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Meeting abstract

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1140 A new method for measuring through-plane strain using slice following with inversion recovery (SFIR)

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Introduction

MRI is a unique modality in imaging the motion of moving tissues including that of the heart. Tagging and phase contrast techniques have been used to noninvasively measure the myocardium motion. In this work, a new technique is proposed to measure the through-plane strain based on the changes in slice profile that occur due to the tissue deformation.

Theory

Slice following imaging

In slice following imaging [1], a thin slice is excited by slice selective inversion while a thicker slice containing the thinner one is imaged. If a deformation of tissue occurs to the excited slice, the slice thickness changes accordingly, accompanied by changes of the slice profile in the frequency domain. In case of a rectangular slice profile, changes in the slice thickness will result in changing the width of the sinc profile in the frequency domain (Fig. 1).

Imaging technique

In order to capture the tissue deformation, complete knowledge about the slice profile in frequency domain is required. For a rectangular slice profile ($s(t) = \mathrm{rect}(t/B)$ and $S(\omega_z) = B\mathrm{sinc}(B\omega_z)$, where B is the slice thickness), two samples at two different z-frequencies (tunings) are sufficient to fully describe the sinc function. This can be done by acquiring two images at two different points (*tunings*) in the k_z direction by applying a suitable gradient moment in the z-direction during the refocusing lobe.

Strain computations

For a voxel with initial slice thickness B_0, two intensities are acquired at two different tuning frequencies, I_0 at ω_0, and I_1 at ω_1. The new slice thickness at time t (B_t) can be estimated as $B_t = \mathrm{sinc}^{-1}(I_1/I_0)/\omega_1$. Then the local strain (ε_t) can be estimated as $\varepsilon_t = (B_t/B_0)$-1.

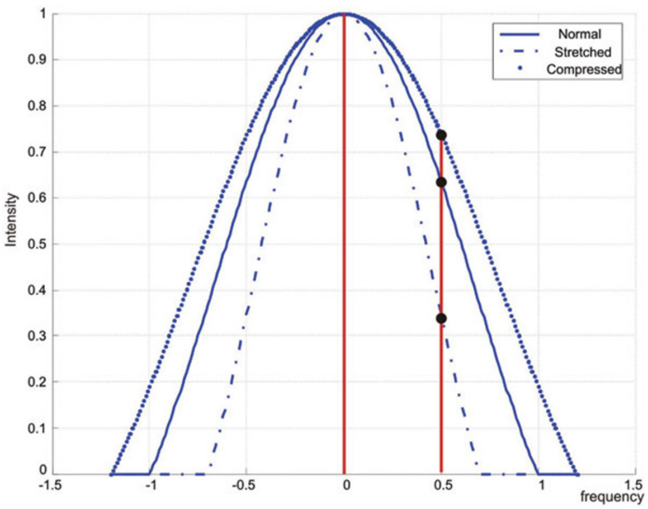

Figure 1

Rectangle slice profile in the spatial domain appears as a sinc profile in the frequency domain for any arbitrary voxel. Tissue deformation reflects on the slice profile, it gets narrower for stretching and wider for shortening. By tracking the change in the intensity at a specific tuning frequency, the slice thickness at this vortex can be estimated.

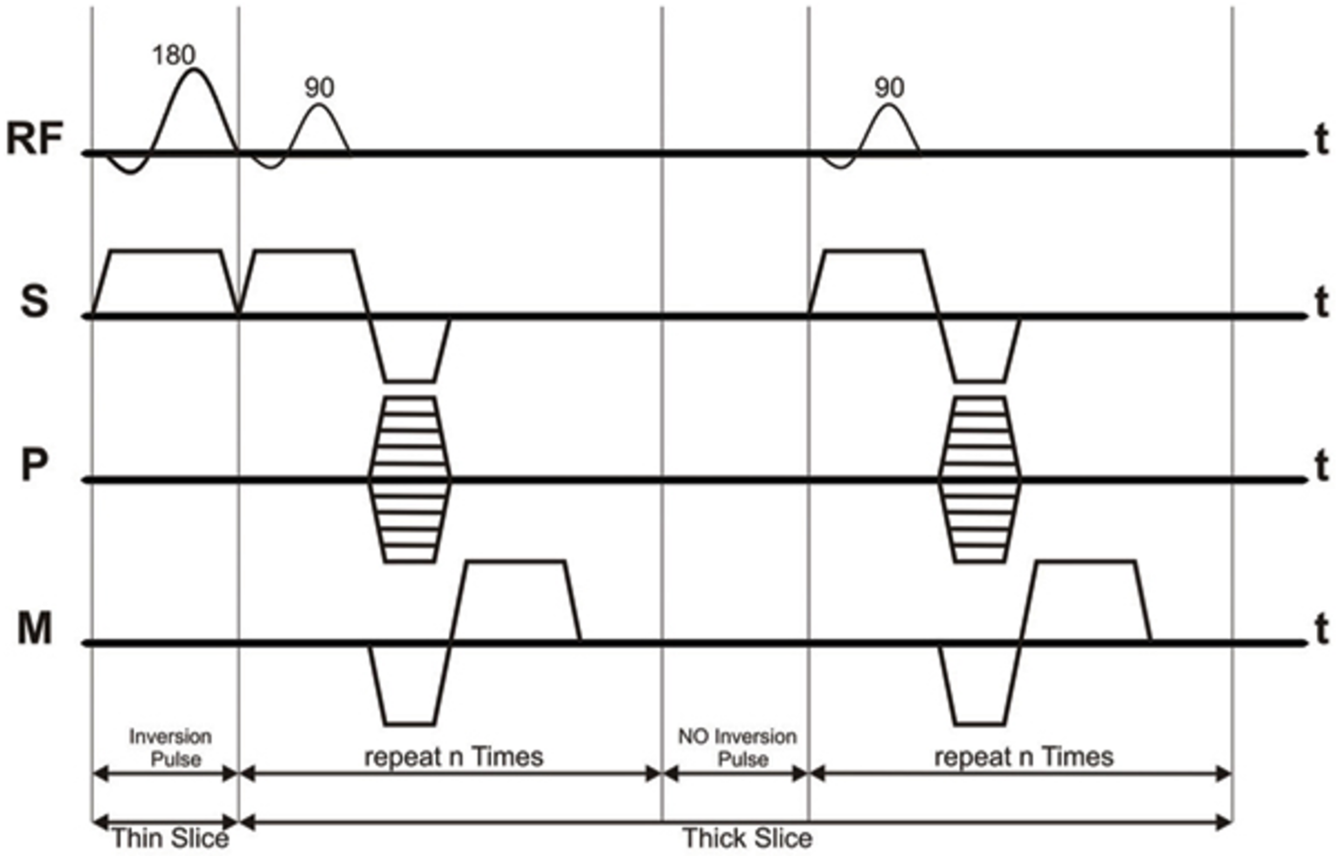

Figure 2

Slice following pulse sequence diagram. Two acquisitions are required. First, a thin slice is inverted with a slice selective 180 inversion pulse, while a thicker slice, thick enough to enclose the initially inverted slice, is selected for imaging. Then the second acquisition is done to image the thicker slice without any inversion. The two acquisitions are then subtracted to yield an image of the tussue of inverted slice.

Methods

Pulse sequence

The SFIR technique was implemented and tested on a 3 T Philips scanner. A schematic of the pulse sequence is shown in Fig. 2. Images were acquired with FOV = 300*300 mm, slice thickness = 8 mm, spatial resolution = 2 mm*2 mm, temporal resolution = 20 ms and spiral acquisition of 10 spirals with spiral window of 10 ms.

Phantom experiment

To validate the proposed technique, a phantom study was conducted. A cubic phantom of side length 10 cm was compressed with a balloon blown with air and purged in constant time intervals, in the normal direction to the image plane. R-wave is simulated exactly before the balloon start to be blown. The balloon diameter was 2 cm during its maximum blowing. During the experiment, the balloon was positioned in one corner of the phantom.

In vivo *studies*

Two normal volunteers were consented and scanned using the proposed sequence. For all experiments, two slice following image sets were acquired at two different tunings (0,0.6). The two sets were used to estimate the strain in each voxel using the proposed algorithm.

Results and discussion

Fig. 3 shows the phantom function images at different time frames of compression. Fig. 4 shows the calculated strain profile through time for two groups of voxels, one inside the compression region confronting the balloon and the other is far away from the balloon. The graph shows that while the second group has a nearly zero strain values, the first group exhibits a strain profile which confirms with the inflation profile of the balloon. Fig. 5 shows short-axis functional images calculated using the proposed algorithm. As expected, the myocardium shows shortening deformation through time while the cavity

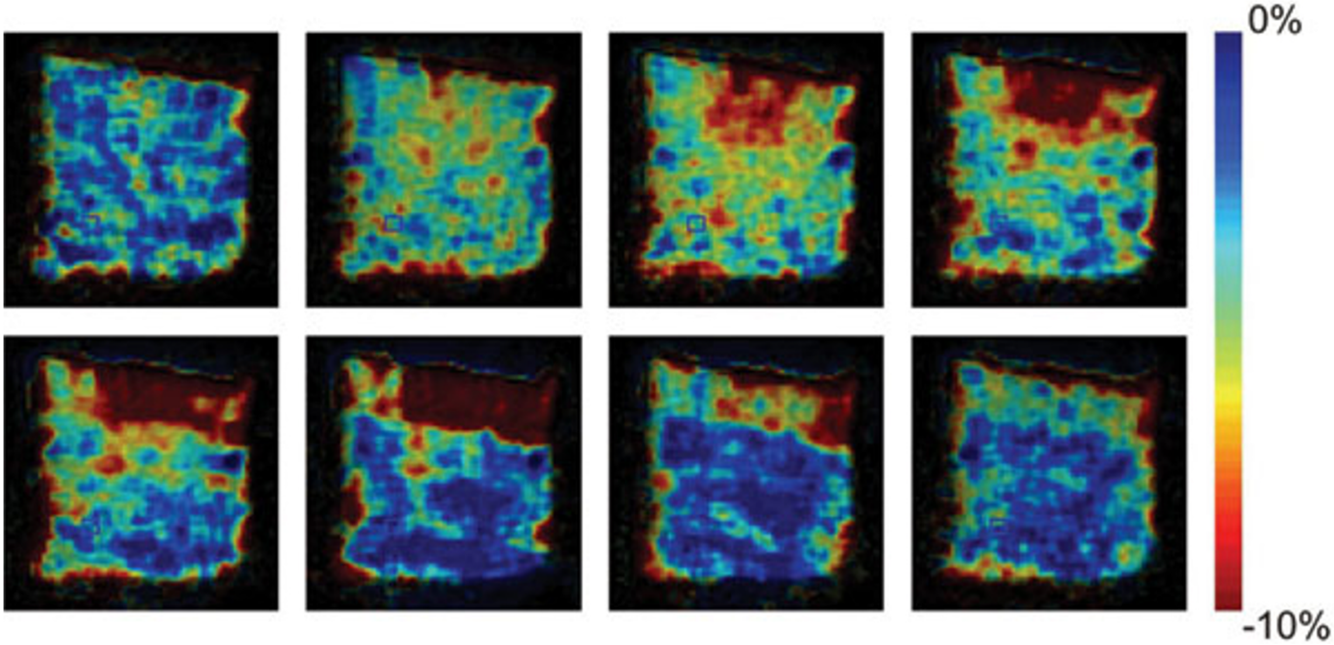

Figure 3
Cine time frames of the constructed function images for the phatom. Time frames (from top-left) are at 40, 120, 200, 280, 360, 440, 520, 600 msec starting exactly when the balloon starts to be blown.

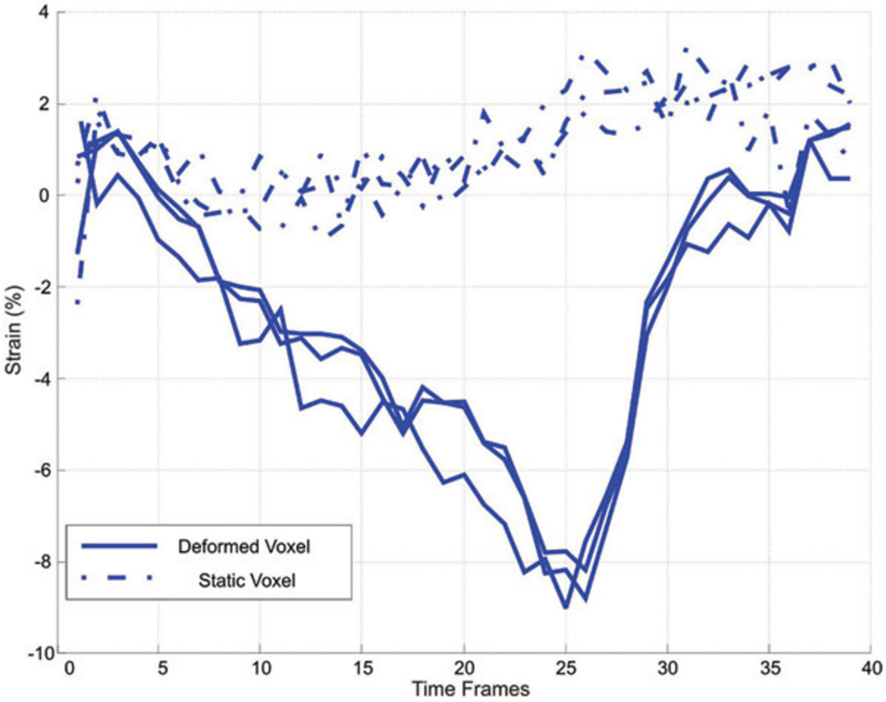

Figure 4
Strain profile for two groups of voxels in the phantom. The solid lines represent the deformed (compressed) region of the phantom while the dotted lines represent the regions that exhibit nearly no deformation.

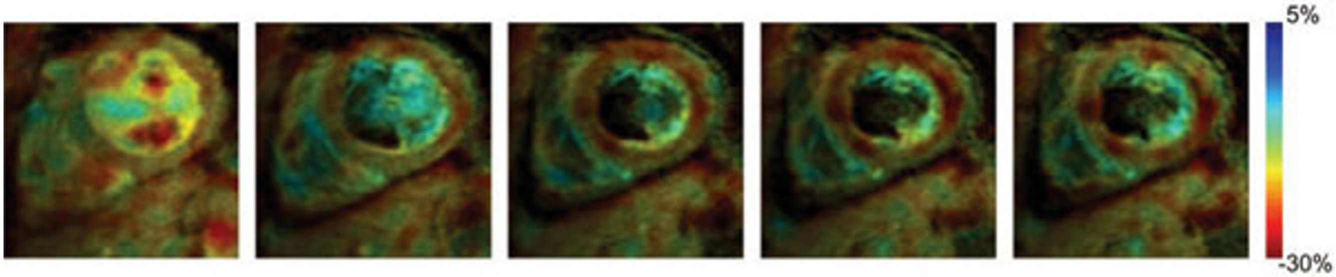

Figure 5
Cine time frames of the constructed function images for a cardiac short axis with ROI around the myocardium. Time frames (from top-left) are at 40, 140, 240, 340, 44 msec starting exactly after the R-wave.

blood and other tissue shows nearly zero strain.

Conclusion

A new technique is proposed for estimating the through plane tissue deformation from the normal slice following images. No special patterns (tags) are needed, so a high spatial resolution can be obtained.

Acknowledgements

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References

1. Stuber , *et al.*: *ISMRM Proc* :418.