FREE-BREATHING COMBINED FUNCTIONAL AND VIABILITY MR IMAGING OF THE HEART

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INTRODUCTION

Composite strain-encoding (C-SENC) MRI provides simultaneous myocardial functional and viability imaging at the same cardiac phase (1). Breath-holding is commonly used to minimize respiratory motion artifacts. However, breath-holding can be difficult or impossible for some patients. Reducing the breath-hold duration restricts the image resolution and signal-to-noise ratio (SNR). Reduced temporal-resolution could result in misregistration between the acquired strain and viability images. Also, reduced spatial-resolution could affect the accuracy of determining the infarcted region. Real-time diaphragm monitoring through navigator-echo (NE) solves the respiratory motion problem while requiring little patient cooperation and producing high-quality images. In this work, the navigator-echo technique is combined with C-SENC for free-breathing C-SENC imaging. The resulting images are found to be superior to those acquired with breath-holding (BH).

METHODS and EXPERIMENTS

In C-SENC imaging, tagging is applied in the slice-selection direction right after the detection of the QRS complex of the ECG signal. At the imaging timepoint, three images are consecutively acquired with different phase-encodings: low-tuning (LT), high-tuning (HT), and no-tuning (NT) images. The LT and HT images are combined to construct a strain image as described in (2). The NT image is a T_1-weighted viability image which, after contrast injection, shows bright infarction. The functional and viability images could be color-coded and combined into one composite image (1).

Because the heart bulk motion is mainly in the craniocaudal direction due to respiration, a 1D navigator image, obtained across the liver-lung interface, is a good indicator of the diaphragm motion and heart position (3). Navigator position is prospectively calculated before image acquisition using cross-correlation. Changes in the cardiac position around the end-expiratory position (within the gating window limit) are corrected by adjusting the location of the imaging plane. Otherwise, collected image data is rejected and is measured in a later cardiac cycle. This allows for the most time-efficient data acquisition with NE.

Figure 1 shows a schematic of the pulse sequence. The navigator-echo consists of a spiral cylindrical excitation followed by a flow-compensated readout along the long-axis of the cylindrical excitation. A shallow NE flip-angle is used to avoid saturation effects. Five human subjects with and without myocardial-infarction (MI) were scanned on a 3T Philips scanner. The imaging parameters for breath-hold (BH) C-SENC: spiral acquisition = 12 spirals×12 ms; TR/TE = 18/2.6 ms; scan-duration ≈ 13 s; FOV = 350×350 mm^2; scan-matrix = 128×256; trigger-delay (TD) ≈ 300 ms; GD-DTPA = 0.2 mmol/kg; images acquired 10-15 minutes post-injection. The imaging parameters for NE C-SENC are the same as BH C-SENC imaging, except: spiral acquisition = 14 spirals×14 ms; scan matrix = 256×256; navigator gating-window = 7 mm; scan-duration = 36 s. Also, standard inversion-recovery delayed-enhancement (DE) images were acquired to determine the existence of MI.

RESULTS

Figure 2 shows the resulting images from a subject who showed a thin subendocardial line of enhancement by DE (Fig. 2a, arrows). This enhanced region could represent MI or fibrosis. With BH C-SENC imaging, the acquired spatial resolution was not sufficient for the detection of the enhanced myocardium as shown in the C-SENC composite image (Fig. 2b). The corresponding NE C-SENC image shows higher resolution and SNR, which enabled the detection of the enhanced region (blue region in the composite C-SENC image, Fig. 2c). White and red represent minimum and maximum strains, respectively. Figure 3 shows the results from a patient without MI. The NE C-SENC image has higher resolution (double) and SNR (40% more) than the BH C-SENC image, which allows for accurate computation of strain values. From all the scans, the total scan time of NE C-SENC imaging (39±8 s), including NE prescan, was similar to that of BH C-SENC imaging (35±6 s), including the BH instructions and recovery time in-between breath-holds (The NE average acquisition-efficiency was 40%). However, the difference in the calculated infarct size was significant ($P<0.01$). The infarct size determined by NE C-SENC was always closer to that by IR-DE than was the one determined by BH C-SENC.

DISCUSSION and CONCLUSIONS

The navigator-echo technique was successfully combined with C-SENC for free-breathing combined viability and functional cardiac imaging. NE C-SENC imaging results in higher resolution, higher SNR, and easier imaging setup without significant increase in the total scan-time. Because of the improved spatial resolution, this technique may support a more accurate assessment of infarct size, location, and quantification of local strain values.

REFERENCES

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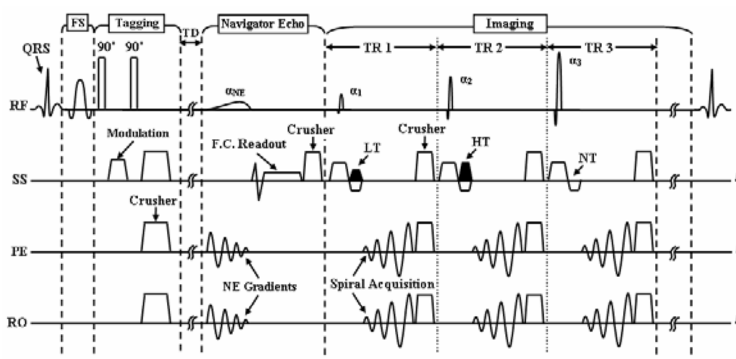

FIG. 1. Pulse sequence diagram for navigator-echo C-SENC (FS = fat suppression)

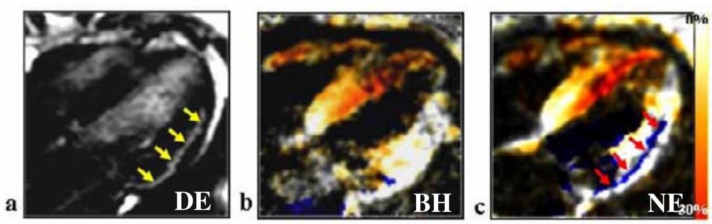

FIG. 2. Results from a subject who showed a thin region of enhanced myocardial signal intensity in the DE image (arrows). (a) DE image. (b) Composite C SENC circumferential strain image acquired with breath-hold. The thin bright myocardial region is missed with this resolution. (c) Corresponding navigator-echo C-SENC image. With this better image quality, the enhanced myocardium is detected (blue). White and red represent min. and max. strains.

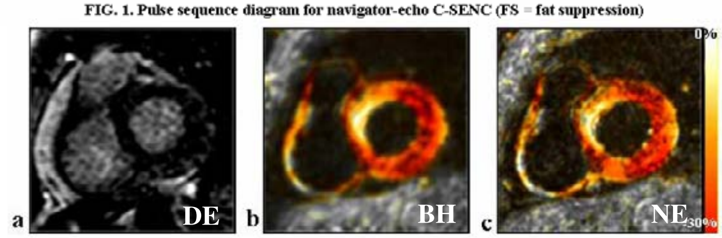

FIG. 3. Results from a patient without MI. (a) DE image showing no infarction. (b)Composite C-SENC longitudinal strain image acquired with breath-hold. The image has low spatial resolution. (c) The corresponding navigator-echo C-SENC image has higher SNR and spatial resolution. White and red represent min. and max. strains.