MR-Elastography of the prostate using an endorectal coil for actuation - a feasibility study

Poster No.: C-0932
Congress: ECR 2011
Type: Scientific Exhibit
Authors: M. Reiss-Zimmermann, T. Kahn, G. Thoermer; Leipzig/DE
Keywords: Technical aspects, Experimental investigations, MR-Functional imaging, MR, Pelvis, Genital / Reproductive system male, Pathology
DOI: 10.1594/ecr2011/C-0932

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR's endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method ist strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys' fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Purpose

Magnetic Resonance Imaging (MRI) represents a sensitive imaging tool for detection and characterization of suspicious lesions in the prostate. Compared to other imaging modalities MRI offers an excellent soft tissue differentiation. Further improvements were made introducing a so-called multiparametric MR-imaging approach, consisting of the evaluation of functional parameters like diffusivity (diffusion weighted imaging), vascularisation (perfusion imaging) and concentration of metabolites (spectroscopy). The elasticity of tissue is another parameter that can be measured using MR elastography (MRE).

MRE is an emerging imaging technique that measures the propagation of mechanical waves in the tissue to noninvasively determine its viscoelastic properties. Recent studies demonstrated its usability in MR mammography as well as liver and brain MRI [1-3].

Despite the fact, that elasticity of prostatic tissue was described as a potential parameter in the diagnosis of early stage prostate cancer [4, 5], there are only few publications dealing with MRE in the prostate. Mainly, this can be attributed to the anatomical position of the organ that limits actuation and propagation of shear waves. So far, an actuator connected to the pubic bone [7] and a transurethral actuator [6] have been presented to generate the shear waves.

This work describes a new concept for endorectal MRE of the prostate and presents with preliminary results on the propagation of shear waves in a phantom setup using a commercially available, self-made modified endorectal coil for both imaging and MRE.

Methods and Materials

Imaging was performed using a clinical 3.0 T MRI, a 16-channel body array coil and a commercial adaptive endorectal coil (eCoil, MEDRAD, Warrendale, PA).

An existing technique [8], originally applied to MRE of the brain, was used for the generation of oscillations and adapted to the prostate.

A custom made, fully MR-compatible mechanism (Fig. 1 on page 3) allowed for periodic movements of the balloon of an endorectal coil. Triggered by the MR sequence, a frequency generator induced electromagnetic oscillations in a standard 12" subwoofer placed inside the MR room but outside the 0.05 mT boundary. The oscillations were
transferred via a telescopic carbon rod to a deflecting mechanism. A dedicated polyamide wire was attached to the balloon of the endorectal coil, converting the oscillations of the subwoofer / carbon rod in contraction and dilation of the balloon (Fig. 2 on page 4).

In a phantom setup (Fig. 3 on page 4), the propagation of the induced shear waves was imaged by using a phase-locked, motion-sensitive single-shot EPI sequence (transverse, slice thickness = 5 mm, TR/TE = 3,000/150 ms, field of view = 181×181 mm², matrix = 128×128). A measurement consisted of 70 acquired phase images, whereas the delay between excitation and begin of frequency encoding consecutively increased by a small amount [8]. The measurements were performed repeatedly with various wave generator frequencies.

To evaluate the propagation of shear waves we chose a phantom with tissue-like rigidity, consisting of 100g gelatine per 1000ml H₂O. In the cylindrical phantom (20 cm diameter, 10 cm height) 4 cuboids (0.5x0.5x0.5 cm, 0.5x0.5x1.0 cm, 1.0x1.0x1.0 cm, 1.5x1.5x1.5cm) with a concentration of 400g gelatine/1000ml H₂O were inserted.

The obtained data was analyzed using Matlab for each excitation frequency (50-150 Hz, increment 10 Hz): Subtraction of subsequent phase images resulted in 35 phase difference images of the propagating shear waves, due to the pairwise opposite polarity of the motion encoding gradient. The temporal variation of the signal intensity was analyzed on a pixel-by-pixel basis and approximated by a sinus function. The local distribution of the shear elasticity was calculated by the wave length [9].

Images for this section:
Fig. 1: The modified endorectal coil is coupled via a carbon rod with a loudspeaker. The transmission of the mechanical excitations of the loudspeaker is secured by a reversing mechanism and a spring and conducted on a polyamide fiber, which induces vibration of the balloon of the endorectal coil. The loudspeaker is driven by a wave generator with sinusoidal frequencies between 50-150 Hz. The wave generator is triggered by the MR scanner.

Fig. 2: The outer cover of the endorectal coil was removed to illustrate how the polyamide wire generates a periodic movement of the blocked balloon. Red circles show the propagation direction of the resulting sheer waves.
Fig. 3: A cylindrical container filled with glaze (1) served as a viscoelastic MRE phantom. A modified commercial endorectal coil was inserted vertically (dotted lines) into the phantom and connected to the receiver channel of the scanner. Electromagnetic oscillations from a loudspeaker placed at the end of the table were transferred via a telescopic carbon rod to a deflecting mechanism (2) which was coupled to the balloon of the endorectal coil via a dedicated polyamide wire. The electromagnetic sine waves generate a periodic translation of the device (black arrows) which served as actuator.
Results

The components of the custom MRE setup (excluding the subwoofer, which is positioned outside the 0.05 mT boundary) are fully MR compatible and mainly "off the shelf". The proposed setup is also capable to be used without further modifications in patients in a supine, feet first position and with no major loss of comfort. The setup also allows unrestricted conventional MR imaging of the prostate.

Using the modified endorectal coil, we were able to induce and detect shear waves (Fig. 1 on page 6) in a phantom. All data were adequate to generate maps representing the local distribution of elasticity (Fig. 2 on page 8).

At a frequency of 150Hz objects with a minimal size of around 5 mm were detectable due to their different sheer modulus (2.3±0.4 kPa) compared to the surrounding gel phantom (1.5±0.7 kPa).

Images for this section:
Fig. 1: Selection of a temporal series of 35 motion sensitive EPI MR images (3s increment) at an excitation frequency of 70 Hz. On the lower right chart with the
corresponding signal intensity values for the marked red circle. The propagation speed of the shear waves can be calculated by the cyclic change of the intensity.

**Fig. 2:** Left: T2-weighted image of the gel phantom (100g gelatine/1l water). Objects with more stiffness (400g gelatine/1l water) and variable size inside the phantom serve as objects with diverse viscoelastic properties. Right: Demonstration of a viscoelastic map. The shear modulus of the marked object (1) was 2.3±0.4 kPa and therefore superior to the surrounding gel (1.5±0.7 kPa).
Conclusion

The presented setup uses a modified commercial endorectal coil as an actuator for mechanical waves in a gel phantom. It is fully MR-compatible and does not influence conventional MR imaging. Due to the direct excitation of the phantom higher frequencies can be applied, compared to a transpubic excitation of the prostate.

We were able to calculate shear moduli for the whole range of frequencies between 50-150 Hz, obtaining viscoelasticity maps. At 150 Hz, objects with a minimal size of around 5 mm were detectable.

In our point of view, these preliminary phantom results are very promising and serve as a starting point for further experiments and detailed analyses under more realistic conditions.

References