Comparison of Spin Echo and Balanced Steady State Free Precession in MR-Elastography - A First Step to Cardiac MR-Elastography

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Synopsis

Analyzing *in-vivo* viscoelastic properties of the heart raises several challenges (short T1 and T2, ECG-gating, respiratory motion). To overcome the time definition problem, a cardiac MR-Elastography could be based on a balanced Steady State Free Precession (b-SSFP) sequence. Viscoelastic maps of a PolyVinyl Acetate phantom are reconstructed using a Spin Echo sequence and a b-SSFP sequence. Obtained values for the viscoelastic properties are compared.

Introduction

Analyzing the local myocardial viability is a major concern after an infarct. Insufficiently perfused regions are likely to develop scar tissue which is expected to exhibit different viscoelastic properties depending on the damage degree. Thus, strain imaging techniques (tagging, DENSE) have been developed to provide information about regional abnormal mobility [1,2], but not on inherent physical properties of the tissue. On the contrary, imaging of mechanical shear waves via MR-Elastography (MRE) allows the assessment of inherent viscoelastic tissue parameters which characterize more objectively the tissue damage and carry the potential to better diagnose myocardial viability. However, cardiac MRE poses several technical challenges: small relaxation times, time dependant viscoelastic properties during the heart beat, respiratory motion. To overcome the short relaxation time problem, the use of a gradient echo sequence is mandatory [3]. Such a technique allows the MRE acquisition to be drastically shorten, about ten times faster than a similar spin echo MRE sequence. To validate the use of the b-SSFP MRE sequence, the viscoelastic properties of an homogeneous PolyVinyl Acetate phantom have reconstructed using a spin echo MRE sequence and this b-SSFP MRE sequence.

Material & Methods

Dynamic steady-state MRE experiments were performed using a 300 Hz mechanical excitation frequency on a clinical scanner (Philips 1.5T Intera). MRE sequences parameters are: FOV=128mm, resolution 64^2 pixels, 2mm slice thickness and 7 slices. The spin echo MRE sequence relies on a spin echo sequence with a flip angle α=90° extended by a 26 $mT.m^{-1}$ sinusoidal motion-encoding gradients (MSG) before and after the π-pulse. The mechanical waves are generated externally by an electrodynamic transducer creating steady state mechanical waves within the phantom, and the scan last for 753 seconds (TE=20 ms , TR=210 ms). The MSG are phase-locked on the mechanical waves frequency. The b-SSFP MRE sequence relies on a b-SSFP sequence with a flip angle α=50° extended by a 39 $mT.m^{-1}$ trapezoidal MSG ending just before the read-out gradient. As for the spin echo MRE sequence, the MSG is phase-locked on the mechanical waves frequency and the scan last for 36 seconds (TE=5 ms, TR=10 ms), approximatively 20 times faster than the spin echo MRE sequence.

Results

Figs. 1 show the mechanical waves propagation within one slice for the different direction of the motion. Qualitatively, the images acquired with both MRE sequences are the same. The spin echo images are more noisy than the b-SSFP images because of smaller MSG and a longer echo time. However, the viscoelastic properties reconstruction was not limited by the noise factor of the spin echo images.

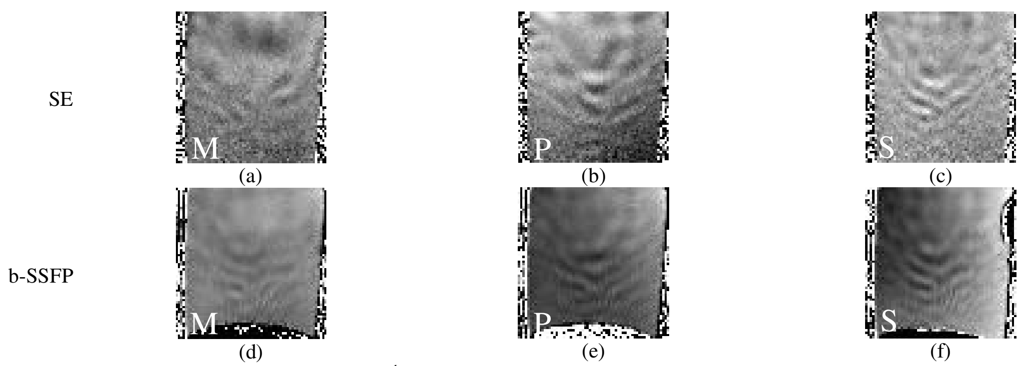

Fig. 1: mechanical wave propagation in the 4th slice acquired with a spin echo MRE sequence in the measurement direction (a), the phase direction (b), the slice direction (c) and acquired with a b-SSFP MRE sequence in the measurement direction (d), the phase direction (e), the slice direction (f).

To compare more precisely the two acquisition methods, viscoelastic parameters were evaluated using the complex shear modulus which links the strain to the stress [4]. The real part of the elastic modulus is called the dynamic modulus, and the imaginary part is called the loss modulus. Due to geometrical considerations, the most accurate viscoelastic properties evaluation is obtained for the central slice, the 4th slice here. The mean value of the dynamic modulus is about 21 kPa with a relative difference between the dynamic moduli of both methods of 2.07 % and a standard deviation of 0.37 %. The mean value of the loss modulus is about 2.8 kPa with a relative difference between the loss moduli of both methods of 6.86 % and a standard deviation of 21.8 %. Although the viscosity is low ($h = Gl/w \approx 1.5$ Pa.s), the error on the loss modulus is pretty low. The strong standard deviation observed on the loss modulus is due to the noisy data acquired with the spin echo MRE sequence. It is not observed with the dynamic modulus because in the inversion algorithm the loss modulus is more sensitive to the noise than the dynamic modulus.

Discussion & Conclusions

This study has shown that the b-SSFP MRE sequence does not add a significant error to the viscoelastic parameters evaluation. Thus, use of a b-SSFP MRE sequence decrease the acquisition time without adding errors on the viscoelastic maps. Moreover, this faster sequence gives the opportunity to make multifrequency MRE analysis for any tissue. For cardiac MRE, this sequence is used with an ECG-gating giving the opportunity to make Elastograms of the myocardium for several heart phases.

References

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