MR-compatible ultrasound for improved biopsy needle guidance

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Methods

Biopsies have become an essential tool for minimally invasive diagnostics and are part of the daily routine of interventional radiologists. Depending on the target organ that has to be sampled, different imaging modalities such as CT, ultrasound or MRI can be used. In particular, when it comes to detection of small tumors having a low contrast in ultrasound or CT, MRI is the method of choice. The risk for being off-target leading to a potentially false-negative diagnosis is reduced due to the better contrast in MRI, which however still has drawbacks with respect to cost issues, patient comfort and time-resolution.

Results

We developed an MR-compatible ultrasound hardware allowing to replace MRI by ultrasound to the greatest possible extent in biopsy guidance. In this concept, simultaneous MR and US scans of the ROI will be performed over several breathing cycles prior to the biopsy, so that an atlas of US/MR data pairs is generated. When the patient leaves the MR-scanner US acquisition is still performed continuously. On basis of this data patient's breathing status can be monitored, allowing the physician to validate correspondence to the planning situation. The developed software “WAVE” accompanies and guides the entire intervention. It leads through the procedure, enables precise intervention planning, especially needle trajectory calculation on MR image data, and controls breathing motion interactively. Finally, an MR compatible mechanical needle guiding system supports needle positioning and insertion.

Conclusion

Our developed MR compatible ultrasound platform consisting of a 256 channel electronics (allowing to drive 2 probes in parallel) and different MR-compatible transducers (128 elements, 3 MHz, 400 µm pitch for motion tracking, 300 µm for real time control of needle insertion) has been successfully tested for MR-compatibility (emission and immunity) on a 1,5 T Siemens MR-scanner. A clinical validation of the concept is in preparation and the first tests for compliance with the medical device directive have been performed.

Identification of hepatic steatosis using machine learning algorithms on high-frequency ultrasound data in patients with non-alcoholic fatty liver disease

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Introduction

Hepatic steatosis is an emerging risk factor for the development of metabolic disease and other chronic conditions including cancer of multiple origins. There is a critical need for non-invasive methods to access and evaluate hepatic steatosis. Commercial solutions exist but are comparatively expensive. With this work, we present a quantitative analysis of raw radiofrequency (RF) ultrasound signals serving as a base for a future low-cost system to accurately assess steatosis stages. We develop and evaluate machine learning algorithms to classify ultrasound RF signals for patients with biopsy-proven Non-alcoholic steatohepatitis (NASH).

Methods

We categorize ultrasound RF signals from 24 patients (15 men and 9 women) with biopsy-proven NASH into different steatosis stages by evaluating annotation schemes relying on different biomarkers, such as the steatosis grade in the liver histology, the “Controlled Attenuation Parameter” of the Fibroscan® system and the MRI-derived proton density fat fraction (PDFF) parameter. The deployed machine learning classifiers using RF data include neural networks, such asResNet and ROCKET and further methods like Dynamic Time Warping and Gradient Boosting Machines (GBM).

Results

GBM methods achieve 77% accuracy (78 % positive precision, 88 % positive recall, 59% negative recall and 83% F1-score) for hepatic steatosis in patients with biopsy-proven NASH. We show that GBM methods achieve better results compared to deep learning approaches, while being much faster.

Conclusion

GBM algorithms using ultrasound RF data are suitable for quantification of hepatic steatosis in patients with biopsy-proven NASH.

Capacitive micromachined ultrasonic transducers for intracorporeal applications

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Introduction

Capacitive micromachined ultrasonic transducers (CMUTs) are a promising technology for generating and detecting ultrasonic waves. In contrast to conventional transducers, they have, among others, an inherently high bandwidth and the advantage of not using problematic materials such as lead, which is an important material for piezoelectric transducers. CMUTs are therefore ideally suited for the extension of various medical implants. For example, they can be used to transfer energy to charge implants or to enable an implant to communicate with the outside world or with other implants. In order to use CMUTs on human patients, they must be encapsulated to protect the CMUTs themselves as well as the surrounding tissue.
In this work, we present the design, fabrication and characterization of encapsulated CMUTs for intracorporeal applications.

Methods

CMUTs were designed using the FEM tool OnScale to have a resonance frequency of 1 MHz in water and to work with a bias voltage of 40 V_{DC}. After fabrication with a wafer bonding approach, the CMUT chips were characterized in air via laser Doppler vibrometry and impedance analyzer measurements. In addition, the signal transmission behavior in immersion was examined by means of transmission measurements in liquid. Based on the results for the bare CMUT, the influence of different encapsulations on the vibration behavior of the CMUT was tested in simulation and experiment.

Results

The resonance frequency that results for the coated CMUT depends significantly on the coating materials used and on the thickness of such coating layers. Results from simulations and experiments for differently coated CMUTs are presented.

Conclusion

If CMUTs are to be designed for applications that require coating of the chip, as for example in medical implants, a major design focus should be on optimizing the coating.