab following") to adjust slab location to follow motion with the aim of improving the acquisition efficiency and image quality of free-breathing 3D T1w imaging.

Methods: A LAVA (Liver Accelerated Volume Acquisition) pulse sequence [1] was modified to include a 25ms, low flip angle, cylindrical navigator excitation pulse, typically prescribed over the subject's right hemi-diaphragm (Fig. 1, left). The navigator echo (NAV) was acquired at the start of every 200ms imaging block (Fig. 1, right), followed by spectrally-selective fat inversion (SPECIR) and segmented data acquisition (ACQ). S/I translation of the lung-diaphragm interface was calculated from the navigator echo in real time using an edge detection algorithm. The transmit/receive frequency and phase for the imaging block was then prospectively adjusted so the excited slab followed the underlying anatomy. Data from a given imaging block was accepted only when the measured diaphragm position fell within the acceptance window (±2mm default width, but could be manually adjusted); otherwise, data was rejected. On a 1.5T GE scanner (Signa HDx, GE Healthcare) using an 8-channel coil, phantom scans were first performed in the presence of software-controlled periodic 20mm S/I table motion to test the slab following feature. Next, 10 contrast-enhanced patient scans were performed with a conventional breath-held LAVA protocol, followed by free-breathing navigated LAVA acquired during delayed enhancement. All scans used 2D-accelerated (2x2) auto-calibrated parallel imaging [6] with ~1.1 x 1.3 x 4.2mm^3 acquired resolution.

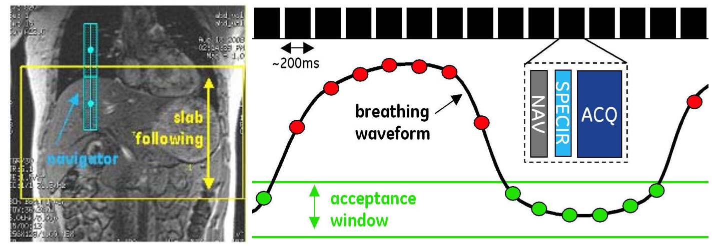

Fig. 1. (left) Navigator prescription and (right) navigator gated acquisition.

Results: Fig. 2 compares navigator-gated LAVA results from a moving phantom imaged (a) without and (b) with adaptive navigator correction, showing the benefit of slab following in reducing motion artifacts compared to gating alone. Fig. 3 compares delayed enhancement images acquired with (a) conventional breath-held LAVA and (b) navigated LAVA in a patient who had difficulty holding her breath. Whereas ghosting/blurring artifacts obscure anatomic detail in (a), image quality is considerably sharper in (b) with improved depiction of hepatic vessels and splenic borders. Fig. 4 compares (a) breath-held LAVA with (b,c) 2 contiguous phases of a free-breathing multi-phase navigated LAVA scan. The navigator acceptance window for this patient was opened up to ±3mm for an acquisition efficiency of 50% (or 40s/phase). Navigated images have comparable quality to the breath-held scan despite the wide acceptance window used, with similar visualization of hypovascular lesions (arrows, inset). Note also the excellent slice registration between navigated phases (b,c) owing to consistent volume position afforded by slab following.

Discussion: This work combines navigator gating with slab tracking to improve the image quality and acquisition efficiency of navigated 3D DCE liver imaging. It allows for continuous multi-phase free-breathing acquisition with inter-phase slice registration. Navigated 3D DCE imaging is a promising alternative to breath-hold imaging, and also has potential for enabling applications such as high spatial resolution scans needed for hepatocellular contrast agents or TRICKS-based methods for high temporal resolution.

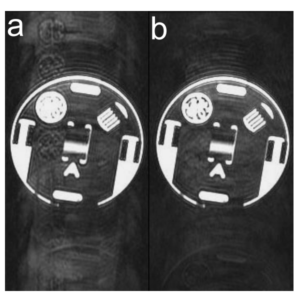

Fig. 2. Moving phantom (a) without and (b) with slab following.

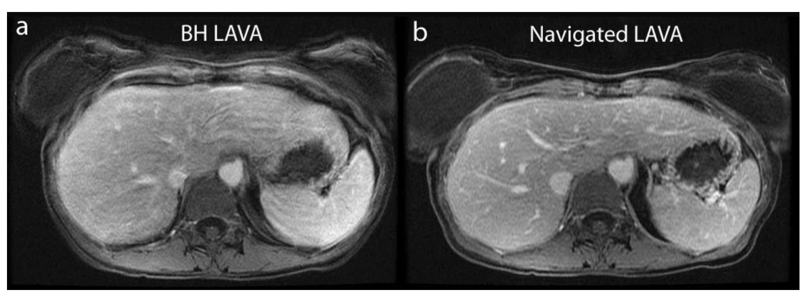

Fig. 3. a) Breath-held vs. b) navigated LAVA in a patient who had difficulty holding her breath.

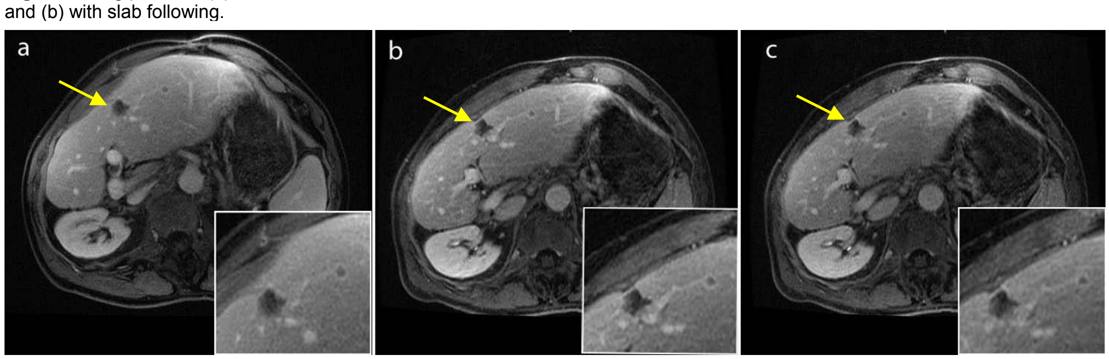

Fig. 4. a) Conventional breath-held LAVA (20s). b,c) Seamless multi-phase navigated LAVA acquired during free-breathing (40s/phase).

References 1. Rofsky et al. Radiology, 212, 876-884, 1999. 2. Brau et al. ISMRM 2009, 4620. 3. Ehman et al. Radiology 173:255–263, 1989. 4. McConnell et al. MRM 37(1), 148-152. 5. Kanematsu AJR 188:W309-W316, 2007. 6. Beatty et al. ISMRM 2007, 1749.