2nd Annual Scientific Symposium

Ultrahigh Field Magnetic Resonance:
Clinical Needs, Research Promises and Technical Solutions

Local organizers: Thoralf Niendorf, Jeanette Schulz-Menger, Bernd Ittermann

Friday, June 24th 2011, 8.50 a.m. – 8 p.m.
Max-Delbrück Communications Center (MDC.C), Berlin

Max-Delbrück-Center for Molecular Medicine (MDC)
Robert-Rössle Strasse 10, 13125 Berlin, Germany
Dear colleagues and friends,

the field of Magnetic Resonance has evolved rapidly over the past quarter of a century, allowing for new applications across a broad spectrum of basic science and clinical research areas. Today, one important development which is in the spotlight of MR research is the move towards ultrahigh field Magnetic Resonance (UHF MR), including a plethora of reports which eloquently speak about pioneering explorations into neurovascular and cardiovascular MR at 7 T.

Inspired by this development, the Berlin Ultrahigh Field Facility (B.U.F.F.) has been established at the Max-Delbrück-Center for Molecular Medicine. This strategic effort is devoted to foster imaging science. It holds a broad range of promises for basic MR research and clinical applications with the ultimate goal to advance the capabilities of imaging in the fields of Cardiology, Neuroscience, Molecular Medicine, Radiology and others.

Realizing these opportunities, we are very delighted to warmly welcome you to the 2nd Annual Scientific Symposium on clinical needs, research promises and technical solutions in ultrahigh field MR. The symposium is designed to provide an overview of state-of-the-art (pre)clinical UHF MR, to discuss the clinical relevance of UHF MR, to explore future directions of UHF MR, to foster explorations into ultrahigh field MR, and to initiate local, regional, national and international collaboration. We are very much honored to present extraordinary speakers including MR technology leaders and distinguished clinical experts, all of whom bridge disciplinary boundaries and stimulate the imaging community to throw further weight behind finding solutions to unsolved problems and unmet clinical needs.

To this end, we would like to draw your attention to the poster presentations. We wish to thank those of you who walked the extra mile and submitted poster contributions. We really appreciate your efforts.
We cordially invite you to attend the technical exhibition which goes along with the scientific program. It also behooves us to emphasize that this is the right moment to acknowledge our generous sponsors who provided marvelous support to the symposiums’ scientific and educational activities.

The scientific program, poster session and technical exhibition will be supplemented by an open day of the Berlin Ultrahigh Field facility as well as a social event held at the famous Naturkundemuseum, where ultrahigh field MR meets history.

We warmly welcome you at the 2nd Annual Scientific Symposium on Ultrahigh Field MR in Berlin. Alongside MR science, Berlin has numerous historical landmarks, highlights and cultural events to offer. Be Berlin. Enjoy the symposium.

Thoralf Niendorf  
MDC & Charité

Jeanette Schulz-Menger  
Charité & HELIOS Clinic

Bernd Ittermann  
PTB
The 2\textsuperscript{nd} Annual Scientific Symposium on Ultrahigh Field Magnetic Resonance: Clinical Needs, Research Promises and Technical Solutions has received official endorsement from the International Society of Magnetic Resonance in Medicine (ISMRM).
The 2nd Annual Scientific Symposium on Ultrahigh Field Magnetic Resonance: Clinical Needs, Research Promises and Technical Solutions has been rewarded by an official endorsement from the European Society of Magnetic Resonance in Medicine and Biology (ESMRMB).

www.esmrmb.org

The European Society for Magnetic Resonance in Medicine and Biology is a non-profit Society, which aims to support educational activities and research in the widest sense in the field defined by the Society’s name. The ESMRMB is open to physicians, engineers, scientists and other individuals who are interested in the developments or the introduction of magnetic resonance techniques in the fields of medicine and biology.
Anzeige Siemens
Program

08.30 Refreshments
08.50 Welcome
Hans Koch, PTB, Berlin, Germany

SCIENTIFIC SESSION I
Chair: Kamil Ugurbil, Minneapolis, USA
       David G. Norris, Nijmegen, The Netherlands

Getting to the matter of the heart: Clinical needs and research promises for UHF MR in Cardiology
09.00-09.30 Unsolved Problems and Unmet Needs of Clinical Cardiovascular MR
         Matthias Friedrich, Libin Center, Calgary, Canada
09.30-09.50 The Bells and Whistles of UHF MR Technology for Cardiac MR
         J. Thomas Vaughan, CMRR, Minneapolis, USA
09.50-10.10 UHF MR: Wild Dreams of a Clinical Cardiologist
         Jeanette Schulz-Menger, Charité, Berlin, Germany
10.10-10.30 Future Directions of Cardiovascular MR @ 7.0 T
         Thoralf Niendorf, MDC, Berlin, Germany

SCIENTIFIC SESSION II
Chair: Daniel K. Sodickson, New York, USA
       Klaas Nicolay, TU Eindhoven, The Netherlands

Getting to the matter of the brain: Clinical needs and research promises for UHF MR in Neuroscience
10.45-11.15 Future Directions of UHF Neuro MR: My Way
         Kamil Ugurbil, CMRR, Minneapolis, USA
11.15-11.35 Role and Research Promises of UHF in Neuroscience
         John Dylan Haynes, Charité, Berlin, Germany
11.35-11.55 Ultrahigh Field MR at the Border Between Physics and Neuroscience
         David G. Norris, MPI FC Donders Center, Nijmegen, The Netherlands
11.55-12.15 Hybrid Brain Imaging: Opportunities and Challenges of MRPET at 9.4 T
         Jon N. Shah, FZ Jülich, Germany
SCIENTIFIC SESSION III
Chair: Jon N. Shah, FZ Jülich, Germany
Bernhard Blümich, RWTH Aachen, Germany

Translational research: From blue sky explorations to clinical applications

13.45-14.15  Molecular MR Imaging: Hype or Hope?
Klaas Nicolay, TU Eindhoven, The Netherlands

14.15-14.35  Insights from Molecular Imaging of Atherosclerosis
René Botnar, Kings College, London, UK

14.35-14.55  Challenges and Opportunities of Nanomolecular MR Probing in Experimental Neuroimmunology
Sonia Waiczies, MDC, Berlin, Germany

Tim Wokrina, Bruker, Ettlingen, Germany

15.15-16.15  Coffee break: B.U.F.F.et + POSTER SESSION

SCIENTIFIC SESSION IV
Chair: Rene Botnar, FC Donders Center, Nijmegen, The Netherlands
J. Thomas Vaughan, Minneapolis, USA

Looking at the horizon

16.15-16.45  What is next in UHF MR?
Daniel K. Sodickson, NYU, New York, USA

16.45-17.05  Lessons Learned from/for Parallel Transmission at Ultrahigh Fields
Bernd Ittermann, PTB, Berlin, Germany

17.05-17.25  Breaking the Limits with Low Field NMR: From Ancient Egyptian Mummies through Ötzi to the Louvre
Bernhard Blümich, RWTH, Aachen, Germany

17.25-17.45  Siemens: Human UHF MR – Mission & Vision
Franz Schmitt, Siemens, Erlangen, Germany

18.00  Tour de Facility

20.00  Reception at the Museum für Naturkunde Berlin
Poster Abstracts
(alphabetical order)
Introduction
At high-fields the intrinsic SNR benefits are challenged by $B_1^+$-field inhomogeneities. These can be corrected with techniques which require fast $B_1^+$-mapping routines. Phase-based methods for $B_1^+$-mapping are insensitive to $T_1$-relaxation effects and allow fast repetition-times ($TR<<T_1$). In this work we compare four phase-based methods [1-6] for proton MRI, in terms of: sensitivity to $B_1^+$ and $B_0$-inhomogeneities and TRs achievable.

Methods
All methods (A[1-2], B[3], C[4-5], D[6]) use non-selective composite-pulses for excitation in 3D gradient-echo sequences. The phase-accrual after excitation determines the sensitivity to $B_1^+$-inhomogeneities and $B_0$-offsets. MATLAB is used for simulations and post-processing. Phantom and in-vivo experiments on the brain of healthy volunteers are performed on 3T and 7T Siemens scanners, using a birdcage coil. Common TRs and identical SAR levels are used for all methods.

Results
A) Shows the smallest sensitivity, resulting in the most noisy $B_1^+$-maps. B) Uses the highest transverse magnetization, resulting in signal saturation. C) Has an intermediate sensitivity and uses small transverse magnetization, resulting in reliable $B_1^+$-maps and good SNR. D) Shows strong $B_0$-dependence, resulting in susceptibility artifacts at air-water interfaces.

Discussion
All four methods provide similar $B_1^+$ maps if used with TR>150ms. In-vivo, when SAR and speed are crucial, C) results the most robust method.

References
Implications of 2D Slice Profile Deformations for Rapid Myocardial T1/T2 Quantification Using Deposit

M. A. Dieringer1, M. Deimling2,3, D. Santoro2, F. Carinci2,4, J. Schulz-Menger1,2, and T. Niendorf2

1Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Humboldt-University, Berlin, Germany,
2Berlin Ultrahigh Field Facility, Max-Delbrueck Center for Molecular Medicine, Berlin, Germany
3Siemens Healthcare, Erlangen, Germany, 4Department of physics, Insubria University, Como, Italy

Introduction
3D DESPOT1/2 [1] have been proposed for rapid T1 and T2 quantification of the brain. Short repetition times (TR) evoke slice profile deformations [2,3] and hence bear the potential to render T1/T2 quantification inaccurate when moving to 2D DESPOT1/2. We examined its impact on T1 and T2 quantification using 2D DESPOT1/2.

Methods
Simulated and measured (Siemens Verio 3T, Siemens Healthcare, Germany) signal intensities were used to calculate T1/T2 with the DESPOT1/2 approach using an oil phantom (T1=200ms; T2=130ms). References values were derived from inversion recovery (IR) and multi-echo spin echo measurements, respectively. The impact of the signal differences on the quantification of T1 and T2 using DESPOT1 and DESPOT2 approach were calculated.

Results
Severe slice deformations were observed for alpha larger than 20 degrees (DESPOT1) and alpha larger than 60 degrees (DESPOT2). Mean T1 deviation between the uncorrected DESPOT1 data and the IR data was found to be -61±5%. The uncorrected DESPOT2 data revealed a mean T2 deviation of +43±11%.

Conclusion
Severe slice profile deformations alter signal intensities rendering rapid myocardial T1/T2 quantification with 2D DESPOT1/2 inaccurate. Consequently, it is essential to correct for slice deformations before T1 and T2 values derived from DESPOT acquisitions can be considered accurate.

Proton Magnetic Resonance Spectroscopy for the Detection of Human Brain Metabolites AT 7T

M. Elywa, S. Mulla-Osman, F. Godenschweger, O. Speck

Department of Biomedical Magnetic Resonance, Otto-von-Guericke-University, Magdeburg, Germany

The increased magnetization and frequency separation at high magnetic field strength, such as 7 Tesla, can provide spectra of high signal-to-noise ratio and spectral resolution which allows the detection of various brain metabolites. Twenty human brain metabolite solutions were used to acquire an experimental basis set of in vitro spectra. This basis set has been used in LC-Model in order to establish a $^1$H MRS method for in vivo human metabolites quantification. This method has been used to analyze the spectra from two brain regions, parietal and pregenual Anterior Cingulate Cortex (pgACC) using STEAM with VERSE pulses with a TE of 20 ms. The peaks of human brain metabolites can be separated, and quantified using LC-Model. The results show that this method can be employed to determine the absolute and relative concentrations of human brain metabolites acquired from different brain regions.

**Keywords:** proton magnetic resonance spectroscopy, in vivo MRS, human brain, metabolites quantification, LC-Model
As (ultra)high-field cardiac MRI becomes more widespread, the sensitivity of ECG recordings to interference from electromagnetic fields and to magneto-hydrodynamic effects increases and with it the ECG failure rate together with the motivation for a robust, practical gating/triggering alternative. Realizing the constraints of conventional ECG, an MR-stethoscope has been proposed to meet the demands of cardiac triggered MRI.

Motivated by the challenges and limitations of conventional ECG together with the advantages of acoustic cardiac triggering (ACT), this study compares phonocardiogram, electrocardiogram and pulse oximetry triggered MRI for LV function assessment at 7.0T. For this purpose, breath-held 2D CINE imaging in conjunction with a retrospective triggering regime was conducted.

The acoustic gating device comprises four main components: an acoustic sensor for phonocardiogram detection, an acoustic wave guide for signal transfer, a signal processing unit and a coupler unit to the MRI system. Signal conditioning and conversion were conducted using dedicated electronic circuits.

ECG waveforms were susceptible to severe T-wave elevation which was pronounced at the isocenter of the 7.0T magnet. In comparison, the MR-stethoscope provided phonocardiograms at 7.0T free of interferences from electromagnetic fields or magneto-hydraulic effects even in the isocenter. This renders ACT suitable for reliable synchronization at ultra-high fields. Conversely, R-wave mis-registration occurred in ECG-triggered acquisitions with a failure rate of appr. 50% which manifest itself in a severe jitter of the R-wave recognition tickmarks. Failure to detect the onset of the cardiac cycle was reduced for pulse oximetry, though a temporal inaccuracy of the triggering of app. 150ms was observed. Full R-R interval coverage, acoustically triggered CINE imaging at 7.0T produced images free of motion artifacts. In contrast, ECG triggered CINE imaging was prone to severe cardiac motion artifacts if R-wave misregistration occurred. In comparison, pulse oximetry triggered 2D CINE imaging was found to be less sensitive to cardiac motion effects although the jitter in the pulse-oximetry recognition constituted a synchronization problem.

This work examined the feasibility of global cardiac function assessment at 7.0T using acoustically triggered 2D CINE SSFP imaging. ACT’s superior robustness has been demonstrated by eliminating the frequently-encountered difficulty of mis-triggering due to ECG-waveform distortions or temporal jittering in the pulse-oximetry synchronization. The MR stethoscope presents no risk of high voltage induction and patient burns, patient comfort and ease of clinical use, which all have practical, patient comfort and safety implications.

MR stethoscope: a practical solution for cardiac gating at 1.5T, 3.0T and 7.0T.

Tobias Frauenrath, Wolfgang Renz, Katharina Fuchs, Fabian Hezel, Matthias Dieringer, Jeanette Schulz-Menger, Thoralf Niendorf

1 Max-Delbrück-Center for Molecular Medicine (MDC), Berlin, Germany
2 Siemens Medical Solutions, Erlangen, Germany
3 Charité, University Medicine HELIOS-Clinics and Max-Delbrück-Center for Molecular Medicine (MDC), Berlin, Germany
From Artifact to Merit: Cardiac Gated MRI at 7T and 3T Using Magneto-Hydrodynamic Effects for Synchronization

Tobias Frauenrath1, Matthias Dieringer1,2, Nishant Patel1, Celal Özerdem1, Jan Hentschel1, Wolfgang Renz1,3, and Thoralf Niendorf1,2

1Berlin Ultrahigh Field Facility, MDC Berlin, Berlin, Germany
2Charité Campus Buch, Humboldt-University, Experimental and Clinical Research Center (ECRC), Berlin, Germany
3Siemens Healthcare, Erlangen, Bayern, Germany

ECG is corrupted by magneto-hydrodynamic effects at higher magnetic field strength. Artifacts in the ECG trace and severe T-wave elevation might be mis-interpreted as R-waves. MHD being inherently sensitive to blood flow and blood velocity provides an alternative approach for cardiac gating, even in peripheral target areas far away from the commonly used upper torso positions of ECG electrodes. This feature would be very beneficial to address traveling time induced motion artifacts and trigger latency related issues raised by ECG-gated peripheral MR angiography. For all those reasons, this work proposes the use of MHD-trigger for cardiac gated MR.
Rapid Myocardial Parametric T2* CINE Imaging at 7T

Fabian Hezel, Thoralf Niendorf1,2

1 Berlin Ultrahigh Field Facility, Max-Delbrueck Center for Molecular Medicine, Berlin, Germany
2 Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Humboldt-University, Berlin, Germany

Introduction
Myocardial T2* mapping is an alternative to first pass perfusion techniques and can help to relax scan time constraints due exogenous contrast agents by facilitating blood as an endogenous contrast agent. With the BOLD effect regional perfusion deficits can be detected and ultrahigh field CMR can profit from an super linear increase in BOLD sensitivity.

Methods
Volunteer experiments were performed on a 7.0 T whole body MR system (Magnetom, Siemens, Erlangen, Germany) together with a dedicated 16-element TX/RX cardiac coil array using a prospectively triggered spoiled 2D CINE multi echo gradient echo sequence. Images were co-registered and T2* was pixel wise calculated by an mono-exponential fit.

Results
No severe susceptibility artifacts were detected in the inferoseptal myocardium and in the anterior lateral wall for TE ranging between 3.06 and 11.22 ms. T2* was found to be at 16±3 ms for all cardiac segments and cardiac phases.

Conclusion
Our findings demonstrate the applicability of a 2D spoiled gradient-echo multi-echo based approach for rapid CINE T2* mapping of the heart by transferring the baseline SNR advantage of 7.0 T into the use of 2.5 mm slices thicknesses and an in-plane spatial resolution of 1.5 mm
In pursuing the goal of non-invasively imaging the function of the brain a range of techniques have been developed. Those can be divided into methods which measure either neuronal activity directly, such as EEG and MEG, or rely on hemodynamic effects as used for instance in fMRI. Whereas the former suffers from poor spatial resolution, the latter represents only an indirect method of measuring neuronal activity. Recent attempts in using high field MR for direct neuronal imaging are still a matter of debate [1]. The alternative approach of utilizing Low Field Nuclear Magnetic Resonance (detection field below the earth field) promises to be a novel tool for the direct detection of time dependent neuronal currents and their associated magnetic fields. As part of the Bernstein Centre for Neurotechnology Berlin, our group at the PTB aims to demonstrate experimentally the possibility of recordings of neuronal currents by means of Low Field Magnetic Resonance.

Influence of loop array geometry on near field transmit properties at 300 MHz

Mikhail Kozlov, Robert Turner

Max Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

We present numerical investigation for a set of loop array geometry/load configurations obtained by RF circuit and frequency domain 3-D EM co-simulation. This is a very powerful and fast method for array coil investigation, since one multi-port 3-D EM simulation, which can be calculated in a reasonable time, is sufficient for obtaining the array transmit properties with several tuning/feeding/decoupling conditions. For circular polarization mode excitation, and ideal array design conditions, the 2-D and 3-D near-field transmit properties vary little between non-overlap, contiguous and overlap array configurations, if the separation between the array and the load is more than 20 mm, despite significant differences in the entire S-parameter matrices.
Disagreement of local RF power deposition and SAR in FDTD simulations

André Kuehne, Frank Seifert, Bernd Ittermann
Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin, Germany

Introduction
Finite differences time-domain (FDTD) simulations using human voxel models become increasingly popular in local-SAR estimations. However, unphysical variations in local-SAR output are occasionally observed after minor mesh variations. Here, we attempt to clarify this by comparing commercial and in-house SAR calculations.

Methods
In XFDTD (Remcom, State College, USA) we modeled a 16-rung low-pass birdcage coil at 123 MHz. A virtual human head (“Duke”) was imported at 0.5 mm isotropic resolution and then remeshed to resolution from 2 mm to 0.5 mm using different meshing modes. From XFDTD’s field data output we calculated the 10-g averaged SAR for ourselves and compared it to the program’s results.

Results
XFDTD’s local-SAR output shows a strong, erratic dependence on the mesh resolution with variations up to 77%. This is not a bug but rather a consequence of the IEC C95.3 standard applied by any commercial FDTD software. The standard’s aim to be conservative occasionally results in unphysical combinations of E-field, conductivity and density at certain material boundaries. This leads to artificial “SAR hotspots” without any corresponding maximum of the local power deposition. Our own algorithm deliberately violates the standard but its results are completely free of erratic SAR variations.

Conclusion
For certain pathological configurations, standard-compliant calculations yield unphysically large local SAR values. Optimized SAR-calculation routines can assist not only in identifying these cases but also in finding meshes where even the standard compliant algorithm produces acceptable results.
Introduction
For spatially selective excitation (SSE), conventionally the excitation magnitude is on/off modulated in- and outside the target region. Recently, the Bruker group introduced a phase-modulation approach and demonstrated its feasibility in phantoms in a small-animal scanner. Here, we compare the performance of both approaches for SSE in the human head.

Methods
SSE images in a water-based phantom and two healthy volunteers were acquired with a 3D FLASH sequence (FA=10°; TE/TR=4.5/15 ms; matrix=128^2x26) on a clinical 3 T scanner (Siemens Verio) with 8-channel Tx-array using an 8-channel Tx/Rx head coil (Rapid Biomedical). SSE target was a homogeneous square, FOX=(80 mm)^2.

Results
In a water-like phantom both methods excite the desired target pattern but background suppression is superior with phase modulation. In vivo only the phase based approach produces convincing results. Generally, phase modulation appears to be the more robust and less artifact-prone approach.

Conclusion
In summary, we obtain excellent performance of phase-modulation SSE in a clinical 3-T scanner. The higher tolerance of this approach to experimental imperfections pays off especially in vivo and appears to outweigh the necessity to acquire two images.
Adapted Tx-SENSE excitation to account for inhomogeneous slice refocusing at 7T

T. D. Lindel¹,², F. Seifert¹², M. Dietterle¹², T. Niendorf², and B. Ittermann¹²

¹Physikalisch-Technische Bundesanstalt (PTB), Braunschweig und Berlin, Germany,
²Berlin Ultrahigh Field Facility, Max-Delbrück-Centrum für Molekulare Medizin (MDC), Berlin, Germany

Introduction
Parallel transmission (pTx) is frequently used to address $B\_1^+$ inhomogeneity issues at ultrahigh magnetic fields. 2D-Tx-SENSE pulses are well established for planar SSE but excite the whole object in the normal direction. We investigate the effect of a (conventional) slice selective refocusing pulse on the quality of SSE images.

Methods
All experiments were performed on a clinical 7-T scanner (Siemens Healthcare, Erlangen) equipped with an 8-channel Tx array. An 8-channel Tx/Rx head coil (Rapid Biomedical, Rimpar) was used to image water-based head phantom. The SSE target pattern was a homogeneous 80x80 mm² square with apodized profile.

Results
Refocusing even with a $B\_1$ shimmmed pulse after homogeneous 2D-SSE results in serious image inhomogeneities as it transfers the limited performance of $B\_1$ shimming back into the image. However, based on measured $B\_1^+$ maps for each coil element the $B\_1$ shimming efficacy and residual distortion due to the refocusing pulse can be determined in advance. By pre-distorting the target pattern correspondingly, adapted 2D-SSE pulses were calculated, compensating the imperfections of the refocusing. With this approach we achieve excellent definition of the target pattern.

Conclusion
We demonstrated the need for and the feasibility of corrective measures if 2D-SSE is to be combined with a conventional (even $B\_1$ shimmmed) slice selective refocusing pulse. The proposed adaptation step can easily be implemented into any existing SSE pulse calculation.
A longitudinal study on status-epilepticus induced neurodegeneration: Observations in a rat model at 7 tesla

M. Meier1, J. P. Bankstahl1, M. Bankstahl1, H. Hedrich2, H. Lanfermann4, W. Löscher2, X. Q. Ding4

1 Small Animal Imaging Unit, Hannover Medical School, Hannover, Germany
2 Department of Pharmacology, Toxicology and Pharmacy, University of Veterinary Medicine, Hannover, Germany
3 Institute of Laboratory Animal Science, Hannover Medical School, Hannover, Germany
4 Institute of Diagnostic and Interventional Neuroradiology, Hannover Medical School, Hannover, Germany

Introduction
Brain insults like status epilepticus (SE) often lead to the development of chronic epilepsy and distinct neurodegeneration. MR relaxometry with T2 relaxation time mapping can be used to determine numeric T2 values of brain tissues. To examine microstructural alterations in the brain this is not only useful in scientific research, but also helpful as a sensitive clinical diagnostic tool. As MR systems with higher field strengths (> 3 T) become more common in research and clinical use, a reliable and practicable method for T2 mapping at higher field strengths is needed.

Subjects and Methods
To generate reference data for our own studies, first three naïve female adult Sprague-Dawley rats underwent consecutive MR examinations on a Bruker Pharmascan 70/16. Our protocol combined a T1-MDEFT sequence for imaging anatomic structures and two different aligned MSME-T2-map sequences containing different echoes. T2 maps were obtained on a voxel-by-voxel basis using nonlinear least-squares fit. T2 values of the grey and white matter were measured in exemplary regions (2) of interest. Following baseline scans, a number of rats were scanned immediately (1h) after a pilocarpine-induced (1) SE. The surviving rats were examined 48 hours, seven days and one, three and six months later. Finally, we compared SE-induced alterations detected by MR with histological alterations in immunostained brain sections.

Results
T2 values of about 49 ms for the cortex and 40 ms for white matter were determined in naïve rats. We observed dynamic brain alterations after SE. Cellular edema and swelling reached a maximum at 48 hours after SE. We found visible lesions in temporal cortex, hippocampus, substantia nigra and thalamus. The hippocampal lesions showed a clear lamellar necrosis. This indicates different vulnerability of the cellular structures. After one week, lesions were reduced, but global brain atrophy occurred and kept in progress until six months after SE. The measured T2 values confirmed these observations.

Conclusion
Morphological findings in the brain after SE are well complemented by T2 relaxation time measurements. T1- and T2-weighted images do sufficiently characterize changes in brain morphology after SE. Thereby drastically reducing the number of animals and otherwise unacceptable time consumption needed for longitudinal studies without MRI.

References
(1) Glien et al., Repeated low-dose treatment of rats with pilocarpine: low mortality but high proportion of rats developing epilepsy, Epilepsy Res. 46 (2001), pp.11-119
MRI Characterization of Pathophysiological Changes in a Mouse Model of Acute Kidney Injury (AKI)

A. Pohlmann1, L. Marko2,3, B. Wagenhaus1, U. Hoff4, E. Seeliger5, D. N. Mueller2,3, and T. Niendorf5

1Berlin Ultra-high Field Facility, Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
2Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
3Experimental and Clinical Research Center, Charité University Medicine, Berlin, Germany
4Clinic for Nephrology, Charité University Medicine, Berlin, Germany
5Institute of Vegetative Physiology, Charité University Medicine, Berlin, Germany

Introduction
Renal medullary hypoperfusion and hypoxia play a key role in acute kidney injury (AKI). Our aim was to assess and quantify changes in renal hemodynamics and oxygenation in mice after ischemia/reperfusion injury (I/R) in a time-dependent manner.

Material and Methods
Using a 9.4T MRI we assessed tissue oxygenation and edema (via T2*(BOLD) and T2 contrast respectively) in the kidneys of male C57BL/6 mice at 6 and 24h after 17.5 (mild AKI) or 30 min I/R (severe AKI) respectively. I/R was achieved by unilateral clipping; the unclipped kidney served as control.

Results
Kidneys after I/R all showed strong changes of T2 and T2* contrast in cortex and medulla. The medulla became darker on T2*-weighted images, suggesting hypoxia, and quantitative mapping of T2* confirmed a T2* decrease of >20%. In contrast, the cortex became brighter on T2-weighted images, suggesting edema. These alterations occurred already in the early phase of AKI at 6h post I/R. Equally dramatic effects were observed even after mild I/R (17.5 min), but particularly highlighted the cortex-medulla interface.

Conclusions
In-vivo MRI characterization of pathophysiological changes in mouse AKI is feasible and a sensitive method. The early changes in T2 and T2* may serve as biomarkers of edema and hypo-/hyper-oxygenation after I/R.
Design and Application of 5 Channel Tx/Rx Coil for High Spatial Resolution Laryngeal MRI at 7 Tesla

Jan Rieger, Christof Thalhammer, Wolfgang Renz, Lukas Winter, Tobias Frauenrath, Andreas Goemmel, Thoralf Niendorf

Introduction
MRI holds great potential for assessment of laryngeal tumor progression and elucidating laryngeal anatomy and physiology of human phonation [1, 2]. Though, it remains very challenging due to the subtle targeted structures, which translates into stringent technical requirements in balancing image contrast, spatial resolution and signal to noise ratio.

Methods
The coil array comprises 5 elements of overall dimensions 6x21 cm$^2$. The layout was etched on FR4 former and placed in ABS casing produced by rapid prototyping. The RF shield was positioned in the distance of 15 mm from the former and 5 cable traps were fixed behind the RF shield. EM simulations were performed (CST MWS, CST AG, Darmstadt, Germany) to assure RF safety.

Results
The reflection: below -33 dB; decoupling: better than -11 dB for neighboring elements; mean unloaded Q = 135; mean loaded Q = 52; mean unloaded/loaded Q = 2.5. SNR provided by the array enabled an acquired spatial resolution of (0.25 x 0.25 x 0.25) mm$^3$.

Conclusion
The laryngeal array was found to meet the needs of isotropic, sub-millimeter spatial resolution imaging of the larynx and the vocal tract at 7.0 T. It provides patient comfort and ease of use due to its light weight. We anticipate using this to study laryngeal tumour progression and phonation processes.

References
Mapping the static magnetic field via the phase evolution over gradient echo scans acquired at two or more echo times is an established method. A number of possibilities exist, however, for combining phase data from multi-channel coils, denoising and thresholding field maps for high field applications. Three methods for combining phase images when no body/volume coil is available are tested: (i) Hermitian product, (ii) phase-matching over channels, and (iii) a new approach based on calculating separate field maps for each channel. The separate channel method is shown to yield field maps with higher signal-to-noise ratio than the Hermitian product and phase-matching methods and fewer unwrapping errors at low signal-to-noise ratio. Separate channel combination also allows unreliable voxels to be identified via the standard deviation over channels, which is found to be the most effective means of denoising field maps. Tests were performed using multichannel coils with between 8 and 32 channels at 3 T, 4 T, and 7 T. For application in the correction of distortions in echo-planar images, a formulation is proposed for reducing the local gradient of field maps to eliminate signal pile-up or swapping artifacts. Field maps calculated using these techniques, implemented in a freely available MATLAB toolbox, provide the basis for an effective correction for echoplanar imaging distortions at high fields.
Measurement of Human Cardiac $T_1$ in vivo at 7 Tesla

Christopher T. Rodgers¹, Stefan K. Piechnik, Lance J. DelaBarre, Stefan Neubauer, Matthew D. Robson, J. Thomas Vaughan

¹University of Oxford, Cardiovascular Medicine, Oxford, UK

Quantitative maps of the longitudinal relaxation time ($T_1$) have proved useful for characterizing diseased tissue at field strengths of 1.5–3T as used in clinical MRI. $T_1$ maps may be reliably measured by Look-Locker inversion recovery sequences; indeed with the ShMOLLI sequence this may be done in a single short breath hold. This work extends the repertoire of 7T cardiac MR by producing what we believe to be the first example of effective inversion over the whole human myocardium of typical adults. This required 16x 1kW RF amplifiers, a 16-element stripline TEM coil and a 10ms HS8 inversion pulse. A variant of the ShMOLLI $T_1$ mapping sequence employing this inversion pulse and TrueFISP or FLASH readouts was then validated on a Gd³⁺ phantom before being used to make the first measurements of myocardial $T_1$ at 7T. In 5 healthy volunteers, the myocardial $T_1$ was found to be 1405 ± 50ms, consistent with previous lower field results (1.5T = 980ms, 3T = 1198ms). Knowledge of the myocardial $T_1$ will be useful for estimating and optimizing the contrast in future MRI experiments at 7T. Furthermore, the FLASH readout was found to be preferable to SSFP at 7T in this application because it demonstrated fewer $B_1$-inhomogeneity artefacts and had less stringent SAR requirements. Blood in-flow effects gave markedly non-exponential magnetisation recovery in the LV blood pool.
Assessment of RF induced heating of coronary stents in 7T MRI

D. Santoro¹, J. M. Vogt², Alexander Müller⁴, W. Renz³, F. Seifert⁴, V. Tkachenko⁵, J. Schulz-Menger⁵, and T. Niendorf¹,⁵

¹Berlin Ultra-High Field Facility (BUFF), Max-Delbrück-Center for Molecular Medicine (MDC), Berlin, Germany
²Department of Physics, Humboldt University Berlin, Germany
³Siemens Healthcare, Erlangen, Germany
⁴Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany
⁵Experimental and Clinical Research Center (ECRC), Charité Campus Berlin, Germany

Introduction
Cardiac MRI at 7T could benefit of the high SNR¹, however intracoronary stents are a contra-indication. The metallic implant together with RF power deposition may induce heating and myocardial tissue damage. Here, we examined RF induced heating of coronary stents in agarose phantoms using electromagnetic field simulations, fiber optic temperature measurements and MR thermometry.

Methods
An eight-rung birdcage RF coil was build to provide RF power up to 50W. Cylindrical phantoms with a cobalt chromium alloy coronary stent were used. EMF simulations were performed using a FDTD method (CST software, Germany). RF heating was achieved with single pulse experiment with for 5 minutes. The proton resonance frequency method (PRF) ² was used to monitor temperature changes in the phantom experiments; also a fiber optics system (Luxtron) was used. Experiments were conducted on a 7T scanner (Siemens).

Results
We found qualitative agreement between simulated and experimental temperature maps. Due to the MRI artifact induced, data obtained right at the stent are not considered. Temperature maps are acquired for 90 minutes of heating with an absorbed power of 11W.

Discussion
For the stent used in this work, no hot spots were evident in the 3D-temperature maps. Further investigations are required before intracoronary stents can be declared safe in a 7.0 T scanner.

References
Periventricular Venous Density in MS Patients Correlates with T2 Lesion Load- A 7 Tesla MRI Study

Tim Sinnecker1, Paul Mittelstaedt1, Jan Dörr1,2,3, Caspar F. Pfueller1,3, Lutz Harms3,4, Thoralf Niendorf5, Friedemann Paul1,2,3, Jens Wuerfel1,6

1NeuroCure Clinical Research Center, Charité University Medicine Berlin, Berlin, Germany
2Experimental and Clinical Research Center, Charité University Medicine Berlin and Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
3Clinical and Experimental Multiple Sclerosis Research Center, Charité University Medicine Berlin, Berlin, Germany
4Department of Neurology, Charité University Medicine Berlin, Berlin, Germany
5Berlin Ultrahigh Field Facility, Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
6Institute of Neuroradiology, University of Luebeck, Luebeck, Germany

Introduction
One century ago, J.W. Dawson histologically described MS plaques to be mostly centred around a small cerebral vein. Today, vascular abnormalities in MS patients can be studied in vivo using MRI. At 7 Tesla (T), FLASH MRI techniques depict small cerebral veins with great anatomical detail due to the gain in signal-to-noise ratio. This work studies the correlation of small venous abnormalities, T2 lesion load and lesion distribution in multiple sclerosis (MS) patients in comparison to healthy control subjects using 7T MRI.

Methods
20 MS patients and 10 matched healthy controls were investigated at 7T. The imaging protocol included 2D FLASH, a fluid attenuated sequence (TIRM) and 3D T1-weighted MPRAGE.

Results
MS patients showed a significantly (p=0.0009) lower amount of periventricular veins (PV) detectable in 2D FLASH images at 7T (mean±SD veins per ROI: 6.5±1.9) compared to healthy controls (mean±SD veins per ROI: 8.6±0.9). Within the MS cohort, the venous density correlated inversely with disease severity as indicated by T2 lesion load. In total, we detected 435 cerebral MS lesions (mean, range: 25.6, 8-72). In contrast, healthy control subjects did not present with any detectable brain pathology.

Conclusions
The density of detectable periventricular veins in MR images obtained at 7T can be used to differentiate MS patients from healthy controls. The reduction of visualized veins in MS correlates with T2 lesion load. Our findings indicate cerebral vascular alterations in MS. It should be also noted, that our findings contradict the hypothesis of increased intracerebral venous pressure resulting from a chronic cerebrospinal venous insufficiency in MS, a recently suggested - but controversially discussed - pathomechanism of MS development and especially “Dawson’s fingers”, and therefore challenge this interpretation.
Is Every Multiple Sclerosis Lesion a “Black Hole”? Comparison of T1-Weighted MRI AT 1.5T and 7.0T

Tim Sinnecker, Paul Mittelstädt1, Jan Dörr1,3, Caspar F. Pfueiler1,3, Lutz Harms3,4, Thoralf Niendorf5, Friedemann Paul1,2,3, Jens Wuerfel1,6

1NeuroCure Clinical Research Center, Charité University Medicine Berlin, Berlin, Germany
2Experimental and Clinical Research Center, Charité University Medicine Berlin and Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
3Clinical and Experimental Multiple Sclerosis Research Center, Charité University Medicine Berlin, Berlin, Germany
4Department of Neurology, Charité University Medicine Berlin, Berlin, Germany
5Berlin Ultrahigh Field Facility, Max-Delbrueck-Center for Molecular Medicine, Berlin, Germany
6Institute of Neuroradiology, University of Luebeck, Luebeck, Germany

Introduction
In current clinical practice, T2-weighted MRI is commonly applied to quantify the accumulated MS lesion load, whereas T1-weighted techniques are used to depict edema, blood brain barrier breakdown after contrast enhancement and irreversible brain tissue damage (commonly called “black holes”). Black holes are histopathologically associated with axonal loss and severe tissue destruction. In this study we demonstrate the potential of 7T 3D T1-weighted imaging using magnetization-prepared rapid acquisition and multiple gradient echoes (MPRAGE) in detecting and characterizing white and grey matter pathology in multiple sclerosis (MS).

Design/Methods
20 MS patients and 10 matched healthy controls were investigated at 7T. The imaging protocol included 2D FLASH, a fluid attenuated sequence (TIRM) and 3D T1-weighted MPRAGE. For comparison, all subjects were scanned on a 1.5T system.

Results
In total, we detected 526 cerebral lesions in the patient cohort (range: 2 – 107, mean: 25.6), but none in healthy controls. In eight patients, we found 3 cortical and 36 mixed cortical/sub-cortical lesions. At 7T, each lesion detected in T2- and or DIR sequences was also clearly delineated in the corresponding MPRAGE images. In contrast, 1.5T MPRAGE only revealed 418 lesions. Furthermore, no cortical and only 20 mixed lesions were visualized by T1-weighted images at 1.5T.

Conclusions
At ultrahigh field strength, T1-weighted MPRAGE is highly sensitive in detecting MS lesions as hypointensities in the white as well as the grey brain matter. Our results indicate a structural damage of every lesion depicted, which is in accordance with postmortem histopathological studies, that demonstrated axonal transection in each MS lesion, visible as terminal axonal ovoids. Furthermore, at 7T, MPRAGE clearly delineated each cortical lesion that was visualized in any other MRI sequence at 1.5T or 7T.
A Two-dimensional 16 Channel Transceiver Coil Array for Cardiac MR at 7.0 T

**C. Thalhammer**, W. Renz\(^1\,\,^2\), H. Pfeiffer\(^3\), J. Rieger\(^1\), L. Winter\(^1\), F. Hezel\(^1\), F. Seifert\(^3\), W. Hoffmann\(^3\), R. Seemann\(^3\), and T. Niendorf\(^4\)

\(^1\)Berlin Ultrahigh Field Facility, Max-Delbrueck Center for Molecular Medicine, Berlin, Germany
\(^2\)Siemens Healthcare, Erlangen, Germany
\(^3\)Physikalisch-Technische Bundesanstalt (PTB), Braunschweig und Berlin, Germany
\(^4\)Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Berlin, Germany

**Introduction**

Several obstacles make cardiac MR at 7.0 T a challenging task, especially effects related to the RF fields at 300 MHz. This work proposes a two dimensional 16-channel transceiver array using loop elements and demonstrates its applicability for cardiac MR at 7.0 T providing a uniform intensity distribution and good parallel imaging performance.

**Methods**

The coil array consists of a planar posterior section and a curved anterior section. Both comprise 2 x 4 rectangular loop elements with a size of 13 cm x 6 cm. Adjacent elements were decoupled by a common conductor and decoupling capacitor. MR experiments were performed on a Siemens 7 T scanner. The RF amplifier output of the scanner was divided into 16 equal intensity signals using a home-built 16 x 16 Butler matrix.

**Results**

An in-vivo study in 9 healthy male subjects was performed. The RF characteristics were satisfying and a modified phase setting of the Butler matrix provided a rather uniform intensity distribution for all subjects. 2D CINE FLASH acquisitions exhibited an excellent myocardium blood contrast. The overall image quality was found to be clinically acceptable. Parallel imaging using reduction factors up to 4 did not impair image quality significantly.

**Conclusions**

The results demonstrate that the proposed coil array is capable of producing highly uniform, high resolution cardiac images at 7.0 T with excellent myocardium blood contrast.
In this study we demonstrate the benefits of cryogenically-cooled RF coil technology to produce microscopic MR images in vivo, with sufficient detail to reveal brain pathology. Using the experimental autoimmune encephalomyelitis (EAE) model, we could visualize inflammatory infiltrates in microscopic detail within various regions of the brain, already at an early phase of disease. Importantly, this pathology could be seen clearly even without the use of contrast agents, and showed excellent correspondence with conventional histology. We generated microscopic MRI images of mouse CNS with a spatial resolution as low as 35 micrometers. This resolution permits the discrimination of anatomical detail in a mouse model comparable to that attainable in human brain using clinical MRI scanners.

Furthermore, the cryogenically-cooled RF coil technology enables the acquisition of these high resolution images with short scan times – an important practical consideration in conducting animal experiments. The detail of the inflammatory infiltrates visualized by in vivo microscopic MR imaging allows the opportunity to follow the processes of neuroinflammation through various phases of disease progression, enabling longitudinal studies of the kinetics and dynamics of inflammatory infiltration and damage, which will complement conventional histological examination. Moreover, the benefits of microscopic MRI go beyond EAE studies, and have applicability to the wider neuroscience community employing other disease models.
Introduction

T_2 relaxation plays an important role in the absolute quantification of brain metabolites. Although T_2 may be subject and even brain-region dependent, global literature values are typically used. We determined T_2 values for five brain metabolites and water and studied their age dependence.

Subjects and Methods

At 3T, six metabolite (TE=30,50,80,135,250,330 ms, TR=3s, 100 averages) and seven unsuppressed water spectra (TE=30,80,160,276, 552,1000,1500ms, TR=10s, 2 averages) were acquired by 1H-MRS (PRESS) in the anterior cingulate cortex (ACC, 2.5cmx4cmx2cm) of ten healthy volunteers. All signals were quantified with LCModel, incorporating basis sets simulated for each TE, and fitted (QtiPlot) with bi-exponential (water) and mono-exponential (metabolites) decay functions.

Results

We obtained average T_2 values in the ACC voxel of (in ms, mean±SD): tNAA 284.7±29.2, tCr: 166.9±11.3, tCho: 292.6±37.9, Ins: 240.2±22.6, and Glu: 148.0±12.1. T_2 values of tCr, tNAA and tCho (trend) decrease with age. Water T_2 was (75.5±4.6)ms for gray and white matter and (675±117)ms for CSF.

Discussion

The T_2 values of five major brain metabolites were measured at 3 T. T_2(Ins) had not been determined before. The observed age dependence of some metabolite T_2’s suggests the need for individual relaxation corrections for MRS at longer TE.
RF multi-channel coil optimization at 7T using a Tx array

Patrick Waxmann, Ralf Mekle, Harald Pfeiffer, Tomasz D. Lindel, and Bernd Ittermann
Physikalisch-Technische Bundesanstalt (PTB) und Berlin Ultrahigh Field Facility, Berlin, Germany

Introduction
Magnetic resonance spectroscopy (MRS) at 7 T needs high $B_1^+$ intensities to limit chemical shift artifacts. For this purpose we built a dedicated two-channel Tx/Rx MRS coil for the back of the head. Conventionally, relative Tx phases are configured for a circularly polarized (CP) mode giving constructive interference in the center of the head. Here, we investigated the possible gain if the Tx phase offsets are optimized individually for different target ROIs.

Methods
The coil was built of thin copper foil strips forming two rectangular, capacitively decoupled surface elements of 13 cm x 11.5 cm each. Measurements were performed on a 7 T scanner (Siemens, Erlangen, Germany), equipped with an 8-channel Tx array. Phase sensitive $B_1^+$ maps for each channel were acquired using a preparation pulse technique. Phase settings for maximum $B_1^+$ in predefined ROIs were derived from these maps. These phase offsets were realized in hardware so the coil could be used on the normal Tx path without the Tx array.

Results/Conclusion
We observe good agreement between predicted and measured $B_1^+$ maps for the combined mode. Relative to the CP mode, up to 36% RF power could be saved just by ROI specific phase optimization. Independent characterization of each coil element using a Tx array facilitates the optimization of the $B_1^+$ performance in any given ROI and thus accelerates hardware development.
MRI.TOOLS
Dear valued guests,

The strong static magnetic field used in MR imaging can interfere with metallic and electromechanical, implantable medical devices in people exposed to the magnetic field. Examples of medical devices are heart pacemakers, clips, prosthesis, stents, mitral and aortic valve replacements, cochlear implants, insulin pumps, neuro-stimulators and others. Interference between the magnetic field and implantable medical devices can cause tissue damage and/or damage to the implantable medical device. Therefore we kindly ask those visitors fitted with a heart pacemaker and/or other implantable medical devices NOT to enter the MR facility during the Open Day session.

Please accept our sincere apologies for any inconvenience this safety measure might cause but your very personal safety always comes first.

your safety comes first!!!

Sicherheitshinweis

Liebe Gäste,


Im Interesse Ihrer eigenen Sicherheit bitten wir um die strikte Einhaltung dieses Sicherheitshinweises und bedanken uns herzlichst für Ihr Verständnis.

your safety comes first!!!
The organizers gratefully acknowledge the symposium’s sponsors who provided kind contributions to foster science and educational activities.

We cordially invite you to visit the technical exhibition!
Exhibition in the MDC.C Foyer

Exhibitors

- Circle
- Stark Contrast
- MRI.TOOLS GmbH
- Medrad
- Tomtec
- Bruker
- CST
- TSB
TSB Innovationsagentur Berlin GmbH
Common Facilities

- A 8 Gate House with Café Max and apartments
- A 9 Reception
- A 13 Life Science Learning Lab; CampusInfoCenter
- A 14 Cafeteria

Guesthouses of the MDC

- B 54 Hans-Gummel-Guest House
- B 61 Kindergarten; Salvador-Luria-Guest House

Research

- Max-Delbrück-Center for Molecular Medicine (MDC)
  - C 27 Walter-Friedrich-House
  - C 31 Max-Delbrück-House
  - C 83 Max-Delbrück-Communications Center
  - C 84 Hermann-von-Helmholtz-House
  - C 87 Timoféeff-Ressovsky-House
  - C 71
  - B 63 Research services
  - B 64
  - B 88 Ultrahigh Field Facility (MRT)
  - A 10 Library

Leibniz-Institut für Molekulare Pharmakologie

- C 81 Leibniz-Institut für Molekulare Pharmakologie (FMP)

Clinical Research

- B 46-51 Clinical Research

Companies

- A 15 car mechanics, EZAG, Charles River, WISAG
- B 55 Oskar und Cécile Vogt House
  - BBB Post office, patent lawyer
  - Dr. Baumbach, FILT, ConGen, E.R.D.E., Höppner, HUMAN, Zell GmbH,
  - TECAN, Dr. Scherrer, ART-CHEM, Roboklon, Gressus, Fresenius, 8sens.biognostic,
  - neptuntec
- B 64 epo
- D 16/23 Eckert & Ziegler AG, NEMOD, Eurotope, Glykotope, BEBIG, Eckert Consult,
  - Isotope Products
- D 79 Erwin Negelein House
  - Glykotope, Isotope Products, celares, imaGenes,
  - BioTeZ, Bavarian Nordic (House 31.1)
- D 80 Otto Warburg House
  - ARISE, Silence Therapeutics, Combinature,
  - PolyPhag Evotec AG
- D 82 Karl-Lohmann-House
  - Eckert & Ziegler, BEBIG, AJ Innuscreen
- D 85 Arnold Graffi House
  - BBB, I.M.S.M., Invitek, aokin,
  - Biosyntan, L.O.S., Clin. Research, rennesens,
  - Prof Wanker, MerLion, emp, Akademie der Gesundheit, Geneo Products
Anzeige Siemens