CIRcumferential COMpression Encoding (CIRCOME)

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Introduction: Left ventricle circumferential strain (LVCS) is an important parameter in the quantitative evaluation of heart failure. LVCS describes the regional and global amplitude of myocardial contraction. Calculation of strains is performed through the spatial differentiation of the myocardial displacement field which is a highly noise sensitive procedure [1,2]. Measuring the displacement field also needs time consuming imaging and post-processing methods. Therefore methods like SENC (Strain ENCoding) MRI that measure the strain directly make the entire process faster and more robust [3]. We propose the pulse sequence and algorithm of a novel method, CIRCOME, that measures the circumferential strain simultaneously in several short axis (SA) planes.

Methods: Since MR images are acquired in the frequency domain (K-space), the compression of the patterned lines may be extracted through the appropriate filtering in K-space. When each SA image is tagged by radial lines that meet in the center of the left ventricle, circumferential strain, which is proportional to the changes in radial line compression, may be directly obtained through simple processing in the K-Space domain. In summary the method contains these steps:

- Tagging the SA slices in the radial direction by appropriate modulation of the longitudinal magnetization.
- Imaging the primary and deformed patterns. (Imaging can be two or three-dimensional with different numbers of phases. This preparation may be combined with any imaging sequence.)
- Finding the circumferential frequency in images by circular filtering of the K-space data.
- Calculating the circumferential strain by frequency shift values.

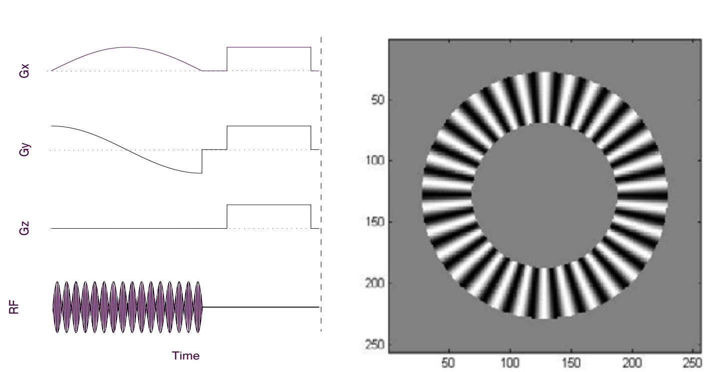

Figure 1. Left, preparation pulse sequence to be used with this method. Right, its expected magnetization modulation.

Description: a) Preparation: CIRCOME practicability depends on the efficient implementation of radial tagging. In this method we modulate the longitudinal magnetization by a preparation pulse sequence which is shown in figure 1-a. For simplicity the center of the Left Ventricle (LV) is assumed to be at the magnet isocenter and the LV long axis is in the Z-direction. In-plane gradients are a pair of 90 degree out of phase sinusoidal pulses which causes the on-resonance plane rotates around the Z axis. Magnitude modulation of the RF pulse results in a periodic longitudinal magnetization like figure 1-b for the whole heart volume. Gradient spoilers then destroy the transverse magnetization. Any imaging readout sequence can follow this preparation. Fast readout should make possible multiphase multilayer imaging before tag lines fade.
b) K-space filtering: Regions with certain degrees of compression of radial tag lines may be reconstructed through the circular bandpass filtering of K-space. These regions become more specific with more selective filters (i.e. thinner circle in K-space). If we reconstruct the image through sequential scanning of the whole K-space by these filters and weigh each recovered region with the corresponding frequency, we'll get the structural image encoded by the level of the compression of radial tag lines. Spiral k-Space sampling may facilitate this step. Figure 2 shows the result of this procedure for a slight deformation in a simulated displacement.
c) Circumferential Strain: Global circumferential strain can be easily determined by the shift of the circumferential frequency average. Regional strain needs comparison of the frequency between corresponding regions before and after deformation. Having radial tags, corresponding regions can be automatically found without time consuming exact tissue tracking techniques.

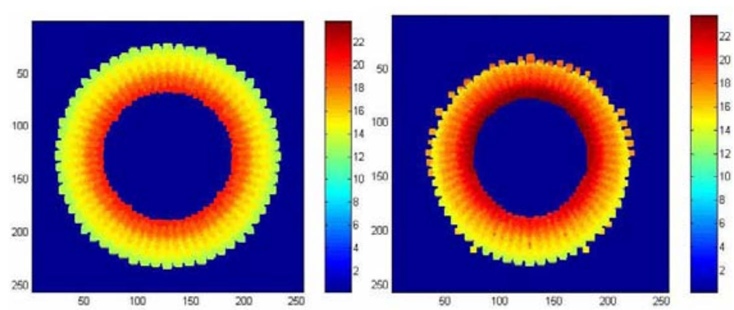

Figure 2. Circumferential Frequency for the images in figure 1-b. Level of compression is shown with color coding. Contraction of the higher half of the circle is obvious in the right image.

Conclusion: CIRCOME can:

1- Encode the circumferential compression of the heart for several Short Axes planes simultaneously and in real-time.
2- Measure the global circumferential strain of those slices in real-time and in a robust way, without taking spatial derivatives.
3- Measure the regional circumferential strain in those planes fast and with minimal calculations for tissue tracking.
4- Be combined with different MRI pulse sequences.

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