Cardiac magnetic resonance elastography with and without external vibrations

PIs: Ingolf Sack, Sebastian Schmitter, Jeanette Schulz Menger

Theme: Mechanics

Cardiac function is mechanical work, and its effectiveness is influenced by myocardial tissues properties. Therefore, magnetic resonance elastography (MRE), which measures the shear modulus of soft tissues, is potentially useful for direct quantification of cardiac function. However, to date, cardiac MRE has only been demonstrated in volunteers or small cohorts of patients because the complex synchronization of the imaging sequence with external vibrations, respiratory motion, and cardiac pulsations makes cardiac MRE time-consuming and error-prone. An alternative approach in cardiac MRE relies on the limited bandwidth of motion-encoding gradients (MEG) for encoding endogenous motion without external vibrations. For example, a typical flow-compensated MEG of 8.8 milliseconds in length has a bandwidth of about 125 ± 60 Hz (see figure 1). Thus, the phase-contrast images generated by such an MEG would primarily represent harmonic frequencies within this band, which could be further refined by spectrally selection over repeated scans with incremental delay between R-wave and MEG. In result, the pre-processed complex-valued wave images show harmonic motion, even without external vibrations, which is related to 125 Hz center frequency plus/minus approximately 10 to 30 Hz frequency band, depending on the number of acquired time steps. The frequency band should be small enough to reliably reconstruct stiffness maps using standard multi-inversion pipelines, which have been developed for cardiac MRE with externally induced waves. Figure 2 shows preliminary stiffness maps taken at 100 Hz with and without external wave stimulation. As can be seen, the driverless MRE can produce stiffness maps of similar quality to the more expensive externally driven MRE. We expect significant improvements in quality and reliability of stiffness maps after optimizing the sequence for frequency band encoding without possible ECG artifacts induced by the drivers and without repetitive frequency acquisitions as performed today in multi-frequency MRE. Translation of cardiac MRE will be fostered by avoiding the setup of additional hardware for wave stimulation as would be required in conventional MRE examinations.

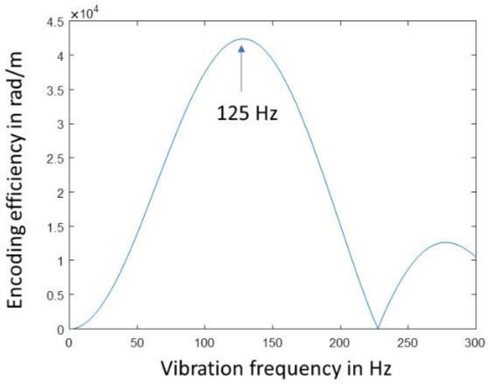

Figure 1: Efficiency of encoding harmonic motion with a cosine-shaped encoding gradient (flow compensated) of 8.8 ms duration and 35 mT/m amplitude. The center frequency is taken as virtual excitation frequency for computing quantitative shear wave speed maps as shown in figure 2.

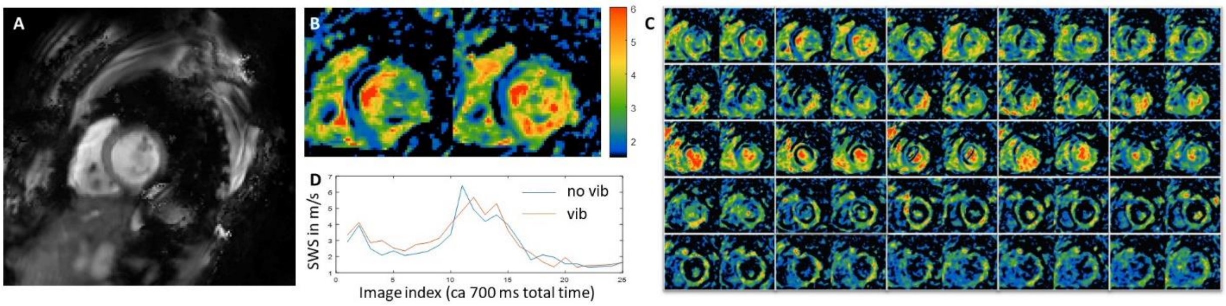

Figure 2: Preliminary data of cardiac MRE with and without external actuation source. A: MRE magnitude image for anatomical orientation. B: two elastograms (SWS maps) generated with (right hand side) and without (left hand side) external vibration of 100 Hz. C: Time-resolved change of SWS maps over ca 700 ms (25 images) with and without external vibration corresponding to the display in B. D: Quantitative change of SWS within the left ventricle.

Please contact Ingolf Sack (ingolf.sack@charite.de) for any further questions on this project.