Motion Detection Improvement of Pencil Beam Navigator Echo with Gradient Reversal Method

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Target Audience: Scientists and engineers who have an interest in navigator echo technique with pencil beam excitation.

Purpose: Pencil beam excitation technique[1, 2] is widely used in respiratory navigator MRI. A spiral k-space trajectory with oscillating gradient waveforms (Fig. 1a) is used during the pencil beam excitation for two-dimensionally selective excitation. This trajectory has discretization in the radial direction and causes undesired excitation outside the beam's area with inappropriate tracker placement, which results in motion detection corruption. The purpose of this work was to develop and demonstrate the feasibility of gradient reversal pencil beam excitation technique to reduce signal contamination by the undesired excitation.

Methods: *Side-lobe Signal Reduction:* The largest effect of undesired excitation comes from the side-lobe with the smallest radius from the beam center. A numerical simulation of the transverse magnetization shows that imaginary components of the first side-lobe magnetization are dominant, when the main lobe magnetization is designed to be aligned to the real axis (Fig. 1c). Moreover, this side-lobe magnetization is anti-symmetric about the beam center. So, addition of the complex conjugate of the magnetization, which is obtained with gradient reversal (Fig. 1b,d) during excitation, to the original magnetization diminishes most of the first side-lobe signal because only the real components remain. In actual scans, navigator signals were acquired with and without gradient reversal sequentially, and the signals were combined vectorially. We refer to this signal combination with gradient reversal as GR-combi technique.

Data Acquisition: We performed the navigator-gated 3D-SPGR scans with and without the GR-combi technique on GE 3 T Discovery MR750w imaging system (GE Healthcare, Waukesha, WI, USA) with floating anterior and fixed posterior coil arrays. The duration of navigator pencil beam pulse was 5.6 ms with 20 mm diameter and a 12-turn spiral, and navigator signals were acquired with 200 mm length and 256 readout points. In static cylinder phantom experiments, an extra sphere phantom was placed at a distance of 24 cm from center to center in order to produce side-lobe signals. Imaging parameters in the phantom scan included: TR/TE = 3.4 ms/1.3 ms, slice thickness = 4.0 mm, 52 slices, FOV = 40 x 40 cm, matrix = 160 x 160, NEX = 0.69, receiver bandwidth = ±62.5 kHz and flip angle = 12°. Imaging parameters in the volunteer scan included: TR/TE = 3.3 ms/1.3 ms, slice thickness = 4.0 mm, 56 slices, FOV = 40 x 40 cm, matrix = 160 x 160, NEX = 0.71, receiver bandwidth = ±62.5 kHz and flip angle = 12°.

Results: In the phantom scan, undesired excitation of the extra sphere phantom caused navigator profile deterioration by generating signals in the superior region indicated by an arrow in Figure 2a. The GR-combi technique diminished the signals, and its navigator profile (Fig. 2b) was similar to that acquired with the conventional method without an extra spherical phantom (Figure 2c). In the volunteer scan, the GR-combi method diminished signals in the lung region (arrows in Fig. 3). This enabled more accurate detection of respiratory motion, and reduced motion artifacts in navigator-gated 3D-SPGR images (Fig. 4).

Discussion: The use of the GR-combi technique is not limited to the spiral k-space trajectory, and this can be applied to other trajectories for multi-dimensional excitation. Main trade-off of the GR-combi technique is the total scan time elongation by about ten percent. However, inaccurate motion detection may result in even longer scan time.

Conclusion: We have demonstrated that the GR-combi technique diminished undesired signal contamination and improved motion detection and correction in navigator-gated 3D-SPGR.

References: 1. Pauly J, Nishimura D, et al. A k-space analysis of small-tip-angle excitation. J Magn Reson. 1989;81:43–56.

2. Hardy C, Cline H. Broadband nuclear magnetic resonance pulses with two-dimensional spatial selectivity. J Appl Phys. 1989;66:1513–1516.

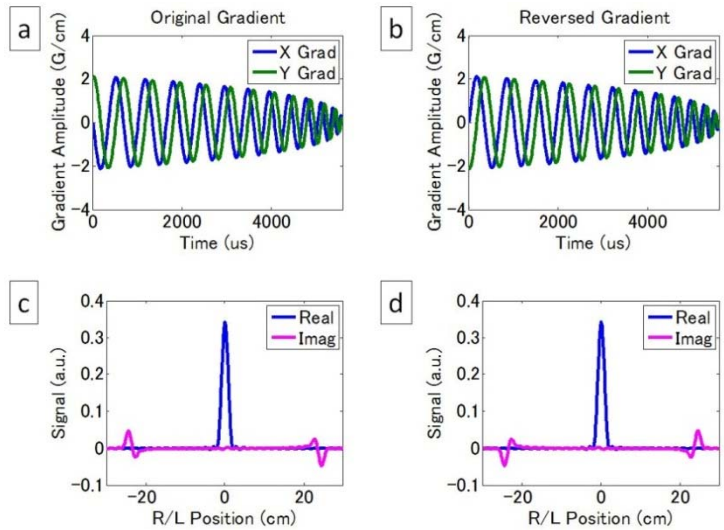

Fig. 1 Waveforms of (a) original and (b) reversed gradients, and simulated transverse magnetization with (c) original and (d) reversed gradients.

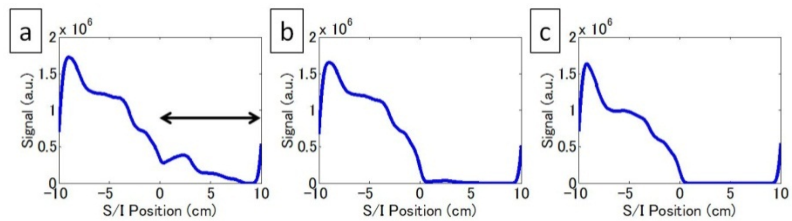

Fig. 2 Navigator profiles of a cylinder phantom with (a,c) conventional and (b) GR-combi methods. Profile in (c) was acquired without a spherical phantom.

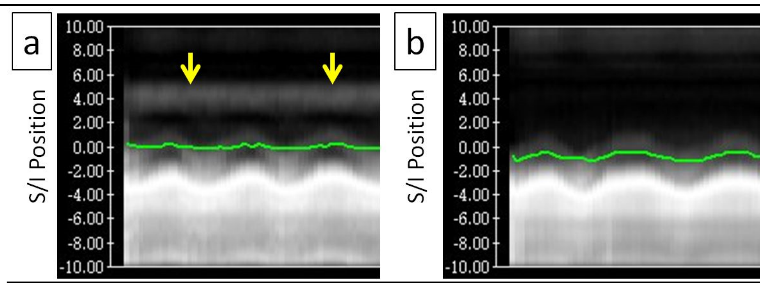

Fig. 3 Volunteer navigator signals and detected liver edges (green lines) of (a) conventional and (b) GR-combi methods.

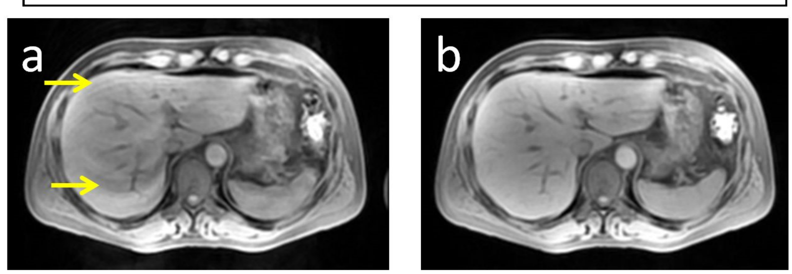

Fig. 4 Navigator-gated 3D-SPGR images of (a) conventional and (b) GR-combi methods. Arrows indicate motion-induced ghosts.