P 1

Development of long-term stable measurement phantoms for quantitative magnetic particle imaging

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Interlaboratory performance evaluation of both commercial and custom-made Magnetic Particle Imaging (MPI) scanners requires dedicated phantoms with defined magnetic nanoparticle (MNP) distributions. Pre-requisite for the development of such phantoms is the establishment of suitable MNP-matrix combinations, which determine the magnetic properties of the phantom. To enable round robin tests using exactly the same measurement phantom in different labs, the magnetic and mechanic properties of the phantoms must be constant over durations of several months. Development of long-term stable phantom materials is therefore needed. To this end, Elastosil (an organic silicone) was used as a matrix material for phantom preparation. Four commercially available aqueous suspensions of MNP were tested for their suitability as MPI tracer materials, and embedded into the Elastosil matrix in various concentrations. The transfer of MNP from aqueous suspensions into organic silicones is a challenging and critical part of the phantom preparation. The obtained MNP-matrix combinations were tested for their mechanical stability by means of shore hardness measurements (Shore A). Furthermore, the homogeneity of MNP distribution within the matrix was determined by optical investigation of the samples with a microscope. Magnetic Particle Spectroscopy (MPS) was applied to investigate the temporal stability of the MPI performance of the MNP/Elastosil combinations. MPS measurements were conducted at regular timepoints spanning a 6 month period; beginning at the material fabrication. Finally, from the most promising material combinations, cylindrically shaped measurement phantoms (D = 12 mm, H = 12 mm) were fabricated and imaged by MPI. In summary, we have developed suitable combinations of MNP and Elastosil for the manufacture of long-term stable MPI phantoms. The prepared phantoms show constant magnetic and mechanical properties for the duration of the study and can be imaged by MPI. Ongoing work is focused on more structured measurement phantoms.

P 2

Spin echo based cardiac diffusion imaging sequences at 7T: performance and feasibilty ex vivo

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The short transverse relaxation time T_2^* of the myocardium limits the echo time (TE) that can be used for cardiac diffusion weighted imaging. This restriction becomes even more prominent at higher field strengths of 7T and above. While measuring at 7T potentially increases signal to noise ratio, B_0 field inhomogeneity is also increased. Purpose of this work was to compare spin echo (SE) sequence performance in cardiac diffusion imaging in ex vivo pig hearts at 3T and 7T.
Measurements were performed on 3T and 7T whole-body MRI systems (Siemens MAGNETOM Prisma and Terra) using a 1Tx/32Rx head coil. For imaging pig hearts were placed in a 0.9% sodium chloride solution. MRI with spatial resolution of 1.3x1.3x1.3mm^3 was performed within 10 hours after cardiac arrest. Using a single shot SE sequence 30 diffusion directions as proposed by Skare and five b_0 images were acquired for analysis of SNR, ADC, fractional anisotropy (FA) and helix angle (HA). To estimate T_2^* relaxation time a segmented EPI measurement with varying echo distance and effective train length was used.
SNR values in the myocardium of the left ventricle determined via single shot SE were 23 and 12 at 3T and 7T, respectively. This shows the significant effect of the T_2^* time at 7T for the TE (55ms) used. Geometrical distortions at 7T become acceptable for TEs below 45ms. Using segmented EPI at 7T resulted in reduced geometrical distortions when either echo distance or echo train length was shortened. Furthermore, reducing the echo distance from 1ms to 0.4ms lead to an SNR-increase of a factor of three. Due to SNR limitations and geometric distortions, SE approaches for cardiac diffusion imaging at 7T are only feasible with a segmented readout.

P 3

Dose splitting using a dual-source computed tomography

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The use of dual-source CT scanners (DSCT) enables to acquire simultaneously three data sets with three different radiation dose levels: two data sets for each X-ray tube and one combined virtual data set. The purpose of the current investigation is to find out the best tube current ratio regarding to the image quality (IQ) and the radiation dose. Thereby, we compared the IQ of an examination using single source CT as a reference with that obtained by virtual dual-source CT data set reconstructed from two raw data sets provided by a DSCT. For this aim a phantom of the type CATPHAN 503 was scanned by a DSCT of the third generation (SOMATOM Force, Siemens Healthcare). The dual-source data was obtained using four different ratios for X-ray tube currents of tubes A and B, i.e. A/B: 80%/20%, 70%/30%, 60%/40%, 50%/50%. The date was collected in the single-source mode by use of 100% tube current for the X-ray tube A. The IQ was evaluated in terms of the dose-normalized contrast-to-noise ratio (DCNR). Three image sets were reconstructed by a filtered back projection kernel (FBP Br40) and two iterative algorithms of different strength, ADMIRE level 2 and 3. Furthermore, we used a slice thickness of 1 mm for images reconstructed by the FBP and ADMIRE2 and 5 mm for the ADMIRE3 to identify the slice thickness influence on DCNR. In order to investigate the impact of the X-ray tube voltage on the results, measurements were performed by X-ray tube voltages of 90 and 110 kVp for both tubes.

P 4

Metabolite diffusion measured by MR spectroscopy without water suppression reveals microstructural information in human gray matter

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Synopsis: Metabolite diffusion was measured in 13 healthy volunteers in occipital gray matter on a clinical 3T system using non-water-suppressed diffusion-weighting magnetic resonance spectroscopy sequence. The fit routine was adjusted with optimized prior-knowledge constraints to resolve apparent diffusion coefficients (ADCs) of as many metabolites as possible. The model quality was evaluated on basis of the resulting relative standard deviation for the cohort.
Methods: The new sequence design uses the water signal as reference allowing for compensation of motion-related signal distortions in post-processing. This improves the spectral resolution on one hand, but more importantly leads to more accurate fitting. The acquired data were analyzed by a newly implemented simultaneous 2D fitting approach in the fitting tool FiTAID to determine the apparent diffusion constants of brain metabolites with use of different prior-knowledge restrictions. Applying most stringent constraints reduces the number of free metabolite ADCs from 19 components to merely 7 contributors, whereas fitting accuracy is improved. Without applying any prior knowledge 17 components are identified, though with strongly reduced fitting accuracy. The reduced number of individual ADCs in the first, and the deteriorated accuracy in the second case prevent resolution of significant ADC differences for viable information on tissue microstructure. Thus, a third prior-knowledge set was developed, able to reveal (highly) significant differences in diffusion properties of 13 metabolite components. Paired t-tests were used to identify significant differences between metabolites.
Results: It is shown in human gray matter that the neurotransmitter glutamate is diffusing significantly faster than the neuronal marker N-acetylaspartate. Further, a significant difference in ADC is found between the intracellular sugars myo-inositol and scyllo-inositol compared to glucose, which may be attributed to the large fraction of extracellular glucose.
Conclusion: Non-water-suppressed MR spectroscopy combined with 2D modeling allows for optimized determination of metabolite diffusion information and, thus, on the tissue microstructure.

P 5

Ultrasound thyroid texture classification using a simple texture pattern characterization

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The thyroid is one of the largest endocrine glands in the human body and is involved in several significant body mechanisms such as the regulation of the temperature of the human body. Hence, it is very important to monitor the thyroid state over time. For that, volume computation of Ultrasound (US) images for tracking changes is of prior importance and segmentation of the thyroid is one of the main steps for this purpose. Several approaches such as edge detection, thresholding, active contours, support vector machines and neural networks approaches have been proposed to correctly classify the thyroid region in US images. However, most of these approaches are not automatic and require long time to correctly classify the thyroid region. In this work a simple texture pattern similarity characterization for thyroid echogenicity matching is proposed. First the user selects in one US slice a point inside the thyroid and a template is generated around the selected pixel. This template is then used to search thyroid echogenicity in the whole set of US slices through the proposed pattern similarity characterization. This similarity is based on two image comparison indicators, one consisting on the mean square error and the other consisting on the correlation between the histograms of both images. The final similarity characterization is computed as the division of both indicators. A high value of this similarity is related with high matching of the template with the image. For evaluation proposes a texture database has been generated extracting several sub-images from six thyroid 3D US datasets obtained using an US device equipped with an electromagnetic tracking (GE Logiq E9). Results show that the similarity characterization is suitable for differentiating thyroid echogenicity from the rest of the US image and can be used as a strong feature for segmenting thyroid using classification methods.

P 7

Using a segmented multi-echo EPI sequence with simultaneous multislice acquisition for dynamic contrast-enhanced MRI

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A new multi –echo imaging sequence for dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) has been developed. To achieve a temporal resolution of 1.3 s a simultaneous multislice (SMS) acquisition has been added to a multi-contrast, segmented echo –planar imaging (EPI) sequence. The purpose of this sequence is to separate the MR signal into T1 and T2* components. If successful, common models could be used to better separate intravascular from interstitial signal contributions, allowing more reliable calculation of perfusion and permeability.
The sequence has been developed for a preclinical perfusion study using fast imaging of multiple contrasts. The sequence was tested in sedated pigs whose right hip and hindleg were scanned to determine signal intensity of the aorta and large muscles. Total acquisition time was 11 min and 0.1 mMol/kg gadolinium-based contrast medium (CM) was injected after the fifth acquisition. To separate the signal into relaxation changes rates (ΔR –maps) of T1 und T2*, the dynamic data acquired with three echo times (TE1=9 ms, TE2=21.5 ms, TE3=34 ms) were fitted. Baseline T1 was calculated from an acquisition with five repetition times but otherwise identical sequence parameters. Baseline T2* was calculated from the averaged signal of the time steps before CM arrival. From the ΔR –maps, regions of interest of the different muscles and of the aorta were generated to extract tissue ΔR –maps and the arterial –input –function (AIF). The validity of the sequence was analysed. The CM concentration change and susceptibility effects can be assessed over time.
Separation of the MR signal into T1 und T2* components is feasible using the sequence presented here. The results are suitable for further pharmacokinetic modelling and analysis of perfusion and permeability. Thus, the MR sequence is suitable for perfusion imaging of larger body regions with a temporal resolution necessary for bolus detection.

P 10

Determination of the volume of microchannels in bone phantoms by magnetic resonance imaging (MRI) and micro computed tomography (µCT)

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For a successful integration of biodegradable bone implants a fast angiogenesis is indispensable. New formed vessels transport necessary nutrition, minerals, growth factors, etc. to the site of implantation for the purpose of forming new bone tissue. Initially these vessels exhibit a diameter of just a few micrometers and are therefore too small to be resolved clearly in standard MRI or µCT. The aim of this study was to quantify the volume of liquid in microchannels in bone phantoms.
To form the microchannels, melt-spun sugar fiber networks were produced using a commercial available cotton candy machine (ZWM 3478, Clatronic, Kempen). The fiber network was doused by a degassed mixture of hardener and resin (Epoxy resin L 385, R&G Faserverbundwerkstoffe, Waldenbruch). After the epoxy had cured, the sugar fibers were dissolved in a water bath for serveral days leaving fine microchannels in the epoxy constructs.
The epoxy phantoms were placed in aqueous solutions of contrast agents (MRI: Dotarem (gadoteric acid); µCT: Xenetix 300 (Iobitridol)) of different concentrations and scanned in MRI (Philips achieva 3.0T TX, Dual Microscopy coil 47 mm) and µCT (Scanco Medical XtremeCT, 60 kV, 300 ms, 82 µm). The scans were analysed using the image processing program ImageJ. The averaged signal intensity in MRI scans and the averaged X-ray absorption in µCT scans were evaluated by manually positioned “region of interests” (ROI) and plotted against the concentration of the contrast agent and the volume of the channels, respectively.

P 11

B_0-mapping and shimming efficiency for ex Vivo MR imaging of the heart at ultra-high field – validation of standard shimming protocols of magnetom terra 7T scanner

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Despite improved signal-to-noise ratio (SNR) the MR imaging of the human heart at ultra-high field (UHF) ($B_0 \geq 7T$) is challenging. The complex structure of the heart and surrounding tissue leads to strong susceptibility induced spatio-temporal B_0-field variations. These gradients lead to significant signal losses and image distortions and, thus, their correction (shimming) both spatially and temporally is an absolute prerequisite of UHF cardiac MRI. B_0-mapping for shimming is based on phase differences of gradient-echo (GRE) images acquired at 2 or more echo times [$TE_{min}..TE_{max}$]. Both TE dynamic range (TE_{max}-TE_{min}=ΔTE) and sufficient image SNR at $TE=TE_{max}$ are important for efficient B_0-mapping. Insufficient ΔTE leads to a low B_0 resolution, while too high $\Delta TE \approx T_2^*$ typically leads to phase-wrapping and deteriorates both mapping and shimming efficiency.
In this work we tested the efficiency of standard shimming protocols available on the first serial Siemens Magnetom™ Terra 7T Scanner (equipped with third order shims) in order to find an optimal strategy for B_0-mapping and dynamic B_0-shimming of the heart at 7T. The B_0-mapping measurements of an excised pig heart (preserved in 0.9% NaCl solution) were performed using a 32-channel head coil. The 3D GRE was used with different TE_{min}=1.0..4.7ms and ΔTE=2.1..6.1ms with different coverage of the measured slices by the shimming volume. The typical pixel resolution was $1mm^2$ in-plane and 1..3mm in-slice. The T_2^* and B_0 (from magnitude and phase images respectively) were calculated using MATLAB.
It was found that for ex-vivo myocardial tissue the scanner's shimming methodology can be efficient in a rather narrow range of TE-times used for B_0-mapping. Only 2 of 8 available shimming algorithms provide consistent B_0-maps without phase-wraps. The typical T_2^*-time is 7ms. The shimming quality improves essentially when using minimal possible echo time (TE_1=1.0ms) in comparison with standard "cardiac" shimming performed at $TE_{1/2}$=4.8/7.2ms. The B_0-maps become inconsistent for ΔTE>3ms.

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Parameter optimization for simulation-based artefact correction in computed tomography

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In computed tomography artefacts reduce the quality of reconstructed volume data. In the past 30 years many different artefact correction methods have been developed. Since every method has its own advantages and disadvantages the choice of the optimal correction method largely depends on the application. Recently presented simulation-based artefact correction methods overcome this problem. Assuming a model of the specimen is known, this approach is able to correct artefacts regardless the complexity of the object or its material composition. During this approach for every original x-ray image two artificial projection images were simulated. One polychromatic image with artefacts and one ideal monochromatic image without artefacts. The ideal monochromatic images can be computed by simply performing a forward projection utilizing the lambert beer law. The linear attenuation coefficient can be obtained from databases. The polychromatic images with artefacts are computed from a weighted sum of monochromatic images that were added by scatter images simulated using a monte-carlo algorithm. Optionally, detector noise can be considered as well. The difference of the two artificial images is used to correct the original x-ray images. Subsequently, the original images can be used for 3D reconstruction. If the artefacts were simulated correctly, the reconstructed volume is free of artefacts. In this abstract we investigate the influence of the monochromatic energy that is chosen for the simulation of the ideal artificial images. The results show that for very low energies total absorption is likely, thus the correction term will be corrupted. For very high energies the contrast of high and low density materials may suffer. Based on the results an approach for parameter optimization is presented, that considers the linear absorption coefficient of the different materials during simulation.