Respiratory Navigation Scheme for Free-Breathing 3D SPGR Liver Imaging: Technical Feasibility

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INTRODUCTION: 3D dynamic contrast-enhanced (DCE) spoiled gradient echo (SPGR) imaging is an important component of abdominal MR exams for the investigation of liver disease. Typically, the acquisition of each enhancement phase (pre-injection, hepatic arterial, portal venous, and equilibrium phases) is performed within a patient breath-hold; however, for patients who cannot breath-hold, such as severely ill and pediatric patients, motion artifacts can compromise the diagnostic utility of the image. Thus a respiratory-navigated acquisition is desirable to reduce motion artifacts in free-breathing 3D SPGR liver imaging.

Ideally, the addition of navigation to any sequence should minimize the impact on both image contrast and scan time. For 3D DCE imaging in particular, the navigated acquisition should remain sufficiently fast to capture the relevant contrast dynamics. In this work, we present the preliminary technical feasibility of a respiratory navigation scheme applied to a conventional fat-suppressed 3D SPGR sequence as well as to a 3D chemical species-based water-fat separation sequence.

METHODS: Studies were performed using investigational versions of GE's LAVA sequence, a 3D T1-w SPGR acquisition with magnetization-prepared fat suppression, and GE's LAVA-Flex sequence, a dual-echo Dixon-based 3D T1-w SPGR acquisition, modified to include a 25-ms, low flip angle, cylindrical 2D RF excitation navigator pulse. The navigator pulse was placed on the subject's right hemidiaphragm (Fig. 1) to track respiratory motion. As shown in Fig. 2, the navigator pulse (NAV) was applied after every 200-ms imaging block (dashed rectangle) to obtain a frequent update of respiratory position. For the LAVA sequence (Fig. 2A), the imaging block consisted of interleaved spectrally-selective inversion recovery (SPECIR) pulses and acquisition segments (ACQ), whereas for the LAVA-Flex sequence (Fig. 2B), the imaging block consisted entirely of data acquisition, since no fat suppression pulses were necessary. Data acquired within each imaging block was then prospectively accepted or rejected based on respiratory position, with an acceptance window of ±2 mm during expiration.

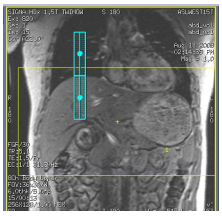

Fig 1. Navigator placement

Adult volunteers and patients were imaged on a 1.5T GE scanner (Signa HDx, GE Healthcare, Waukesha, WI) using an 8- or 12-channel torso coil. For each subject, non-navigated and respiratory-navigated LAVA and LAVA-Flex images were acquired during free breathing. Where possible, a breath-hold image was acquired as well. For patient scans, images were acquired in the post-contrast delayed phase. All scans used 2D-accelerated 2x2 auto-calibrated ARC parallel imaging (1) with either a separable sampling pattern and conventional segmented view ordering or a non-separable sampling pattern with adaptive centric view ordering (2), depending on desired net acceleration factor. The LAVA-Flex sequence used a Dixon-based reconstruction (3) to decompose water and fat images.

RESULTS: Fig. 3 compares non-navigated and navigated LAVA and LAVA-Flex images in free-breathing patients after contrast injection. Navigated image quality is visibly improved compared to non-navigated images, with fewer ghosts and blurring artifacts that obscure anatomical delineation. The image contrast of non-navigated and navigated scans is comparable, indicating that the navigation scheme did not significantly alter detected magnetization. Furthermore, no navigator saturation bands are observed, owing to the low-flip-angle cylindrical excitation. Navigated scan efficiency averaged 40% for a total navigated scan time of ~50s. Fig. 4 compares a breath-held LAVA image (Fig. 4A) to navigated LAVA images acquired with a separable (Fig. 4B) and non-separable (Fig. 4C) sampling pattern in a volunteer without contrast. The increased net acceleration achieved with non-separable sampling reduced the navigated scan time from 50s to 30s—a more reasonable target for capturing contrast dynamics—although with an expected drop in SNR.

CONCLUSION: This work presents the technical feasibility of a respiratory-navigated scheme for 3D SPGR liver imaging, showing that image contrast is preserved and scan times can be kept to within reasonable limits for potential DCE imaging. Further study is warranted to assess the ability of the navigated 3D SPGR sequence to capture multiple dynamic contrast enhancement phases.

References 1. Beatty et al. ISMRM 2007, 1749. 2. Bayram et al. ISMRM 2008, 463. 3. Ma et al. MRM, 52:415-419, 2004.

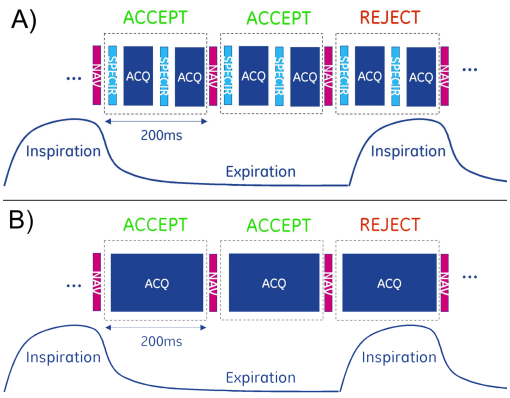

Fig 2. Navigator acquisition scheme for (A) LAVA and (B) LAVA-Flex. [Note: not drawn to scale.]

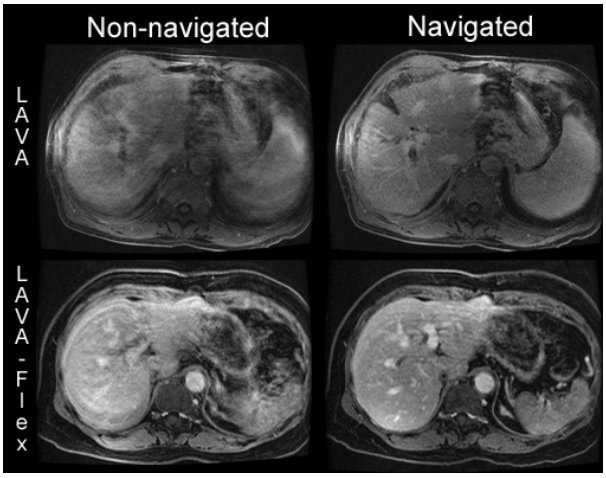

Fig 3. Non-navigated vs. navigated LAVA (top) and LAVA-Flex (bottom) in free-breathing patients after contrast injection. Motion artifacts are considerably reduced with navigation, with no observed impact on image contrast. Scan times increased from ~20s for non-navigated scans to ~50s for navigated scans, for an overall navigated scan efficiency of ~40%. Acquired resolution: 1.0x1.2x4.4mm^3.

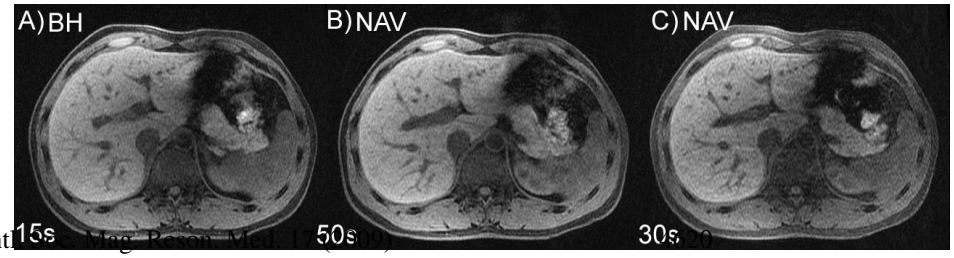

Fig 4. A) Breath-held LAVA, 15s scan time. B) Navigated free-breathing LAVA with separable sampling pattern, 50s scan time. C) Navigated free-breathing LAVA with non-separable sampling pattern, 30s scan time. The image quality of navigated acquisitions is comparable to the breath-hold scan. The increased net acceleration in (C) permits shorter navigated scan time. Acquired resolution: 1.1x1.5x4.2mm^3.