Enhancement of Respiratory Navigated 3D Spoiled Gradient-Recalled Echo Sequence with Variable Flip Angle Scheme

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Introduction

Respiratory-gated fat-suppressed 3D spoiled gradient-recalled echo with navigator echo (Navigated LAVA) enables 3D T1-weighted imaging of free breathing patients with considerably reduced motion artifacts [1, 2]. In this method, the navigator sequence runs immediately after the imaging sequence, and navigator signal is sensitive to spin saturation effect of imaging excitation RF pulse especially when the imaging flip angle is high such as 30 degrees. In this work, enhanced navigated LAVA was developed to address the spin saturation effect utilizing a wait insertion and a variable flip angle scheme, while maintaining or even improving the image quality.

Methods

Pulse Sequence Design: We inserted a 20ms wait period just before navigator sequence (fig. 1) to wait T1 recovery and reduce spin saturation effect. This increases not only a navigator signal but also the imaging signals acquired immediately after navigator, resulting in point spread function deterioration (fig. 2a). The deterioration was caused by emphasized edge with partial kz scheme and data discontinuity with interleave slice ordering in k-space. Variable flip strategy of imaging sequence was taken to overcome image degradation by wait insertion. Ramp-up of the first four RF flip angles and ramp-down of the last two RF flip angles were implemented to make ripple level smaller (fig. 2b). The first and last flip angles were designed to be half of the maximum flip angle, and ramp-up and ramp-down were done linearly. To make the signal intensities similar between the first segment and the following segments, 20 percent of the flip angles were attenuated in the first segment (fig.2c). By doing this the signal discontinuity was remarkably reduced in k-space and ghost artifact components were much smaller than without attenuation.

Data Acquisition: We conducted 3D Navigated LAVA (TR/TE=3.3ms/1.6ms, FOV=340mm^2, matrix=256x192, partial kz factor=0.7) with and without wait insertion. Variable flip strategy was also tried with the wait. We performed all scans on GE Signa 1.5T HDxt MR imaging system (GE Healthcare, Waukesha, WI, USA) with an 8-channel cardiac array coil, and informed consent was obtained from a volunteer.

Results

SNR of navigator signal was improved with wait insertion Variable flip angle further improved the signal and resulted in accurate edge detection of the liver (fig. 3). Image data showed that combination of wait insertion and variable flip method produced better homogeneity and higher SNR than the conventional and the wait-insertion images (fig. 4).

Discussion

Variable flip strategy improved not only the image quality but also navigator signal. This was caused by the ramp-down of flip angle just before navigator sequence. Tradeoff of the wait insertion is scan time elongation (about 10 percent). However, noisy navigator signal can lead to much longer elongation or even to scan failure due to misdetection of the diaphragm movement, so this method can stabilize scan time as well as image quality, especially for high flip angle scan such as 30 degrees.

Conclusion

Combination of the wait insertion and the variable flip method improved both navigator signal and image quality in navigated LAVA study.

References

1. Vasanawala et al., Pediatr Radiol 40:340-4 (2010). 2. Young et al., AJR Am J Roentgenol 195:687-91 (2010).

Fig. 1 Schematic description of navigated LAVA with a 20ms wait before navigator sequence (arrow). Image data acquisition does not start with kz of 1 due to partial kz acquisition scheme. Data are acquired in an interleaving way in the z direction.

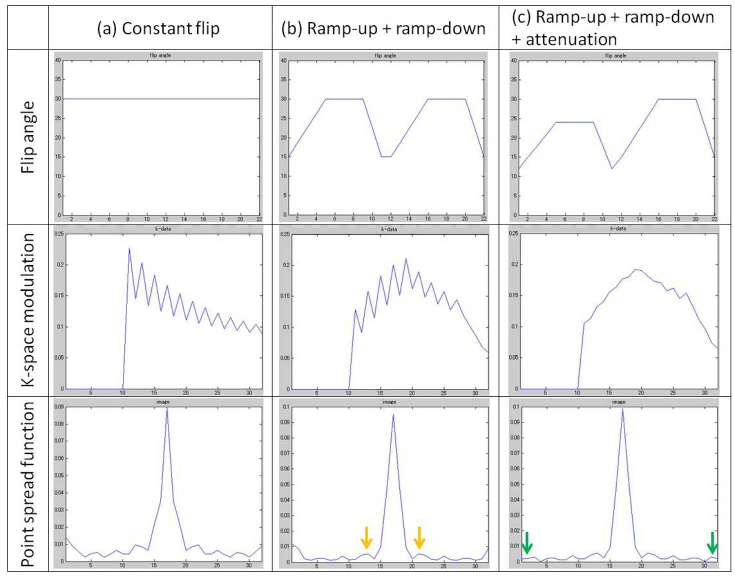

Fig. 2 Effects of flip angle modification on k-space and resulting point spread function in image space. In image space, ramp-up and ramp-down of flip angle reduced ripple (orange arrows), and flip attenuation in the first segment reduced ghost component near the FOV edge (green arrows). Interleaving slice order resulted in the k-space data discontinuity in (a) and (b).

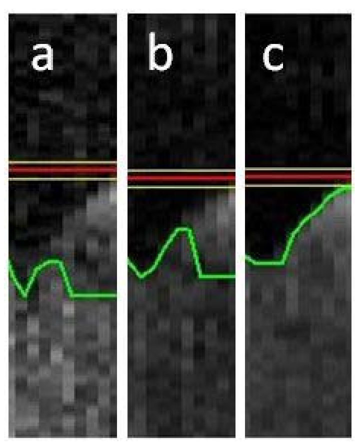

Fig. 3 Navigator signals and detected edges (green lines) of navigated LAVA with (a) conventional method, (b) wait, and (c) wait and variable flip. The maximum flip angle was 30deg.

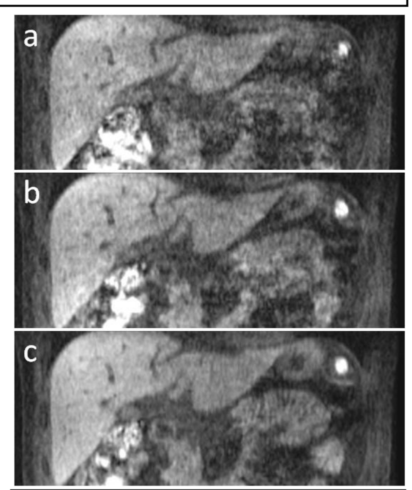

Fig. 4 Reformatted navigated LAVA images with (a) conventional method, (b) wait, and (c) wait and variable flip. No contrast agent was injected. The maximum flip angle was 20deg.