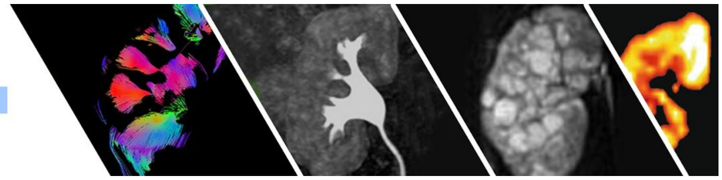


Renal MRE

Action number 40219
STSM start date 2018/03/19
STSM end date 2018/03/24
Grantee name Marcos Wolf

PURPOSE OF THE STSM

Motivation

Renal Magnetic Resonance Elastography (MRE) is a novel approach that holds the promise the assess renal interstitial fibrosis directly, which could be used as a bio-marker with regards to chronic kidney disease (CKD). But measuring native kidneys in vivo remains a challenge, which is also observed on liver applications.[1]
Ralph Sinkus and his team at the King's College London (KCL) have proposed a new 'gravitational' transducer, together with a sophisticated MRE sequence and post processing software, which have the highly promising potential to improve renal MRE on native kidney.[2]

Aim

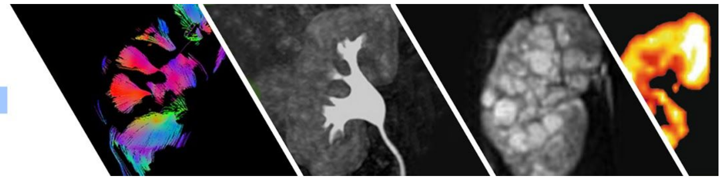
The goal of this application is to gain firsthand experience on the novel gravitational transducer and the associated MRE sequence as well as the post processing software. Together with the KCL-Team we want to set up a first preliminary study protocol to evaluate the performance between the envisioned system at the KCL and the system in Vienna (pneumatic transducer).[3]

Proposed contribution to the scientific objectives of the Action

A direct measurement of the mechanical properties of native kidneys can pave the way to assess renal interstitial fibrosis directly, which could be translated into a biomarker for chronic kidney disease in the clinical practice.[4]

Techniques

The proposed novel gravitational transducer uses a rotational eccentric mass, which creates a low-frequency vibrational wave without significant impurities (e.g. no significant upper harmonics compared to a pneumatic transducer). These shear waves are captured with an inhouse programmed phase sensitive Spin Echo MRE sequence. Thereafter an inhouse post processing software is used to evaluate the stiffness.



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4. Venkatesh, Sudhakar K., Meng Yin, and Richard L. Ehman. 2013. “Magnetic Resonance Elastography of Liver: Technique, Analysis, and Clinical Applications.” Journal of Magnetic Resonance Imaging: JMRI 37 (3):544–55.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

I. Preliminary discussion regarding a future collaboration to validate renal magnetic resonance elastography (MRE) and ultrasound elastography (USE) acquisitions

Initiated: University College London (UCL), Great Ormond Street Institute of Child Health (GOSH), King’s College London (KCL).

Present: Fabio Nery (UCL), Maria Theodorou (UCL), Isky Gordon (UCL), Chris Clark (UCL), Matt Hall (UCL), Ralph Sinkus (KCL), Marcos Wolf (Medical University of Vienna).

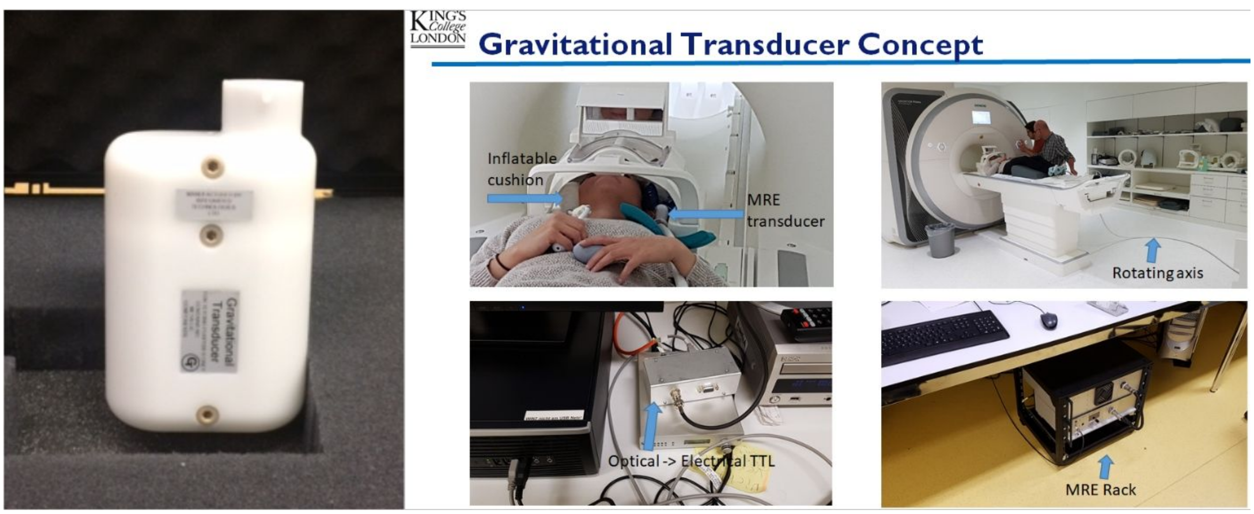
Potential future participating countries: United Kingdom, Italy, France, Germany, Austria.

- Maria Theodorou presented a potential research topic: Validation of MRE for USE and MRE.
  A detailed protocol will be submitted by Fabio Nery.
- National Physical Laboratory (NPL) has no experience in MRE.
- Multinational funding for one PhD and post doc on each side for 3 years (open task for the participating sites).
- Discussion with regards to the creation of a phantom to represent real human tissue properties, accounting for
  - Human equivalent MRI parameters T1/T2/PD,
  - Complexity of human tissue of interest with regards to, e.g. scattering (Euclidean vs fractality distribution of microscopic perturbations),
  - Stiffness/damping-values like human tissue (e.g. the CIRS Phantom has almost no damping),
  - Stability of the phantom (reproducibility over time and resilient to transportation).

II. Preliminary renal magnetic resonance elastography measurement using the envisioned gravitational transducer

We had a scanning session on the 3 Tesla whole-body MR system (Siemens Prismafit) at GOSH. We used an 18-channel flex coil and a 32-channel spine coil. A phase-sensitive spin-echo sequence with four consecutive scans (TR=65ms; TE=7.38ms; voxel size: 3x3x3mm^3; phase encoding left-right) was applied; one reference scan without motion encoding gradient (MEG) and three consecutive scans with an applied MEG in each direction (slice, phase, readout; MEG strength: 55mT/m). The gravitational transducer was synchronized with the MEG and vibrated with 40Hz.

The following figures show the gravitational transducer with its rotational eccentric mass, which induces an external wave with significantly less impurities compared to a pneumatic system (e.g. no upper harmonics, less image artefacts in nearby field of view, sustains wave amplitude at higher frequencies also if a patient lies directly on it). Further information can be extracted from the ISMRM submission: Runge JH et al.: A novel MR Elastography transducer concept based on a rotational eccentric mass: the gravitational transducer. ISMRM 2017).



DESCRIPTION OF THE MAIN RESULTS OBTAINED

I. Preliminary discussion regarding a future collaboration to validate renal magnetic resonance elastography (MRE) and ultrasound elastography (USE) acquisitions

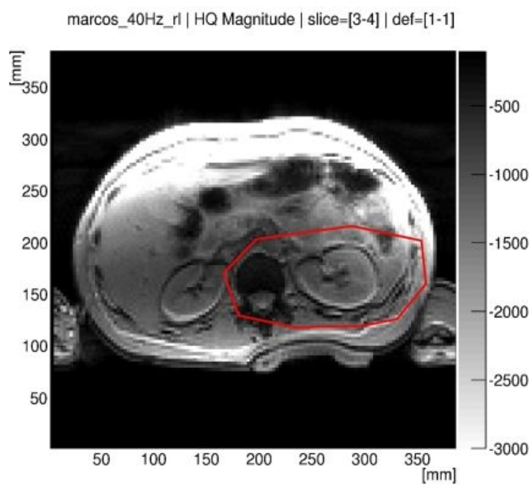
The proposal for the potential research topic (MRE and USE validation and standardisation) is important for the promotion of renal elastography measurements in clinical practice. The setup of multiple sites throughout Europe allows to coordinate these efforts. The upcoming tasks are the following:

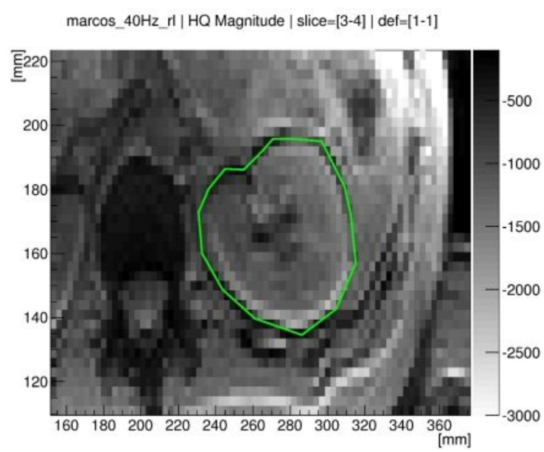
- Updating last proposal (methodology and work plan) – Maria Theodorou.

- Identifying potential grants/sponsoring on each site and future personnel setting (PhD- and post-doc positions per site)
- Organizing next meeting in 6-8 weeks
- How to create/buy a realistic human like elastography phantom.
- How to distribute the phantom (resilience to changes over time and transport)
- How to coordinate the measurement protocol throughout multiple sites and vendors (different elastography measurement systems, e.g. pneumatic, gravitational transducer)

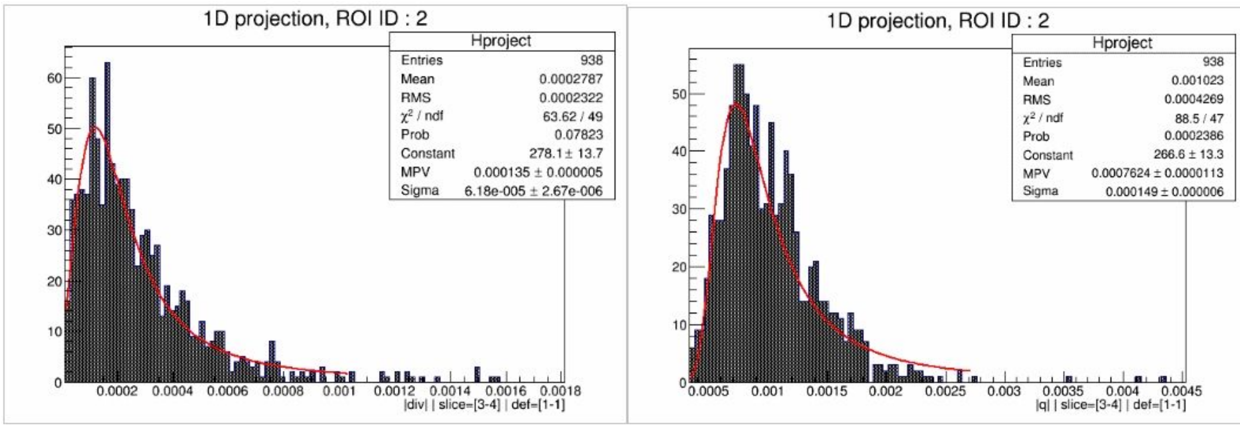
II. Preliminary renal magnetic resonance elastography measurement using the envisioned gravitational transducer

The gravitational transducer showed very promising results for the evaluation of kidneys in vivo. The following images show an axial image of the volunteer laying (head first, supine) on a foamed material on top of the spine coil. A MR-visible gel pad is placed upon the gravitational transducer to reduce the effect of shear waves generated by the transducer on the skin. The gravitational transducer is placed paraspinal left. The right image shows the zoomed in picture of the left kidney with the region of interest (ROI; green line).

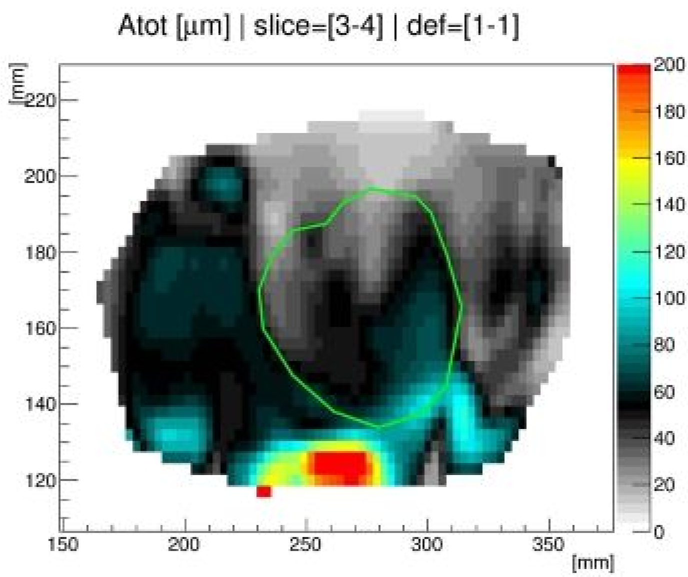




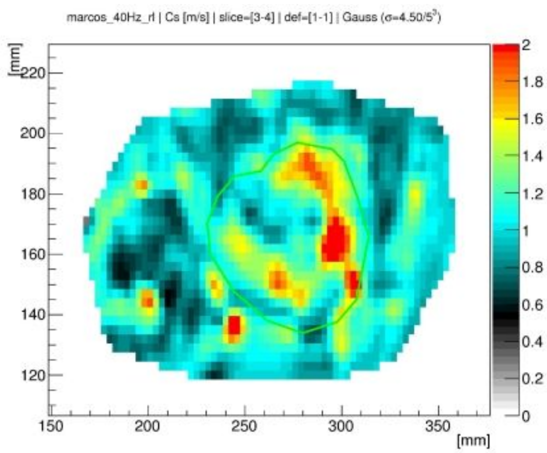
The divergence of the displacement field as quantified within the kidney is measuring the relative volume change generated by the vibrations. As tissue is quasi incompressible, this must be close to zero. Any deviation from zero quantifies noise. The magnitude distribution of the divergence (complex scalar) is shown in the next image indicating a mean-peak-value of about 0.00001. The magnitude of the curl of the displacement field characterizes on the contrary the degree of signal we have in our data. The according distribution shows a mean-peak-value around 0.00007. Hence, curt/div is about a factor of 7, which indicates very good data quality.

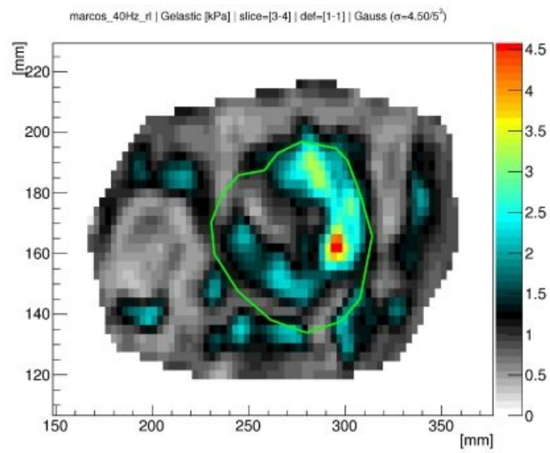


The following picture shows the total amplitude of the induced mechanical wave in units of micrometres. The location of the transducer, as expected, exhibits the strongest waves. Subsequently, due to scattering and absorption, the intensity decreases.



The following left image represents the shear wave speed, which can be translated to the magnitude of the shear modulus on the right image (color-coded bar in kPa). A clear visualization of the renal cortex and medulla is present. The renal medulla shows apparently a higher stiffness than the renal cortex and renal sinus. And the renal sinus appears softer than the renal cortex.





However, further improvements are required to improve the data quality:

- Placement of the transducer; e.g., less foamed material for better coupling of the transducer to the torso in order to increase the energy delivered to the kidneys.
- Frequency adjustments; yet we could not depict a clear recommendation regarding the optimal transducer frequency. It must be considered that patients might have significantly more subcutaneous and visceral fat. A lower frequency might be needed.
- Distance between spine coil and the volunteer was too big (thick foamed material) which reduces the signal to noise ratio/sensitivity.
- Optimizing the sequence to cover the whole kidney within one breath-hold (e.g. resolution, acceleration).
- More weight on the eccentric mass to couple more energy into the abdomen.

FUTURE COLLABORATIONS

I. Preliminary discussion regarding a future collaboration to validate renal magnetic resonance elastography (MRE) and ultrasound elastography (USE) acquisitions

A multi-centre and multi-national collaboration is feasible and should be discussed in the next upcoming meeting(s).

II. Preliminary renal magnetic resonance elastography measurement using the envisioned gravitational transducer

We will continue our collaboration with the KCL-team and Ralph Sinkus to optimize renal MRE and to accumulate expertise for upcoming studies. In addition, we plan to compare our “pneumatic system” versus the “gravitational system”. If possible, further meetings should be planned to speed up this process.

Acknowledgement

This STSM was based upon work from COST Action PARENCHIMA (CA16103), supported by COST (European Cooperation in Science and Technology).

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