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3D-ultrasound-angiography – a new technique for diagnosis of vascular liver diseases

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Introduction: Transabdominal sonography is the imaging method of choice for the diagnosis of liver diseases. In addition to examination of the liver parenchyma, ultrasound is very helpful to characterize vascular structures in the liver. However, the visualization of complex vascular structures is limited in common 2D-sectional planes and/or short video sequences. The 3D-ultrasound-angiography, based on digital image reconstruction, can improve vascular diagnostics.
Objectives: Evaluation of advantages and limitations of novel 3D-ultrasound-angiography techniques.
Methods: For this case series, three patients with different vascular anomalies of the liver were examined with a conventional ultrasound transducer. The common 2D B-mode images, which were grabbed from the video port of a Toshiba Aplio 500 ultrasound system, were concatenated with spatial information using magnetic field information and stored in a virtual 3D-volume. The reconstruction of this 3D-volumes was realized by a 3D-ultrasound software application on a conventional PC workstation.
Results: Patient 1 (female, 66 years) suffered from Hepatitis C induced liver cirrhosis. A portal-venous shunt was detected and visualized in the 3D-reconstruction. Using the spatial information, the shunt course could be depicted with high precision.
In patient 2 (male, 32years), diagnosis of Budd-Chiari-syndrome (occlusion of liver veins) was established. Ultrasound revealed a diaphragmatic stenosis of the left liver vein. The complex altered venous anatomy including collaterals and shunts was displayed in a 3D-reconstruction, which also revealed compression of the inferior cava vein caused hepatomegaly.
The third patient (female, 56 years) suffered from liver cirrhosis induced portal hypertension. Distinct umbilical collaterals were visualized using 3D-ultrasound reconstruction.
Conclusion: Ultrasound-angiography based on 3D-image reconstruction provides valuable additional diagnostic information in patients with complex vascular anomalies of the liver

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Magnetic manipulation in combination with preclinical magnetic particle imaging

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Magnetic manipulation is of high interest in terms of drug targeting and minimal invasive surgery. Drugs as chemotherapeutics are bound to magnetic beads which can be directed by external magnetic fields towards a targeted volume. This allows lower dosages and healthy tissue is less affected. It is also possible to direct micro surgical devices, video or drug filled capsules into tissue regions which are difficult to access or into highly sensitive organs.
It needs to be considered, how to image and monitor the manipulation process: For in-vitro experiments microscopy methods are possible, but in-vivo experiments need to be imaged with a tomographic and real time imaging technique – here, Magnetic Particle Imaging (MPI) is a promising method.
MPI is an imaging modality determining the spatial distribution of superparamagnetic nanoparticles. It is highly sensitive and enables real time imaging with a resolution in the submillimeter range. It is based on the nonlinear response of the particles to alternating magnetic fields. A gradient field, forming a field free point (FFP), encodes the signal spatially.
The magnetic fields of existing MPI scanners can also be used for magnetic manipulation. Since the magnetic force always points along the field gradient towards the highest field amplitudes, magnetic devices can be moved and rotated by moving the FFP, e.g. on circular path ways.
The possible forces applied by a commercially available preclinical MPI system are investigated and the size of the devices movable by the available field gradients is determined. Since the administered force does not only depend on the size of the device and the magnetic field gradient, but also on the magnetization, it is aimed at analyzing the degree of magnetic saturation of the used devices and particles.

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Remote sensing of vital signs in neonatology – a multispectral, camera-based approach

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Preterm babies (neonates) need special medical care. Thus, monitoring of their vital signs is essential. The monitoring techniques that are currently used in neonatology, such as electrocardiography (ECG) or photoplethysmography (PPG) for oxygen saturation, are contact-based and often rely on adhesives to attach the required sensors to the skin. Unfortunately, in its immature state, the neonatal skin can easily be injured when these are removed. This further weakens the already vulnerable neonates and increases the risk of germ invasion and infection. These considerations and the gain of patient comfort motivate non-contact monitoring techniques, especially for this group of patients.

We present the first measurements of a multispectral camera-based setup for remote sensing of vital signs and its application in neonatology. The setup consists of six synchronized cameras which record videos in different bands of the electromagnetic spectrum, namely visible light (VIS), near-infrared (NIR) and long-wavelength infrared (LWIR). Vital signs are extracted via photoplethysmography imaging (PPGI), which requires active illumination, and infrared thermography (IRT), which is a passive technique that measures heat radiation. For PPGI, light-emitting diodes (LEDs) provide light that is selectively attenuated by optical filters, which are attached to the cameras.

Based on our multispectral measurements, we show that heart-related biosignals can be extracted via the photoplethysmographic principle in the VIS and NIR bands while temperature changes are visible in the LWIR band. Furthermore, respiratory signals are extracted by detecting and analyzing the neonate's movement. The study was approved by the Ethics Committee of the RWTH Aachen University Hospital, Aachen, Germany EK 327/16.

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Hyperspectral imaging – preoperative analysis of kidneys during normothermic extracorporeal machine perfusion

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Compared to traditional static cold preservation of donor kidneys, normothermic machine perfusion provides the possible benefits of improving graft viability and allowing its assessment before transplantation. However, methods of monitoring the functional parameters of ex-vivo kidneys have yet to be developed. In this respect, hyperspectral imaging (HSI) offers great potential as a noninvasive diagnostic tool to analyze the organ graft prior to the transplantation.
The hyperspectral imaging technique was used to measure the kidney status. Simulating a typical transplant setting, landrace porcine kidneys were prepared. Afterwards organs underwent normothermic perfusion, consisting of flow- and temperature-controlled pulsatile perfusion of the kidneys arteria with whole-blood. The kidney was illuminated with visible/near-infrared light and hyperspectral images were obtained before, during and after the preservation period. Suitable calibration and validation models were realized to closely approximate tissue characteristics. Based on multivariate data analysis, the oxygen saturation and the water levels were calculated from HSI recordings.
Experiments were carried out to show the feasibility of a hyperspectral imaging system for analyzing the kidneys status. Appropriate wavelength regions between 500 and 1000 nm for the detection of physiological kidney parameters were identified. After the conditioning, a correlation between the kidney status and the spectral data was detected.
Hyperspectral imaging was shown to be a potent tool for assessing different tissue characteristics of kidney grafts during normothermic machine perfusion.

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Influence of orthogonal receive channels on the spatial resolution in magnetic particle imaging

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In magnetic particle imaging, superparamagnetic nanoparticles are excited by an oscillating magnetic field. Due to the non-linear magnetisation behaviour of the particles, the receive signal is a distorted version of the excitation signal. Harmonics of the fundamental frequency can be detected. Introducing a magnetic gradient field in order to spatially encode the receive signal, the spatial distribution of particles inside a field of view can be reconstructed by using e.g. a system matrix.
Typically, the receive signal is detected by receive coils that are parallel to the send coils. In a multidimensional setup, the distinct send and receive coils are orthogonal to each other in order to excite and detect in orthogonal spatial directions. When having a multi-dimensional setup but exciting in only fewer directions than possible, the receive signal of the supernumerary spatial direction is usually discarded (e.g. when acquiring 1D line scans or 2D slices in a 3D setup).
In this work, it is determined if the receive signal of the supernumerary spatial direction may improve the reconstruction result in terms of spatial resolution and image quality. For this, two 1D hybrid system matrices are acquired in a 2D magnetic particle spectrometer. Then, a resolution phantom is emulated using one of the system matrices. The other system matrix is used for reconstructing the resolution phantom. It is evaluated if the image quality and spatial resolution improve when additionally using the second receive channel for reconstruction.

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Real-time functional magnetic resonance imaging neurofeedback as a neuroscientific tool

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Biofeedback and neurofeedback using electroencephalography has already a long history in the realm of clinical therapies, for example to treat migraine, anxiety or hyperactivity. Functional magnetic resonance imaging (fMRI) has received increasing attention in this regard in recent years because it provides unprecedented spatial resolution to specifically alter activity even in deep brain regions. Because of this unique strength, fMRI neurofeedback can be of interest not only for clinicians but also for neuroscientists to study functional brain networks by disturbing brain activity in a hypothesis-driven manner. We will present an example of this, were we have used fMRI neurofeedback to alter activity in the amygdala, a core region for the processing of emotions in the inferior brain. Activity in the amygdala is known to increase in response to arousing or negative images, which also slow down a simple reaction time task when used as a distractor, in comparison to neutral images. We tested the hypothesis that lower amygdala activity before task onset would lower the distractor effect of negative images. We found that down regulation of the amygdala was indeed associated with the abolishment of the distractor effect and that the reduction of the distractor effect was correlated with the capacity of a subject to down regulate. However, we could not show a direct trial-by-trial influence of baseline amygdala activity on reaction times. In summary, we demonstrated how fMRI neurofeedback can be used to affect behaviour and study functional brain networks.

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Image to phantom registration for CT dose calculation using the software tool GMCTdospp

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For the estimation of organ and effective patient dose of CT scans software tools like GMCTdospp can be used. GMCTdospp calculates the dose values for ICRP human phantoms based on actual CT studies of a patient using a set of source parameters e.g. utilized CT, the kVp, mAs and scan region. For statistical evaluation of large numbers of patients this could be a time consuming task and the determination of the scanned region, is user dependent and error-prone.
The aim of this work was to automate the transfer of the scan region from the CT study to the phantom and to maximize the accuracy of the determination in order to accelerate the dose estimation. The approach is based on the registration of CT localizer data to the ICRP phantom. First, a projection of the 3D ICRP phantom data along the y-axis was performed to create an artificial “phantom localizer”. Then, the real CT localizer image was cropped to the actual scan region based on DICOM header information and both datasets were matched.
The registration algorithm estimated the start and the end slice of the scan region in the phantom for nine CT studies. The results were compared to the manual determination of an experienced user. The deviation of the user and the algorithm for the start slice was 5,67±3,16 and for the end slice 5,83±5,85, respectively.
The method was able to determine the CT scan region and to transfer it to GMCTdospp for dose calculation in good agreement to the reference user for the start slice. For the end slice the standard deviation is higher due to the rigid registration approach. It is a first step towards a framework that can be used for dose management in a clinical environment to automatically estimate the effective patient dose of CT studies.

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Temperature measurement during focused ultrasound treatment with diagnostic ultrasound

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Ultrasound therapies are promising and non-invasive applications. They are used e.g. for cancer therapies like viro- or immunotherapy, various surgical applications of the prostate or liver, and blood-brain-barrier opening. A crucial step towards patient safety and comparability of treatments is still missing: easy-to-handle and affordable tools to assure the quality and accuracy of therapy devices and ways to verify treatment planning algorithms. To overcome this deficiency accurate spatial and temporal temperature maps of the treated region could be used.
Possibilities for non-invasive therapy monitoring by measuring temperatures or temperature changes are either done with magnetic resonance or diagnostic ultrasound imaging. Temperature measurement with diagnostic ultrasound during focused ultrasound heating is based on the echo-time-shift method. Speed of sound of tissue, and therefore the backscattered ultrasound signals, change with temperature resulting in a shift of the backscattered signal. This shift is used for temperature calculation. We monitored temperature changes induced with a focused ultrasound transducer (1.1 MHz) in an agar-graphite phantom with a linear diagnostic ultrasound array (10 MHz). A sigmoid function fit was used during calculation. The emergence of uncertainties due to intrinsic principles of the method and due to calculation was examined.
Depending on the purpose of the measurement, a compromise has to be made between the following: calculation accuracy, tolerance towards small patient or organ movements, reproducing large temperature changes or cooling processes, speed of the algorithm, and spatial accuracy. Within the range from 20 °C to 44 °C, in a tissue mimicking phantom uncertainties as low as 12.4% are possible, being mainly due to medium and therefore tissue properties.
The method of monitoring temperature changes for laboratory and clinical quality assessment of therapy devices might be a comparatively accurate, fast, and affordable one.

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An investigation of the modeling error of linearization for EIT reconstruction

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Electrical Impedance Tomography is an imaging method which attempts to reveal the conductivity distribution of a domain based on the electrical boundary condition. For time difference EIT, the voltage difference at two time steps is employed for reconstruction. This is an ill-posed inverse problem, especially, it is non-linear. The currently available EIT devices are all based on linearized reconstruction algorithms. The linearized reconstruction employs a reconstruction matrix which is essentially a regularized pseudoinverse of the Jacobian matrix. This reconstruction matrix multiplying the voltage differences will provide a distribution of conductivity changes. However, the linearized reconstruction contains modeling error. In this paper, we study the modeling error caused by linearization based on the complete electrode model through simulations. Specifying a current injection pattern in simulation, at each time step a simulated voltage measurement can be calculated from Maxwell's equations. The voltage difference between two time steps can be obtained. On the other hand, according to the assumption of linearized reconstruction, the voltage difference is assumed to be the Jacobian matrix multiplying the conductivity distribution changes. The discrepancy between these two voltage differences will be studied. This information will further be used for reconstruction to alleviate the modeling error.