Comparison of different data acquisition strategies in myocardial strain assessment using strain-encoded (SENC) MRI

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Introduction: Strain-encoding (SENC) MRI was recently introduced for measuring myocardial through-plane strain with high resolution and simple post-processing (1). Figure 1 shows the SENC pulse sequence. In a typical sequence, k-space data is acquired line by line in a rectilinear fashion, which results in long scan time and renders the technique impractical in many applications. Nevertheless, fast imaging techniques, e.g. radial or spiral acquisition, allow for reducing the scan time while maintaining adequate image quality. In this work, radial and spiral acquisitions were implemented in SENC for improved performance. The developed sequences were tested on volunteers and compared to standard Cartesian acquisition.

Methods: Spiral, radial, and Cartesian acquisitions were implemented in SENC. Spiral acquisition was designed as described in (2). The different sequences were tested on four volunteers on a Siemens Tim Trio 3.0-Tesla scanner. The imaging parameters were: FOV = 350 mm, slice thickness = 10 mm, flip angle = 15°, # heart phases = 25, and scan time = 17 s. The sequences were optimized for the same scan-time. Achievable resolutions were 160×160 for Cartesian (80% phase-encoding coverage) and radial (128 radial spokes), and 256×256 for spiral (10 spirals with two averages). The low-tuning (LT) and high-tuning (HT) images were combined as described in (1) to construct the strain images. Strain values were measured at five different points along the lateral wall of the left ventricular on all volunteers. Circumferential and longitudinal strains were computed from long-axis and short-axis SENC images, respectively. Bland-Altman analysis (3) was conducted to investigate biasness among different sequences.

Results: Figure 2 shows example of the acquired SENC images. The strain values measured at the same position were similar in different images, as shown in the strain curves in Figure 3. The Bland-Altman analysis showed no bias between strain measurements from different acquisitions (Figure 4). The mean ± SD of the (circumferential/longitudinal) strain differences were -0.2±1.53 / 0.0±0.83 % and 0.39±2.13 / 0.33±1.3 % for the spiral-Cartesian and radial-Cartesian measurements, respectively. All the differences lied within the ± 2SD limit.

Discussion and Conclusions: Data acquisition strategy (k-space trajectory) affects scan time and the resulting image quality in SENC. Image quality was similar in Cartesian and radial acquisitions. Partial radial acquisition can be achieved to reduce scan time without much affecting the image quality. However, due to its acquisition nature, spatial resolution is compromised with radial k-space. For the same scan time, spiral acquisition allowed for improving resolution by more than 60% and doubling # averages, compared to Cartesian or radial, despite longer reconstruction time. High spatial resolution would allow for accurate measurements in small structures, e.g. thinning myocardial wall, or it can be traded for faster or real-time imaging. The choice of the acquisition technique depends on the patient condition, available scan time, and imaging features of importance.

References: [1] Osman et al, MRM 2001, 324-334. [2] Glover, MRM 1999, 412-415. [3] Altman and Bland, Statistician 1983, 307-317.

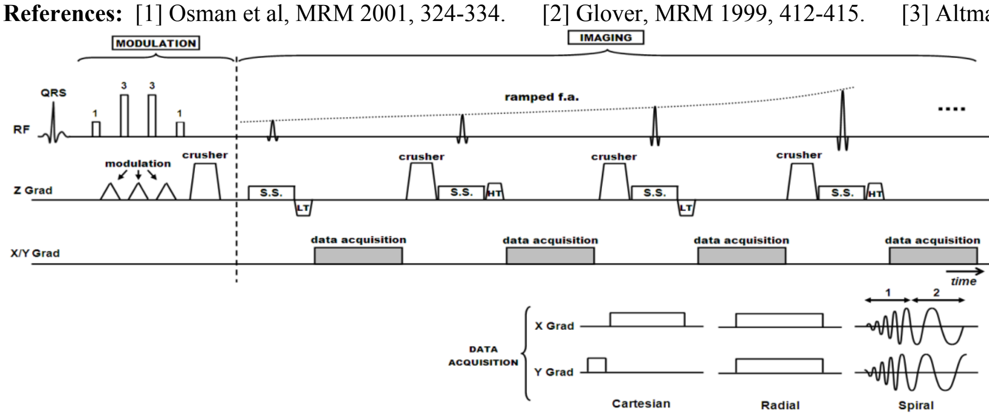

Figure 1. SENC pulse sequence. The pulse sequence consists of two parts: modulation and imaging. The modulation part is composed of binomial (1-3-3-1) non-selective RF pulses, interspersed by modulation gradients in the slice-selection direction, and followed by a crusher gradient. The imaging part is composed of a series of ramped slice-selective RF pulses, each followed by a demodulation (tuning) gradient in the slice-selection direction, and then data acquisition. Interleaved tunings were implemented to reduce scan time. Data acquisition can be either Cartesian, radial, or spiral as shown in the bottom. Spiral gradients were designed to consist of two parts: 1) slew-rate limited and 2) amplitude limited modes.

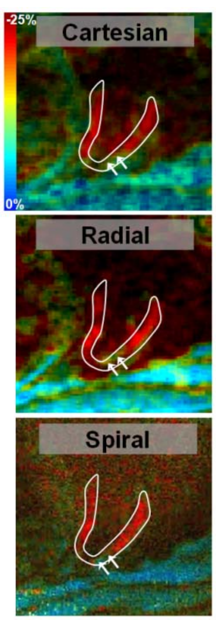

Figure 2. SENC long-axis images from Cartesian (up), radial (middle), and spiral (down) acquisitions showing circumferential strain at end-systole. Cartesian and radial show similar image quality, while spiral shows superior resolution. All images show similar contracting pattern in the heart. The arrows point to part of the apical wall showing low strain, which appeared in all images.

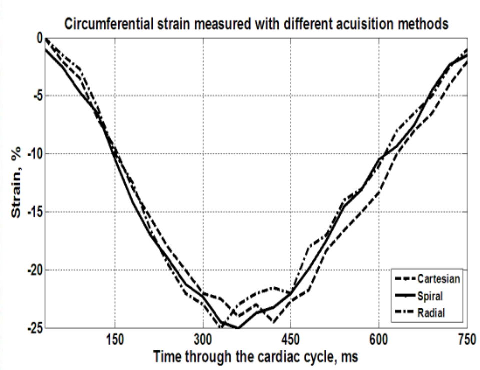

Figure 3. Circumferential strain through the cardiac cycle measured from SENC images with spiral (solid), Cartesian (dashed), and sadial (dot-dashed) acquisitions. The curves show similar contracting pattern and strain measurements irrespective of the acquisition strategy.

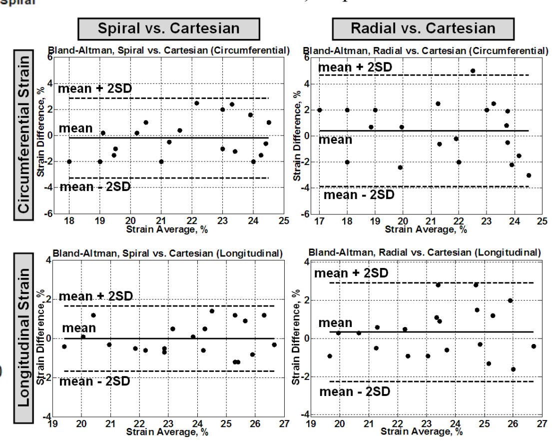

Figure 4. Bland-Altman plots for the correlation between circumferential (up) and longitudinal (down) strains from SENC with different acquisitions: spiral vs. Cartesian (left) and radial vs. Cartesian (right). The plots show good agreement between different techniques. All differences lie within the ± 2SD limits. The measurements from radial acquisition show larger variabilities than from spiral.