The Effect of k-Space Trajectory on Strain-Encoded Cardiac MRI

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Introduction: Strain encoding (SENC) is a newly developed MRI technique for measuring myocardial strain in the through-plane direction [1]. It requires simple post-processing and gives resolution on the pixel level. With conventional SENC sequence, two separate scans are required to obtain two sets of images (low-tune (LT) and high-tune (HT)), which are combined to result in the strain images. Such approach increases scan time and could result in image misregistration in post-processing. Non-Cartesian k-space trajectories are becoming more popular because they allow for large undersampling with acceptable image quality [2]. In this work, SENC was combined with undersampled radial k-space acquisition and interleaved SENC tunings to reduce scan time to one breath-hold with comparable image quality.

Methods: Fig. 1 shows the modified SENC pulse sequence. Five volunteers were scanned on a 3T MRI system (Siemens TIM TRIO, Erlangen, Germany). For each volunteer, four SENC scans were conducted in four separate breath-holds. Conventional SENC pulse sequence was used in the first and second scans: in the first scan, a set of cine LT images was acquired with Cartesian k-space (no undersampling). The second scan was the same as the first scan, but with HT images. In the third scan, the modified SENC sequence (Fig.1) was used: interleaved LT and HT tunings with radial undersampling (60%). The fourth scan was a repetition of the third scan, but with undersampled Cartesian instead of radial (same ratio), for comparison. The imaging parameters for conventional SENC were: 2D FLASH sequence; Cartesian trajectory; # segments = 10; # heart phases = 13 (single tune); # averages = 1; percent phase encoding = 100%; matrix = 256×256; slice thickness = 10 mm; TR/TE = 61/3 ms; bandwidth = 400 Hz/pixel; flip angle = 15° (ramped fashion); acquisition time = 20 s. The imaging parameters for radial acquisition differ in: Radial trajectory; # segments = 6; # heart phases = 22 (interleaved LT and HT); radial undersampling = 60 %; TR/TE = 36/3 ms. The LT and HT images were combined as described in [1] to result in the strain images. Each SENC image was used twice (view-sharing) to reduce apparent temporal resolution in half. Signal-to-noise ratio (SNR) was measured in each image by dividing myocardial mean signal intensity by standard deviation (SD) of background noise. Strain values were calculated at different left ventricular locations from corresponding Cartesian and radial images, and Bland-Altman analysis [3] was conducted between the two measurements.

Results: Fig.2 shows the resulting strain images. The undersampled radial images show similar image quality to conventional Cartesian images. No streak artifacts were observed in the resulting images (the undersampled Cartesian images (scan # 4) resulted in deteriorated image quality). SNR was 15 and 20 for the radial and Cartesian images, respectively. Bland-Altman plot (Fig.3) shows no bias in strain measurement between the two methods (all differences lie within the ± 2SD limits).

Discussion and Conclusions: SENC imaging results in high resolution myocardial strain images without complicated image processing. Radial k-space acquisition allows for SENC imaging in one breath-hold with satisfactory image quality. Image misregistration artifacts due to different breath-hold positions or varying heart rate would be minimized using the proposed method. Employing the same undersampling ratio with Cartesian acquisition resulted in deteriorated image quality and introduced artifacts. Using high-field 3-Tesla system compensates for the SNR loss associated with reduced data acquisition. Future studies will address implementing 3D radial acquisition for achieving higher SNR and lower slice thickness.

References [1] Osman *et al*, MRM,46:324-334. [2] Shankaranarayanan *et al*, Radiology,21:827-836. [3] Altman *et al*, Statistician,32:307-317.

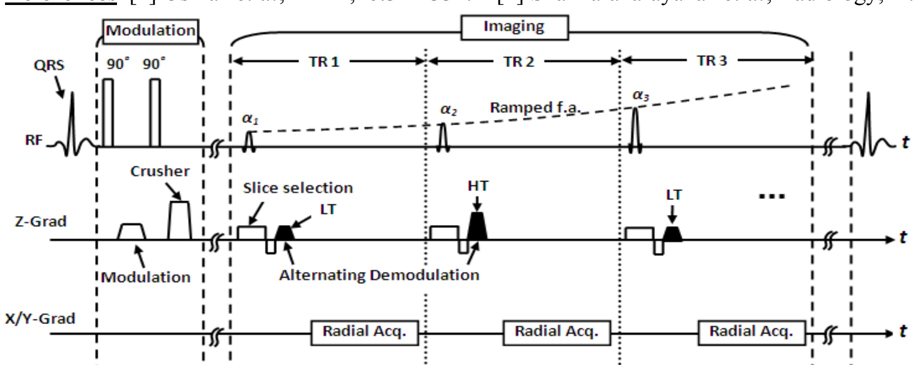

Fig.1. Modified SENC pulse sequence. The sequence consists of two sections: modulation and imaging. Magnetization is modulated using non-selective 90°-90° RF pulses with z-gradient in-between. During imaging, alternating low-tuning (LT) and high-tuning (HT) demodulations are implemented. Radial k-space reading is used with 60% undersampling. Imaging RF pulses are ramped during the cardiac cycle to compensate for modulation fading.

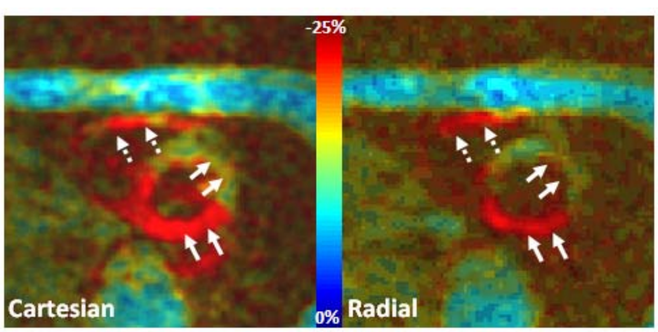

Fig.2. Short-axis SENC images showing longitudinal strain at the same heart phase. Cartesian (left) and Radial (right) acquisition. Arrows point to high-strain inferior and low-strain anterior LV myocardium. Dotted arrows point to RV. The radial image has acceptable image quality and was acquired in half the time as the Cartesian.

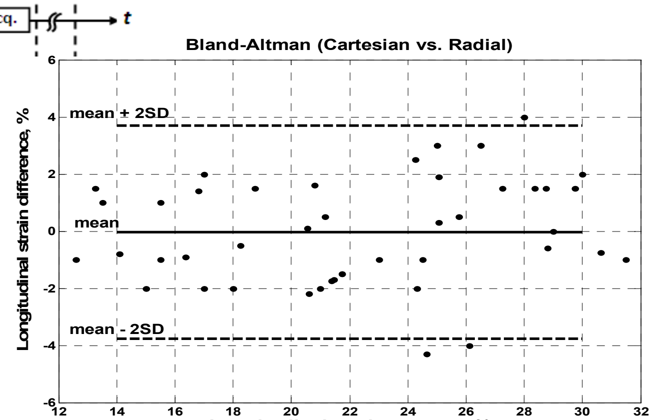

Fig.3. Bland-Altman plot for the correlation between myocardial longitudinal strain from Cartesian and radial SENC images. The plot shows no bias between the two methods.