Physics-informed deep learning for motion-corrected 3D high-resolution cardiac mapping

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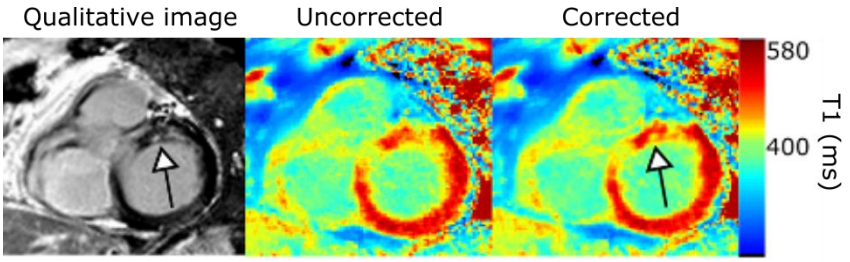
Theme: Tissue structure

Background: The most important quantitative MR approach for cardiac tissue differentiation is T1 mapping, which provides a map of T1 relaxation times in milliseconds. Fibrotic tissue and other pathologies in the heart have different T1 values compared to healthy myocardium, enabling the diagnosis of a wide range of different cardiac pathologies. One of the main challenges of cardiac T1 mapping is that image resolution is restricted due to respiratory and cardiac motion of the heart which means T1 mapping in clinical practice is usually only carried out in a few 2D slices with medium in-plane resolution (e.g. 2 x 2 mm) and low through-plane resolution (8 mm slice thickness). Although this can provide reliable diagnosis of a wide range of pathologies in the myocardium, the poor image resolution restricts T1 mapping to the left ventricle. In addition, T2 mapping is also of great clinical interest as it provides information about edema.



Cardiac motion correction improves the visualisation of small pathologies (arrow) in the heart for T1 mapping. This was confirmed by contrast-enhanced qualitative imaging.

Hypothesis: Physics-informed machine learning can enable 3D super-resolution T1 and T2 mapping allowing for more accurate diagnosis especially of small pathologies and for mapping not just in the left ventricle but in the entire heart.

Methods: In this project, we want to build on a 3D super-resolution cardiac T1-mapping technique developed in a previous BIOQIC project. Multiple 2D T1 maps are acquired over multiple breathholds and combined to a 3D volume. In this project we want to extend this approach using physics-informed machine-learning techniques to improve the quality of the T1 maps while further reducing scan times. Respiratory motion correction will be incorporated into the ML-based reconstruction to allow for 3D T1 mapping during free-breathing. To provide further quantitative imaging markers, the developed techniques will be extended to multiparametric MRI including T2 mapping. All the developed methods will be evaluated in phantoms, volunteers and patients.

Collaboration: The PhD students will take part in regular meetings of Prof. Schulz-Menger's team to get continuous clinical feedback on any developed techniques. Furthermore, BIOQIC projects concerned with MR elastography in cardiac applications can add direct measures of tissue mechanics to the cardiac mapping techniques developed herein.

Impact: The outcome of this project will enable the detection of fibrosis and edema in thinner structures such as the right ventricle and the atria which are of high clinical value.

Please contact Christoph Kolbitsch (christoph.kolbitsch@ptb.de) for any further questions on this project.