Respiratory-navigated free breathing 3D-SPGR sequence for contrast-enhanced examination of the liver: Diagnostic utility and comparison with free breathing and breath-hold conventional exams.

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Introduction: Contrast-enhanced 3D spoiled gradient-echo (SPGR) sequences are widely used for investigation of liver diseases (1) because they allow continuous coverage of the liver with high spatial resolution and T1 weighting in a single breath hold for most patients. However, patients with diminished or no breath-hold capacity present a challenge to this approach since either coverage or resolution must be sacrificed in order to shorten the acquisition time to the patient's breath holding limit. Respiratory navigation of 3D-SPGR sequences may provide a method to image these patients with maintained resolution and anatomical coverage. We present our initial clinical experience with a research version of GE's LAVA-flex sequence for liver imaging.

Methods: GE's LAVA-Flex pulse sequence, a 2D-accelerated dual-echo 3D SPGR acquisition, was modified to acquire periodic navigator data using a low flip angle cylindrical excitation pulse. 14 patients were imaged for clinical indications on a 1.5T GE scanner (Signa HDx, GE Healthcare, Waukesha, WI) using a 12-channel torso coil. After conventional imaging with contrast injection, 3 sequences were performed: a standard breath-held LAVA-Flex, a repeat of the same sequence with the patient breathing freely, and a respiratory navigated LAVA-flex. Both navigated and conventional sequences were performed with the following parameters: TR 6.9, TE 2.4, Flip angle 15, FOV 34, 320x192 matrix, Pixel BW 391Hz. Both sequences used ARC parallel imaging reconstruction (2) and 2-point Dixon reconstruction with a phase correction algorithm (3) to decompose water-only and fat-only images. A typical scan acquisition time was 1 minute. The navigator tracking pulse was placed on the highest point of the right diaphragm, with the trigger set to end expiration with an acceptance window of +/- 2mm. Images were graded independently by 3 board certified radiologists according to criteria in Table 1. The three sequences for each patient were also directly compared and ranked on a 5-point scale (Table 2).

Results: Average overall image quality ranking for the navigated images was 1.45 (STD 0.63), versus 1.90 (STD 0.30) for the standard breath held images, and 0.52 (STD 0.71) for the free breathing images (Figure 3). Comparison between series for each given patient indicated that image quality was better on the navigated images than the free breathing series (average score 1.10, with STD 1.01) (Figure 4). However, image quality for the navigated sequences did not match the breath held sequences (average score -0.98, STD 0.81). Although statistical power is limited by the small sample size, this suggests that while respiratory navigated images were inferior to breath-held images, they provided modest improvement over free breathing images. The residual motion artifacts on the respiratory navigated sequences probably result because the navigated acquisition does allow a small range of free-breathing motion within its data acceptance window. No saturation effects from the navigator pulse were observed in the volume of interest due to the low flip angle excitation. Radiologist preference for navigated images compared to free breathing images reached statistical significance, as did preference for standard breath-held images to navigated images.

Table 1: Ranking of Image Quality

Good
- Vessels and liver margins well delineated
- Motion does not obscure anatomic landmarks
- Generally of diagnostic quality

Moderately limited
- Vessels, lesion margins, or liver margins blurred by motion
- Motion could obscure subtle lesions

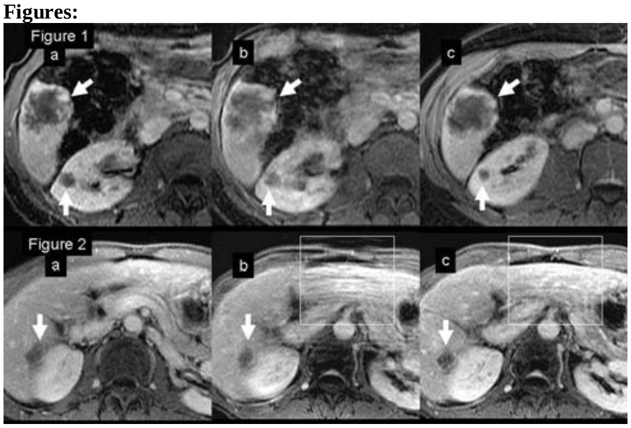
Motion renders nondiagnostic

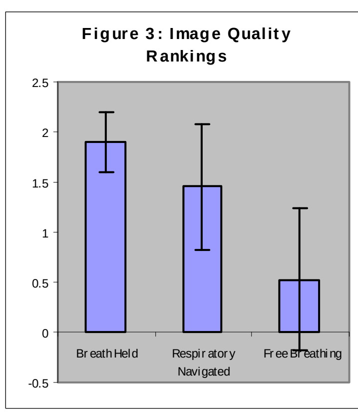
Table 2: Comparison of Overall Diagnostic Quality

	Nav vs. Breath held		Nav vs. Free Breathing
2	Navigated is much better	2	Nav is much better
1	Navigated is slightly better	1	Nav is slighly better
0	Image quality is comparable	0	Image quality is comparable
-1	Breath held is slightly better	-1	Free breathing is slightly better
-2	Breath held is much better	-2	Free breathing is much better

Conclusion: Although performance of the navigated sequence was inferior to breath-held examinations in our study, there was a modest improvement when compared to free-breathing series. Since the only current clinical alternative for patients with limited or no breath holding capacity is to decrease the inherent resolution of the images, even a modest improvement is useful if the residual ghosting artifacts can be "read through" and the inherent resolution of the images is preserved. A significant drawback to the technique is the additional scan time required for respiratory navigation, which prohibits acquisition of discrete hepatic arterial and portal venous phase images. This dynamic perfusion imaging provides important information in many situations. A clinical approach to such patients might involve initial sequential acquisition of low spatial/high temporal resolution images within the patient's breath hold time, followed by higher spatial resolution imaging with respiratory navigation. Further work is needed to optimize this technique, including investigation of patients with truly diminished breath holding ability.

Figures:





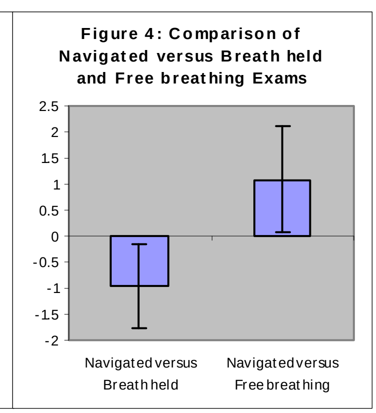


Figure 1. Comparison of breath held (a), free breathing (b), and navigated LAVA-flex (c) in a patient with Gaucher's disease. Note blurring of the edges of a liver hemangioma and renal cyst (arrows) on 1b, with restoration of lesion margins on 1c.

Figure 2. Comparison of breath held (a), free breathing (b), and navigated LAVA-flex(c) in a patient with areas of prior radiofrequency ablation for hepatocellular carcinoma (arrows). Note blurred lesion boundaries on 2b, with edges better seen on 2c with minimal respiratory ghosting (white boxes).

References:

1. Lee VS et al. Radiology 2000;215:365–372. 2. Beatty et al. ISMRM 2007, 1749. 3. 2. Ma, J., et al. MRM, 52:415-419, 2004.