PhD8

CT quantification of poroelastic properties of the liver

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Application Area: Cardiovascular, Cancer **Modality:** CT, MRI **Related:** PhD 1, 7, 9

Background

The accumulation of tissue matrix during hepatic fibrogenesis impacts poroelastic properties of liver tissue related to solid-fluid interactions, interstitial pressure, effective compressibility, vascular compliance and filtration rate(1). In tumors, leaky blood vessels and impaired lymphatic drainage additionally cause further accumulation of interstitial fluid and rise in hydrostatic pressure. Standard clinical imaging methods are limited in quantifying interstitial pressure and mechanics-related parameters(1).

Hypothesis

Deformable image registration of 4D-CT data provides compression-related volumetric strain in the liver, which, in combination with perfusion quantification, allows deduction of poroelastic parameters, which correlate with the degree of liver function and tumor aggressiveness than morphometric imaging markers.

Methods

4D-CT perfusion(2) and compression-sensitive MRE(3) will be applied to phantoms and tissue specimens and combined with deformable 3D image registration to deduce volumetric strain. Perfusion of whole-organ specimens will be simulated by water entering the liver through the portal vein at different pressure levels. Volunteer experiments will be performed with time-harmonic ultrasound elastography to better understand vascular coupling of liver mechanical parameters.

Work Packages

WP1: Phantoms and specimens

WP2: Compression MRE / volunteer studies

WP3: Analysis tools

year 1 → *year 2* → *year 3*

WP1: Construction of a compressible phantom made from waterous gel with dispersed air cavities to develop and test acquisition and postprocessing methods. Whole organ specimens such as bovine liver will be used to measure the effect of vascular pressure on the effective tissue.

WP2: Experiments of compression sensitive MRE and time harmonic ultrasound elastography in the livers of healthy volunteers at different physiological states altered by breathing maneuvers and water intake.

WP3: Development of processing methods to deduce poroelastic parameters from 3D wave fields, time-resolved with respect to harmonic vibrations and physiological deformation (see figure).

Clinical Translation

Pilot studies are envisioned to use 4D-CT perfusion as imaging marker for liver function and tumor aggressiveness.

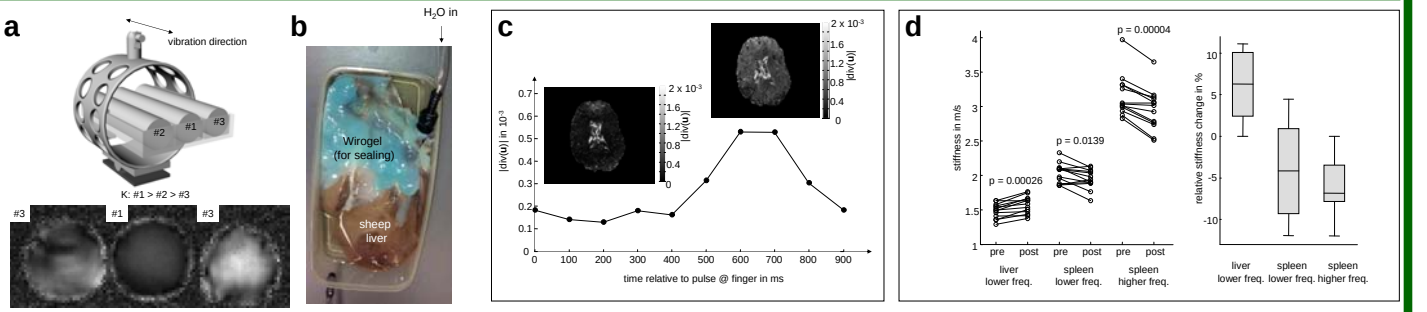

Figure: Compression-sensitive MRE und time-harmonic ultrasound elastography. a) Phantom experiments to demonstrate the sensitivity of the divergence (volumetric strain) of a wave field to compression modulus K(3), b) Sheep liver specimen investigated by compression-sensitive MRE at different levels of portal pressure(4). c) in vivo compression MRE of the brain showing a higher compressibility of the tissue at passage of the arterial pulse wave(5). d) Sensitivity of ultrasound elastography to stiffness changes induced by an altered blood perfusion due to water drinking in healthy volunteers(6,7). Time harmonic vibrations were induced at two different frequency ranges (low: centered at 50 Hz, high: centered at 110 Hz)(7).

Literature

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