Rapid 3D periodic motion-encoding using steady-state FFE pulse sequence: applicaton towards multi-frequency rheology

Philippe Garteiser[1], Ramin Sahebjavaher[2], Ralph Sinkus[1], Leon Ter Beek[3], Bernard E Van Beers[4], Septimian E Salcudean[2], and Ralph Sinkus[1]

[1]*CRB3 U773 Université Paris Diderot, Sorbonne Paris Cite, INSERM, Paris, 75018, France,* [2]*University of British Columbia, Vancouver, Canada,* [3]*Philips Medical Systems, Netherlands,* [4]*Service of Radiology, Hopital Beaujon, Clichy, France*

Introduction

Tissue motion can be phase-encoded using motion sensitizing gradients (MSG) synchronized to an externally applied excitation. Conventional methods result in extended scan time for quality phase images. For practical scan times, many researchers have thus been relying on 1D or 2D motion-encoding in limited number of slices. Here, we introduce a rapid multi-slice pulse sequence capable of 3D motion-encoding that is also suitable for encoding motion with multiple frequency components.

Methods

Bipolar trapezoidal MSGs were superimposed on a steady-state FFE pulse sequence. The duration of each shot was adjusted such that an integer multiple of shots fit within a vibration cycle T_0. Thus, the duration of the MSG was only a fraction of the period of vibration (T_0). For the acquisition, one k-line per slice was acquired, thereby maximizing the TR. After a dwell time, the same k-line was acquired for the next vibration phase (Figure 1). This was repeated to build up the k-space. In-vivo liver experiments were carried out at the inphase TE of 6.8ms and a TR of $(4+1/8)\cdot T_0$ = 147ms. The number of slices (eight) was at a multiple of shots per T_0. Eight vibration phases were used to encode excitation at 28, 56 and 84hz. A reference scan was used to compensate for the electromagnetic transducer. An 80^2 matrix, $4mm^3$ isotropic voxels, reduced FOV and SENSE factor 2 was used. The entire acquisition of 59s was divided in four 15s breathholds.

Results

The magnitude images (on healthy liver) of the conventional SE-EPI motion-encoded sequence and the 3D steady-state FFE are shown in Figure 2. The magnitude images are dramatically improved in terms of artifacts and signal dropouts with the SS-FFE sequence. Results for the mono- and multi-frequency at 56hz are shown in Figure 3, where the waves are clearly visible and the shear moduli match (Table 1). This validates that the 3D SS-FFE sequence is well suited for multi-frequency MR rheology.

Discussion and Conclusion

A novel pulse sequence is introduced that strikes the balance between imaging speed, motion-encoding efficiency and high quality phase images. This pulse sequence was experimentally validated as capable of acquiring full 3D motion-encoding in a volume in less than a minute, and as suitable for mono- and multifrequency MR rheology experiments.

References

R. Muthupillai et al., Nat Med, vol. 2, May. 1996, p. 601-603.

J. Rump et al., MRM, vol. 57, 2007, p. 388-395.

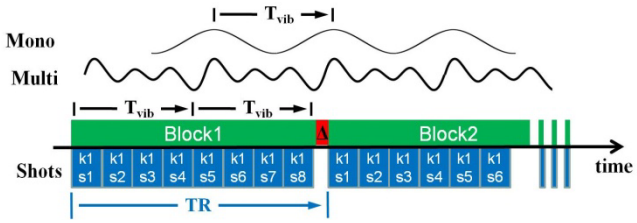

Figure 1 : Depiction of the pulse sequence

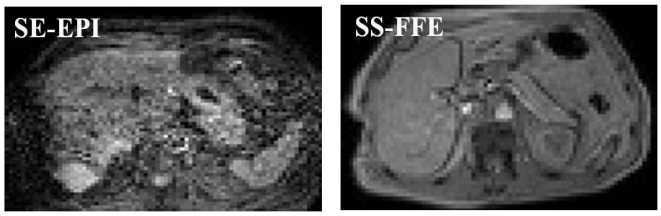

Figure 2 : Comparison of the magnitude image from SE-EPI (left) and SS-FFE (right)

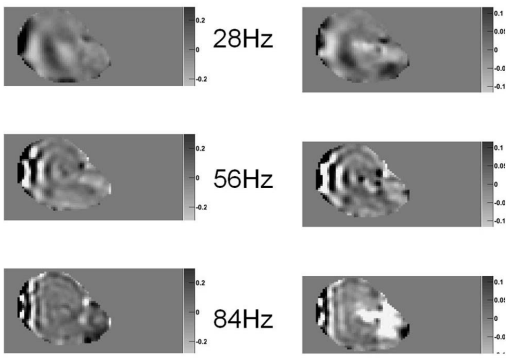

Figure 3: Comparison of the multifrequency experiment (right) with the separate acquisition of the different frequencies using eXpresso