IGIC 2021 – Abstracts

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Medical Imaging, Medical Devices and Robot Applications for Image-Guided Interventions

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CONTENT

Invited Talks

Effiziente Prozesse für eine präzise Medizin: Ein Lösungsansatz am Beispiel des Forschungscampus M²OLIE – Mannheim Molecular Intervention Environment

Prof. Dr. Jan Stallkamp, Universitätsmedizin Mannheim

Moderne Diagnose- und Therapieverfahren erfordern heute vor allem bei schweren Erkrankungen eine umfangreiche Abfolge von einzelnen Arbeitsschritten. Die Präzision und Effizienz der Behandlung hängen dadurch nicht nur von der Qualität der einzelnen Maßnahme, sondern immer stärker von der konzertierten Durchführung des gesamten organisatorischen und medizinischen Prozesses ab. Die Verwirklichung einer effizienten Präzisionsmedizin erfordert den Wandel zu hochintegrierten, prozessorientierten Abläufen in den klinischen Strukturen und stellt damit das ganze Spektrum von medizinischer, technisch-naturwissenschaftlicher Forschung und organisatorischer Umsetzung vor gewaltige Herausforderungen. Im BMBF-Forschungscampus M2OLIE – Mannheim Molecular Intervention Environment – wird an der Universitätsmedizin Mannheim zurzeit mit einem großen, interdisziplinären Team ein durchgehender Behandlungsprozess für Patienten mit Oligometastasen prototypisch entwickelt. Am Beispiel von M²OLIE werden die technischen Entwicklungen erläutert und insbesondere die Herausforderungen bei der Umsetzung solcher prozessorientierten Lösungsansätze in die Praxis der modernen medizinischen Versorgung beschrieben.

Interventional neuroradiology – current developments and trends

Dr. Daniel Behme, Universitätsklinikum Magdeburg)

Interventional neuroradiology has experienced magnificent changes over the last decades. These include relevant advances in CT and MRI imaging as well as game changing developments in the treatment of neurovascular diseases like stroke by interventional means. Beside the overwhelming success of endovascular stroke treatment, several new devices have widened the indications for intracranial aneurysm treatment, especially for those aneurysms with wide neck. Simultaneously the development of tools allowing for virtual simulation of neurointerventions has more and more impact on our daily routine. These developments are cornerstones of patient specific devices and interventions in the future. Beside these novelties, bioengineering has become a relevant issue in neuro-intervention with coatings for Nitinol devices enabling for less antiplatelet therapies or helping for a faster healing of aneurysms. Aside these changes peri-interventional imaging facilitated by flat panel imaging has opened several opportunities to optimize workflows for neuro-interventional treatments, especially stroke treatment. These new workflows will be supplemented by the use of robotics to the field of neuro-intervention.

Clinical application: Microwave ablation of the liver

Prof. Dr. med. Kristina Ringe, Medical School Hanover

Microwave ablation (MWA) is an established technique for treatment of primary and secondary liver tumors. In the first part of this talk, a short introduction to thermal ablation in general is given. In more detail, the basics of MWA including specific technical considerations in the context of clinical tumor treatment will be reviewed. The second part of this talk focuses on the clinical application of hepatic tumor ablation, including indications, pre-procedural planning and treatment outcome. Combination therapies and adjunct techniques for tumor targeting and applicator positioning during the intervention are discussed based on cases from daily routine.

guidoo – Towards Clinical Application

Andreas Rothfuss, BEC GmbH

We present the robotic intervention assistant guidoo by BEC for fast and precise needle placement as well as its development journey from the original idea over several prototype stages from experimental proof-of-concept to pre-production prototype to market-ready medical product towards clinical application. Original applied research took place in the BMBF research campus M2OLIE, resulting in a viable proof-of-concept system. The technology was then transferred to BEC GmbH and developed into a mature, market-ready medical product. We will describe user studies and necessary preclinical trials that were undertaken, including first trials on medical phantoms, as well as successful first-in-animal study and plans for a first-in-human study. Additionally, we will present the next steps for guidoo.

Towards vendor-independent image-guided interventions

Prof. Dr. Matthias Günther, Fraunhofer MEVIS

Towards vendor-independent image-guided interventions In interventional therapy MRI is one of the options for localization and guidance of the treatment. MR sequences have been developed to allow for fast and robust real-time slice update to follow the catheter tip. More sophisticated sequences allow for advanced contrast options to improve workflow and treatment. However, all of these dedicated MR sequences are rather dependent on the underlying MR scanner hardware and the specific software platform. This makes it challenging to distribute novel techniques to various users and blocks seemless commercialization. In the presentation, a framework will be presented, which aims at a vendor-independent MR sequence development and deployment with medical product level implementation in mind. Some examples are presented for vendor-independent real-time update used for catheter tracking.

Image-based therapy simulation in cardiac valve surgery

Prof. Dr. Anja Hennemuth, Charité – Universitätsmedizin Berlin

tbd

Metal Artifact Correction in End-to-end Deep Learning CT Image Reconstruction

Dominik Bauer, Tom Russ, Constantin Ulrich, Alena-Kathrin Golla, Lothar Schad, Frank Zöllner
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Introduction:

Metal artifacts are common in CT-guided interventions due to the presence of metallic instruments and iodine-based contrast media in patients. This often leads to the obstruction of clinically relevant structures, which can complicate the intervention. We present a CT reconstruction method for metal artifact reduction (MAR).

Materials & Methods:

The concept of our iCTU-Net displayed in Fig. 1 is inspired by the common filtered back projection. The sinogram is refined and filtered before being back projected into the image space, where the images are further refined by employing a U-Net.

We used the XCAT phantom to simulate training data. First, thin metal catheters were added inside the blood vessels of the 512x512 px XCAT images. Metal sinograms were then generated via forward projection using a parallel beam geometry with 736 projection beams and 360 projection angles. Beam hardening was simulated by using a 100 keV x-ray spectrum obtained from the SpekCal software and utilizing the energy-dependent attenuation coefficients of the XCAT. Afterwards Poisson and Gaussian noise were added to the projection data. The reconstruction is learned end-to-end, i.e. the input of the iCTU-Net are the metal sinograms and the labels are artifact-free ground truth reconstructions. 40 Phantoms were used for training and 10 additional phantoms for testing.

Results:

In Fig. 2 a reconstructed slice using the FBP, linear interpolation MAR (LIMAR) and our iCTU-Net is compared to the ground truth. The FBP contains strong streaking and extinction artifacts, obscuring objects near to the metals. LIMAR suppresses these artifacts, but streaking is still visible. Our network is able to reconstruct an image without any streaking artifacts, but bones appear slightly blurred. The iCTU-Net provides a similar PSNR and a superior SSIM compared to LIMAR. LIMAR is outperformed for strong metal artifacts.

Conclusion:

In the future, we will use the FBP and LIMAR images as additional inputs to decrease blurring of high contrast structures.

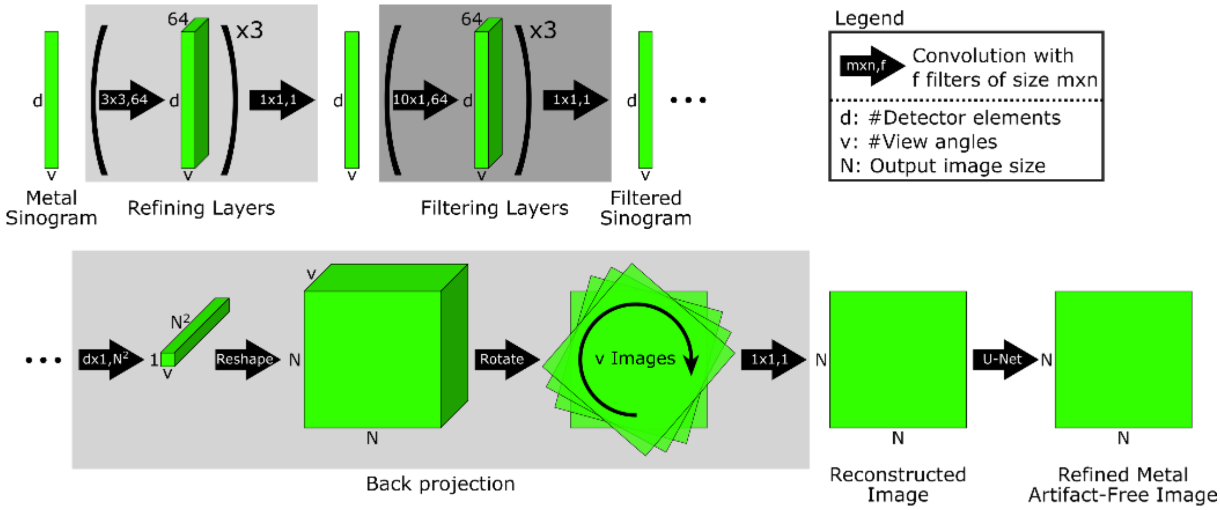

Figure 1: iCTU-Net end-to-end CT reconstruction network architecture adapted for metal artifact reduction.

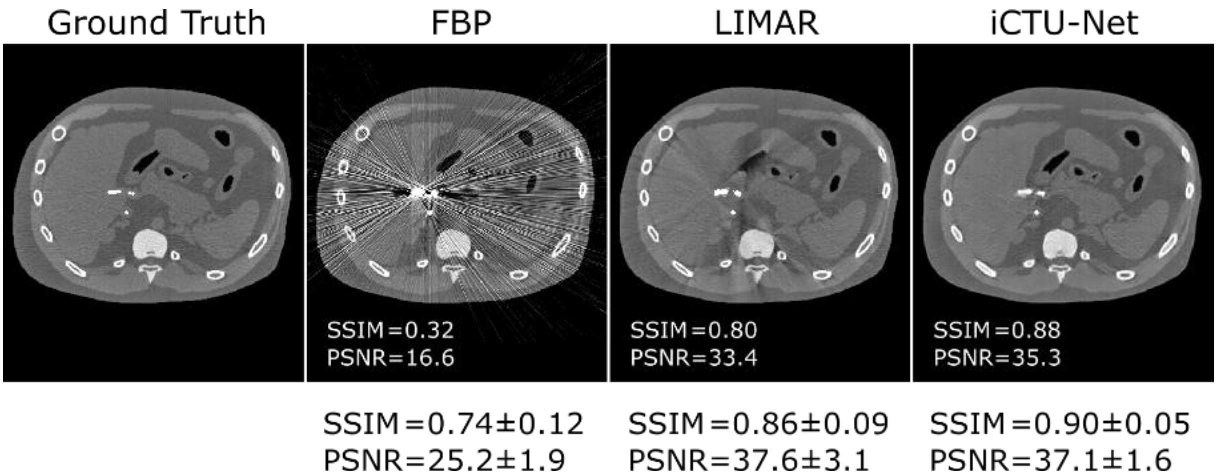

Figure 2: Ground Truth compared to FBP, LIMAR and iCTU-Net. The chosen slice is a case with especially severe metal artifacts, where the iCTU-Net outperforms LIMAR in both SSIM and PSNR. The SSIM and PSNR values below are the averages over all test slices.

CBCT translational Self-Calibration using Feature Detection and Matching

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Introduction:

Modern robotic CBCT systems support the use of task-based, non-circular trajectories. For the reconstruction, the exact position and rotation of every acquired projection needs to be known. This can be achieved by registration on a prior image.

Materials:

We acquired two scans of a lumbal spine phantom on a CBCT Artis Zeego (Siemens Healthineers, Forchheim, Germany). In the first CBCT scan a needle is inserted into the phantom, in the second CBCT there is an additional metal object and the needle position was changed. We added noise from an equal distribution between -5 and 5 detector pixel distances for the in-plane translation and up to 5% zoom.

Methods:

The developed algorithm uses AKAZE feature detection [1] to find the correct translations to 2D-3D register a projection onto the CT image. The distance between matching points in the acquired image and a simulated projection determines the translation in the plane of the detector, while the zoom factor, or movement perpendicular to the detector, is defined by the ratio of the length between points within an image.

We compare our approach to two L-BFGS-B minimizations, one using our distance measurement for the objective function, the other using the normalized gradient information. The evaluation metric is the normalized gradient information, higher is better.

Results:

Runtime (8 parallel processes):	Mean NGI:
L-BFGS-B (NGI): 4h:35m:19s	L-BFGS-B (NGI): 0.63 ± 0.033
L-BFGS-B (Our Objective): 4h:09m:42s	L-BFGS-B (Our Objective): 0.63 ± 0.021
Our Algorithm: 9m:58s	Our Algorithm: 0.64 ± 0.017

Conclusion:

We demonstrated that our algorithm could find the actual position of the acquired images with an equal accuracy as a state-of-the-art algorithm, but in less than 10 minutes instead of four hours. Our current research aims to include detector rotation in our calibration algorithm.

Reference:

[1] Alcantarilla et al. (2011). IEEE Trans. Patt. Anal. Mach. Intell, 34(7), 1281–1298. http://dx.doi.org/10.5244/C.27.13

Robustness evaluation of grangeat registration for prior-based reconstruction

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Introduction:

Clinical interventions performed under C-arm fluoroscopy guidance often require the acquisition of a final flat-detector computed tomography (FDCT) scan to verify the success of the intervention. In an earlier work we presented an approach to register a prior to a truncated FDCT acquisition by making use of interventional guidance images. This considerably reduces truncation artifacts in the region-of-interest reconstruction and therefore improves the overall image quality. Here, we investigate the robustness of this method under the presence of two independent rigid motions of the patient and the patient table.

Materials & Methods:

Cranial CT volume data from the low-dose CT grand challenge dataset [1] was used. First, the volume was decomposed into 2 different volumes of the patient table and the patient respectively by manual segmentation. The rigid motion parameters estimated between a clinical prior and following intervention were then applied to the patient volume while the patient table volume remained in its original position. This modified combination of patient and patient table volumes was reprojected and subsequently registered to the prior state using the grangeat registration method [2].

Results:

To assess the accuracy of the registration, the mean target registration error (mTRE) with respect to the known ground-truth displacement was computed. The grangeat registration is compared to a conventional digitally reconstructed radiograph (DRR) registration method. With an average mTRE of 0.64mm the grangeat registration outperforms the DRR method which achieves an average mTRE of 1.75mm.

Conclusion:

It was shown that the grangeat registration is able to outperform established DRR-based registration methods also in cases of non-rigid motion which might appear in interventional scenarios when the patient is placed differently on the patient table. Truncation is still a limiting factor for the grangeat registration which has to be investigated further.

Adjusting the Acquisition Parameters of Spherical Ellipse Tomosynthesis Scan Orbit for Guiding Interventional Bronchoscopy

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[2]Research Campus STIMULATE, Otto-von-Guericke University, Magdeburg, Germany;
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Introduction:

The guidance of lung biopsy procedures with chest radiography is challenging due to the superimposition of the different structures in a 2D image. While CBCT might provide exact 3D information, it poses a high radiation dose and impede the workflow in the operating room. Recently we proposed a new spherical ellipse digital chest tomosynthesis DCT scan orbit (Fig1) to mitigate these limitations and improve the limited depth resolution of linear DCT. In this work, we investigate further this orbit and study the impact of the different acquisition parameters (number of views N, tomographic angle, and projection density) on the image quality.

Materials & Methods:

DCT projection data were simulated from real chest CBCT images assuming a spherical ellipse geometry and using our CTL toolkit. The spherical ellipse is defined by two tomographic angles $\pm\alpha$ and $\pm\beta$ ($\alpha>\beta$). While β was fixed to 15°, α and N have been varied from 20° to 60° and from 10 to 72, respectively. The different acquisition and reconstruction parameters are summarized in table1.

Results:

A selected reconstructed coronal slice with different combinations of α and N is shown in Fig2. Pearson Correlation PC between the reconstructed images and the reference CBCT image was computed in the ROI highlighted in yellow in the CBCT slice and is plotted in Fig3 as a function of α and for different values of N. Overall, improved image quality (mainly for large N) is observed when increasing α up to a certain value. However, increasing α beyond this value deteriorates the image quality with strong ripple artefacts and decreases the PC (more emphasized for small N). For a fixed N, increasing α results into a larger spacing between the projections and subsequently a lower projection density which causes the appearance of the ripple artefacts.

Conclusion:

Our evaluation shows that large tomographic angles require more projection views. In a further study we will investigate whether projection density acts as a common parameter independent of the trajectory chosen.

Extraction of prior knowledge basis function set for model-based perfusion reconstruction of the liver

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Introduction:

Accurate perfusion imaging is important to evaluate the success of embolization therapy for liver cancer. Using C-arm CT it would be possible to obtain perfusion images and monitor therapy intraoperatively. To overcome the problem of temporal undersampling of acquired projections due to slow C-arm rotation, a model-based approach Time separation technique using an analytical basis function was applied. Here we investigate the possibility of extracting a basis function set based on prior knowledge.

Materials & Methods:

A prior knowledge basis function set is extracted from reconstructions of two CT perfusion datasets of swine liver using singular value decomposition. From every dataset we select slices where embolized and non-embolized regions are well visible. From these slices the non-liver tissue, artifacts caused by embolization material and bones are excluded.A fixed number of basis functions is selected based on the singular values and TAC profiles of one voxel located in tissue, see Figure 1.

Results:

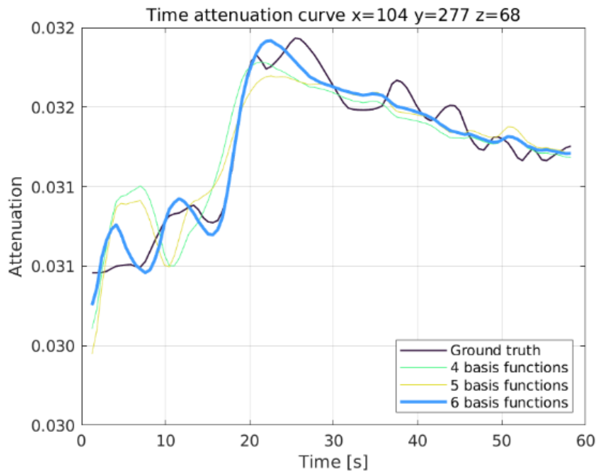
The extracted basis function set, shown in Figure 2, is fitted to CT reconstruction data and compared to original CT reconstructions (ground truth). The perfusion maps are compared by determining the Pearson correlation coefficients (0.99 for blood flow and blood volume, 0.85 for mean transit time and 0.91 for time to peak). We observe that the difference between embolized and non-embolized regions is preserved, see Figure 3.

Conclusion:

The selected basis function set compresses the relevant information about the contrast agent dynamics. However, the basis functions could be generalized by performing SVD on more datasets and the number of basis functions used should be lower to minimize computing complexity.

Acknowledgment:

This work was conducted within the International Graduate School MEMoRIAL at OVGU Magdeburg, supported by the ESF (project no. ZS/2016/08/80646). This work is partly funded by the German BMBF within the FC STIMULATE (13GW0095A).



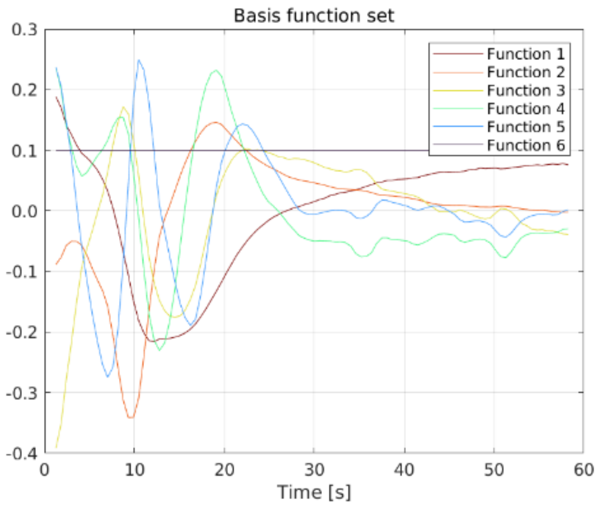


Figure 1: Time attenuation curve of one voxel for prior knowledge basis function set of different size. Figure 2: Basis function set extracted from prior knowledge.

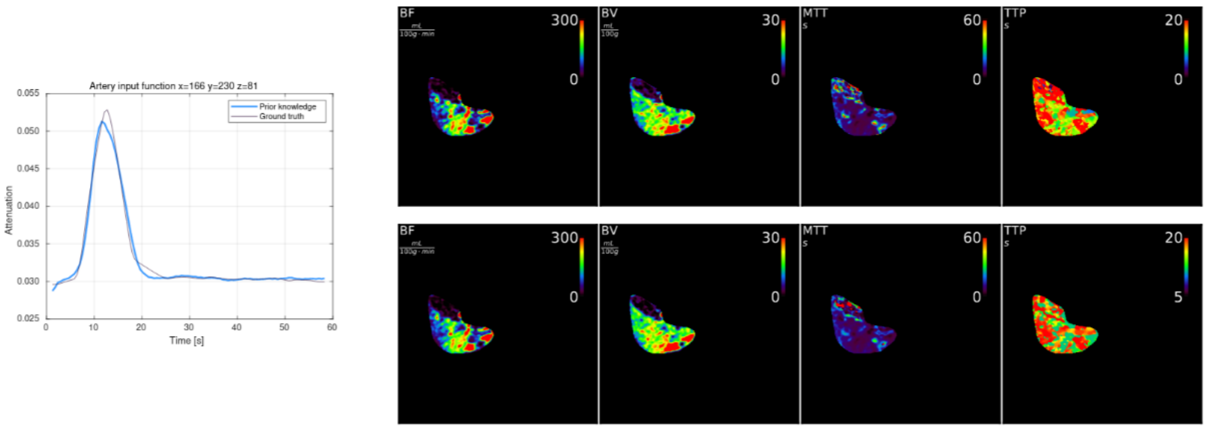


Figure 3: Artery input function and perfusion maps. Second row are perfusion maps generated by fitting prior knowledge to CT reconstructions.

Liver ablation segmentation of CT images in microwave ablation therapy

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Introduction:

Treating cancer is an important task e.g. in the liver which is one of the solid organs with a high incidence of tumor. Due to the technical improvement on biomedical systems and minimal invasive therapies microwave ablation (MWA) therapy as an invasive minimal therapy gets a lot of attention for destroying the cancer cells in its location by using electromagnetic waves. The technique is widely used in liver tumor therapy by placing the needle in the tumor location and destroying the cells by sending microwave signals. The process is finalized by visual inspection of the ablation area [1,2].

However, despite that many CT scan images are taken pre-ablation and post-ablation for monitoring the therapy process, that is still the problem that incomplete ablation therapy leads to tumor recurrence which is one of the biggest challenges in MWA. The use of a tool to automatically and precisely segment the tumor and ablation area in CT images has proven to be advantageous reducing the cancer cells' survival rate by suporting physicians with visual feedback. Although, both of these tasks are very time-consuming, but physicians carry them out manually for performing the therapy good enough to prevent tumor recurrence [3].

A lot of research on medical image segmentation was performed at the Otto-von-Guericke University that can assist humans in different applications [4]. Various segmentation methods and algorithms such as Active contours, statistical methods, graph-based approaches, machine learning, and deep learning methods were proposed. In particular, we aim to employ deep learning methods to perform the task more precise and faster. Ablation segmentation using deep learning can contribute to a better understanding of the tumor recurrence. Therefore, it could lead to better cancer treatment during interventional CT MWA therapy.

Offcenter MRI-Thermometry

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Introduction:

In recent years interventional magnetic resonance imaging (MRI) became more and more popular. Since most MR systems are designed for diagnostic purposes, interventional imaging poses many challenges. This work will address the tight space inside the MR system and combine this with a therapy control aspect.

Materials and Methods:

Patient accessibility during MR-guided interventions is a main challenge. One option to generate better access is shifting the imaging volume and thus the patient out of the magnet isocentre. This, however, can lead to spatial image distortions due to the non-linear gradient fields.

In 2D imaging, standard retrospective distortion correction methods don't correct the slice positioning, which leads to mispositioned slices.

In this work we present a method to correct the slice position and apply it to MR thermometry. The PRF thermometry only uses phase difference images and thus is immune to gradient induced intensity variations.

The proposed correction method exploits the known gradient distribution field to predict the mispositioning of the slice prospectively and additionally calculates a tilt angle to compensate the local slice curving. This allows live 2D imaging of the structure of interest.

This method was tested using a heated mango as phantom and observing the cooling process via thermometry imaging in the isocentre, an uncorrected offcenter position and a corrected offcenter position. To verify the results an optical temperature sensor was used as reference.

Conclusion:

The results show a large improvement in Thermometry values when using the new offcenter correction. The uncorrected values do not show any cooling as they were measured at the wrong positions. The measurement with the correction shows a similar trend as the measurement in the isocentre and the reference.

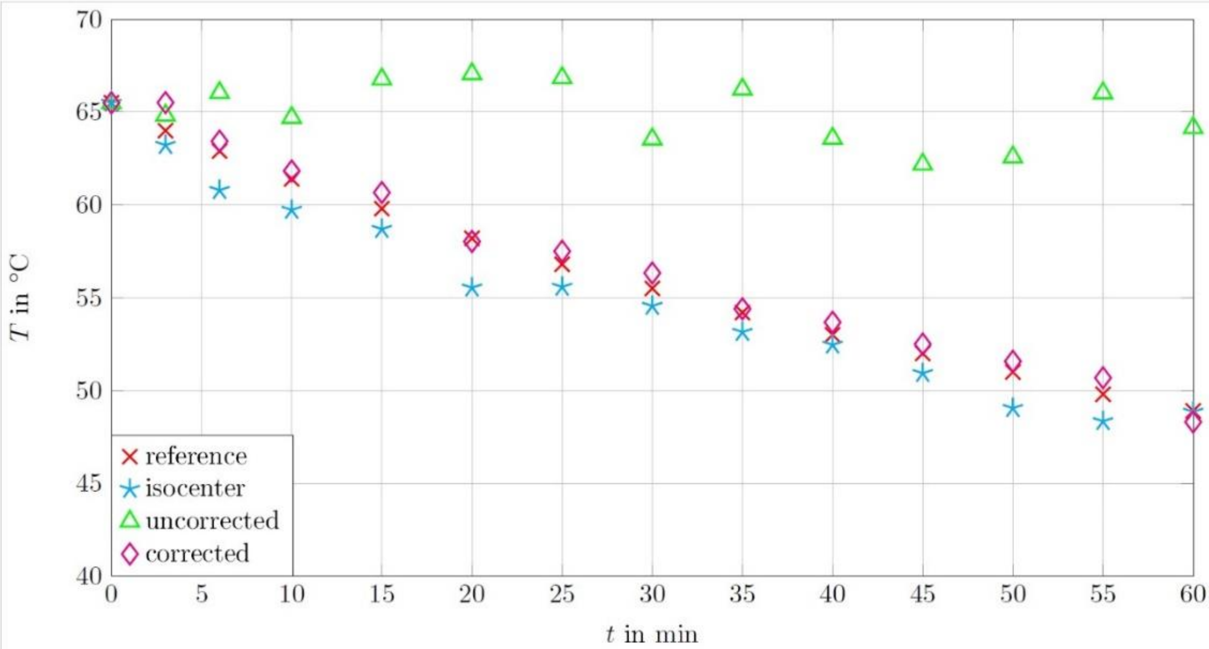

Figure 1: Experimental results of the thermometry data and the optical sensor.

Efficient modification of the 2.5D thermometry by locating the best trade-off between spatial and temporal resolution

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Introduction:

In addition to open surgery, a variety of minimally invasive techniques have been developed for cancer therapy. Microwave ablation (MWA) is one of these techniques. Magnetic resonance (MR) imaging is a modality which allows treatment monitoring through MR thermometry. One method to generate volumetric temperature maps is the 2.5D proton resonance frequency-based MR thermometry. This technique uses evenly distributed 2D MR phase images rotated around the applicator's main axis. We propose an improved sequence protocol with the best trade-off between temporal and spatial resolution, which results in an improved prediction of the real coagulation zone.

Materials & Methods:

Images were acquired with a 1.5T MRI system using a gradient echo sequence. MWA ablation was performed in a bio protein phantom. A permittivity feedback controlled MWA system was placed outside the scanner room, connected to the applicator with two coaxial cables passed through a waveguide. Electromagnetic interference was reduced by the addition of chokes and electrical grounding. A MWA lasted 15 minutes with a temperature limit of 90°C. 2.5D MR thermometry was performed during ablation with different angles of rotation and voxel resolutions. Performance of MR thermometry was evaluated with the dice similarity coefficient (DSC) using a manually segmented ablation zone of post-ablative 3D turbo spin echo MR-imaging, but also taking the acquisition time into account.

Results:

Evaluation of a first test series using our updated sequence protocol showed an improvement in temporal resolution without a decreased DSC.

Conclusion:

The improved temporal resolution with our updated 2.5D thermometry protocol allows a faster intrainterventional evaluation of the growing coagulation zone, without decreasing the spatial accuracy. In a clinical context, this may improve controlling the ablation zone relative to the treated tumour and therefore may improve the outcome of MWA based tumour treatment.

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number 13GW0473A, 13GW0473B and supported by PRACTIS – Clinician Scientist Program, funded by the German Research Foundation (DFG, ME 3696/3-1).

Proton Resonance Frequency-based 3D Magnetic Resonance Thermometry using a Stack of Stars Sequence for Monitoring of Hepatic Microwave Ablation

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Introduction:

With its temperature-dependent parameters such as the proton resonance frequency (PRF), magnetic resonance (MR) imaging offers an excellent option for interventional monitoring of thermal ablations [1]. However, due to respiratory motion PRF-based MR thermometry of hepatic microwave ablation (MWA) is challenging. Current clinical thermometry is limited by its sensitivity to motion as well as by an insufficient coverage of the ablation zone and a low spatial and temporal resolution [2]. Aim of this work was to develop and test the feasibility of three-dimensional (3D) PRF-based MR thermometry for monitoring of MWA in the liver.

Materials & Methods:

A stack of stars MR sequence was implemented on a 1.5 T MR scanner. During image acquisition, MWA was performed in a linearly moving phantom of chicken meat to simulate respiration. Motion correction was performed retrospectively using DC gating [3]. A fiber optic temperature sensor was inserted near the microwave applicator for validation of MR thermometry. To reduce interference with MR imaging, the MWA generator was placed outside the MR room [4].

Results:

A motion-corrected 3D MR thermometry map during ablation of the moving phantom was calculated (figure 1). Significant interferences of the MWA system in active mode were observed. The comparison with the temperature sensor resulted in an accuracy of up to 1.08 °C ± 1.25 °C (figure 2). Using post-ablative MR images as reference, a dice score of up to 64 % was achieved.

Conclusion:

This experiment showed promising initial results of 3D PRF-based MR thermometry during MWA using a stack of stars MR sequence. However, further improvement of 3D MR thermometry and the reduction of interferences caused by the MWA system need to be addressed. To ensure a more accurate detection of the ablation zone a protein phantom should be used in future experiments.

[1] 10.1002/jmri.21265

[2] 10.1002/mrm.26797

[3] 10.1002/mrm.25665

[4] 10.1016/j.ejmp.2019.10.020

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number 13GW0473A and 13GW0473B and supported by PRACTIS - Clinician Scientist Program, funded by the German Research Foundation (DFG, ME 3696/3-1).

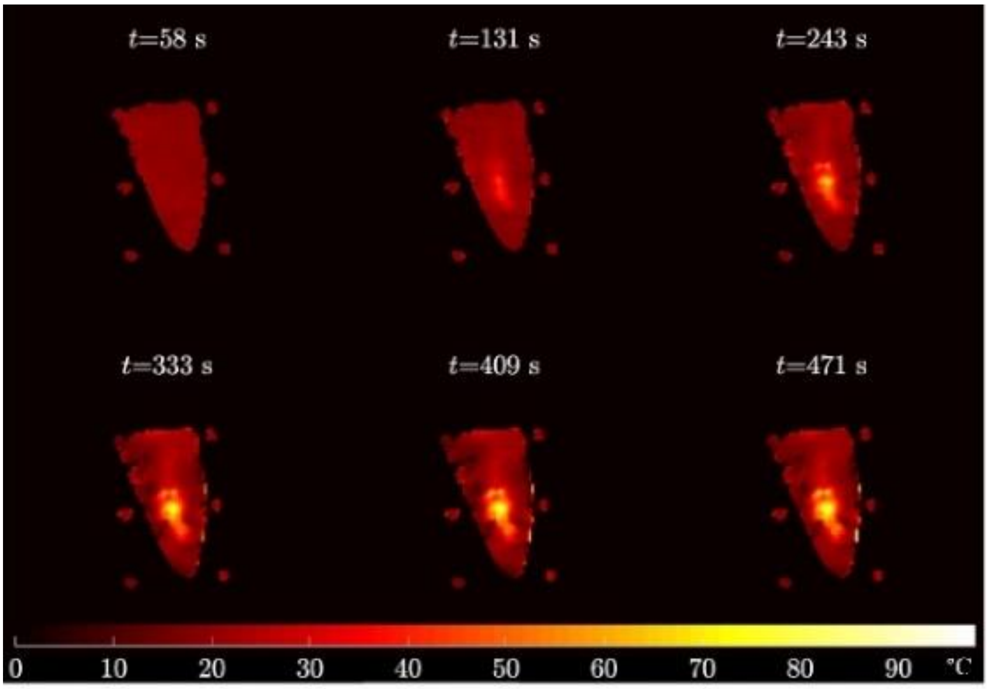

Figure 1: A single slice of the motion corrected 3D MR thermometry map during ablation of the moving phantom. The microwave ablation started at t = 0 s.

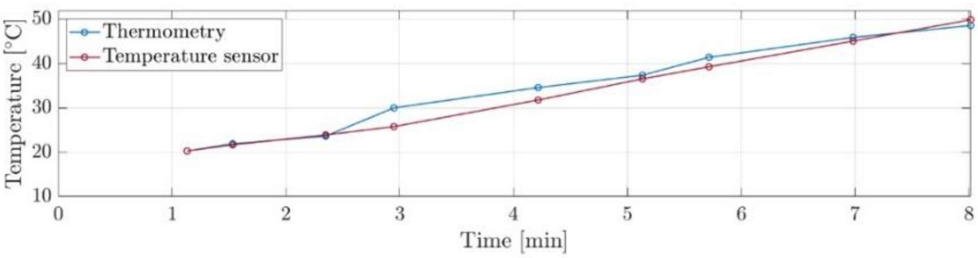

Figure 2: Comparison between the temperature sensor and the calculated MR thermometry.

Feasibility study of MRI-guided IRE

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Introduction:

Irreversible electroporation (IRE) is a non-thermal, minimally invasive tumor ablation method using strong electrical fields. It is characterized by its sharp ablation margins, only low effect on connective tissue, and no heat sink effect [1].

Materials & Methods:

For the IRE procedure, electrodes are placed around the tumor and pulsed electrical fields are generated between the electrodes. These electrical fields are critical for the ablation area so that electrode movement can possibly disturb the ablation. Hence, real time monitoring of the electrode position and the ablation area can positively influence the therapy outcome [2]. Due to the possibility of real-time acquisition of slices in arbitrary orientations, MRI is an appropriate choice for a guided IRE procedure [3]. Within this abstract, the feasibility of IRE inside an MRI environment will be tested.

The IRE generator is placed outside the MRIs shielding cabin and the electrodes are placed inside a phantom in the isocenter of the 3T MRI. Two aspects will be examined. First, the image degradation due to the IRE generator according to IEC standards [4] and second, the current induced movement of the electrodes due to the Lorentz force using an optical Moire phase tracking system [5].

Results:

The acquired images using a GRE sequence (Figure 1a) show that in stand-by (2) and during ablation (3) the image quality is degraded, represented by a decrease in SNR from initially 63.29 to 42.25 for stand-by and 40.55 for ablation. The result displayed in Figure 1b shows that the displacement after 70 pulses is 4mm, whereby some pulses generate stronger movements.

Conclusion:

The image quality degradation when turning on the IRE generator is due to radio frequency coupling through the wires to the system and could be reduced by filtering the generator output. Nonetheless, imaging is already possible with the setup. This, in addition to the small displacement, indicate that MRI-guided IRE is generally feasible, with further research being promising.

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number 13GW0473A.

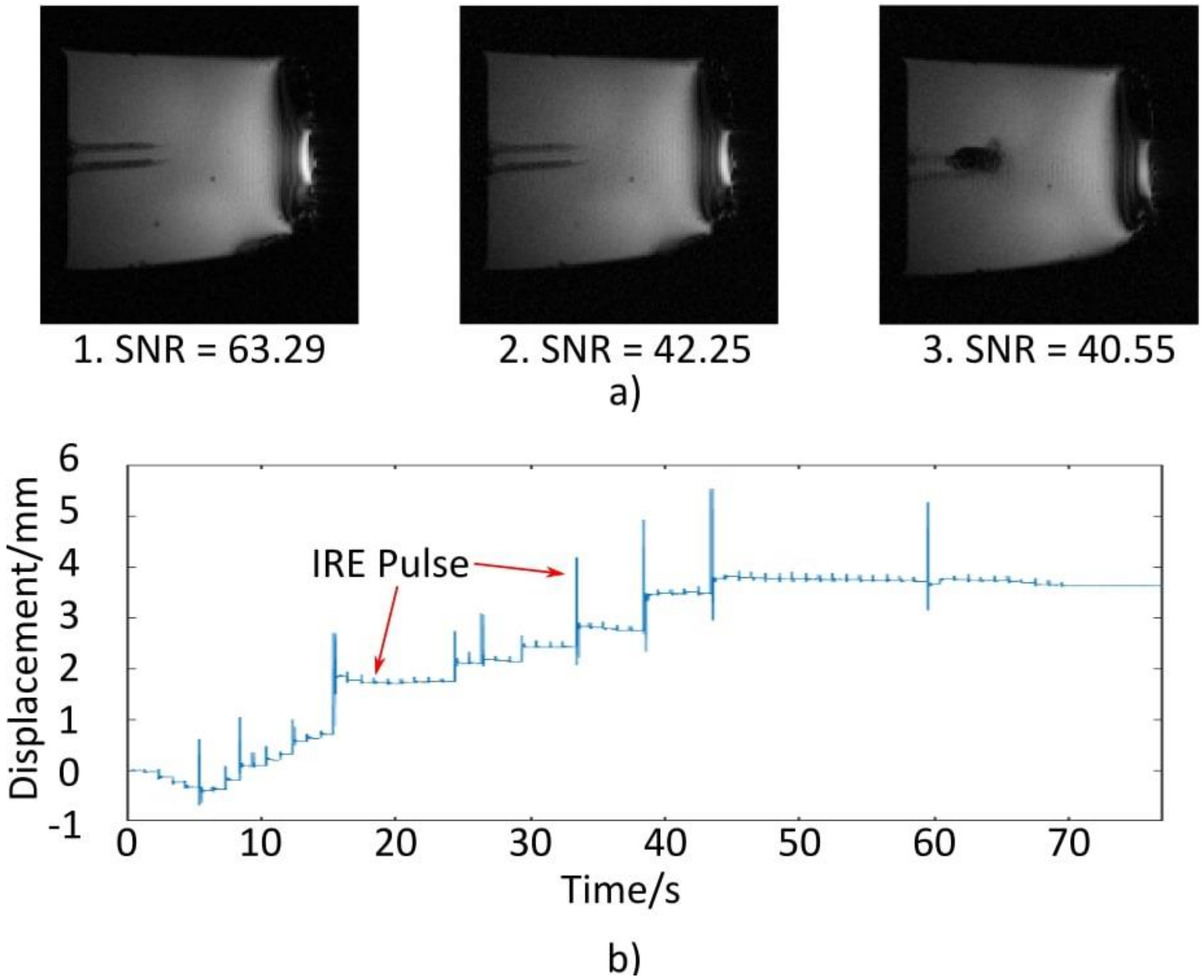

Figure 1: a) Images acquired with the gradient echo sequence for a switched off IRE generator (1), a generator in stand-by (2) and during ablation (3) and (b) the electrode displacement during the ablation.

An Anthropomorphic Pelvis Phantom for MR-guided Prostate Biopsy

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Introduction:

With multiparametric MRI (mpMRI) it is possible to localize prostate lesions, which enables focal therapies for prostate cancer. Minimal invasive focal therapies such as brachytherapy seed placement benefit from novel technologies like robotic guided needle placement. Imaging phantoms are a save way to validate such technologies. However, established phantoms in literature are either not puncturable or not anthropomorphic. Here, we present an anthropomorphic pelvis phantom for transrectal prostate interventions.

Materials & Methods:

A CAD model of the phantom is displayed in Fig. 1 (a) and the manufactured phantom is shown in Fig. 1 (b). The phantom is puncturable and the prostate containing four lesions is accessible through a hollow rectum. A bladder, a urethra and bones serve as inhibitions for needle-based intervention planning. The phantom is reusable and is suitable for MR, CT and US imaging. We used synthetic ballistic gelatin as a tissue surrogate, which mimics the properties of muscle tissue. Thus, the phantom simulates realistic haptic feedback during needle insertion and can be used to train surgical personnel.

Results:

To demonstrate the feasibility of the phantom for minimal invasive MR-guided interventions, a targeted inbore biopsy was performed. The needle probe was rectally inserted and guided using an MR-compatible remote-controlled manipulator (RCM, Soteria Medical) as shown in Fig 2 (a). A T2w MRI image shown in Fig. 2 (b) was acquired to localize the needle probe and prostate lesions. The biopsy target was determined and the needle probe was remotely steered towards the target position. After the application of an MR-compatible titanium biopsy needle, a T2w MRI control scan shown in Fig. 2 (c) was acquired to confirm that the needle hit the lesion.

Conclusion:

The pelvis phantom can be used for a variety of minimal invasive interventions and will be used for the validation of an MR-guided brachytherapy seed placement workflow with the RCM in the future.

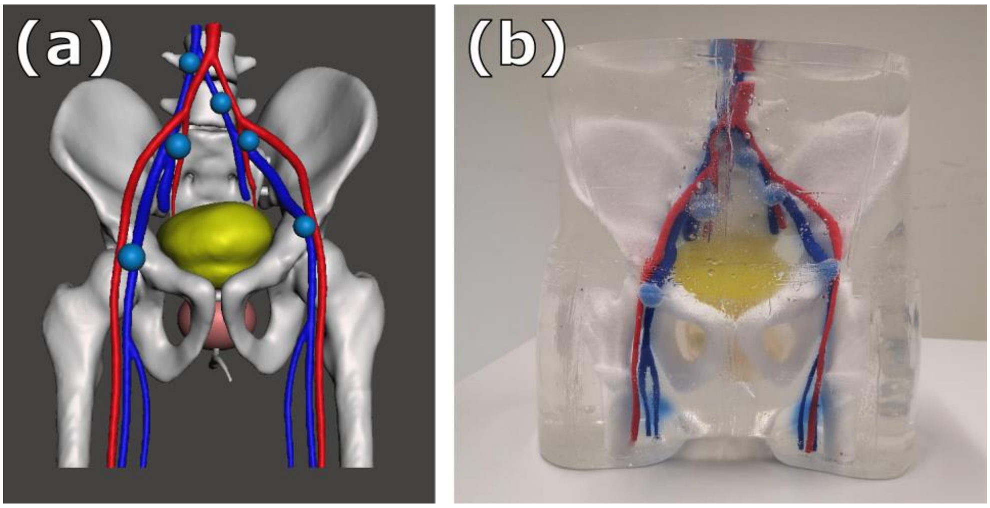

Figure 1: (a) 3D model of the phantom. (b) Manufactured phantom with the organs embedded in ballistic gelatin.

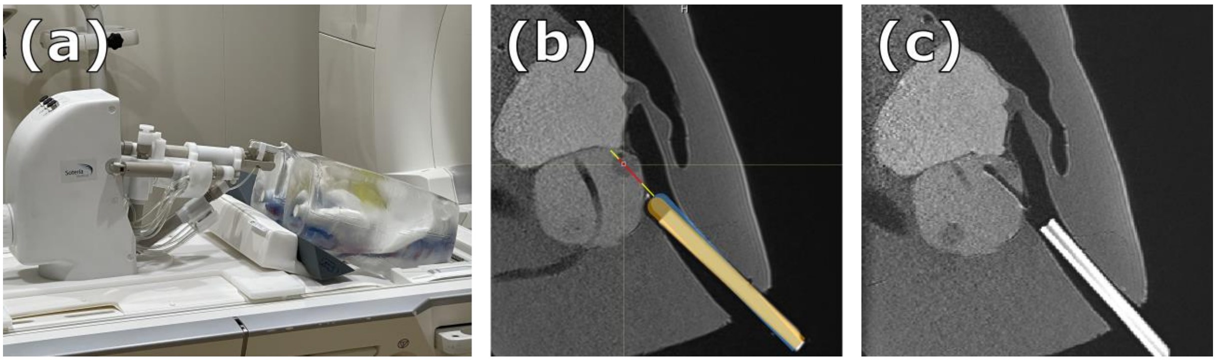

Figure 2: (a) Inbore-MRGB setup. (b) Initial T2w MRI scan, where the current position of the needle probe is shown in yellow. (c) Control T2w MRI scan.

Disposable Receive Coils for MR-guided Interventions

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[4]USE-Ing. GmbH, Stuttgart, Germany; [5]NORAS MRI products GmbH, Höchberg, Germany;
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Introduction:

Receiving coils are the basis of signal acquisition in Magnetic Resonance Imaging (MRI), and thereby essential for MR-guided minimally invasive therapies. Loop coils can be used to provide trajectory visualization of instruments in conjunction with auxiliary multi-channel coils to improve the image quality. To be used during intervention, the coils must be prepared in a sterile condition (e.g. wrapped) before fixation to the patient [1]. This work presents a concept of a sterile disposable coil and associated streamlined workflow.

Materials & Methods:

Specifications for the receiver coil (technical details in [2]) were defined with interventional radiologists including but not limited to sterility, flexibility and adhesion on the patient skin. Sub-components were optimized in terms of physical dimensions and material for usability between device, user and patient. The specifications were evaluated by experienced radiologists in a simulated liver biopsy MR-guided under the "freehand technique" [3].

Results:

The coil system is composed by single and multi-use components (Figure 1). The radiologist was capable of intuitively withdrawing the sterile single-use component from the package. A flexible housing encloses the coil and is fixed to the patient skin. The coil was successfully glued on a human phantom through an adhesive layer. The material deformation was optimal to wrap the phantom shape. Embedded in a surgical drape the coil ensures sterility of the surrounding. By connecting to a complementary multi-use subsystem, the signal transfer to the scanner is established. This can be realized by an interface-box mounted on top of auxiliary coils or the patient table.

Conclusion:

The presented coil system creates a sterile area and can simplify the basic workflow of an MR-guided intervention. It thereby provides a reduction in time and effort during preparation.

References:

[1] Truwit et al., ONS, 2006

[2] Pannicke et al., IGIC, 2017

[3] Fischbach et al., CVIR, 2011

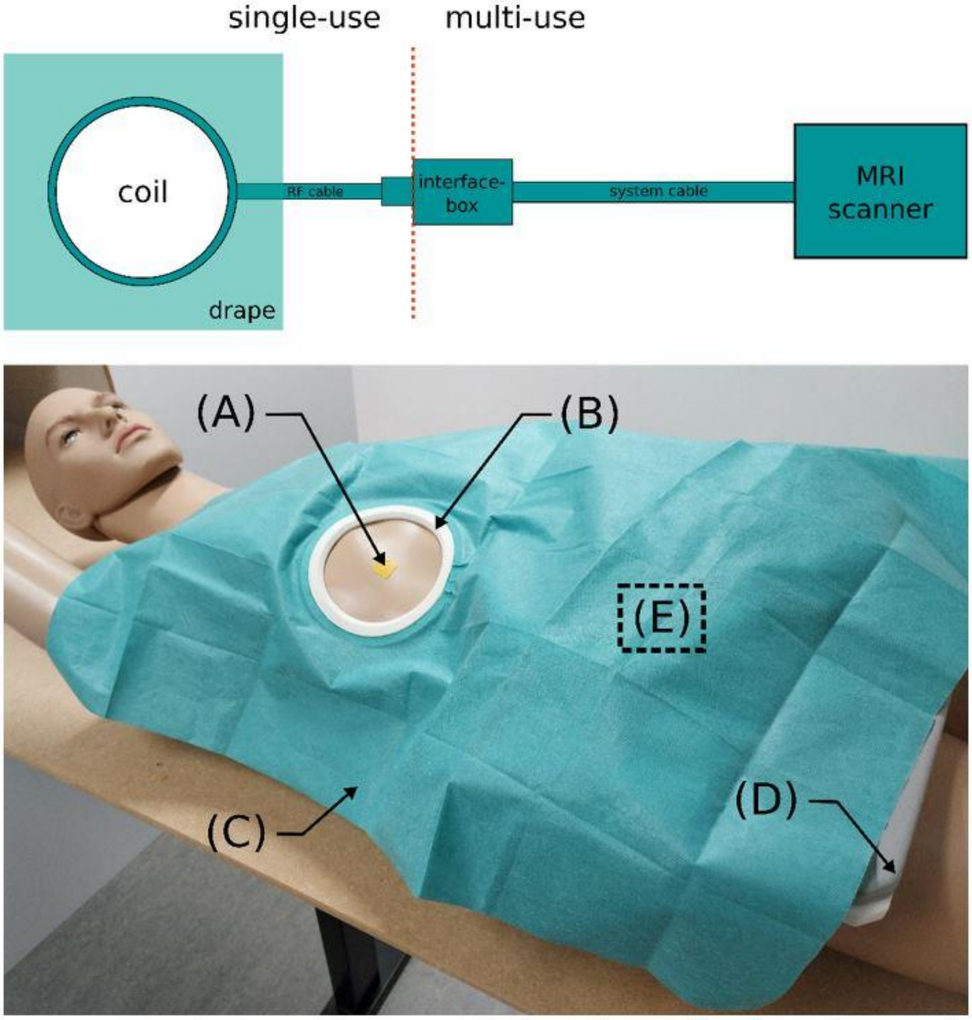

Figure 1: **Concept and application of the interventional coil.** Top: Schematic of the coil system featuring single- and multi-use components. Bottom: The entry point (A) is in the center of the coil (B). The surgical drape (C) prepares the area for intervention in an MR-guided liver biopsy and covers non-sterile surfaces, such as the auxiliary multi-channel coil (D) and the interface-box (E).

Combining Receive Coils with Microposition Robotics for MRI Guided Interventions

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[2]Institute for Medical Engineering, Otto-von-Guericke University, Magdeburg, Germany;
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Introduction:

For optimal local image quality, surface coils are often used for signal acquisition in image-guided interventional magnetic resonance imaging (iMRI). The coil, however, must first be brought into a sterile condition for interventions [1]. Concepts have already been developed for this application in the form of flexible single-use drape coils [2,3]. Limited space within the MR bore emphasizes the advantages of support systems for applicator positioning [4]. This work introduces a concept to combine the single-use receiving coil with a micropositioning unit to improve the iMRI workflow.

Materials & Methods:

The all-in-one package is designed to both establish the area for intervention with a sterile drape, enable imaging, and provide user-friendly robotically assisted instrument placement (see Figure 1). Therefore, the instrument positioning unit (IPU) provides a mounting for instruments to allocate a remotely controllable puncture in 5 degrees of freedom [5]. The key component is the integrated single-use bayonet adapter to lock the IPU with one hand. To verify the instrument's trajectory, fiducial markers placed inside the IPU and the coil housing capitalize on the space that is in any case necessary for patient safety.

Results/Conclusion:

The presented concept ensures that the MR markers are located within the sensitivity profile of the coil. This defined setup can increase the marker visibility and registration reproducibility to decrease the possibility of navigation errors during image-guided procedures. Furthermore, the workflow is improved by removing several conventional steps for ensuring sterility at the intervention area.

References:

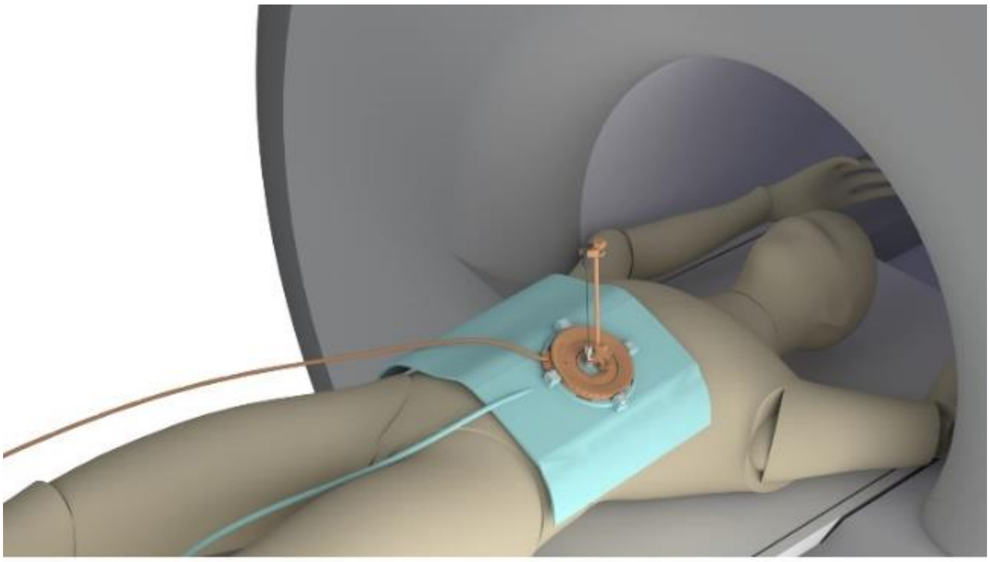
[1] Truwit et al., ONS, 338-346, 2006

[2] Pannicke et al., IGIC, 20, 2017

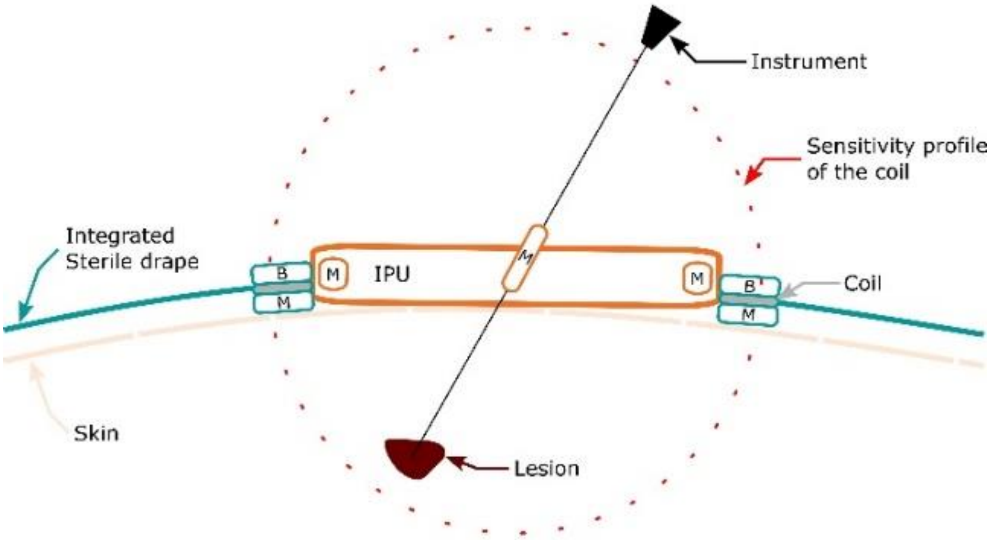
[3] OVGU, Pannicke, DE102018109540A1, 2018

[4] Monfaredi et al., BMES, 1479-1497, 2018

[5] Fomin et al., CDBME, 2021 (submitted)



(a)



(b)

Figure 1: (a) Concept of the sterile all-in-one package. (turquois, single-use) The coil and bayonet lock inside the surgical drape is fixated to the patient's skin using adhesive film. (orange) The IPU can be attached to the single-use components using the bayonet lock. (b) Illustrative cross-view of the combined devices through a bayonet lock (B) featuring different MR-visible fiducial markers (M) as well as the symbolic sensitivity profile of the coil.

Integration of MR Compatible Bowden Cables with Position Feedback Sensors into Compact Microposition Robotics

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Introduction:

Image-guided interventions offer great opportunities to precisely position the needle in the target tissue for biopsy or ablation. Due to the small bore of MRI systems, physicians are faced with a physically challenging work environment that can limit the success of needle placement. Robotic assistance systems provide reliable tools to ease the burden on radiologists during their interventions [1]. To ensure accurate and precise needle placement, an MR-compatible and compact positioning feedback of the actuators is needed. The technology of fiber Bragg grating (FBG) sensors can be used to determine the exact position of the respective degree of freedom (DoF) [2]. As a proof of concept, an integration of FBG into µRIGS [3] and the simultaneous use as Bowden cables are discussed.

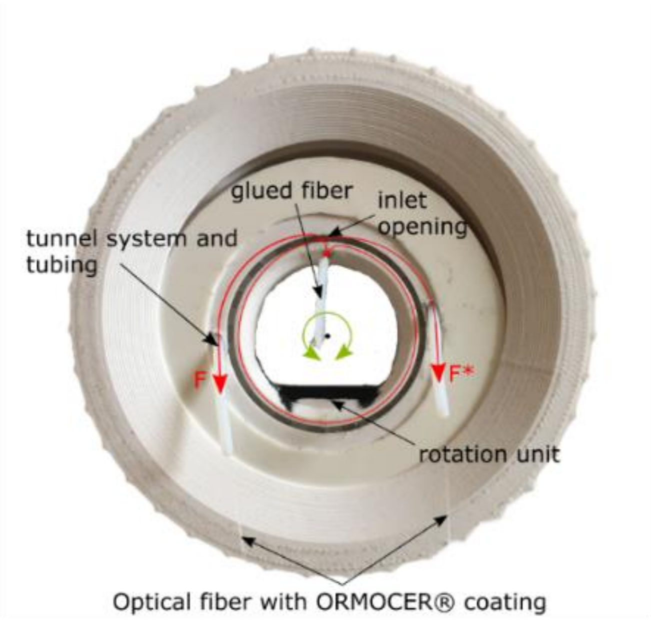

Figure 1: Integration of the OFs (Ø125 µm) into the rotation unit of the IPU. The OFs are covered with a layer of ORMOCER® to protect the OF against shear forces. The forces F and F* are exerted to the respective OF.

Materials & Methods:

Optical fibers (OF) (FBGS Technologies GmbH, Jena, Germany) were integrated into the rotation unit of the current instrument positioning unit (IPU). Tests applying different tensile forces as well as bending tests were performed to investigate the properties of the OF.

Results:

The system integration fully meets the intended requirements of the rotational movements (0–360°). Thereby, a maximum tensile force of F(*) = 10 N can be applied to the OF before it breaks at the inlet opening, as it is sensitive to shear forces when pulled over small radii or sharp edges.

Conclusion:

OFs offer a promising way of transmitting the tensile forces from the drive unit to the IPU and simultaneously sensing the current position of the mechanical parts. The novel concept needs to be further investigated in the future and the design of the IPU needs to be improved to the specific requirements of OFs. The use of hybrid cables, one cable for transferring force and one other for encoding the current position should be considered.

References:

[1] Monfaredi et al., BMES, 1479–1497, 2018

[2] Su et al., IEEE Sens. J., 1952–1963, 2017

[3] Fomin et al., CDMBE, 2021 (submitted)

A novel tool for interventional support of thermal hepatic ablations

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Introduction:

Thermal ablative techniques like microwave ablation represent an efficient, tissue-sparing and overall gentle treatment strategy in terms of small or non-resectable hepatic lesions. The acquisition of MR thermometry imaging during such interventions enables a direct monitoring of the ablation progress. Considering this, the proposed work presents a proof-of-concept intervention monitoring and outcome assessment tool in order to comprehensively support radiologists.

Materials & Methods:

The proposed tool combines MR images of the liver with simulated 3D+t temperature maps, which temporarily replace real-time MR thermometry images in order to track the ablation progress at this proof-of-concept stage. Additionally, segmentations of the lesion and other relevant anatomical structures, like the liver outline or nearby vessel structures are taken into account. The tool is essentially divided into four parts: data import, ablation monitoring, outcome validation, and export of the intervention results. It comprises intuitive 2D and 3D visualisations, quantitative feedback of the ablation progress and the resulting necrosis and provides various modifiable settings to adapt to different evaluation aspects.

Results:

For evaluation purposes, an exemplary patient case was used to demonstrate the features and benefits of the presented tool, as well as to assess the functional range with regard to the predefined clinical requirements. The integrated monitoring features enable a visual and quantifiable tracking of the heat propagation during the ablation progress, while the outcome validation part could support the radiologists with detailed feedback to assess the treatment results. This may benefit interventional decision-making and optimal ablation results.

Conclusion:

The proposed tool could be a significant step towards a more computer-assisted and sophisticated interventional workflow of thermal ablations, with benefits for both, patients and radiologists.

Histogram-based approach for MRI needle artefact detection

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Introduction:

Thermal ablation procedures of a liver tumor include planning the intervention, navigation to the target position and monitoring of the ablation. To avoid deviations from the planned path, the position of the applicator may be monitored using image guidance like magnetic resonance imaging (MRI). Different approaches with neuronal networks, k-space analysis of MRI images or bending-sensitive fibers have been developed for needle tracking.

Materials & Methods:

We present a histogram-based approach for segmentation of needle artifacts. A threshold using Otsu's method separates the low intensity background and needle artifact from the high intensity liver tissue. A skeletonization reduces all structures to single lines. In the region of interest possible needle tip pixels can be backtracked by a pathfinding algorithm to the insertion point. In consideration of certain criteria like length and bending of the path the most likely trajectory for the needle is detected.

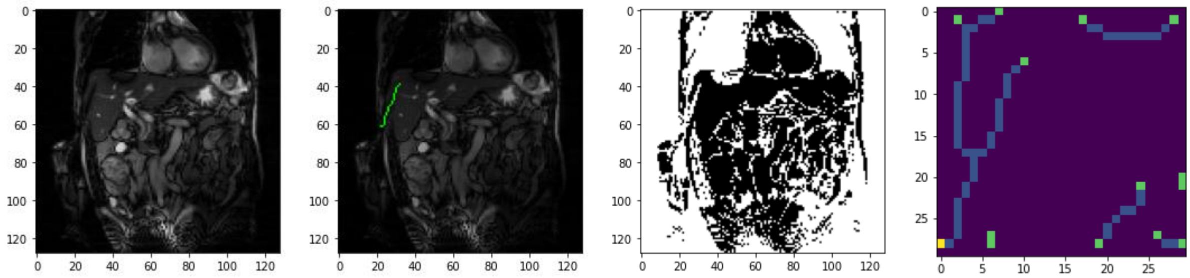

Figure 1: From left to right: Frontal generated MRI image, threshold-based (Otsu) segmentation, skeletonization with insertion point (yellow) and possible needle tips (green), most likely trajectory for the needle (green).

Results:

On two clinical datasets with an isotropic pixel spacing of 3.125mm the needle artifacts are correctly identified. The average Euclidean distances over up to ten time steps between the detected needle path and the ground truth determined by hand are 4.53 ± 2.75 mm and 2.34 ± 1.03 mm.

Discussion:

The chosen threshold only works for frontal MRI generated slices, otherwise the threshold results in wrong segmentations. Nonetheless, the initial threshold value has the potential to be fine-tuned by extracting more detailed features from the histogram. The backtracking algorithm has to be improved for a reliable finding of the path corresponding to the needle artifact.

Conclusion:

These initial results show that a histogram-based approach is able to detect needle artifacts correctly. For a robust tracking of needles in diverse MRI images the algorithm has to be developed in future work considering a priori knowledge about the needle artifact.

Supported by the BMBF; grant number: 13GW0473A

Docker Framework for MRI-Realtime-Reconstruction

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Introduction:

Realtime reconstruction of magnetic resonance (MR) imaging requires great computational power that approaches or even exceeds the limits of common MR-systems. Therefore, we developed a containerized reconstruction framework that allows establishing and performing MRI-realtime reconstruction pipelines on an external server.

Materials & Methods:

For high performance GPU reconstruction, the framework is based on an Ubuntu Docker image supporting GPU-accelerated software via Cuda. The Docker engine enables full access to the hardware of the underlying system including GPU. With Gadgetron [2] being optimized for running in Docker containers we use a reconstruction software that provides not only interfaces for fast data transfer between server and client but also supports several open-source languages as well as the ISMRMRD format [3]. The reconstruction framework additionally provides powerful image registration tools and is represented by one portable Docker image making expanding or adjusting the framework simple.

Results:

Using Docker guarantees multi-platform portability and reproducibility of our framework. Therefore, we tested it on a powerful Linux reconstruction server with several GPUs and CPUs as well as on less powerful laptops. Only the reconstruction speed differs depending on the hardware of the system.

Conclusion:

We presented an open-source reconstruction framework for MRI-Realtime-Reconstruction that is independent of the MR-system and stands out for its high compatibility and performance. It is based on open-source software only and can be expanded arbitrarily.

References:

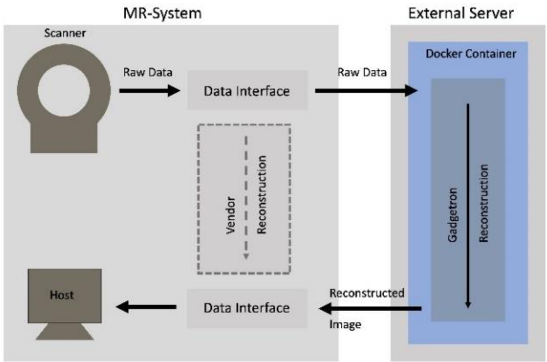
[1] www.docker.com

[2] Hansen, Michael S., Hui Xue, and Peter Kellman. "Gadgetron: Open Source Image Reconstruction."

[3] Inati, Souheil J., et al. "ISMRM Raw data format: A proposed standard for MRI raw datasets." Magnetic resonance in medicine77.1 (2017): 411-421.

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number 13GW0473B.



Modified from [2]

Facial Feature Removal for Anonymization of Neurological Image Data

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Introduction:

To enable the sharing of neurological imaging data, special care must be taken to protect the privacy of patients. This requires the anonymization of these data and the associated removal of facial features. We developed and present a prototype that is able to remove identifiable facial features from neurological DICOM datasets and simultaneously keeping important structures. The prototype contains a clear and easy-to-understand user interface. We investigated how robust the tool is to image datasets that differ in image modality, image cropping, and image orientation.

Materials & Methods:

In order to cover different variations of medical image data that play a role in daily clinical practice, we analysed 16 different image datasets. Among them are seven datasets acquired with MRI and T1 weighting, six with MRI and T2 weighting, two black blood MRI's and one CT dataset. Through the user interface it is possible to remove the nose, ears and/or chin. The algorithm is able to identify the position of these features in the data set. The defacing of the facial features is defined by an adjustable threshold, which indicates the depth of the deformity in mm.

Results:

Currently, the challenge is to ensure that the rendered volume is as free of artifacts as possible. Image distortions in the vicinity of the ears are particularly problematic. The processing time of the defacing algorithm including volume rendering and elimination of artifacts was 13,724 seconds on average. Overall, we found that the defacing algorithm effectively removes facial features, whereby no brain tissue is sacrificed.

Conclusion:

We provide a software tool for removal of facial features thus enabling anonymization of neurological datasets in image space complying with the guidelines of security of personal patient data. We provide the prototype for free:

https://gitlab.stimulate.ovgu.de/sylvia/deface.

Volumetric Heat Map Reconstruction for Minimally Invasive Cancer Treatment

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Introduction:

Several minimally invasive therapies for cancer treatment have been developed in the recent years. One of these methods is the use of thermal ablation procedures like microwave ablation. To ensure a successful treatment a proper monitoring of the target structure has to be provided during ablation. This may be achieved using magnetic resonance (MR) thermometry mapping. Aim of this work was to develop a novel method for volumetric heat map reconstruction using the Siemens Healthineers Access-I Framework to rotate the MRI plane around the applicator's main axis.

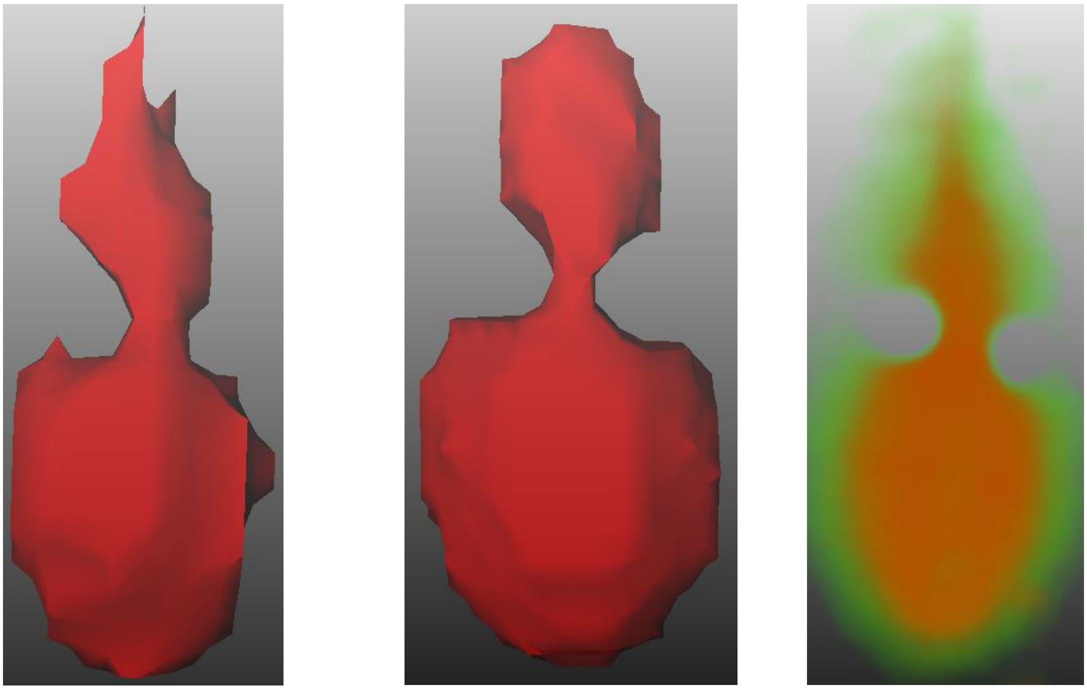

Figure 1: Reconstruction result after the ablation procedure of a heat sink phantom. Left: Color-coded reconstruction of the heat map with red representing the necrotic tissue and green the transition zone. Middle: Computation of the necrotic area based on the critical temperature model. Right: Ground truth manually created by our clinical expert.

Materials & Methods:

2D thermometry maps with several rotation angles were computed using the proton resonance frequency shift method. Based on a population map, the sparsely sampled volume was used to interpolate the missing information. This resulted in a 3D heat map approximation, which allows for visual exploration of the complete coagulation zone.

Results:

13 bio protein phantoms were created. For six phantoms, additional PVC tubes were integrated to simulate a possible heat sink effect. All phantoms were ablated and compared to a manually segmented ground truth of post-ablative MR imaging. Results show an overall Dice score of 0.75 ± 0.07 and a sensitivity of 0.77 ± 0.04.

Discussion:

The proposed method is promising for volumetric heat mapping but still shows disadvantages. First, the rotation of the MRI planes might miss important structures. An adaptive spatial and temporal sampling is therefore advised. Second, the time difference between samples may be very high and data out of date. An integrated bio heat simulation might solve this problem.

Conclusion:

The initial results show promising results. The rotation around the applicator's main axis and the following reconstruction of the 3D volume yield a high potential for improving the outcome of minimally invasive thermal procedures. Future work should address the improvement of the reconstruction e.g. through model-based approaches.

Visualisations for Improved Navigation and Assessment in Aneurysm Clipping Simulations

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[2]University Hospital Magdeburg, Germany;
[3]Forschungscampus STIMULATE, Magdeburg, Germany;
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Introduction:

Intracranial aneurysms are preferably treated endovascularly, however some complex cases have to be treated microsurgically. Less interventions and complex cases necessitate additional training for neurosurgeons.

Materials & Methods:

We developed an accessible simulation that only requires a monoscopic display, mouse, and keyboard [1]. In this setting, two types of visualisations were developed. The first type shows the distance between the moving clip and the vessels and aims at compensating the lack of depth cues, thus enhancing spatial relations, and improving the navigation. Three distance visualisations were developed: a colour map displayed on the vessel, a cylinder showing the smallest distance and semi-transparent rays showing distances smaller than a threshold. The second type shows the force magnitude and, if applicable, the direction acting on the vessel surface when closing the clip, which can lead to injuries. Four visualisations were developed: A colour map, semi-transparent rays, arrow glyphs and drop glyphs.

Results:

The force visualisations were evaluated via an online survey, the distance visualisations via the think-aloud method by a neurosurgeon. The distance visualisations are crucial, as the surgeon was not able to properly navigate without them. Here, the semi-transparent ray supported best.

The colour map is the most appropriate force visualisation that could also compensate for the lack of haptic feedback to a certain degree.

Conclusion:

The presented training environment is enhanced by the two visualisations and thus an accessible training possibility is provided.

Reference:

[1] Allgaier, M., et al. Distance and force visualisations for improved simulation of intracranial aneurysm clipping. Int J CARS (2021). https://doi.org/10.1007/s11548-021-02413-1

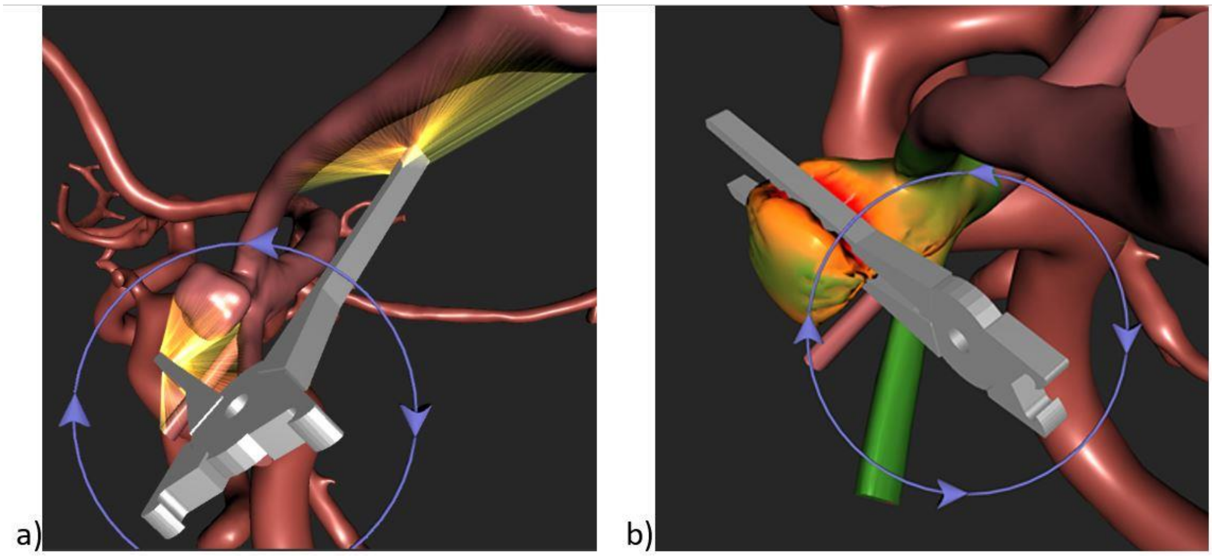

Fig. 1: Distance rays (a) and force map (b).

Correlations between black blood MRI and hemodynamics in intracranial aneurysms

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[2]Department of Fluid Dynamics and Technical Flows, University of Magdeburg, Magdeburg, Germany;
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Introduction:

Intracranial aneurysms (IAs) are abnormal dilations of the cerebral vessel wall, which often result in fatal outcomes in case of aneurysm rupture. Black blood MRI (BB MRI) has the unique feature of visualizing a vascular wall. In addition, aneurysms that are prone to rupture have been associated with the hyper-enhanced wall signal detected by BB MRI. This was associated with wall inflammation and hemodynamic parameters (HP). Still, the causes of these enhanced signals are not yet fully understood. Therefore, we aim to investigate other blood flow-related parameters inside IAs, using computational fluid dynamics (CFD).

Materials & Methods:

To allow for the comparison of BB MRI to CFD, three differently shaped IA models were analyzed. Flow experiments and simulations were carried out using low and high flow rates. CFD outlet boundary conditions were set to pressure curves obtained during the flow experiment. Blood mimicking fluid was used. Resulting HP were mapped onto the BB MRI signal intensity (SI) values. With a point-wise comparison, the correlation between SI and local hemodynamic parameters inside the IAs was calculated. Moreover, massless tracer particles were included in the simulations to gain a Lagrangian perspective of the flow, further elucidating the hemodynamics.

Results:

Focus was given to the extreme IA-characteristic behavior of the flow and compared to the BB MRI SI. Specifically, the analysis of relevant HP reveals a high correlation between kinetic energy, and vorticity to the SI ($p\text{-value} < 0{,}05$). Concerning the particle tracers, certain elements show high vorticity inside the IA prior to washout. Few particles remain even after four cardiac cycles.

Conclusion:

Various blood flow conditions in the aneurysm were reflected by different BB MRI SIs. Comparison of these SIs to the underlying flow field shows a high correlation to specific HP. Smaller BB MRI signal implies higher kinetic energy and higher vorticity magnitude values.

Towards truncation handling in Grangeat-based registration of flat-panel projections

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Introduction:

Recently, Grangeat-based 2D/3D (projection to volume) registration was successfully applied to C-arm CT data. [1] A principal disadvantage of methods based on Grangeat's intermediate function is that they are strongly susceptible to data truncation in the projection images. In this study, we investigate two simple approaches to screen for intermediate function values that are possibly disturbed by truncation in order to subsequently reject them in computations of a 2D/3D registration.

Materials & Methods:

Each intermediate function value is associated with a line integral on the detector. In a first approach we select only lines that are close to the detector center, as they are generally expected to be less affected by truncation. Secondly, we detect lines that hit high attenuation values at the boundaries of the projection images.

Results:

We performed a Monte Carlo simulation of 1000 simulated random geometry variations on a clinical CT volume of a head [2], which exhibits moderate projection truncation as it includes the shoulder area. The failure rates of the 2D/3D registration were evaluated by counting trials with a mean projection distance (mPD) larger than 2.5 pixel as an unsuccessful attempt (with an initial mPD of approx. 87 pixels). By carrying out the first approach, we limited the line distance to 80% of the image diagonal and could effectively reduce the registration failure rate from 30% to 7.4% (see Figure 1). For the second approach, we set an attenuation threshold for the boundary pixels to 4 and achieved a failure rate of 12.3%. Combing both approaches yield a further strong reduction to only 2.3% failures.

Conclusion:

We could show that the robustness of 2D/3D registration can be significantly improve by simply discarding probably corrupted intermediate function values. The same procedure can be transferred to 2D/2D (projection to projection) Grangeat-based correction methods, which is subject to future work.

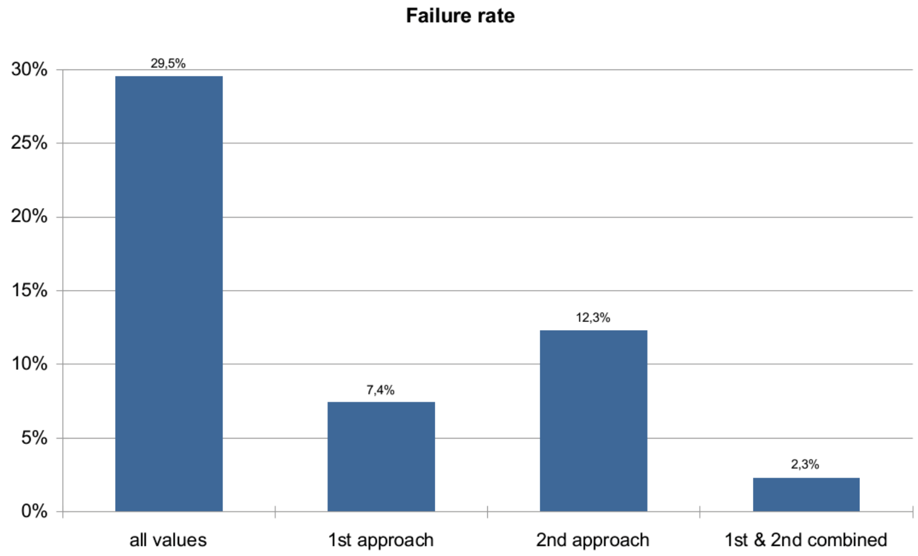

Figure 1. Portion of unsuccessful registration trials (all values) without any compensation, (1st approach) with usage of lines close to the detector center, (2nd approach) with rejection of lines intersecting high attenuations at the detector boundary and (1st & 2nd combined) the combination of both methods.

Developing fast tools to perform deconvolution-based C-arm perfusion processing using Time separation technique and algebraic CT reconstruction in a diagnostically acceptable time

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Introduction:

Perfusion imaging with C-arm CT scanners is used to evaluate patients with suspected ischemic stroke. Lower dynamic range, higher noise and slow rotation of current C-arm CT systems make C-arm perfusion processing a computationally challenging problem. Although there is a requirement for fast data processing within the intervention, computationally intensive methods such as algebraic reconstruction or deconvolution processing of perfusion data are the ones that yield significant improvements in the quality of results. Thus, our goal was to improve the speed of our current implementation of these methods so that processing of C-arm perfusion data is possible in diagnostically acceptable times.

Materials & Methods:

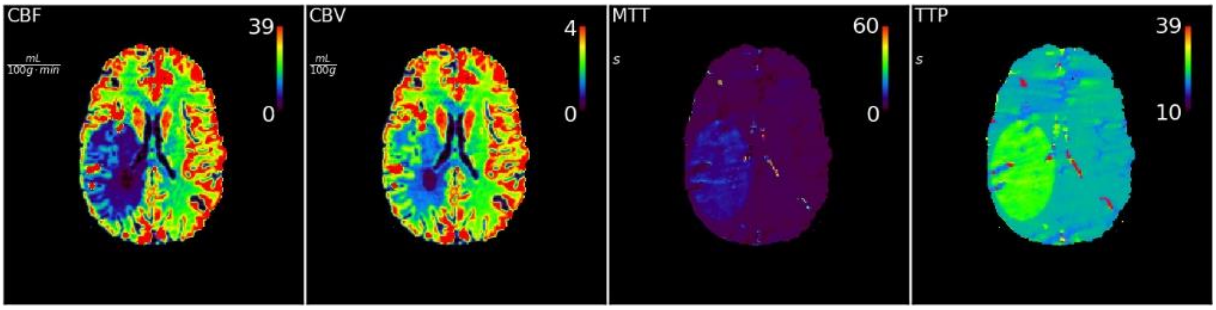
We have implemented software for processing CT perfusion data on the C-arm. It includes a time separation technique (TST) with 5 basis functions, CGLS reconstruction and deconvolution processing. Two example problems with volume sizes of 512x512x31 and 256x256x256 voxels were selected. We used 5 RTX2080 Ti GPUs for reconstruction and a server with four Intel Xeon E7-8890 processors for the other processing. Where possible, we use parallel processing.

Results:

Fitting the basis functions in the TST algorithm takes 71s and 85s, respectively. Reconstruction using CGLS took 128s and 186s, respectively. Deconvolution processing took 81s and 121s, respectively. The total run times were 4m57s and 6m47s, respectively. Classic processing would take 5m47s and 8m7s, respectively, and more GPU cards would be needed to speed it up.

Conclusion:

We accelerate perfusion processing, including TST, algebraic reconstruction, and deconvolution processing to make run times diagnostically acceptable.



Example of perfusion data processing, software phantom [DOI:10.1109/NSSMIC.2013.6829168].

Multimodal Image Fusion for Determination of Electrode Location in Deep Brain Stimulation

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Introduction:

Deep Brain Stimulation (DBS) is a neurosurgery procedure that involves placing a medical device referred to as a neurostimulator or sometimes as a brain pacemaker. It consists of an electrode, a lead, a subcutaneous extension, and a pulse generator [1]. The DBS is able to change activities of the brain directly in a controlled manner [2]. The DBS is used as a treatment for many diseases of movement disorders such as Parkinson disease, tremor, dystonia, obsessive-compulsive disorder, and epilepsy [3].

Materials & Methods:

The image fusion techniques for DBS mostly rely on time-consuming manual approaches that are not suitable for clinical routine procedures and this is where the use of deep learning methods seems most promising. We aim at determining the precise orientation of DBS electrodes using deep learning algorithms. Our approach used spatial tracking of the DBS electrodes in CT and DynaCT images by identification of a region of interest (ROI) which is the region of similarity by creating a ground truth and applying an image segmentation model using U-Net. The multimodal image fusion approach combines the advantages of CT imaging with a wider scan area with the high-resolution properties of DynaCT imaging.

Results:

A comprehensive workflow consisting of image analysis and segmentation by convolutional neural networks such as supervised learning, similarity measurements using the Structural Similarity Index (SSIM), and image fusion using bit-processes for fusion of CT and DynaCT slices was developed and tested for selected brain image data sets.

Conclusion:

Deep learning-based determination of exact electrode location in DBS applications will help reducing the risk of complications caused by unwanted stimulation-related side effects. Therefore, this work is crucial in patient-tailored clinical imaging workflows and improves the therapeutic outcome by detection of misplaced electrodes, the identification of target regions in the brain or the assessment of complications.

Virtual Reality-based usability laboratory for interventional MR applications

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[2]USE-Ing. GmbH, Stuttgart, Germany;
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Introduction:

To help optimizing future applications and products for MRI-guided interventions in terms of usability, the shortcomings of current workflows need to be identified. However, clinical MR workspaces have limited access and only allow for limited usability evaluation methods. With the goal of creating an environment for reproducibility, standardization, and quantification of interventional workflows, a dedicated usability laboratory is demonstrated.

Materials & Methods:

To gain an understanding of the context of use and workflows of MR-guided interventions, observation sessions are carried out in various clinics and interviews are conducted with interventionalists. Applying usability engineering methods, environment descriptions and workflow diagrams are deducted and serve as the basis for the design of the usability laboratory. The laboratory resembles the real environment in all relevant aspects and it is possible to systematically collect all relevant process metrics there. At the same time, the lab is flexible enough to be adapted to different research questions, procedures, and magnet designs.

Results:

The proposed usability laboratory concept incorporates Virtual Reality (VR) and real-world aspects. A physical MR room was created that resembles the test persons' own workspace. It includes physical mock-ups of an MR tabletop and instruments that add haptic feedback to the visual experience to enable realistic interaction. In addition, motion sensors allow for the measurement of the subjects' postures and their direct mapping to the VR. Eye tracking adds information on the test persons' attentional focus.

Conclusion:

We hypothesize that the combination of an individual workspace in VR with a physical standardized use-lab environment can provide an environment that enables the flexible use and interaction of design and evaluation methods in early development phases.

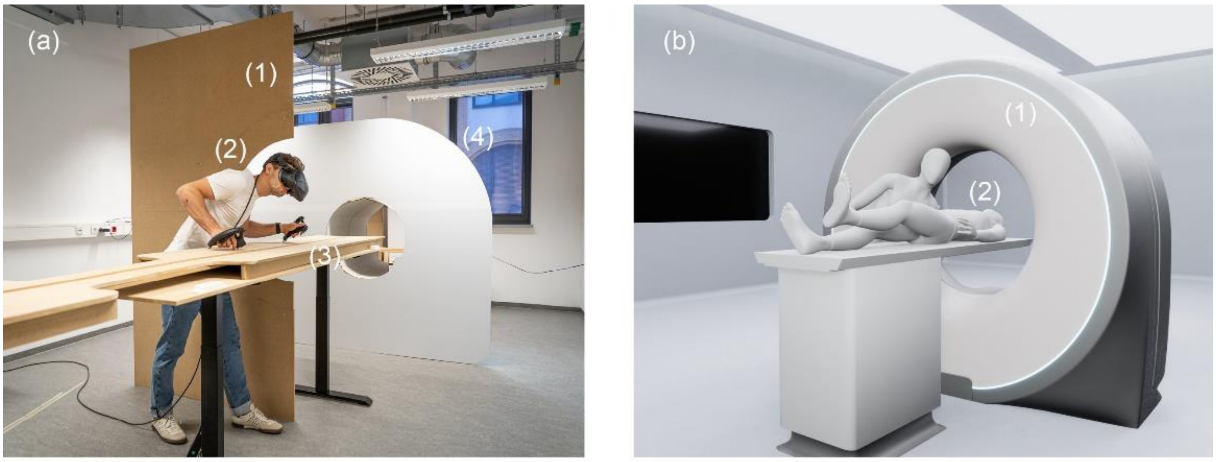

Figure 1: Illustration of the combination of virtual reality and physical environment (a) the usability-laboratory environment (1) physical mock-up for a wide bore concept (2) VR-Headset for visualization and interaction (3) height adjustable table (4) MR Mock Up in the background (b) corresponding VR environment (1) a CAD model in an early design phase (2) patient visualization

In-vitro and in-silico investigation for image-guided microwave ablation

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Introduction:

Compared to radiofrequency ablation (RFA) microwave ablation (MWA) is a relatively new thermal modality for minimally invasive procedures. Recently MWA has become more popular since it produces larger ablations volumes in shorter ablation times and is very effective in many tissue types. Furthermore, it is less susceptible to the heat-sink effect, which is a problem while using RFA near large vessels.

Materials & Methods:

To support the treatment planning of image-guided interventions, in-vitro as well as in-silico investigations were carried out. Specifically, experiments with polyacrylamide gel phantoms with electrodes from MedWaves were performed to monitor thermal expansion and ablation volumes. Afterwards, numerical results were acquired using the software STAR-CCM+ to reproduce these MWA ablation volumes. Hence, potentials and limitations of those simulations can be evaluated with respect to the support of MWA procedures.

Results:

Initial simulation results reveal that simple approximations considering electric fields (e.g., using 30, 60 and 60 V) around the measured needle geometries can be obtained. The comparison of these ablation volumes with the experimentally acquired references show a good qualitative agreement. However, it must be noted that the software is not capable of simulating microwaves at specific frequencies like 915 MHz, which are used in MWA tumor treatments. Furthermore, it was not possible to recreate complex MWA-antenna designs and allocate their parameters.

Conclusions:

The outcome of this study demonstrates the potential of the numerical approach, but also highlights the need for more in-depth investigations for realistic MWA predictions. Therefore, the use of more sophisticated software packages with specific features for the simulation of microwaves and radiofrequency heating is suggested.

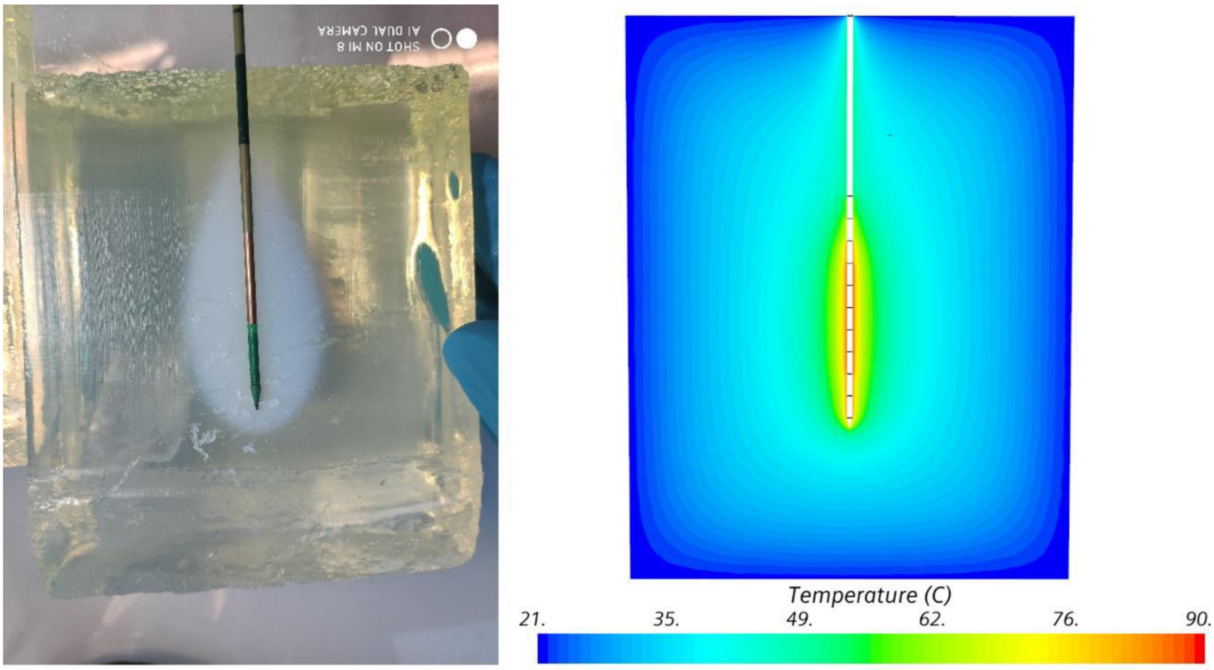

Figure 1: cut through polyacrylamide gel phantom, and MedWaves electrode (left); 2D-temperature profile (simulated at: 90°C; 60 V) (right)

An Ex-Vivo Study of an MRI Hybrid Ablation System

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Introduction:

Magnetic resonance imaging (MRI) offers the possibility of real-time MR thermometry to guide radiofrequency ablation (RFA). However, thermal monitoring requires that the ablation generator does not cause RF interferences for MR imaging. The MRI hybrid ablation system is an innovative approach to use the MR scanner itself as a therapeutic device [1]. Here, the applicator is directly connected to the coil port, and thus gaining access to the MR RF amplifier. During an MR RF pulse sequence, many high-power RF pulses are applied to heat tissue. This work will show that this concept can be used with ex-vivo tissue.

Materials & Methods:

The ablation setup is shown in Figure 1a. A bipolar ablation electrode was directly connected to the coil port of a 3T MR scanner. The bipolar electrode was placed in a pork liver. Turbospin-echo (TSE) sequences and gradient-echo (GRE) sequences were applied in a sequential manner. The TSE sequences had a mean RF power of 20W, with which the tissue was heated. By applying GRE sequences, temperature maps could be recorded with the electrode as an imaging element.

Results:

Figure 1b shows the temperature evolution during the procedure. The temperature increases during the TSE sequences, whereas the temperature decreases during the GRE sequences. At the time t=730s, sparking occurred, which lead to sharply increased temperatures for a short time. Figure 1c shows a thermometry image acquired during the procedure, which can be compared to the destroyed tissue as shown as in Figure 1d. However, larger errors between the thermometry values and sensor values can be observed as soon as sparking happened.

Discussion:

It has been shown that the MR hybrid ablation system can be used in biological tissue. However, care must be taken to ensure that the temperature development does not exceed temperatures above 100°C. Otherwise, sparking can appear which impedes the ablation process.

References:

[1] 10.1109/EMBC.2019.8857894

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number “13GW0473A” and “13GW0473B” and by the “European Structural and Investment Funds“ (ESF) within the context of the International Graduate School MEMoRIAL at the Otto-von-Guericke University (OvGU) Magdeburg, Germany (project no. ZS/2016/08/80646).

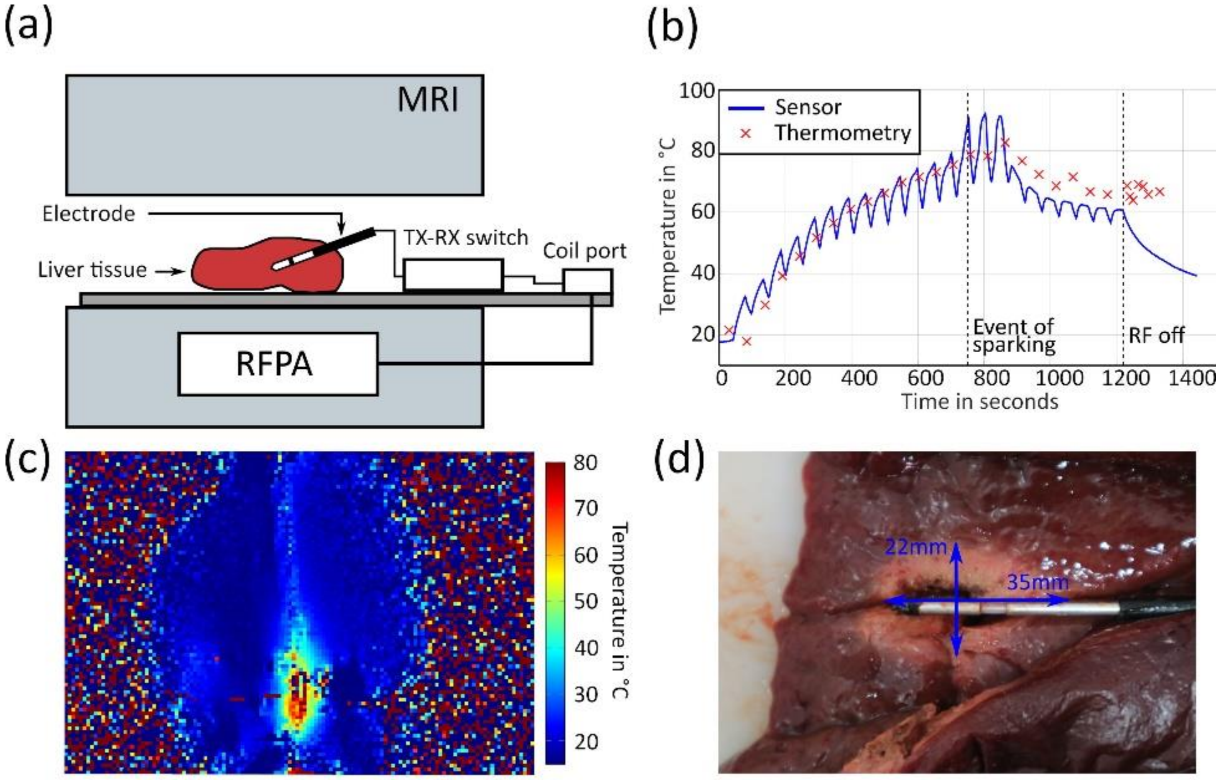

Fig.1: (a) Setup of the MRI hybrid ablation system; (b) Temperature development during the ablation; (c) MR thermometry map; (d) Destroyed liver tissue after the ablation.

Reduced electromagnetic interferences of a microwave ablation system by an external shielding enclosure for improved real time magnetic resonance guided monitoring of percutaneous thermal tumour therapy

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Introduction:

Magnetic resonance thermometry offers real-time monitoring of microwave ablation used for minimal invasive thermal tumour treatment. However, microwave ablation (MWA) systems may increase noise and reduce image quality of magnetic resonance (MR) imaging due to electromagnetic interference (EMI). An extended length of the cable between the microwave applicator and generator may drastically reduce the energy and therefore decrease the maximum volume of the ablation zone that can be achieved with the microwave generator. The purpose of this work was to develop an EMI shielding enclosure (SE) which allows the use of the MWA system with low EMI while retaining a short cable between the microwave generator and the applicator.

Materials & Methods:

The SE was made of aluminium parts with a closable opening to place the clinically certified MWA system. To ensure sufficient EMI shielding of the SE, all edges and corners were sealed with aluminium tape. The interfering signal transferred by the cable to the microwave applicator was reduced in the frequency range of the MR system via a high-pass power filter. To pass the cooling water for the microwave applicator through the SE, a circular waveguide with a cut-off frequency of approximately 700 MHz was installed. Spoiled Gradient-Echo (GRE) imaging and noise spectrums were measured on a 1.5 T scanner to evaluate the effectiveness of the SE to reduce the EMI of the MWA system.

Results:

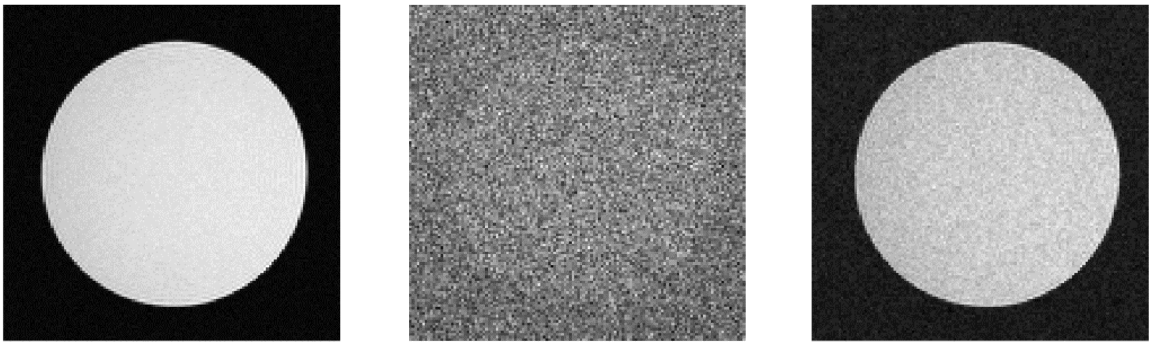
The signal-to-noise ratio of GRE imaging was significantly increased with EMI shielding in comparison to no shielding (Fig.1). The spectrums show that with use of a SE the noise amplitude in all relevant frequencies of the MR system were significantly lower than measurements without the SE (Fig.2).

Conclusion:

The presented SE significantly reduced the noise of MR imaging introduced by EMI of the MWA system. This may help establishing MR-thermometry for monitoring of MWA.

Acknowledgement:

This project was funded by the Federal Ministry of Education and Research within the Forschungscampus STIMULATE under grant numbers '13GW0473A' & '13GW0473B'



(a) (b) ©

Fig. 1: GRE MR-images with and without shielding measures during active operating mode. The MWA output power was 100 W. (a) reference, MR-system unaffected, SNR: 13.48 (b) unshielded, SNR: 1.99 (c) shielded, SNR: 5.36.

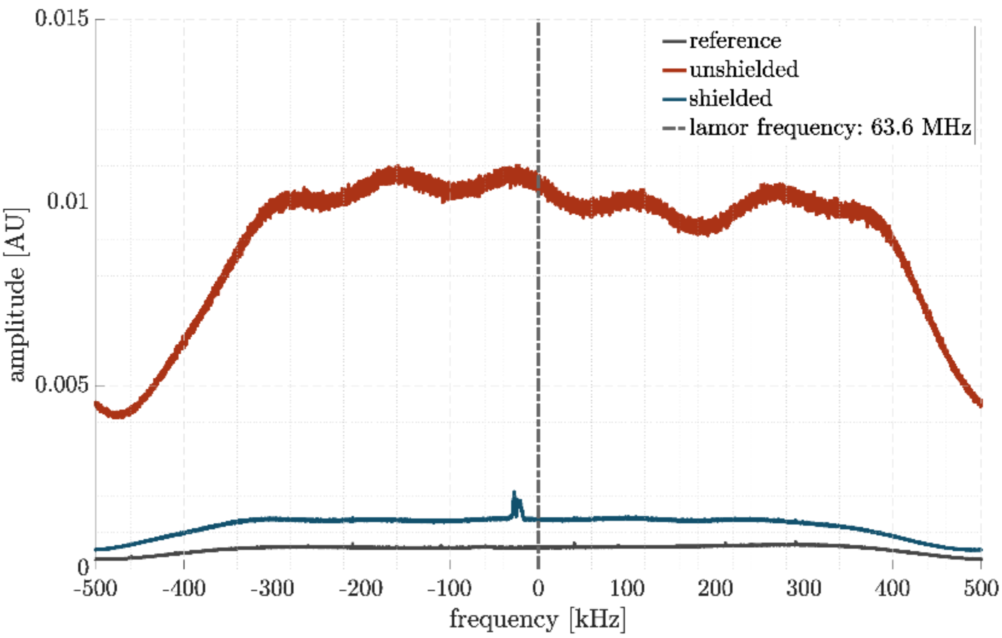


Fig. 2: Frequency-dependent noise spectrum for the shielded, unshielded, and unaffected MR system as reference. The MWA output power was 100 W.

Electromagnetic Simulations of Different Electrode Shapes for an MRI Hybrid Ablation System

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Introduction:

Radiofrequency ablation is a thermal ablative intervention in which electromagnetic energy is converted into heat to annihilate tissue thermally. Monitoring of the temperature development during this hyperthermal procedure is crucial for therapy success [1]. The MRI hybrid ablation system is an alternative approach for performing RF ablation [2]. To acquire RF power, electrode is directly connected to the coil port of the MR scanner eliminates the need for an external RF ablation generator. The MR hybrid system can destroy tissue and concurrently record MR temperature maps to monitor the thermal process in real-time. This study aims to numerically design electrodes for usage with MRI hybrid ablation system. Here, Heating efficiency and MR imaging capabilities (B1+ field distribution) are compared.

Materials & Methods:

Simulations were performed in a homogeneous cylindrical liver phantom using CST for a frequency of 123MHz. Bipolar umbrella and spherical-shaped electrode were designed for this study [3]. At the tip of the electrodes shaft, multiple expandable wires (0.5mm) were outward-facing for the umbrella electrode and inward-facing for the spherical electrode (Fig. 1a,1b). Specific absorption rate (SAR) and B1+ field distribution were calculated for both electrodes.

Results:

Fig 1c and 1d shows high power absorption rates close to the wires where active heating zone for the umbrella electrode is extended. The spherical electrode shows a spherical power loss distribution with very sharp boundaries. The B1+ field distribution from the umbrella electrode (Fig. 1e) can cover a larger field of view than the spherical electrode (Fig. 1f).

Discussion:

Different electrode types can be used for different shapes and sizes of tumors. Significantly, the spherical electrode has the possibility to achieve spherical ablation zones with sharp boundaries to protect healthy tissue. MR validation measurements are required to determine the imaging capabilities.

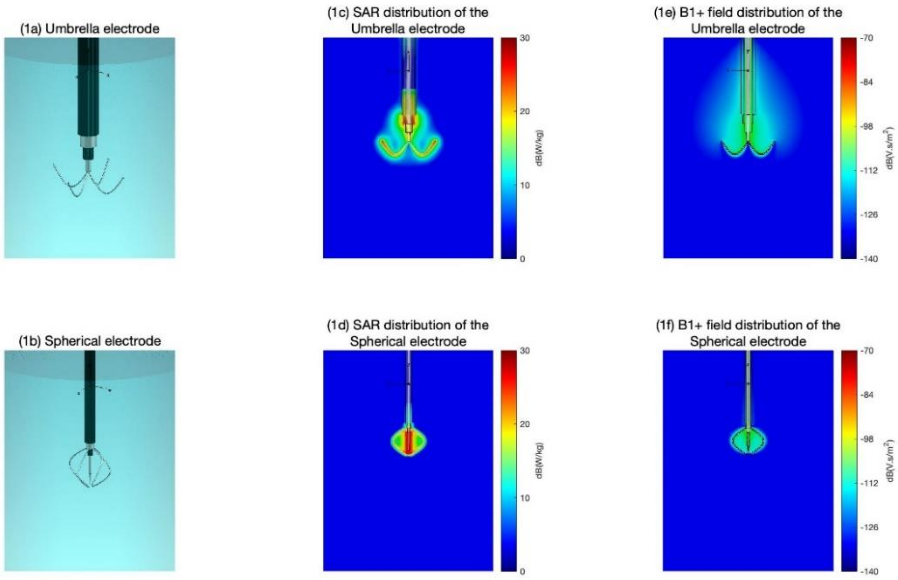

Figure 1: Comparing the SAR and B1+ field distribution of an Umbrella and a Spherical electode.

RF Field Mapping with an Ablation Electrode

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Introduction:

The MRI hybrid ablation system is an intuitive method to use the MR-internal power amplifier for RF ablation [1]. While performing MR-imaging sequences, the electrode emit in transmission mode high power RF pulses for heating. Since the ablation current is driven at the Larmor frequency, the ablation electrode can also be used for MR signal excitation and reception. This allows monitoring of the ablation process using MR thermometry and RF Field mapping. Hereby, the acquisition of RF field maps can give additional information of the power loss distribution [2]. In this abstract, we demonstrate the possibility of RF mapping with an ablation electrode using the concept of the MR hybrid ablation system.

Materials & Methods:

The experiments were done inside a 3T MRI scanner. An ablation electrode was placed inside a cellulose phantom. The electrode was connected to the MR scanner using the coil port of MR scanner. A dual angle method (DAM) based on GRE imaging sequences was used for the RF/flip angle mapping [3]. EM simulations were done to compare the measured flip angle map with the expected MR signal distribution.

Results:

The flip angle maps estimated from the dual angle GRE method in sagittal plane can be seen in figure 1. The sagittal view of the electrode shows larger flip angles distributed along the electrode axis till it approaches the active electrode segments, similar to the behavior of the MR signal distribution from the EM simulations. With the DAM approach, only flip angles between 0 and 90° can be measured, resulting in signal voids in the center of the electrode.

Conclusion:

Using EM simulations and dual angle GRE imaging sequence, we have demonstrated that flip angle maps can be obtained using the ablation electrode. The inclusion of phase information would allow measurements of flip angles up to 180°.

References:

[1] doi: 10.1109/EMBC.2019.8857894

[2] doi:10.1109/TMI.2009.2015757

[3] doi:10.1088/0031-9155/55/20/008

Acknowledgement:

The work of this paper is funded by the "European Structural and Investment Funds" (ESF) within the context of the International Graduate School MEMoRIAL at the Otto-von-Guericke University (OvGU) Magdeburg, Germany (project no. ZS/2016/08/80646).

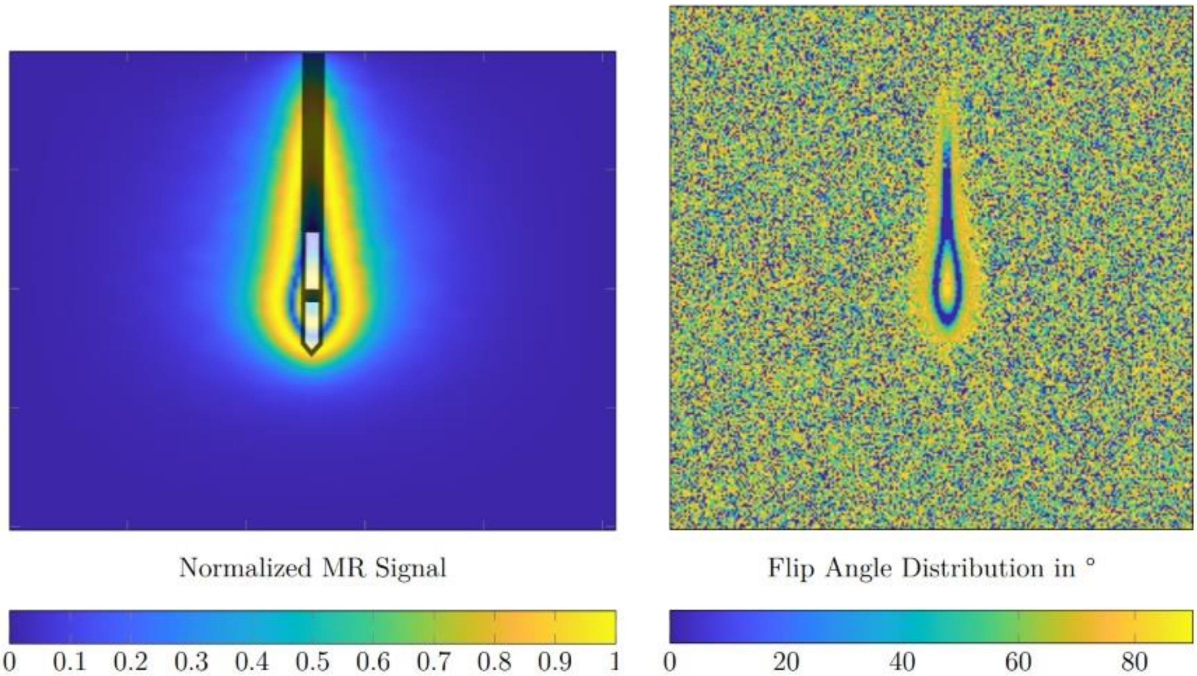

Fig.1: Comparing calculated MR signal distribution and measured flip angle distribution

Correction of heat induced magnetic susceptibilities changes for improved proton resonance frequency based MR temperature mapping of hepatic microwave ablation

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Introduction:

In microwave (MW) ablation the induced heat near the applicator may lead to tissue carbonization and gas release causing a significant change of the magnetic susceptibility. These susceptibility changes impair proton frequency resonance (PRF)-based MR temperature mapping and therefore significantly reduce its accuracy of treatment monitoring. Aim of this work was to correct for heat induced susceptibility changes to improve PRF-based MR thermometry of hepatic MW ablation.

Materials & Methods:

In a study of five domestic swine, 2D PRF-based MR thermometry was applied during hepatic MW ablation. Two slices perpendicular to the MV applicator were acquired. To correct for magnetic susceptibility changes caused by increased heat induction near the MW applicator, the contour of the signal void surrounding the needle was automatically segmented. Field distortions were modelled by a cylinder of infinite length with the segmented contour as base area. Ablation zones of susceptibility corrected and uncorrected MR thermometry were calculated with three different tissue damage models and compared to the manually segmented ablation zone of contrast-enhanced (CE) MR imaging after MW ablation.

Results:

Using CE MR imaging as reference, the dice coefficient of the ablation zone of susceptibility corrected MR thermometry was significantly increased compared to uncorrected thermometry. While the minor and major axis length and the area of the ablation zone were not significantly different comparing susceptibility corrected thermometry and CE MR imaging, a significant bias was found for uncorrected MR thermometry.

Conclusion:

Correction of heat induced susceptibility changes near the microwave applicator significantly improves the accuracy of MR thermometry to assess the ablation zone of hepatic MW ablation. 3D imaging may further improve modelling of susceptibility induced impairment.

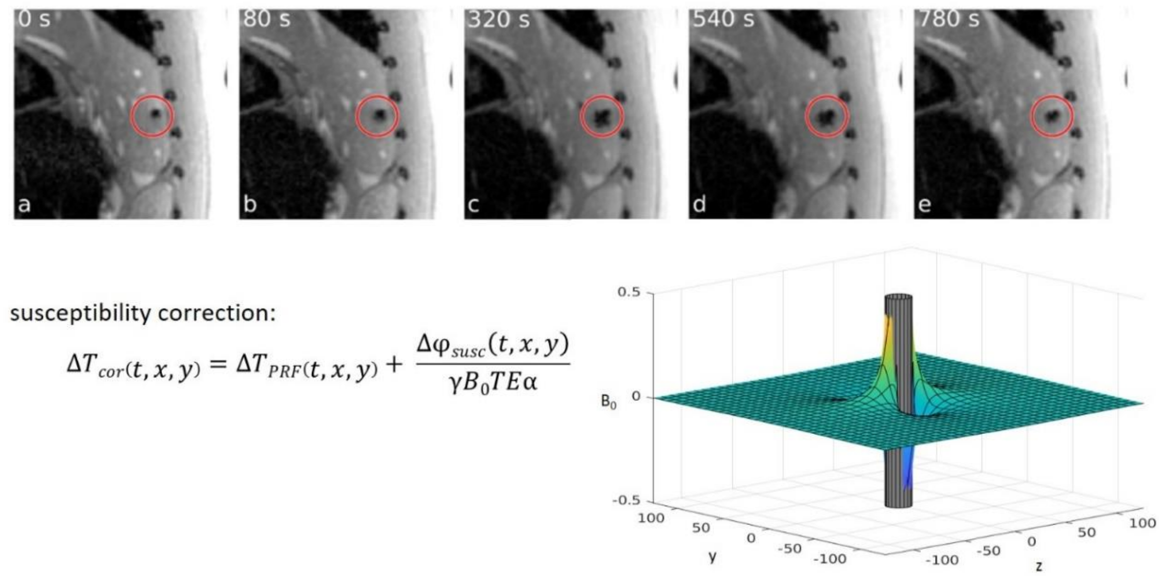

Figure 1: The signal void surrounding the microwave applicator increases during ablation (top row). The apparent temperature difference caused by the susceptibility changes near the applicator is modelled and corrected by a field distortion of a cylinder of infinite length.

Measurement Setup for Needle Artifact Optimization

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Introduction:

Magnetic resonance (MR) guided minimal invasive intervention allows targeted local tumor treatment. Despite modifications for the MR environment, metallic parts of the interventional devices lead to signal void and distortions of MR imaging known as susceptibility artifacts. The size and the appearance of this artifact depend on the interventional device and the applied MR sequence. Aim of this work was to determine the needle artifact for several MR compatible interventional devices depending on the MR sequence and its parameters.

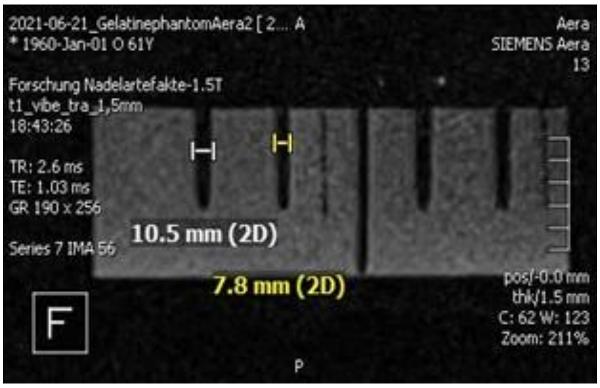
Materials & Methods:

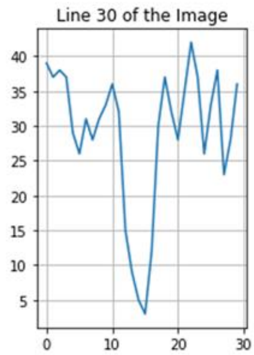
In an experimental setup of a 1.5 T scanner the needle artifact of several interventional devices was measured. Therefore, in a holder, which can be rotated from 0° to 90° in relation to the B0 field of the MR system, multiple needles were placed in a gelatin phantom. In several sequences used for clinical needle guidance (based on spoiled gradient echo, balanced steady state free precession and turbo spin echo), the needle artifacts were measured depending on echo time, slice gap, slice thickness, the angle related to B0, the flip angle, bandwidth and the spatial resolution.

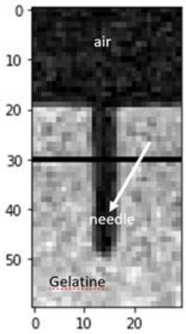
The artifact diameter is measured by an algorithm: an upper threshold defining the artifact area extracted from the maximum, minimum and saddle point of the histogram from the MR signal surrounding the needle.

Results:

With the designed holder the sequence variations for different applicators are measured in a very time efficient way. It is possible to measure up to seven needles at the same time and efficiently change the rotation angle.





Conclusion:

The developed setup allows performing measurements for needle artifact optimization very efficiently. This may help to optimize the imaging protocol and therefore the image quality of MR guided intervention.

Reference:

Huebner, Svenja. „Konzeptentwicklung einer MR-geführten Brustbiopsie am geschlossenen 3 Tesla Magnetresonanztomographen“, Masterarbeit in 2015

Unsupervised segmentation of glioma tumor subregions in MRI using a method from Mass Spectrometry Imaging on radiomic feature maps

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Introduction:

Mass spectrometry imaging [1] (MSI) enables spatially resolved measurement of mass-to-charge ratios of ions in tissue samples. MSI data are hyperspectral images with typically thousands of features for each pixel. Segmentation methods for MSI, like the spatially-aware shrunken centroid (SSC) clustering algorithm [1], are required to process large numbers of features. In radiological imaging, radiomic features [2] have attracted increasing attention as non-invasive imaging biomarkers. In this work, we investigate how the SSC clustering algorithm performs on a large number of radiomic feature maps to generate segmentations of glioma tumor subregions.

Materials & Methods:

From the BraTS2020 Challenge dataset [3-5], we selected 81 MRI scans of glioma patients with T1, T1Gd, T2 and T2-Flair contrasts and ground-truth segmentations of three tumor subregions (WT=whole tumor, ET=enhancing tumor, TC=tumor core), 93 radiomic feature maps for each contrast were extracted with PyRadiomics [6] in voxel-based extraction mode. The MRI and radiomic feature maps were used as input for the SSC clustering to generate segmentations of the glioma subregions. The approach is unsupervised and fully automatic.

Results:

The average DICE score was 0.65 for WT, 0.57 for ET and 0.63 for TC. This puts the results below the average for BraTS2020 submissions, but unlike most submissions, the investigated approach does not require any training data.

Conclusion:

SSC clustering of radiomic feature maps may have potential as an approach for segmentation of tumor subregions when a sufficiently large training dataset for supervised methods is not available.

References:

[1] K. D. Bemis et al., Mol. Cell. Proteom. 2016

[2] A. Zwanenburg et al., Radiology 2020

[3] B.H. Menze et al., IEEE Trans Med Imaging 2015

[4] S. Bakas et al., Sci. Data 2017

[5] S. Bakas et al., arXiv 2018

[6] J.J.M. van Griethuysen et al., Cancer Res 2017

Heating measurement of different ECG cable lengths and system states

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Introduction:

Electrocardiography (ECG) is a common method for monitoring patient status during image guided interventions with Magnetic Resonance Imaging (MRI). To ensure the safety of the newly developed 12-lead ECG heating measurement have to be performed. For this purpose, pre-measurements on a 3-lead ECG are done to investigate the use of different cable lengths and their heat input to the patient.

Materials & Methods:

Measurements had been leant to the EEG-System (ASTM F2182 - 19E2). Therefor a HEC-Phantom had been built as patient dummy [1]. An optical temperature measurement (FOTEMP, Weidmann Technologies, Deutschland) was used to evaluate the temperature change. The sensor tip was located at a distance 5 cm away from the ECG electrode on the cable, see figure 1. The cables of length 57 cm and 131 cm, as well as the device in OFF-state and ON-state were examined. To induce radio frequency power into the cables a Turbo-Spin-Echo sequence with a TR of 4830 ms, TE of 13 ms, Turbo Factor of 7 and duration of 15 minutes was applied.

Results:

The combination of the long cable and the device in ON-state shows yielded the best result with the lowest temperature rise to the surrounding. Short cable and the device in OFF-state indicated a high rise of the temperature. OFF-state in combination with a short cable showed always worse results then ON-state and long cable. See Figure 2.

Conclusion:

The 3T MRT has a lamour frequency of 123 MHz and thereby a quarter-wavelength of approximatly 60 cm in air. The short cable has the highest temperature rise, because its resonant quarter-wavelength of 57 cm is close to the quarter-wavelength of the 3T MRT. The long cable shows less temperature rise, because of its non-resonant length to the lamour frequency and its divider. Floating ports in the OFF-state can explain the higher temperature towards defined ports in the ON-state.

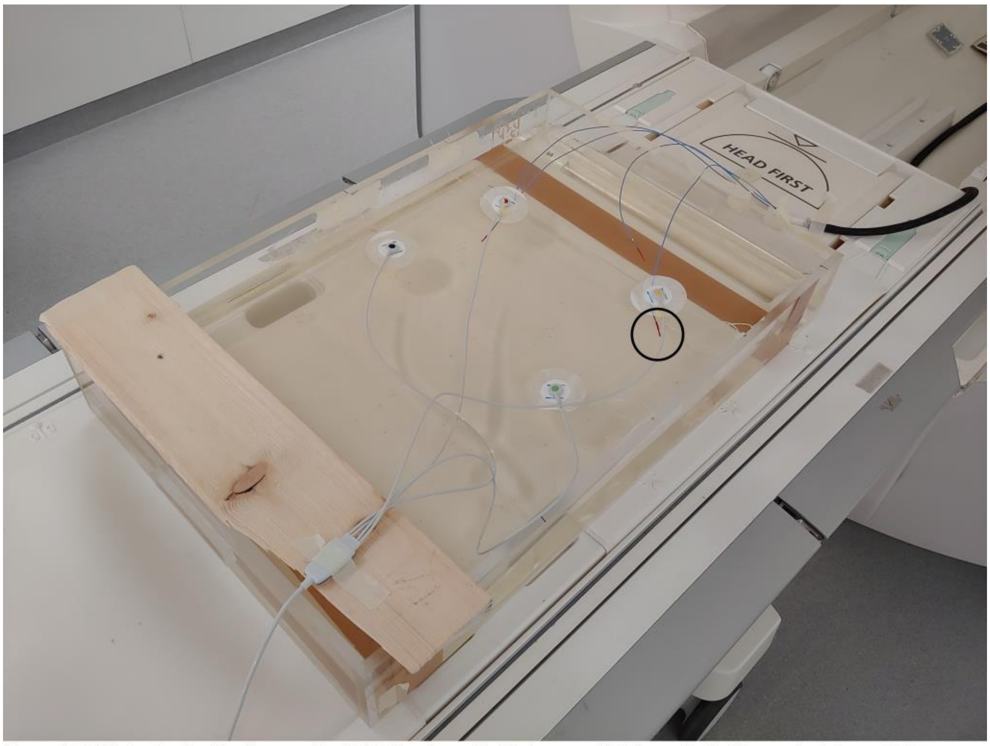

Figure 1:ECG electrodes floating on the HEC-Phantom. Cable harness(light grey) slightly pushed beneath the surface. Fiberoptical sensors(blue cables with red tips) placed near electrodes and cable harness. Evaluated temperature sensor marked with black circle.

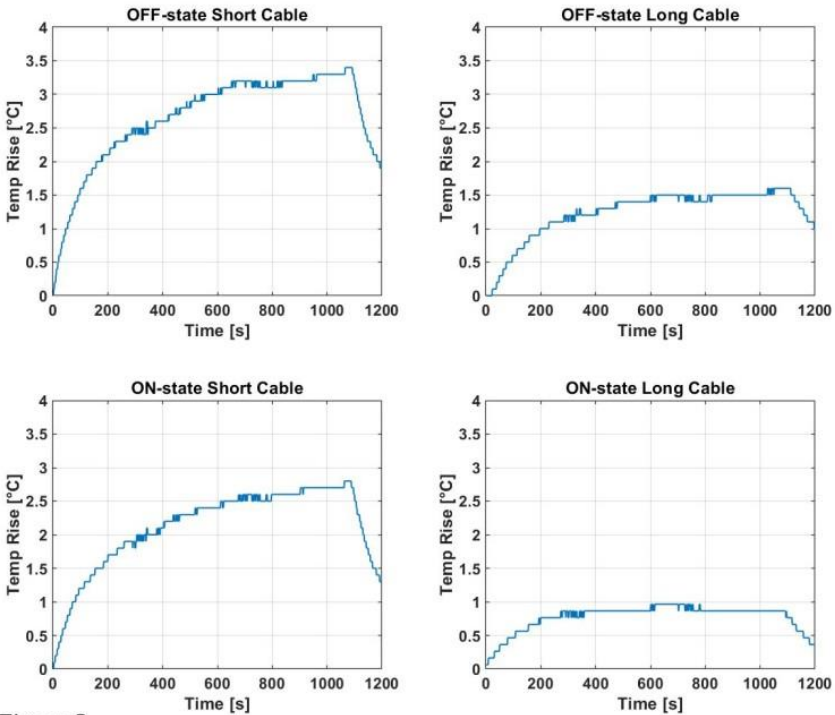

Figure 2

Using Deep Learning for Dose-Reduced Marker-less Instrument Tracking in CT Guided Interventions

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Introduction:

Tumours in the liver are commonly treated through a procedure called ablation, where a radiologist has to insert a needle-like instrument into the organ and position it accurately in the target tissue, i.e. the tumour. Computed tomography (CT) is commonly chosen for guidance because it can deliver real-time images of the internal organs of the patient with good visibility of the needle. In order to find the needle in the CT slices, the radiologist has to adjust the patient position and trigger the imaging multiple times, which exposes both patient and radiologist to large amounts of radiation. In this research we seek to reduce the amount of CT images, and therefore radiation dose needed for needle localisation, by significantly narrowing the search corridor prior to CT imaging. To achieve this, we aim to develop a fast, marker-less external pose estimation system.

Materials & Methods:

We propose an automated 2-stage approach. In the first stage, an external camera system will be used to obtain a rough estimation of the instrument position both outside and inside of the patient by employing deep learning (DL). As this estimation cannot account for needle bending inside the patient and the accuracy will likely be insufficient, a second stage will be included, where the previous information about the needle location can be used to find the exact internal position with only few CT scans.

Results:

Our approach should enable faster needle localization with consequently less radiation exposure while retaining the same levels of instrument localization accuracy.

Conclusion:

We present an idea for a novel needle tracking approach for ablation therapy. Our method is based on marker-less external tracking using deep learning for pose estimation. It should enable a faster workflow which also reduces radiation exposure.

Interactive subgroup identification for medical research based on arbitrary features

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Introduction:

We present an analysis tool for subgroup identification in medical research based on feature analysis. Our use case is intracranial aneurysms.

Materials & Methods:

In the tool, an aneurysm-of-interest's most similar aneurysms within a database are found [1]. Similarity is defined via user-selected parameters, which can be entirely arbitrary, supporting continuous and categorical data. For intracranial aneurysms, we used morphological and hemodynamic parameters and metadata.

Interactive outputs and visualizations include a heatmap view and a graph (see Figure 1), which provide intuitive feedback to support researchers in the consideration of research questions, which in the present use case often relate to rupture risk analysis.

The tool furthermore features a classification via three k-nearest-neighbor classifiers, a preselection, and can account for missing data values.

Results:

The application was evaluated with a pilot study and phantom database and received favorable results for its requirements of being reliable and having appropriate and clear outputs.

Conclusion:

We provide an interactive tool for the identification of subgroups in medical research. User-selected, arbitrary parameters define the similarity between cases, making the tool suitable for other clinical application areas.

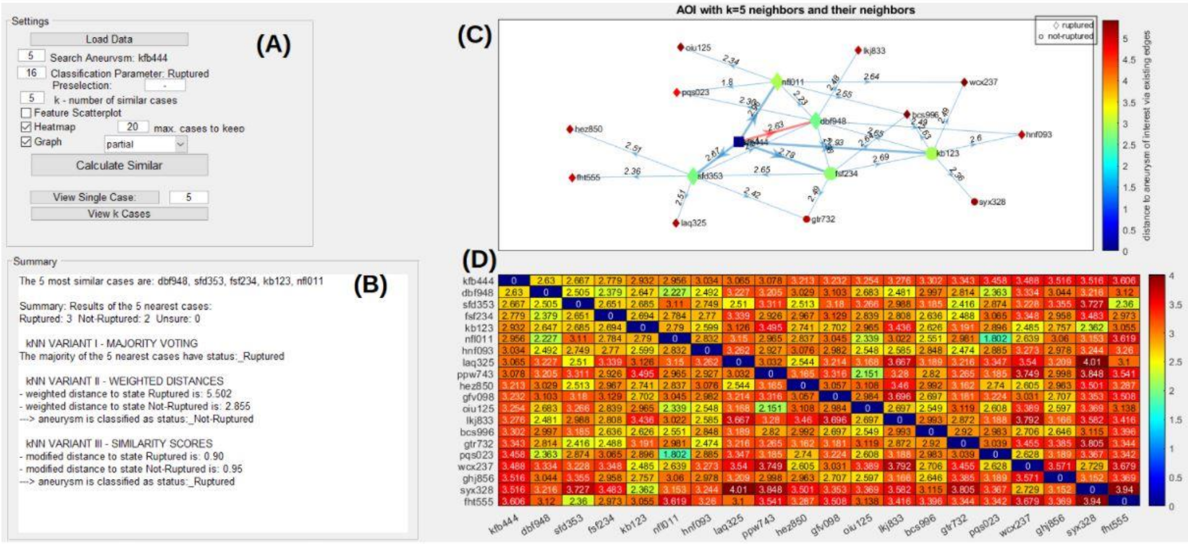

Figure 1: The interactive subgroup selection tool [1]. (A) is a setting panel, (B) a results tab returning classification results, (C) is a graph visualization where a user can explore neighborhood relationships, and (D) an interactive heatmap. Distances are color-coded and represent similarity.

Reference:

[1] Spitz et al., An interactive tool for identifying patient subgroups based on arbitrary characteristics for medical research, In: Proc of CURAC, vol. 2021

Analysis of the intracranial aneurysm wall using histologic images

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Introduction:

Understanding the development of intracranial aneurysms and the reasons behind aneurysm rupture is necessary to develop new treatment methods. Often, histologic images are used to analyze the aneurysm wall and the remodeling of the aneurysm wall. This analysis can be supported with various algorithms.

Materials & Methods:

21 images showing a post-mortem collected aneurysm, including the aneurysm neck, were segmented with different techniques (filter- and threshold-based segmentation, clustering of similar textures, deep learning segmentation) [1]. A 3D model based on manual segmentation into 9 classes (intact wall, degenerated wall, inflammatory cells, myointimal hyperplasia, organizing thrombus, red thrombus, white thrombus, decellularized organizing thrombus, and mixed textures) was generated [2]. Corresponding areas of the same tissue type in consecutive slices were connected. A 3D model consisting of several meshes showing the aneurysm wall with different tissue types was generated.

Results:

Filter- and threshold-based segmentation and texture clustering are robust against new or uncommon tissue types or pathologies in the data. In contrast to these segmentations, deep learning segmentation could also provide semantic information about the tissue. Deep learning segmentation requires a suitable large amount of representative training data. It can only segment tissue types present in the training data.

The overall most common classes were myointimal hyperplasia, red thrombus, and white thrombus. For individual slides, the tissue distribution varies. Especially the amount of red and white thrombus changes throughout the image stack.

The 3D model with information regarding the aneurysm wall composition can be used for simulations.

Conclusion:

Automatic segmentation and detailed 3D models of the intracranial aneurysm wall can be used for automatic analysis, support visual exploration, and improve the understanding of aneurysm development.

Towards an Energy Monitoring System for an MRI Hybrid RF Ablation System

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Introduction:

The MRI hybrid ablation system is an innovative approach for performing RF ablation inside an MR environment [1]. For this procedure, an electrode is connected to the coil port of the MR scanner. Thus, it is possible to gain access to the MR RF power amplifier. While executing MR pulse sequences, the energy from the RF pulses are absorbed inside the tissue. Monitoring the absorbed energy inside the patient can provide information about the ablation status. In this abstract, an energy monitoring system for an MRI hybrid ablation system will be presented.

Materials & Methods:

The energy monitoring system is based on an ADL5511 True RMS Power detector [2]. The RMS signal is sampled every 11us via an analog to digital converter of an STM32 board. On the microcontroller, the energy input is calculated via integration of the measured power. The energy value is then forwarded to a host PC every second via a serial interface.

The setup in Fig 1A was used to validate the monitoring system. Here, an amplitude-modulated signal was generated using the waveform and the function generator. The carrier frequency is 123 MHz and the modulated signal is a Gaussian pulse with a bandwidth of 500 Hz (see Fig. 1B).

Results:

Fig. 1C shows the measurement results of the energy monitoring system and compares them with the calculated data. While switching on the sequence, the measured energy increases linearly. A small drift of the measurement results can be seen with increasing time. A relative error of 1.5% could be determined.

Discussion:

It has been shown, that the ADL5511 can be used in combination with an STM32 board to measure the energy of an RF pulse sequence. This system can be used independently of the MR-internal SAR system for an MRI hybrid ablation system.

References:

[1] 10.1109/EMBC.2019.8857894.

[2] Prier, Hubmann, et al. SAR Monitor based on low cost Electronic Standard Components. ISMRM (2021)

Acknowledgment:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number “13GW0473A” and “13GW0473B”.

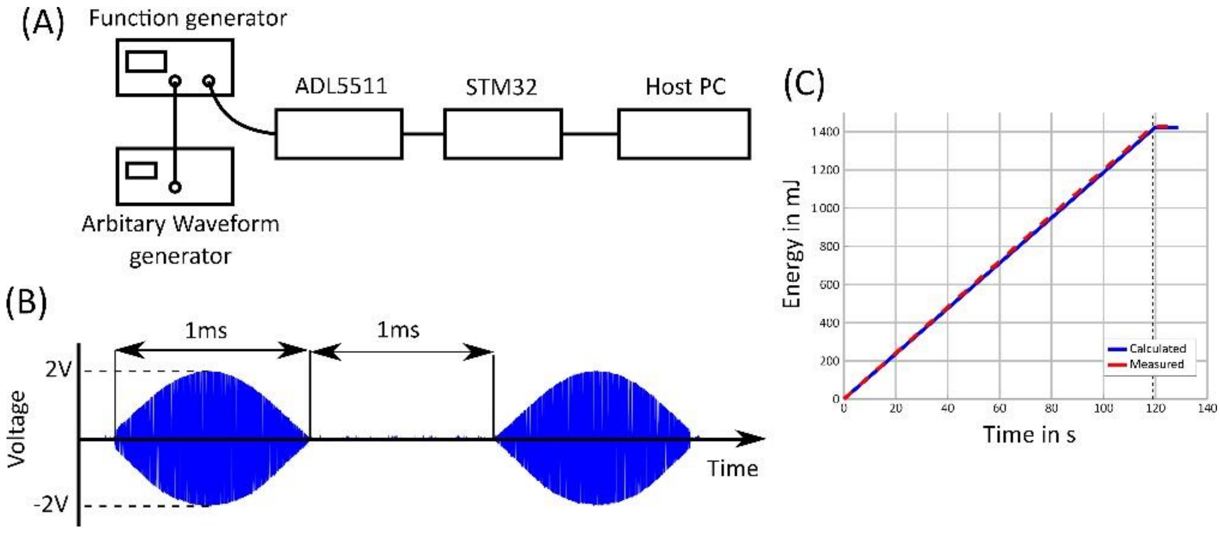

Fig. 1: (A) Measurement Setup; (B) RF pulse sequence; (C) Energy measurement results.

MRI safety evaluation of flexible coil

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Introduction:

Magnetic Resonance Imaging (MRI) frequently relies on surface coils to gain high imaging Signal to Noise Ratio (SNR). Previous work demonstrated an alternative implementation for dedicated interventional coils including a new concept for the so called “Active Decoupling” (AD). In this work, a flexible surface receives coil design [1] (see Fig. 1), which uses the new AD method [2], are tested regarding aspects of their MRI compliance and safety.

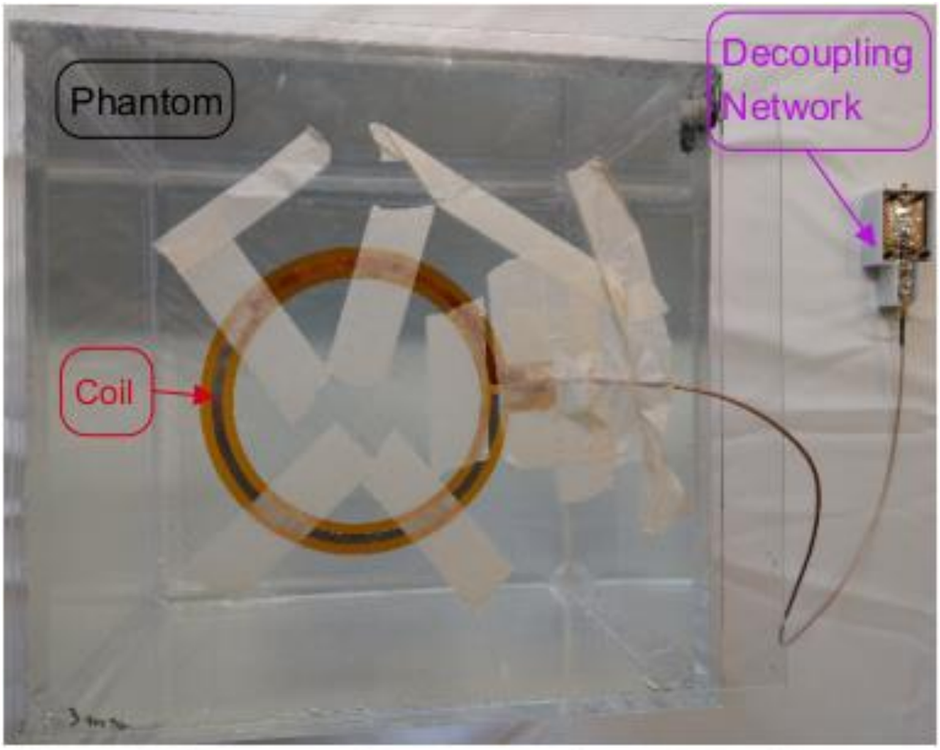

Figure 1: Close up of the used coil on the loading phantom. The coil is connected to the decoupling network.

Materials & Methods:

To validate the proposed setup, the tuned and matched coil is placed on a dissipative phantom (see Fig. 2). The setup is placed in the isocenter for MR-imaging. Sequences with high transmit amplitudes and short duty cycles were used to evaluate heating under worst-case conditions, which was monitored with a thermal camera. Furthermore, transmit radio frequency (RF)-field distortion measurements are performed, which show flip angle variations and indicate the quality of the AD-implementation. For quantitative statements, a reference measurement without coil demonstrator must also be performed.

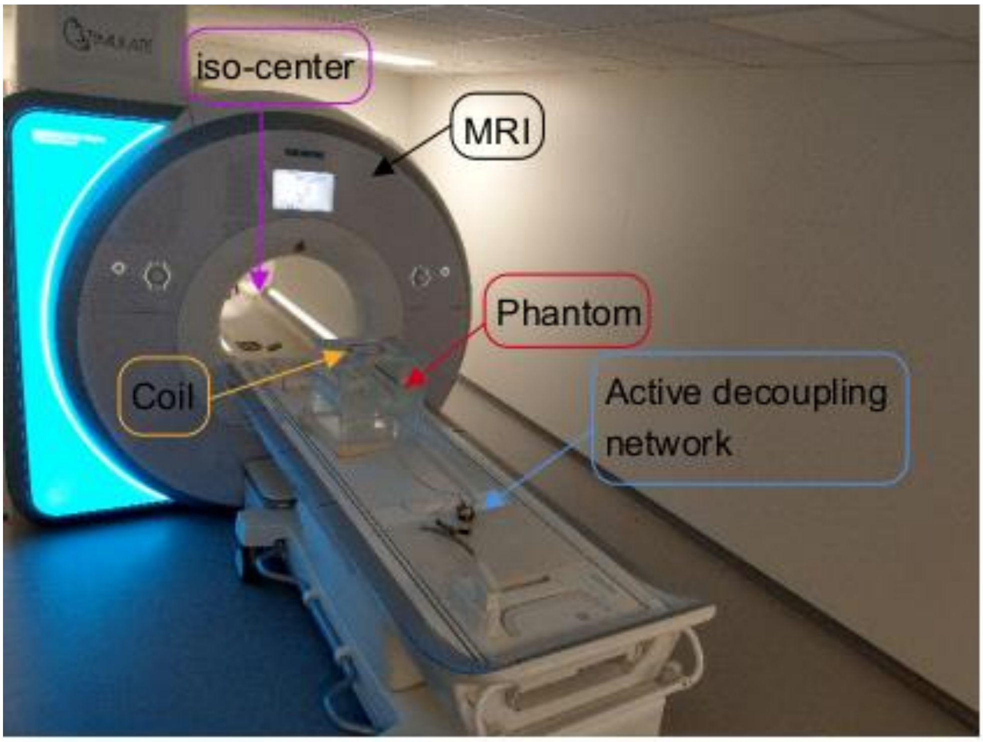

Figure 2: Measurement setup in the MRI.

Results:

Temperature measurements show 22 °C before and after the respective sequences. The quality of AD-measured is encoded in the maps by the change of transitions (see Fig. 3). There is just one additional transition observable, which corresponds to a change of flip angle (RF-Map) of 6.25 %.

Design and Implementation of a Test Procedure for the Evaluation of Interference Coupling in Magnetic Resonance Imaging

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Introduction:

External therapy devices in the shielded room of a magnetic resonance imaging (MRI) system can cause radio frequency (RF) imaging artifacts, which renders the image useless for diagnosis, image guidance of instruments or therapy monitoring. A major obstacle in ensuring compatibility with MRI is the lack of standard procedures. Since the interference of the image due to RF-emissions from equipment is extremely dependent on the position and routing of cables, an evaluation using a reverberation chamber (RVC) approach is proposed.

Materials & Methods:

The RVC-methods are transferred to the MRI cabin, and a mode stirrer was developed for this purpose. This allows statistically isotropic and homogeneous measurements inside the MRI cabin, which provides a reproduceable measurement setup. An important factor for the interpretability of the results is the quality factor of the shielding cabin which has to be determined for each environment. For a proof-of-concept (POC) the emission of a therapy device is measured, with altered positions and compared with a static position and RVC measurement with different stirrer angles.

Results:

The quality factor of the MRI cabin is similar to the RVC. When comparing the emission from the MRI system and the setup, a qualitative agreement is found. Comparing the POC-measurement, a numerical match was found, although the worst case is not yet completely covered by the setup.

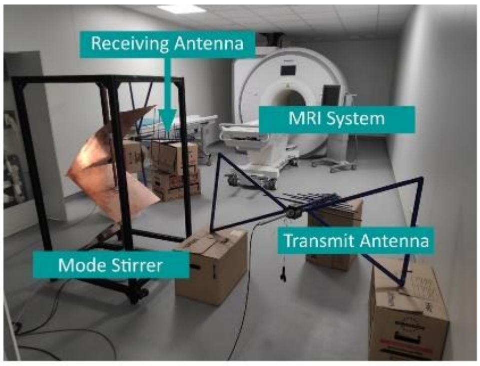

Figure 1: Transferred RVC-setup to measure the shielding cabin quality factor. The developed setup is MR compatible.

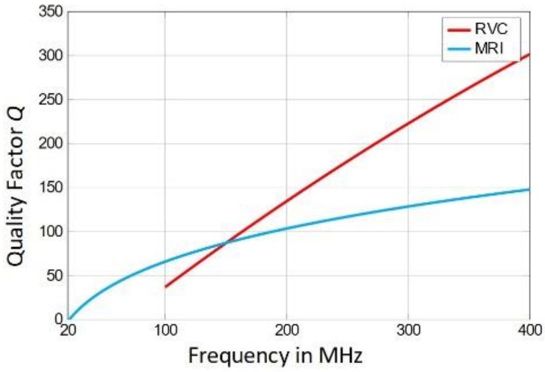

Figure 2: Quality Factor comparison of the RVC and MRI cabin. The MRI cabin shows similar values . In the higher frequency range The quality factor of the shielding cabin is reduced by absorbers.

Discussion:

The measurements proved that the shielding cabin and the setup are suitable for RVC measurements. In the POC measurement, it is shown that the statistical variation of device position and cable guide is given. These deviations are probably due to the stirrer efficiency. Moreover, it is shown that the developed setup picks up the disturbances in the MRI bore. In the future, the transferability and predictability will be proven as well as correlating emission with the imaging quality.

Acknowledgement:

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Polymer Optical Fibers (POF) for Motion Detection in Magnetic Resonance Imaging

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Introduction:

Motion artifacts in magnetic resonance imaging (MRI) lead to a reduction of image quality, what renders the images useless for diagnosis or image guided surgeries. To increase the image quality, a motion correction can be done. Existing methods can be used parallel to or after the image acquisition. In this abstract, a method based on polymer optical fibers (POF) and the suitability of these sensors for motion detection in MRI is presented.

Materials & Methods:

The schematic of the sensor system can be seen in Figure 1. The application of a force to the fiber leads to a change of the cross-section and the light intensity inside the fiber decreases. A reduced photocurrent can be measured at the photodiode. The suitability of this method is tested with a test bench. This can repeatedly apply a defined force to a single fiber. For further processing, the photocurrent gets amplified and changed into a voltage.

Results:

Figure 1 shows the curves of the force and the measured voltages. The application of a force leads to a reduction of the voltage. This change is proportional to the magnitude of the force. Even small applicated forces in a range of 1 - 5 N lead to changes in light intensity. Additionally, a change in the maximum force from 30 N to 40 N leads to a lower minimum value with of the voltage with 2.2 V instead of 2.4 V.

Conclusion:

Based on the measurements it is possible to use POF for motion detection. Due to the sensitivity of the sensors, strong movements can be detected. The fibers are made of plastic, which does not interact with the high electromagnetic fields in the MR. With a single fiber it is not possible to detect the position of the diameter's change along the fiber. In future works, a method to localize the position of the force has to be developed. Additionally, the sensitivity has to be investigated at lower forces to get information about the behaviour and the sensitivity at weak movements.

Acknowledgement:

The work of this paper is funded by the Federal Ministry of Education and Research within the Research Campus STIMULATE under the number '13GW0473A', '13GW0473E' and '13GW0473H'.

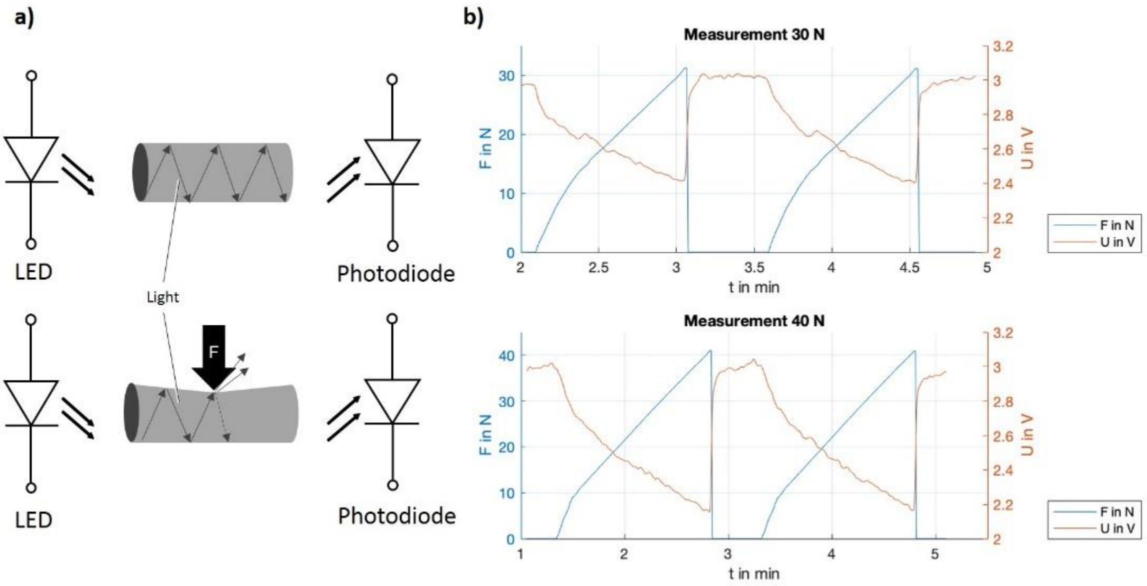

Figure 1: a) Schematic of POF sensors, **b)** Curves of the force F and the measured voltages at 30 N and 40 N