PhD6

Time-resolved quantification of myocardial microstructure by cardiac MR elastography

PI Ingolf Sack, Co-PI Jeanette Schulz-Menger, Associate-PI Bernd Ittermann

Application Area: Cardiovascular **Modality:** MRI **Related:** PhD 2, 7, 9, 10

Background

Cardiac work is linked to the alteration of myocardial shear modulus[1]. Current imaging markers of cardiac failure cannot measure forces and are limited in assessing the mechanical function of cardiac tissue. Cardiac elastography is sensitive to myocardial shear modulus and hence to mechanical relaxation abnormalities of myocardial tissue[2]. However, current cardiac elastography does not account for the anisotropy of myocardial tissue and is thus non-quantitative[3].

Hypothesis

Anisotropic myocardial shear modulus quantification based on multifrequency MR elastography (MMRE) is feasible and provides an imaging marker of the mechanical function of myocardial tissue at work and across multiple scales.

Methods

The project is centered on cardiac MRE and will be complemented by other quantitative BIOQIC-available methods sensitive to fluid transport such as cardiac perfusion MRI, DTI and vector flow MRI. Moreover, mechanical tissue function will be compared with echocardiography and cardiac ultrasound elastography.

Work Packages

WP1: Sequence / actuator setup
WP2: Tissue specimen experiments
WP3: In vivo tests / inversion algorithms
WP4: In vivo reference values

year 1 → *year 2* → *year 3*

WP1: Development of non-Cartesian single-shot cardiac MMRE with fractional motion encoding[4] and pressurized air drivers placed beneath the thorax. Test in pulsating phantoms, followed by healthy volunteers experiments.

WP2: MMRE and DTI of tissue specimens of swine hearts for anisotropic shear modulus recovery. Anisotropic inversion based on Three-parameter inversion[5] accounting for transverse isotropy.

WP3: Comparison of isotropic and anisotropic inversion, tests of consistency and reproducibility, acquisition of in vivo data in cohorts of asymptomatic volunteers accounting for age, sex and physiological preload alteration through water ingestion.

WP4: Comparison of elastography with other imaging markers such as volumetry, hemodynamic parameters obtained from 4D flow[6,7], myocardial perfusion, tissue Doppler sonography and ultrasound elastography[8] (see Figure).

Clinical Translation

In the follow up of this project, clinical pilot studies are envisioned to directly detect pathologically increased myocardial shear modulus values in patients with diastolic dysfunction and predefined focal scar tissue.

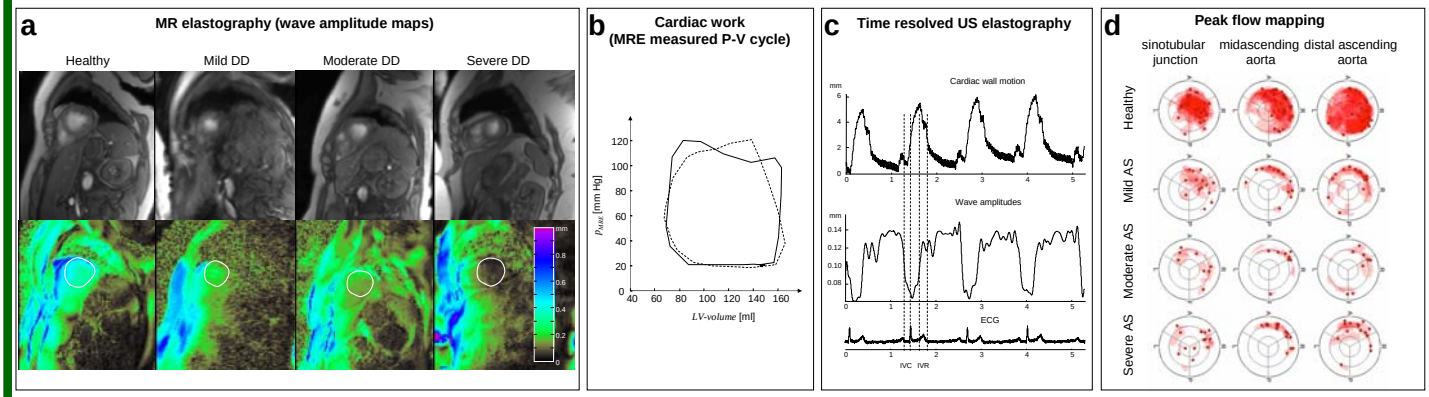

Figure: State-of-the-art cardiac elastography based on MRI and ultrasound. a) Cardiac MRE in patients with diastolic dysfunction (DD) (from [2]). b) Cardiac work (area of the P-V cycle) measured by MRE in a patient with mild mitral valve insufficiency (dashed line) and a healthy volunteer (from [1]). c) Cardiac ultrasound elastography show the alteration of elasticity over the cardiac cycle by in real time (from [7]). d) 4D-flow quantification of systolic peak flow in patients with aortic stenosis (AS, from (6)). The proposed project will investigate the relationship between myocardial tissue elasticity and function parameters such as vortex flow formation.

Literature

1. Hirsch, Braun, Sack (2016) MR Elastography: Physical Principles and Clinical Applications, Wiley-VCH
2. Elgeti, Knebel, Hattasch, Hamm, Braun, Sack (2014) Radiology. 271: 681-7
3. Wassenaar, Eleswarpu, Schroeder, Mo, Raterman, White, Kolipaka (2015) Magn. Reson. Med. 75:1586-93.
4. Dittmann, Hirsch, Tzschaetzsch, Guo, Braun, Sack (2015) Magn. Reson. Med. in print
5. Guo, Hirsch, Scheel, Braun, Sack (2016) Magn. Reson. Med. 75:1537-45.
6. Knobelsdorff-Brenkenhoff, Karunaharamoorthy, Trauzeddel, Barker, Blaszczyk, Markl, Schulz-Menger (2016) Circ Cardiovasc Imag. 9:e004038.
7. Schmitter, Schnell, Ugurbil, Markl, Van de Moortele, (2016) J Magn Reson Imaging doi: 10.1002/jmri.25164.
8. Tzschatzsch, Hattasch, Knebel, Klaua, Schultz, Jenderka, Braun, Sack (2013) Ultrasound Med Biol, 39:2272-8.