Traditional Posters: Pulse Sequences, Reconstruction & Analysis

B1 +/- Mapping
Hall B Monday 14:00-16:00

2828. B1 Mapping of an 8-Channel TX-Array Over a Human-Head-Like Volume in Less Than 2 Minutes; The XEP Sequence
Alexis Amadon1, Nicolas Boulant1, Martijn Anton Cloos1, Eric Giacomini1, Christopher John Wiggins1, Michel Luong2, Guillaume Ferrand2, Hans-Peter Fautz3
1Neurospin, CEA/DSV/I2BM, Gif-sur-Yvette, France; 2IRFU, CEA/DSM, Gif-sur-Yvette, France; 3Siemens Healthcare, Erlangen, Germany

Efficient mitigation of the RF inhomogeneity using transmit coil arrays relies on the knowledge of the individual B1-maps. As the number of transmit channels increases, so does the acquisition time of all maps. Here we focus on a fast 2D sequence proposed by Fautz et al. which we adapt for multi-slice B1-mapping. We compare its results with that of the 3D AFI sequence on a spherical phantom surrounded by 8 transmit elements at 7T. We show comparable performance with a 12-fold increase in speed, making accurate B1-mapping of the human head feasible in 1.5 minutes for 8 transmit channels.

2829. B1 Mapping with Whole Brain Coverage in Less Than One Minute
Steffen Volz1, Ulrike Nöth1, Ralf Deichmann1
1Brain Imaging Center (BIC), Goethe University Frankfurt, Frankfurt am Main, Germany

There is great demand for fast B1 mapping techniques, e.g. for correction of quantitative T1 maps. However, most methods suffer from long experiment durations. The technique presented here is based on magnetization prepared FLASH imaging with specially designed preparation and excitation pulses to allow for multislice imaging, speeding up the acquisition. Systematic errors due to relaxation effects are avoided by intensity correction of individual k-space lines. The method allows for fast B1 mapping with whole brain coverage, an in-plane resolution of 4 mm, a slice thickness of 3 mm, and an accuracy of 2% within 46 s.

2830. Fast RF Flip Angle Calibration by Bloch-Siegert Shift
Laura Sacolick1, Ling Sun2, Mika W. Vogel1, Ileana Hancu3
1GE Global Research, Garching b. Munchen, Germany; 2GE Healthcare, Waukesha, WI, United States; 3GE Global Research, Niskayuna, NY, United States

Here we present a novel method for automated RF flip angle calibration based on the Bloch-Siegert shift. The Bloch-Siegert shift is an effect where spin resonance frequency shifts when an off-resonance RF field is applied. Two off-resonance RF pulses were added to a slice-selective spin echo sequence. The off-resonance pulses induce a phase shift in the acquired signal that is proportional to B1. The signal is spatially localized in two dimensions- by slice selection and readout filter, and the signal weighted average k-space lines. The method allows for fast B1 mapping with whole brain coverage, an in-plane resolution of 4 mm, a slice thickness of 3 mm, and an accuracy of 2% within 46 s.

2831. Fast and Robust B1 Mapping at 7T by the Bloch-Siegert Method
Mohammad Mehdi Khalighi1, Laura I. Sacolick2, W Thomas Dixon2, Ron D. Watkins4, Sonal Josan4, Brian K. Rutt4
1Applied Science Lab, GE Healthcare, Menlo Park, CA, United States; 2Imaging Technologies Lab, General Electric Global Research, Garching b. Munchen, Germany; 3GE Healthcare, Waukesha, WI, United States; 4Department of Radiology, Stanford University, Stanford, CA, United States

B1 mapping is a critical step in the design of RF pulses for parallel transmit systems. We used the Bloch-Siegert (BS) B1 mapping method and a 2-channel parallel transmit enabled 7T scanner to produce fast, robust and accurate B1 maps through the human brain. Both B1 magnitude and phase are obtained from a single sequence, employing +/-4kHz off-resonance BS pulses. B1 magnitude and phase maps acquired with a 26s BS scan are compared with those acquired with a 640s classical double angle scan, showing that the BS method is a very good candidate for efficient B1 mapping at 7T.

2832. Practical Vector B1 Mapping at 7T
Douglas Kelley1, Janine Lupo1
1Applied Science Laboratory, GE Healthcare, San Francisco, CA, United States; 2Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, CA, United States

Compensation of B1 variations in vivo requires mapping both the magnitude and the phase of each channel's RF magnetic field. Since the field distribution is strongly dependent on the specific size, shape, and positioning of the tissue, such mapping must be made for each subject. We present a practical method for acquiring these maps within 10 minutes in phantoms and human subjects at 7T.
The potential to accelerate the B1+ mapping measurement by means of compressed sensing (CS) was investigated. Joint sparsity constraint accounting for the common sparsity support in different TX channels, and higher dimensional undersampling space, also including the coil dimension, allow for considerable acceleration even for the low resolution data acquired in B1+ mapping. The basic feasibility of the proposed method is evaluated on simulations and in vivo data from a 3T 8-channel parallel transmit system.

We present a simultaneous δ B0 and high-dynamic range B1 mapping technique using an adiabatic partial passage pulse. The double angle method, the gold standard for B1 mapping, requires 66% longer to acquire the same B1 range. The high dynamic range is useful for mapping the fields from ablation wires or surface coils, where significant B0 variation will also be present.

We present a fast B1+ mapping method for parallel transmit system and validate the performance on water phantom in 7T. The measured flip angle matches with the flip angle simulated by the Bloch equation.

The purpose of this study was to develop a rapid, image-guided RF transmitter gain calibration procedure for high-field MRI and evaluate its performance through phantom and in vivo experiments at 3T and 7T. Using a single-shot TurboFLASH pulse sequence, a series of “saturation-no-recovery” images was acquired by varying the flip angle of the preconditioning pulse. In the resulting images, the signal null occurs in regions where the flip angle of the preconditioning pulse is 90°, and the mean signal within a region-of-interest can be plotted as a function of the nominal flip angle to quantitatively calibrate the RF transmitter gain.

The double angle Look-Locker method is an efficient 3D method of mapping transmit B1 inhomogeneity. It makes uses inversion pulses and samples the recovering magnetization using SPGR trains at two different angles. This leads to two time constants that can be combined to find the achieved flip angle. If the SPGR trains at the two angles are interleaved the inversion pulses can be omitted entirely, and the same information can still be extracted. This reduces SAR, simplifies data analysis and still yields nearly the same performance in terms of measuring the flip angle.

In this work, using 3D numerical simulations and verifications with a 7T scanner equipped with a transmit array system we conduct a comprehensive study using B1 shimming for potential 7T whole-body applications. Different from previous works [2], this study includes the optimizations of the B1+ field, local/average SAR and the resulting temperature elevation in the tissue.

RF inhomogeneity greatly affects the quality of MR imaging at high field strength, and compensation methods typically require accurate B1+ maps for optimum performance. Comparison of B1+ mapping methods based on experimental results alone is limited by lack of knowledge of the true B1+ field distribution. MRI simulation allows for comparison of the true, input B1+ field distribution
with a simulated map. This study simulates AFI and a flip angle series method at 3T, utilizing MRI and electromagnetic field simulations. The simulation maps correspond closely to the input B1+ and one another. Experimental maps deviate significantly from one another.

**B1 Mapping**

**Hall B Tuesday 13:30-15:30**

**2840. 3D Phase Sensitive B1 Mapping**

Steven Paul Allen1, Glen R. Morrell2, Brock Peterson1, Daniel Park1, Josh Kaggie2, Ernesto Staroswiecki1, Neal K. Bangerter1
1Department of Electrical and Computer Engineering, Brigham Young University, Provo, UT, United States; 2Department of Radiology, University of Utah, Salt Lake City, UT, United States; 3Department of Radiology, Stanford University, Stanford, CA, United States

Accurate quantification of tissue sodium concentration is an important component of several potential applications of sodium MRI. Quantitative analysis of sodium concentrations requires accurate measurement of B1. However, the low SNR typical in sodium MRI makes accurate B1 mapping in a reasonable time challenging. Phase-sensitive B1 mapping techniques are particularly robust in low SNR environments. In this work, we apply phase sensitive B1 mapping to sodium MRI, and compare it to a standard dual angle B1 mapping method. The phase sensitive method is shown to perform much better than the dual angle method, allowing rapid acquisition of reliable sodium B1 maps.

**2841. Image Inhomogeneity Correction in Human Brain at High Field by B1+ and B1−**

Hidehiro Watanabe1, Nobuhiko Takayama1, Fumiuki Mitsumori1
1Environmental Chemistry Division, National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan

We propose a correction method of image inhomogeneity at high field. The inhomogeneity is originated from B1+ and measurable B1−. We confirmed that a ratio map of B1− to B1+ (ρ) has a similar spatial pattern throughout human various brains from experimental results. The ratio map ρ in human brain was calculated from B1− maps and images obtained with adiabatic pulses. Then, B1− was calculated by ρ × B1+. Homogeneous intensity was achieved in the corrected images by B1+ and B1−. Water fractions in gray and white matters obtained from corrected M0 image were in good agreement with reported values.

**2842. Signal to Noise Ratio Analysis of Bloch-Siegert B1+ and B1− Mapping**

Mohammad Mehdi Khalighi1, Laura I. Sacolick2, Brian K. Rutt0
1Applied Science Lab, GE Healthcare, Menlo Park, CA, United States; 2Imaging Technologies Lab, General Electric Global Research, Garching b. Munchen, Germany; 3Department of Radiology, Stanford University, Stanford, CA

The Bloch-Siegert method (BS) has been recently introduced as a fast, robust and accurate method for B1− mapping. To compare it with other existing methods, we derived analytical expressions for SNR in BS, Actual Flip Angle Imaging (AFI) and Double Angle (DA) B1+ maps. Both theoretical and experimental comparisons show that the BS method has a higher SNR at low flip angles than the other methods, despite the shorter scan time of the BS method, making it a promising choice for B1− mapping for parallel transmit pulse design, especially in situations where there is highly non-uniform B1− across the object.

**2843. Sa2RAGE - A New Sequence for Rapid 3D B1−-Mapping with a Wide Sensitivity Range**

Florent Eggenschwiler1, Arthur Magill1,2, Rolf Gruetter1,3, José P. Marques1,2
1EPFL, Laboratory for Functional and Metabolic Imaging, Lausanne, Vaud, Switzerland; 2University of Lausanne, Department of Radiology, Lausanne, Vaud, Switzerland; 3Universities of Geneva and Lausanne, Department of Radiology, Switzerland

Sa2RAGE is based on the rapid acquisition of two images with low flip angles just before and after a saturation pulse. The ratio of the signals from the images can be linked to a specific B1−. Optimization of the sequence parameters allowed the derivation of a protocol that performs 3D B1−-mapping in ~30s (matrix size 64x64x16) with limited T1 dependence. Experimental work showed the accuracy of the B1−-mapping over a 10 fold range of B1−. In-vitro and in-vivo B1− maps were performed to demonstrate the applicability of the method on the context of parallel transmission.

**2844. Smoothing and Interpolation of In-Vivo B1+ Images**

Andreas Petrovic1,2, Yiqiu Dong1, Stephen Keeling2, Rudolf Stollberger4
1Institute of Medical Engineering, University of Technology Graz, Graz, Austria; 2Ludwig Boltzmann Institute for Clinical Forensic Imaging, Graz, Austria; 4University of Graz

MR images at high field strengths (≥1.5T) suffer from artifacts caused by the inhomogeneity of the RF excitation field B1+. In the human body. Measurements of B1+ can be used for the correction of those artifacts. However, these B1+ images suffer from perturbations themselves and have to be smoothed and interpolated. In this work a new variational approach for smoothing is compared to a standard median filter for test images, as well as real in-vivo data. Simulations show that the variational approach combined with an outlier suppression algorithm outperforms the median filter in terms of accuracy and precision. In contrast to the median filter the variational approach produces very smooth results that are physically likely.
B1 maps help scan set up and then aid in extracting quantitative results. Maps can be made by comparing either amplitudes or phases of two different images. Phase methods, with no waiting for T1, are fast. Phase avoids T1 issues but what about phase effects from flow and the chemical shift of fat? With a Bloch-Siegert, phase-based method, steady 0.5 m/s flow shifts phase 120° but leaves calculated B1 unchanged. Similarly, oil and water indicate the same B1 regardless of the fat-water phase difference. These results portend robust, phase-based B1 maps.

Small Animal MR Imaging Using a 3.0 Tesla Whole Body Scanner: Rapid B1+ Field Mapping for Quantitative MRI

Ryutarō Nakagami1,2, Masayuki Yamaguchi1, Akira Hirayama1,3, Akira Nabeta1,3, Atsushi Nozaki3, Takumi Higaki3,4, Natsumaro Kutsuna4,5, Seiichiro Hasezawa4,5, Hirofumi Fujii1,3, Mamoru Niitsu6

1Functional Imaging Division, National Cancer Center Hospital East, Kashiwa, Chiba, Japan; 2Graduate School of Human Health Sciences, Tokyo Metropolitan University, Arakawa, Tokyo, Japan; 3GE Healthcare Japan Ltd., Hino, Tokyo, Japan; 4Graduate School of Frontier Sciences, University of Tokyo, Kashiwa, Chiba, Japan; 5Institute for Bioinformatics Research and Development, Japan Science and Technology Agency, Chiyoda, Tokyo, Japan; 6Faculty of Health Sciences, Tokyo Metropolitan University, Arakawa, Tokyo, Japan

There has been growing interest in MR imaging studies of small animal models of human diseases as small animal MRI systems using a combination of 3.0 Tesla whole-body scanners and highly sensitive solenoid coils, which provides high spatial resolution and high sensitivity, as they are preferable for translational research. In this study, we demonstrate the feasibility of these MRI systems for quantitative MRI research by showing B1+ homogeneity in the mouse brain. In vivo B1+ maps were obtained by a rapid B1+ field mapping technique using a SPGR sequence and a brand-new calculation method for determining the 180° null signal.

Rapid RF Field Mapping Using a Slice-Selective Pre-Conditioning RF Pulse

Soehae Chung1, Daniel Kim1, Elodie Breton1, Leon Axel1

1Radiology, NYU Langone Medical Center, New York, NY, United States

The B1 field uniformity plays an important role in determining the image quality in MRI, since such an RF pulse excitation causes flip angle variations that confound quantitative results. In this study, we describe a novel and efficient method for rapid B1 mapping using a slice-selective pre-conditioning RF pulse followed by TurboFLASH pulse sequence. This method is insensitive to off-resonance, with less than 1.4% B1 measurement error up to 500 Hz off-resonance and the total scan time is less than 2 s with SR module.

Fast Phase-Modulated B1+ Mapping in the Low Flip-Angle Regime

Astrid L.H.M.W. van Lier1, Johannes M. Hoogduin2, Dennis J.W. Klomp2, Jan J.W. Lagendijk1, Cornelis A.T. van den Berg1

1Radiotherapy, UMC Utrecht, Utrecht, Netherlands; 2Radiology, UMC Utrecht, Utrecht, Netherlands

In high-field MRI, phased-arrays are used to mitigate RF issues as excitation field inhomogeneities. In order to design RF pulses that can produce a desired excitation field, the B1+ field per coil must be mapped. We show that it is possible to measure B1+ maps for phased arrays in the low flip angle regime using phase-modulation (PMLF). This technique was validated by a contemporary high-flip angle technique and electromagnetic simulations. The advantages of the PMLF technique over the high-flip angle techniques are its low SAR cost and higher speed.

RF Excitation Using Time Interleaved Acquisition of Modes (TIAMO) to Address B1 Inhomogeneity in Highfield MRI

Stephan Orzada1,2, Stefan Madervald1, Benedikt Poser1,3, Andreas K. Bize1,2, Harald H. Quick1,2, Mark E. Ladd1,2

1Erwin L. Hahn Institute for Magnetic Resonance Imaging, Essen, NRW, Germany; 2Department of Radiology and Neuroradiology, University Hospital Essen, Essen, NRW, Germany; 3Donders Institute for Brain, Cognition and Behaviour, Centre for Cognitive Neuroimaging, Radboud University Nijmegen, Nijmegen, Netherlands

Signal dropouts in high and ultra-high field MRI pose a substantial problem. Several approaches including transmit SENSE and RF shimming have been proposed. Here we propose a new imaging scheme to tackle this challenge. Using TIAMO, two or more inhomogeneous images acquired using different RF-transmit modes are combined to one homogeneous image. The cost in time for multiple acquisitions can be partially compensated by using the different acquisitions to generate virtual receive channels in a parallel imaging reconstruction. A mathematical theory is developed, and the results of phantom studies as well as first 7T in vivo abdominal imaging are presented.

Enhanced Parallel Imaging Acceleration with a B1 Accelerated Reconstruction Sequence (BARS)

Gigi Gallianda1, Jason P. Stockman1, Robert Todd Constable1

1Diagnostic Radiology, Yale University, New Haven, CT, United States

This work presents an approach to accelerated imaging via RF and surface coil localization using a multishot acquisition. The sequence can be described as creating "effective sensitivity profiles" for each acquisition window using the in-plane RF profiles to
multiply and sculpt the sensitivity profiles of multichannel receivers. Rectangular RF profiles are chosen so as to efficiently encode along the phase encode-direction, improving the ability to unwrap aliasing caused by extreme undersampling along this direction. We present both numerical studies and experimental verification of the approach.

2851. Comparison of Different Methods for B1+/flip Angle and Reception Sensitivity Mapping

Valentina Hartwig1,2, Nicola Vanello3, Giulio Giovannetti1, Maria Fillomena Santarelli1, Luigi Landini2
1Institute of Clinical Physiology, CNR, Pisa, Italy; 2Department of Electrical Systems and Automation, University of Pisa, Pisa, Italy; 3Department of Information Engineering, University of Pisa, Pisa, Italy

Knowledge of transmission field B1+, and reception sensitivity maps is important in high field (>=3T) human Magnetic Resonance (MR) imaging for several aspects: these include post acquisition correction of intensity inhomogeneities, that may affect the quality of images, and modelling and design of radiofrequency (RF) coils and pulses. Moreover, in recent works, it has been demonstrated that B1 maps can be used for the direct calculation of tissues electrical parameters and for estimating the local Specific Absorption Rate (SAR) in vivo. In this study a comparison among known methods for B1+/flip angle and reception sensitivity mapping is introduced.

2852. Simultaneous B1 and B0 Mapping at 7T

Walter RT Witschey1, Ravinder Reddy1, Mark A. Elliott1
1Radiology, University of Pennsylvania, Philadelphia, PA, United States

A modification of the actual flip angle (AFI) method for measuring B1 is presented which simultaneously acquires spatial maps of both B0 and B1, allowing for accurate calculation of the radiofrequency field in the presence of off-resonance effects. An analytical expression for the actual B1 field is derived, given the apparent flip angle and the B0 map. Application of the new method is demonstrated at 7 tesla in phantom images.

B1Insensitive RF

Hall B Wednesday 13:30-15:30

2853. BIR-4 Based B1 and B0 Insensitive Velocity Selective Pulse Trains

Eric C. Wong1, Jia Guo2
1Radiology and Psychiatry, UC San Diego, La Jolla, CA, United States; 2Bioengineering, UC San Diego

The BIR-4 pulse was recently shown to be useful for B1 and B0 insensitive T2 preparation. We report here an extension of this concept that includes the use of symmetrical gradient pulses inserted at the zero points of the BIR-4 pulse to impart velocity selectivity. The resulting velocity selective module is time efficient, and has better B1 insensitivity than existing methods based on adiabatic double spin echoes. Application to velocity selective arterial spin labeling is demonstrated.

2854. Broadband, Shallow Tip NMR Pulse Design Providing Uniform Tipping in Inhomogeneous RF Fields

Hui Liu1, Gerald Matson1,2
1CIND, Veterans Affairs Medical Center, San Francisco, CA, United States; 2Pharmaceutical Chemistry, University of California, San Francisco, San Francisco, CA, United States

Although high-field MRI offers increased signal-to-noise (S/N), the non-uniform tipping produced by conventional RF pulses leads to spatially dependent contrast and sub-optimal S/N, thus complicating the interpretation of the MR images. The aim of this research was to develop broadband RF pulses with immunity to B1 inhomogeneity. To accomplish this, we developed an optimization routine based on optimal control theory to design RF pulses with a desired range of immunity to B1 inhomogeneity and to resonance offset. The resulting pulses were more efficient than analogous pulses in the literature. These pulses have promise for certain MRI experiments at high field.

2855. Adiabatic Pulses Revisited Through Averaging

Bahman Tahayori1,2, Leigh Andrea Johnston1,2, Peter Mark Farrell1,2, Iven Michiel Yvonne Mareels1,2
1EEE Department, The University of Melbourne, Melbourne, Victoria, Australia; 2NICTA Victoria Research Laboratory, Melbourne, Australia

In this paper, the Bloch equation is scaled and averaged consequently to find the magnetization behaviour in a simple way with a negligible error for adiabatic passages. The novel framework presented here may be used to optimise the modulation functions of the adiabatic passages.
increasing spectral selectivity. In this study broadband refocusing pulses with immunity to $B_1$ variations are designed using optimal Broadband radio-frequency pulses are of great interest for reducing chemical shift displacements, anomalous J coupling, and saturation preparation pulse. correctly and became insensitive to $B_1$ inhomogeneity. This preparation pulse suppressed flow signal and can also be used as flow least two of the refocus pulses became near to 180 degree between -20% and +40% of delta $B_1$, magnetizations were refocused and flow sensitivity were measured. Flip angle of MLEV-4 sequence was modified to (90x,140y,-200y,-140y,200y,-90x). Because at occurs. T2-prep often uses MLEV-4 type sequence. In this study, $B_1$ insensitive MLEV-4 type preparation pulse was designed and $B_1$ T2-prep is important for cardiovascular applications. However, because of $B_1$ inhomogeneity on 3T, inhomogeneous signal loss compared to a broadband SLR pulse, and validated experimentally. Numerical optimization of hyperbolic secant waveform parameters ($\beta$ and $\mu$) is shown to result in noticeably improved inversion uniformity as compared to pulses with the same bandwidth and $\mu/\beta$. Urgur bil et al. proposed the use of a Numerically Optimised Modulation (NOM) scheme to improve the adiabaticity over the whole length of a BIR4 pulse and this method provides better performance for shorter pulses. NOM resamples the AM and FM functions with reference to the adiabatic condition and is restricted to looking at on-resonance effects. Following from this work, we attempted to optimize the resampling function via a Genetic Algorithm. The evaluation function considers $B_1$ and $B_0$ inhomogeneities to tailor the optimization to 7T conditions, requiring the study of off-resonance behaviour.

A design of a composite refocusing pulse suitable for use in human imaging at 7T is presented here. With the assumption that it is preceded by a slice-selective excitation, the refocusing solution is immune to inhomogeneities within a predefined space of $B_1$ and $\delta B_0$ values for 7T human head imaging. Narrow radio-frequency pulses are of great interest for reducing chemical shift displacements, anomalous J coupling, and increasing spectral selectivity. In this study broadband refocusing pulses with immunity to $B_1$ variations are designed using optimal control theory. The pulse design concentrates on posing least constrains on the optimization. The refocusing pulse presented here reaches a ratio of pulse bandwidth to peak RF amplitude of 2.1 and immunity of -10 % to +20 % $B_1$ variations. The optimized pulse is compared to a broadband SLR pulse, and validated experimentally.

B2 Insensitive Genetically Altered Refocusing Pulses for Ultrahigh Field Spin Echo

A Slice-Selective $B_2^+$-Insensitive Composite Pulse Design for Improved Excitation Uniformity at 7 T

A Slice-Selective $B_2^+$-Insensitive Composite Pulse Design for Improved Excitation Uniformity at 7 T

B1 Insensitive MLEV-4 Pulse Sequence for T2-Prep

B1 Insensitive MLEV-4 Pulse Sequence for T2-Prep

T2-prep is important for cardiovascular applications. However, because of B1 inhomogeneity on 3T, inhomogeneous signal loss occurs. T2-prep often uses MLEV-4 type sequence. In this study, B1 insensitive MLEV-4 type preparation pulse was designed and B1 and flow sensitivity were measured. Flip angle of MLEV-4 sequence was modified to (90x,140y,-200y,-140y,200y,-90x). Because at least two of the refocus pulses became near to 180 degree between -20% and +40% of delta B1, magnetizations were refocused correctly and became insensitive to B1 inhomogeneity. This preparation pulse suppressed flow signal and can also be used as flow saturation preparation pulse.
2862. Zoomed Spin-Echo Echo Volumar Imaging of the Mouse Brain in Vivo Using Adiabatic Pulses

Julien Flament, Sidi Mohamed Ould Ahmed Ghaly, Benjamin Marty, Céline Girardeau, Sébastien Mériaux, Gilles Bloch, Denis Le Bihan, Franck Lethimonnier, Julien Valette, Fawzi Boumezbeur

1NeuroSpin, FBM, Commissariat à l'Énergie Atomique, Gif-sur-Yvette, France

Many developments in the field of fast preclinical imaging are based on EVI sequences. We propose here an optimized protocol designed for preclinical in vivo imaging combining a quadrature surface coil with a zoomed Spin Echo EVI sequence using two orthogonal slice-selective adiabatic pulses (designated as ZEVIA) for volume selection. Brain coverage and time resolution are improved substantially without any drawbacks in the mouse brain in vivo at 7T.

2863. Improved Non-Selective T2-Prep with Adiabatic Vs. Composite Pulses for Whole-Heart T2w Edema Imaging in Mice

Ronald J. Beyers, Yaqin Xu, Michael Salerno, Stuart S. Berr, Craig H. Meyer, Frederick H. Epstein, Brent A. French

1Biomedical Engineering, University of Virginia, Charlottesville, VA, United States; 2School of Medicine, University of Virginia, Charlottesville, VA, United States; 3Radiology, University of Virginia, Charlottesville, VA, United States

T2w MRI of the heart allows imaging post-infarct myocardial edema—a key indicator of area at risk and possibly salvageable tissue. For high-field, 7 Tesla imaging in mice, we compared composite and adiabatic RF pulses in T2-Prep sequences. By simulation, phantom and in vivo imaging, we developed a flexible adiabatic T2-Prep method for whole-heart imaging of myocardial edema from onset within hours through resolution past the 20 day point.

MRI of Conductivity

Hall B Thursday 13:30-15:30

2864. Propagating RF Phase: A New Contrast to Detect Local Changes in Conductivity


1Radiotherapy, UMC Utrecht, Utrecht, Netherlands; 2Institute for Biomedical Engineering, ETH Zurich, Zurich, Switzerland; 3Radiology, UMC Utrecht, Utrecht, Netherlands

From basic EM (electromagnetic) theory we know that the wavelength, thus the propagating phase, depends on the permittivity and conductivity. Analysis, based on simulations, showed that local changes in the conductivity, have the largest effect on the propagating phase in the physiological range. We demonstrated that it is possible to measure the effect both in phantoms and in vivo, with results comparable to results of EM simulations. This new contrast mechanism might be useful for the detection of conducting malignancies, such as breast tumours.

2865. In Vivo Quantitative Conductivity Imaging Based on B1 Phase Information

Tobias Voigt, Ulrich Katscher, Olaf Doessel

1Institute of Biomedical Engineering, University of Karlsruhe, Karlsruhe, Germany; 2Philips Research Europe, Hamburg, Germany

In this work, in vivo conductivity values of human tissue are obtained using standard MRI. Conductivity is a new and quantitative contrast for MRI. It can be obtained in 3D within 5 min by means of phase-based reconstruction presented in this abstract. Phase-based reconstruction is motivated analytically and validated in FDTD simulations and in in vivo experiments.

2866. Estimation of the Anisotropy of Electric Conductivity Via B1 Mapping

Ulrich Katscher, Tobias Voigt, Christian Findeklee

1Philips Research Europe, Hamburg, Germany; 2Institute of Biomedical Engineering, University of Karlsruhe, Karlsruhe, Germany

Electric conductivity might be used as diagnostic information due to its ability to reflect the grade of tissue damage. In general, the conductivity is given by a tensor including anisotropic cases of conductivity, as can be found in vivo in tissue with preferred cell direction like muscles or nerves. Measuring conductivity, characterizing the underlying cell structure, might increase diagnostic information. The recently presented “Electric Properties Tomography” (EPT) is able to determine tissue conductivity in vivo by post-processing B1 maps. This study demonstrates the ability of EPT to estimate also the anisotropy of the conductivity using an electrically anisotropic phantom.
Parallel Imaging
Hall B Monday 14:00-16:00


Sumati Krishnan1, David Moratal2, Lei-Hou Hamilton3, Senthil Ramamurthy4, Marijn Eduard Brummer5
1Emory University, Atlanta, GA, United States; 2Universitat Politècnica de València, Valencia, Spain; 3Georgia Institute of Technology, Atlanta, GA, United States; 4Emory University, Atlanta, GA, United States

A well-known reconstruction method, based on “error energy” reduction [1], is adapted to sparsely sampled dynamic cardiac MRI. Inherent temporally band-limited properties of known static regions in the FOV, are used to recover additional resolution from information embedded in the acquired k-t samples. The algorithm converges as the error due to residual dynamic content in the static region is minimized. Reconstructions equivalent to direct matrix-inversion [2] are achieved with significantly reduced computational costs, while convergence properties are related to the sampling patterns. The proposed iterative method has potential applications for a variety of non-Cartesian grids as well as sparse-sampling patterns.

2868. Null Space Imaging: A Novel Gradient Encoding Strategy for Highly Efficient Parallel Imaging

Leo Tam1, Jason Peter Stockmann1, Robert Todd Constable, 12
1Biomedical Engineering, Yale University, New Haven, CT, United States; 2Diagnostic Radiology & Neurosurgery, Yale University, New Haven, CT, United States

Null Space Imaging (NSI) defines nonlinear encoding gradients to complement the spatial localization abilities of a parallel receiver array. To complement coil sensitivities, gradients should encode where coil sensitivities poorly distinguish signal. The singular value decomposition analyzes coil sensitivities to generate a complete basis set of vectors spanning the null space of sensitivities. By interpreting the orthogonal vectors in the null space as a complementary gradient set, NSI enables highly accelerated (R=16) parallel imaging as demonstrated by simulated spin echo experiments. NSI suggest complementary gradient design is a powerful concept for parallel imaging requiring only a limited set of receivers.

2869. GPU Accelerated Iterative SENSE Reconstruction of Radial Phase Encoded Whole-Heart MRI

Thomas Sangild Sørensen1, Claudia Prieto2, David Atkinson3, Michael Schacht Hansen4, Tobias Schaeffter2
1Aarhus University, Aarhus N, Denmark; 2King's College London; 3University College London; 4National Institutes of Health

Isotropic whole-heart imaging has become an important protocol in simplifying cardiac MRI. The acquisition time can however be a prohibiting factor. To reduce acquisition times a 3D scheme combining Cartesian sampling in the readout direction with radial sampling in the phase encoding plane was recently suggested. It allows high undersampling factors in the phase encoding plane when obtaining data with a 32-channel coil array and employing non-Cartesian iterative SENSE for reconstruction. Unfortunately this reconstruction is a time consuming process. We demonstrate however that the reconstruction time can be brought to a clinically acceptable level using commodity graphics hardware (GPUs).

2870. Calibrationless Parallel Imaging Reconstruction by Structured Low-Rank Matrix Completion

Michael Lustig1,2, Michael Elad3, John Mark Pauly2
1Electrical Engineering and Computer Science, University of California Berkeley, Berkeley, CA, United States; 2Electrical Engineering, Stanford University, Stanford, CA, United States; 3Computer Science, Technion IIT, Haifa, Israel

A new method for parallel imaging that requires no special autocalibration lines or calibration scans is presented. Instead, the method jointly calibrates, and synthesizes missing data from the entire acquired k-space. The proposed method is based on low-rank matrix completion, which is an extension of the compressed sensing theory to matrices. It is implemented by iterative singular value thresholding. The method can be used to reconstruct undersampled data, to generate calibration data for GRAPPA-like methods, or just to improve calibration when the calibration area is too small.

2871. Context Based GRAPPA Reconstruction Using a Small Kernel

Berkay Kanberoglu1, Lina J. Karam1, Josef P. Debbins2
1Electrical Engineering, Arizona State University, Tempe, AZ, United States; 2Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, AZ, United States

For GRAPPA reconstruction, large kernel sizes can be disadvantageous in some cases due to the large number of GRAPPA coefficients. A system like this needs a large number of equations to construct an over-determined system. Small kernel sizes can be advantageous when there is a small number of equations. Proposed algorithm employs a small kernel size and a clustering method to produce more than one set of GRAPPA weights within a slice.
Perturbing EPI phase encoding lines in a sinusoidal fashion improves the g-factor map for SENSE reconstruction. Concurrent field monitoring ensures artifact-free reconstruction for 3-fold undersampled data.

Recently, iterative joint estimation algorithms have been proposed to reconstruct aliasing free images and coil sensitivities in a single step from self-calibrating sampling trajectories such as Cartesian with variable density. Due to the non-linearity of the reconstruction method, their behavior with respect to noise amplification is more difficult to predict. In this work, we extend the non-linear inversion algorithm (NLINV) by incorporating the noise covariance of the coil array in the minimization function and by applying additional regularization for the coil sensitivities, both with the aim of improving the SNR of the reconstructed image. We present detailed results on the noise amplification properties of this joint reconstruction scheme and evaluate the proposed algorithm in vivo.

The performance of GRAPPA-based parallel imaging methods can suffer when the size of the auto-calibration signal (ACS) region becomes small. Based on an analysis of condition number for GRAPPA calibration equation, an optimal Tikhonov regularization factor is proposed to improve the quality of image reconstruction. Alternatively, an optimal amount of noise can be added to the ACS data to stabilize the system. The technique was applied to both GRAPPA and GRAPPA operator for wider radial bands (GROWL), a self-calibrated radial parallel imaging methods. Results show that minimal reconstruction errors are always obtained with the proposed automatic regularization scheme.

The ABSINTHE technique has been shown to allow better GRAPPA reconstructions at high undersampling factors by sparsifying the undersampled image to reconstruct. This study seeks to further increase the effectiveness of ABSINTHE by improving the PCA approximation which generates the sparse imaging. After a first standard ABSINTHE estimation, iterative ABSINTHE uses fully-undersampled image to reconstruct. This study seeks to further increase the effectiveness of ABSINTHE by improving the PCA approximation which generates the sparse imaging. After a first standard ABSINTHE estimation, iterative ABSINTHE uses fully-undersampled eigenvectors to generate an even sparser representation of the undersampled data. The efficacy of this technique for simulated data and longitudinal simulations is demonstrated, and an improved image quality is shown for iterative ABSINTHE in comparison to the standard ABSINTHE and GRAPPA techniques.

The idea of randomized 3D Cartesian subsampling was proposed within the framework of compressed sensing. The optimal design of these sampling patterns is an open problem, especially the determination of the correct ratio of low to high frequency sample points. The goal of this work is to show that it is possible to construct an adapted random sampling pattern by using measured k-space data as a reference, which automatically ensures an appropriate distribution of sample points for different types of scans. In this work, these sampling patterns were used in combination with regularized nonlinear inversion for parallel imaging. This allows the use of very high acceleration factors while still yielding images with excellent image quality.

It has been shown that joint image reconstruction and sensitivity estimation in SENSE (JSENSE) can improve image reconstruction quality when acceleration factor is high. However, existing methods for JSENSE need long reconstruction time and/or optimal termination condition, which have hindered its clinical applicability. In this work, a fast non-iterative JSENSE technique, based on pseudo full k-space, is proposed to improve the clinical applicability of JSENSE. Using the proposed method, the computation time for sensitivity maps could be reduced from minutes to a few seconds without degrading the image quality.
2878. Parallel Imaging Using a 3D Stack-Of-Rings Trajectory

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We present an efficient parallel imaging strategy for the 3D stack-of-rings non-Cartesian trajectory to further enhance its flexible trade-offs between image quality and scan time. Due to its distinct geometry, parallel imaging reconstruction for the 3D stack-of-rings trajectory can be decomposed directly into a series of 2D Cartesian sub-problems, which can be solved very efficiently. Experimental results demonstrate that a 2-fold reduction in scan time can be achieved on top of the 2-fold speedup already offered by the rings (compared to Cartesian encoding). Our approach combines the acceleration from both non-Cartesian sampling and parallel imaging in an efficient and easily deployable algorithm.

2879. Coil-By-Coil Vs. Direct Virtual Coil (DVC) Parallel Imaging Reconstruction: An Image Quality Comparison for Contrast-Enhanced Liver Imaging

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Compared to coil-by-coil reconstructions, Direct Virtual Coil (DVC) parallel imaging reconstructions improve computational efficiency for high channel count coil arrays by only synthesizing unacquired data for one virtual coil instead of synthesizing a separate dataset for each physical coil. In this study, image quality is compared between coil-by-coil and DVC parallel imaging reconstructions in the context of contrast-enhanced liver imaging. Results showed no significant difference in the image quality achieved by the two reconstruction methods.

2880. Towards a Geometry Factor for Projection Imaging with Non-Linear Gradient

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Conventional parallel imaging performance is assessed either by computing the analytical geometry factor or, if necessary, comparing the SNRs of fully-sampled and undersampled Monte Carlo reconstructions. The empirical g-factor is unsuitable, however, for methods such as O-Space imaging in which non-linear gradients are used to obtain projections of the object. Since O-Space point spread functions are highly variable with position, the g-factor must be corrected for voxel-size in order to distinguish intra-voxel blurring from true noise amplification. This work shows the limited utility of uncorrected empirical g-factors for O-Space imaging and discusses how to compute the PSF for this class of non-linear projection imaging methods.

2881. Selection of Image Support Region and of an Improved Regularization for Non-Cartesian SENSE

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Even though non-Cartesian parallel imaging has demonstrated increasing potential for an acquisition tool in MRI, there are still drawbacks such as reduced SNR and incomplete suppression of the undersampling or aliasing artifact. In suppressing such artifacts, the selection of image support, specifying a reconstruction region of interest is an important factor, due to the complex aliasing pattern associated with undersampling. Proper selection of image support can improve the conditioning of the reconstruction by constraining regions that are known to be zero. In this study, we investigate how the selection of image support region affects the performance of non-Cartesian SENSE reconstruction applied to undersampled spiral k-space data. Considering a potential effect of the sharp edges of a conventional mask on aliasing artifact, we also applied a smoothed mask through an additional regularized term to give smoothness to the mask edges. We tested our hypotheses on masking effects with the simulation and in-vivo human data and our results show that using a moderate size of mask can improve the image quality and the smoothing the mask is effective in suppressing aliasing artifact. Functional MRI result also indicates that softening function further increases the number of activated pixels and tSNR, and reduces image domain error.

2882. Variable-Density Parallel Imaging with Partially Localized Coil Sensitivities

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PILS is a very fast reconstruction method for both Cartesian and non-Cartesian sampling; however, it can suffer from residual aliasing artifacts when coupled with variable-density acquisitions. In this work, we propose an improved variable-FOV method that suppresses the aliasing artifacts, while optimally utilizing the densely sampled low-spatial-frequency data. Individual coil images are then linearly combined using data-driven sensitivity estimates. In vivo comparisons with PILS and SENSE are provided.
Synthetic Target Combined with PILS (ST-PILS) for Improving SNR in Parallel Imaging

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The abstract introduces a novel rapid reconstruction algorithm called ST(Synthetic Target)-PILS. It improves the original Synthetic Target method by achieving a higher SNR. We also studied reconstruction speed comparing to coil-by-coil reconstruction.

Iterative IIR GRAPPA: A Novel Improved Method for Parallel MRI

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GRAPPA proves to be an effective constrained parallel MRI method. However, it does not exploit the acquired data to the utmost. In our investigation to produce a superior parallel Magnetic Resonance Imaging (MRI) reconstruction technique, we propose the novel method of Infinite Impulse Response Iterative GRAPPA (IIR iGRAPPA). This method uses both acquired and reconstructed data points to iteratively interpolate downsampled k-space data, achieving excellent reconstruction quality without the need to acquire much additional data for calibration purposes. Experimental results clearly demonstrate the superiority of the proposed method over the conventional GRAPPA method.

Applying Parallel Imaging for SNR Enhancement

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Typically in fast MRI, the measurements are carried out using a high readout bandwidth, leading to a generally low SNR. In this work undersampling k-space, while maintaining the image acquisition time is proposed. Consequently, TR and the signal acquisition time can be raised and the SNR is increased. For image reconstruction, parallel imaging techniques are utilized. As the SNR gain is considerably influenced by the geometry factor crucial investigations are required. g-factors are minimized by homogeneously distributing the phase encoding steps over k-space. Thus, in terms of SNR, the use of additional reference scans or techniques like TGRAPPA, TSENSE and Auto-SENSE is advantageous.

Noise Weighted T2*-IDEAL Reconstruction for Non-Uniformly Under-Sampled k-Space Acquisitions

Curtis Nathan Wiens1, Shawn Joseph Kisch2, Catherine D. G. Hines3, Huanzhou Yu4, Angel R. Pineda5, Philip M. Robson6, Jean H. Brittain7, Scott B. Reeder38, Charles A. McKenzie12
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Using different undersampling patterns for the non-calibration and calibration echoes has been shown to improve SNR per unit time of Parallel Imaging accelerated IDEAL reconstructions by up to 40%. The different acceleration factors and k-space undersampling patterns result in different noise enhancement in the non-calibration and calibration echoes. In this work the T2*-IDEAL reconstruction is modified to include noise weighting and demonstrate that SNR improves with the modified reconstruction. For 14.2 fold accelerated phantom data, an 11.9% increase in mean SNR for all phantoms and a maximum 27% increase in SNR over a single phantom was measured.

Three-Dimensionally Accelerated Radial Parallel MRI with a 32-Channel Coil System

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Established parallel-imaging techniques include the one-dimensional or two-dimensional acceleration of the data acquisition with Cartesian or non-Cartesian trajectories. However, state-of-the-art receiver coil arrays with 32 and more coil elements that are distributed approximately uniformly in space should also enable a three-dimensional parallel-imaging acceleration, i.e. simultaneous sparse sampling in all three k-space directions. The purpose of this study was to demonstrate three-dimensional parallel-imaging acceleration with high acceleration factors up to 32 based on a three-dimensional radial gradient-echo sequence.
A Rapid Self-Calibrating Radial GRAPPA Method Using Kernel Coefficient Interpolation
Noel C. Codella\textsuperscript{1}, Pascal Spincemaille\textsuperscript{2}, Martin Prince\textsuperscript{2}, Yi Wang\textsuperscript{2}
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This work proposes a rapid self-calibrating radial GRAPPA method that eliminates the need to change domains, calculate sensitivity maps, generate synthetic calibration data, or perform extra gridding operations before the derivation of the GRAPPA kernels.

Zoomed GRAPPA (ZOOPPA) for Functional MRI
Robin Martin Heidemann\textsuperscript{1}, Dimo Ivanov\textsuperscript{1}, Robert Trampel\textsuperscript{1}, Fabrizio Fasano\textsuperscript{2}, Josef Pfeuffer\textsuperscript{3}, Robert Turner\textsuperscript{1}
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The increased SNR of ultra-high field MR scanners permits improved resolution of fMRI acquisitions. Unfortunately, both high field and high resolution amplify artifacts such as geometric distortions and blurring. Parallel imaging and zoomed imaging can each mitigate these effects. However, highly accelerated parallel imaging is affected by residual artifacts, while excessive zooming sacrifices spatial coverage. A robust combination of both methods is optimized here (Zoomed imaging with GRAPPA - ZOOPPA) to provide high quality single-shot EPI human brain images with reasonable coverage and an isotropic resolution of 0.65 mm.

Conjugate Gradient PINOT Reconstruction with a Fast Initial Estimate
Lei Hou Hamilton\textsuperscript{1}, Benjamin Russell Hamilton\textsuperscript{1}, David Moratal\textsuperscript{2}, Senthil Ramamurthy\textsuperscript{3}, Marijn Brummer\textsuperscript{3}
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PINOT (Parallel Imaging and NOquist in Tandem), a fast imaging method combining SPACE-RIP and Noquist, favorably preserves edge detail at a cost of increased SNR. PINOT involves a large matrix inversion for each read-out coordinate to combine data from all frames and coils. We use iterative conjugate gradient (CG) to reduce this computational burden. An initial estimate based on the projection matrix’s structure allows CG-PINOT to converge quickly. We simulate this CG-initiated PINOT (CGi-PINOT) with phantom and in vivo studies, showing it provides better reconstructed image quality with an order of magnitude less time than direct inversion PINOT.

Computationally Rapid Method for Estimating SNR of Arbitrary Parallel MRI Reconstructions
Curtis Nathan Wiens\textsuperscript{1}, Shawn Joseph Kisch\textsuperscript{2}, Jacob David Willig-Onwuachi\textsuperscript{3}, Charles A. McKenzie\textsuperscript{1}\textsuperscript{2}
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Existing approaches for measuring parallel MRI SNR are limited because they are not applicable to all reconstructions, require significant computation time or need repeated image acquisitions. A new SNR estimation approach is proposed that is a hybrid of the two acquisition and multiple pseudo replica methods. The difference of two pseudo-images is used to estimate the noise in the acquisition. This gives a computationally rapid method of measuring SNR from a single acquisition. SNR maps using the two pseudo-image method were compared to pseudo-replica. All tests of the proposed method were on average within ±1.75%.

Virtual Coil Phase Determination Using Region Growing: Description and Application to Direct Virtual Coil Parallel Imaging Reconstruction
Philip James Beatty\textsuperscript{1}, Shaorong Chang\textsuperscript{1}, Ersin Bayram\textsuperscript{1}, Ananth Madhuranthakam\textsuperscript{3}, Huanzhou Yu\textsuperscript{1}, Scott B. Reeder\textsuperscript{4}, Jean H. Brittain\textsuperscript{1}
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Setting the phase of the virtual coil in the Direct Virtual Coil (DVC) reconstruction technique is both critical to achieving a high quality reconstruction and challenging, especially with high channel count arrays. In this work, a region growing approach to setting the virtual coil phase is described and evaluated in the context of the DVC technique. We demonstrate that the approach is able to generate sensible virtual coil phase even in challenging situations.

Random Phase Modulation of Spatial Aliasing in Temporal Domain for Dynamic MRI
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\textsuperscript{1}Advanced Concept Development, Invivo Diagnostic Imaging, Gainesville, FL, United States

In this study, we propose a new k-t space sampling trajectory for parallel dynamic MRI. This method applies random phase modulation to the spatial aliasing of images in temporal domain. As a result, the spatial aliasing induced by k-space undersampling at every time frame has a noise pattern in temporal dimension. By applying a temporal constraint that can be known from the priori
knowledge of dynamic MRI data, the noise-like aliasing can be easily removed. This work uses the fMRI and cardiac imaging applications as examples to demonstrate the feasibility of the proposed method.

**2894. Rapid 3D Parallel Imaging of Non-Cartesian Data**

Nicholas Ryan Zwart, James Grant Pipe

1Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, AZ, United States

A 3D parallel imaging reconstruction technique is presented. This technique is a coil sensitivity based method used for reconstructing undersampled arbitrary 3D k-space trajectories. Iterations enforce receive b1-field and sampled data consistency without degridding/gridding operations improving the computational speed compared to similar reconstruction methods. The 3D trajectory used is Spiral Projection Imaging.

**2895. Improvement of Quantitative MRI Using Radial GRAPPA in Conjunction with IR-TrueFISP**

Martin Kunth, Nicole Seiberlich, Philipp Ehues, Vikas Gulani, Mark Griswold

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While the use of IR-TrueFISP to quantify the relaxation parameters T1 and T2 and the proton density M0 has been demonstrated, these values can be difficult to quantify in species with fast relaxation because the first points along the relaxation curve are hard to assess. This abstract explores the use of the recently proposed technique through-time radial GRAPPA to reconstruct highly undersampled radial images acquired along the relaxation curve. In this way, the first few points after the inversion can be assessed and the relaxation parameters more accurately quantified.

**2896. Maxwell’s Equation Tailored Reverse Method of Obtaining Coil Sensitivity for Parallel MRI**

Jin Jin, Feng Liu, Yu Li, Ewald Weber, Stuart Crozier

1ITEE, The University of Queensland, St Lucia, Queensland, Australia

A new method is proposed to obtain noise-free RF coil sensitivity maps. This is highly desirable, considering the fact that the sensitivity encoding (SENSE) method imposes ultimate dependence of successful full FOV image reconstruction on the correct sensitivity map of each individual coil. The proposed method differs from traditional methods in that, instead of refining the measured sensitivity maps by means of numerical approximation and/or extrapolation, it is based on physics of electromagnetics, parameterization and optimization algorithms. Preliminary simulations show substantial improvement in sensitivity maps constructed by proposed method compared to traditional polynomial fitting method and consequently in reconstructed images.

**2897. Sub-Sampling Parallel MRI with Unipolar Matrix Decoding**

Doron Kwiat

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A method is proposed of parallel array scan, where signals from coils are combined by a summing multiplexer and decoded by unipolar matrix inversion is suggested, which reduces acquisition channels to a single pre-amp and A/D. The results would be, an independent individual separated signals as if acquired through multiple acquisition channels, and yet at a total acquisition time similar to acquisition time of multiple channels. Background: In a standard parallel array technology, N coils simultaneously cover N FOVs by reading N k-space lines simultaneously over N independent data sampling channels. These k-space lines are phase weighted to maximize SNR and then FT converted to N independent images with an increased SNR [1]. In current accelerated PI techniques, some of K-space lines are skipped physically, and are replaced by virtual k-space substitutes using presumed spatial sensitivities of the coils in the PE direction [2-5]. Based on the method described recently [6,7] a new scanning procedure is described here. The Method: 1. Have all coils be connected through a single summing multiplexer unit (MUX) which allows, at our discretion, selecting N-1 coils to be actively connected while a single coil is deactivated electronically, to a single summing common output (SCO). Let the summed signal from these N-1 coils be sampled by the single acquisition channel (ACQ) having a single pre-amp and single A/D. 2. Scan 1/Nth of the total k-space lines while having N-1 coils actively connected to the ACQ by the MUX unit. Repeat the above scan procedure over another 1/Nth part of k-space, this time with another set of N-1 coils actively connected, and 1 coil deactivated. Keep these scan procedures N times, until all k-space lines were acquired over all N possible permutations of selections of N-1 coils out of N. 3. There are now exactly N summed acquisitions at our hands. Using an inverse of a unipolar matrix, these can be now decoded back to the original individual k-space lines.

**Non-Cartesian Imaging Methods**

**Hall B Tuesday 13:30-15:30**

**2898. 3D Dual VENC PCMRA Using Spiral Projection Imaging**

Nicholas Ryan Zwart, James Grant Pipe

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This work focuses on the reduction of scan time required by the phase-contrast MRA technique. The proposed method consists of a 3D variable density spiral projection imaging trajectory (SPI) combined with a dual velocity encoding technique. SPI is a rapid imaging technique that improves acquisition time through the intrinsic efficiency of spirals and through undersampling. The dual-VENC method improves SNR by allowing low-VENC (high SNR) data to be reconstructed without phase aliasing of the velocity measurements.
Dynamic 3D Contrast Enhanced Liver Imaging Using a Novel Hybrid Cartesian-Radial Acquisition with Flexible Temporal and Spatial Resolution
Pascal Spincemaille', Beatriu Reig', Martin R. Prince', Yi Wang'
1Radiology, Weill Cornell Medical College, New York, NY, United States

High temporal resolution dynamic contrast enhanced liver imaging is achieved using a novel k-space sampling method that samples the phase and slice encoding plane along true radial trajectories with an angularly varying field-of-view and resolution. Combined with an adapted golden ratio view order, it eliminates the need for accurate bolus timing and allows the retrospective selection of the optimal arterial enhancement for the detection and characterization of liver lesions.

Magnetization-Prepared Shells with Integrated RadiaL and Spirals
Yunhong Shu', Matt A. Bernstein'
1Department of Radiology, Mayo Clinic, Rochester, MN, United States

In this work, we demonstrate the initial feasibility of combining the SWIRLS trajectory with the MP-RAGE acquisition for volumetric T1-weighted brain imaging. The SWIRLS trajectory uses one continuous interleave to cover the surface of a spherical shell from pole-to-pole, which offer more flexibility for magnetization prepared (MP) design than the traditional shells trajectory. Meanwhile, it also shares the advantages of shells trajectory, including optimizing the contrast between WM and GM with reduced scan time.

High-Field MRI for Non-Invasive Preclinical Imaging in Free-Breathing Mice
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The requirements for preclinical cancer imaging are high spatial resolution, good soft tissue differentiation, excellent motion immunity, and fast and non-invasive imaging to enable high-throughput, longitudinal studies. Here we describe a PROPELLER-based technique, which with its unique data acquisition and reconstruction overcomes the adverse effects of physiological motion, allows for rapid setup and acquisition and provides excellent tissue contrast. Hardware optimization as well as sequence modification enable us to obtain heavily T2-weighted images at high-fields in tumor-bearing mice with in-plane resolution of 117 μm and slice thickness of 1mm. Multi-slice datasets covering the entire thorax and abdomen are acquired in ~40 minutes.

ZOOM-PROPELLER-EPI: Non-Axial Imaging at Small FOV with PROPELLER-EPI
Hing-Chiu Chang1,2, Chun-Jung Juan3, Yi-Jui Liu4, Chao-Chun Lin5,6, Tzu-Chao Chuang7, Hsiao-Wen Chung2
1Applied Science Laboratory, GE Healthcare Taiwan, Taipei, Taiwan; 2Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan; 3Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan; 4Department of Radiology, Tri-Service General Hospital, Taipei, Taiwan; 5Department of Automatic Control Engineering, Feng Chia University, Taichung, Taiwan; 6Department of Radiology, China Medical University Hospital, Taichung, Taiwan; 7Applied Science Laboratory, GE Healthcare, Beijing, China; 8Electrical Engineering, National Sun Yat-sen University, Kaohsiung, Taiwan

Current implementation of PROPELLER-EPI exhibits difficulty in small FOV or non-axial acquisition due to the aliasing artifact along the phase-encoding direction of each blade. In this work, we propose a ZOOM-PROPELLER-EPI technique, which combines the reducing-FOV (rFOV) EPI to obtain sagittal images with a small FOV. We combined PROPELLER-EPI with three types of rFOV EPI technique based on inner volume excitation, both phantom and in vivo results demonstrated effectiveness of ZOOM-PROPELLER-EPI. The proposed method may find applications in non-axial high-resolution scans such as diffusion-weighted imaging of the cerebellum.

Fat-Water Separation
Hall B Wednesday 13:30-15:30

2902. QUANTIFICATION OF FATTY ACID COMPOSITIONS USING MR-IMAGING AND SPECTROSCOPY AT 3 T
Pernilla Peterson1, Håkan Brorson2, Sven Månsson1
1Medical Radiation Physics, Lund University, Malmö, Sweden; 2Plastic and Reconstructive Surgery, Lund University, Malmö, Sweden

This phantom study aims at investigating the potential of multi-echo imaging and spectroscopy to quantify the fraction unsaturated fatty acids (UF) and compare the results against known values. Six oil phantoms (UFs: 8%-92%) were measured in a 3T Siemens scanner with PRESS-localized spectroscopy and multi gradient echo sequences. Two fat resonances were separated from the acquired spectra using jMRUI and from multi-echo images using a linear least-squares approach. Both methods successfully quantified UF with slopes/intercepts 0.886/3.80% and 0.956/11.3% for imaging and spectroscopy, respectively. This experiment successfully demonstrates the ability of multi-echo imaging and spectroscopy to evaluate fatty acid compositions.
In this work, a bipolar acquisition with 3D-FSE-IDEAL is presented that reduces total scan time by acquiring all three images required for IDEAL processing in a single repetition. To eliminate phase errors that arise from alternating polarities of the readout gradients, a novel 2D phase correction method was implemented. High-resolution 3D T₂-weighted images with uniform fat-water separation are demonstrated in breast and knee applications with less than 5-minute acquisition times.

Flexible and Efficient Data Acquisition Technique for 3D-FSE-IDEAL

Ananth J. Madhuranthakam¹, Huanzhou Yu², Ann Shimakawa³, Martin P. Smith³,⁴, Scott B. Reeder³, Neil M. Rofsky³,⁴, Charles A. McKenzie⁵, Jean H. Brittain¹
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FSE-IDEAL requires at least three echoes for uniform fat-water separation. The three echoes are commonly acquired in multiple repetitions. Recently, methods have been proposed to reduce total scan time by acquiring multiple gradient echoes in a repetition. Acquisition of a fourth echo increases the flexibility for choosing the gradient echo spacing to enable higher resolution acquisitions in reasonable scan times. We test this hypothesis in phantom studies and show a new data acquisition approach to acquire high-resolution 3D T₂-weighted fat-water separated images of the breasts and knee with higher SNR in reduced scan times.

Single-Image Water/fat Separation

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A post processing method is presented, that separates water and fat from a single complex image. Initially, each voxel is assumed to be either water- or fat dominant, giving two alternative field heterogeneity phasors. Spatial smoothness of the field map is imposed by formulating an optimization problem, which is solved approximately using a multiscale belief propagation algorithm. Smoothing of the field map relaxes the initial assumption of water- or fat dominance. Water and fat signals are found analytically in each voxel. Initial results from abdomen and whole-body datasets at 1.5 T and 3.0 T were found promising.

Noise Analysis for Chemical Shift Based Water-Fat Separation with Independent T2* Correction for Water and Fat

Venkata Veerendranadh Chebrolu¹, Huanzhou Yu², Angel R. Pineda³, Charles A. McKenzie⁴, Jean H. Brittain⁴, Scott B. Reeder⁴,⁵
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The noise analysis for chemical shift based decomposition of water and fat was theoretically computed for methods that account for single and dual exponential T₂* correction along with spectral modeling of fat. The Cramer–Rao bound (CRB) formulation was used to study the variance of the estimates of the water and fat images by computing the maximum effective number of signals averaged (NSA) for a range of echo combinations and fat-water ratios. These theoretical results predict that noise performance degrades with independent estimation of T₂* of water and fat.
2909. **Lipid Suppression Using Spectral Editing of Fast Spin Echo Trains**

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The REFUSAL [REFocusing Used to Selectively Attenuate Lipids] technique incorporates a spectrally-selective editing pulse in the position of the first refocus pulse of an RF echo train. By fully refocusing water and while minimally refocusing lipid resonances, fat signal is “refused” from evolving in the RF echo train. The phase-modulated REFUSAL pulse is designed for B1-robustness with a sharp transition between fat and water for good dB0-insensitivity. REFUSAL produces images with uniform, T1-insensitive fat suppression over a wide range of B1.

2910. **PASTA++: B1- And T1-Robust Fat Suppression at 3T**

*Andrew J. Wheaton¹, Robert Anderson¹*

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PASTA uses a combination of low RF excitation bandwidth and alternate excitation and refocus slice selection gradient polarities to remove fat signal via chemical shift. PASTA++ is an improved version of PASTA designed for 3T. Using 3T-tailored RF pulse choices and irregular echo spacing, PASTA++ can be included in an fast spin-echo readout with short echo spacing. PASTA++ delivers high SNR images with uniform fat suppression even in the presence of B0 inhomogeneity. Since PASTA++ does not use a prepulse, it delivers fat suppression immune to B1- and T1-variation without increasing SAR.

2911. **A Joint Estimation Method for Two-Point Water/fat Imaging with Regularized Field Map**

*Diego Hernando¹, Peter Kellman², Zhi-Pei Liang¹*

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Two-point methods for water/fat imaging are attractive because of their moderate acquisition time. In this work, we adapt a previously proposed joint estimation approach for two-point acquisitions and demonstrate its performance using simulations, phantom results and in vivo data. The proposed method, based on a regularized formulation and a graph cut solution, results in good noise properties and the ability to handle large B0 field inhomogeneities.

2912. **Multiplex RARE Dixon: A Novel Multislice RARE Sequence Applied to Simultaneous Slice Fat-Water Dixon Imaging**

*Kuan J. Lee¹, Benjamin Zahneisen¹, Jürgen Hennig¹, Weigel Matthias¹, Jochen Leupold¹*

¹Medical Physics, University Hospital Freiburg, Freiburg, Baden-Württemberg, Germany

Multiplex RARE is a new sequence in which multiple slices are simultaneously excited and refocused in a spin-echo train. The echo trains are interleaved in such a way that CPMG conditions are fulfilled at all times, and signals from slices can be separated, preventing aliasing. This work demonstrates how the sequence may be used in a novel fat-water Dixon method, which enables fast volume coverage of multiple, simultaneously excited slices. The technique is demonstrated in-vivo and compared with iTED, another fast Dixon method.

2913. **Cardiac Imaging with Chemical Shift Based Water-Fat Separation at 3T**

*Karl Kristopher Vigen¹, Chris J. Francois¹, Ann Shimakawa², Huanzhou Yu¹, Scott K. Nagle¹, Mark L. Schiebler¹, Scott B. Reeder¹,³*

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Chemical shift based water-fat separation methods have recently been demonstrated for 1.5T cardiac imaging. Higher field strengths (most notably 3T) are increasingly used in cardiac imaging, but water-fat separation techniques can be challenging due to proportionately higher resonance frequency offsets. An interleaved multi-echo sequence using the IDEAL water-fat method has been developed for cardiac imaging at 3T and applied to the evaluation of delayed-enhancement imaging and other fat-containing pathologies.

2914. **Feasibility of T2* Estimation with Chemical Shift-Based Water-Fat Separated Cardiac Imaging**

*Karl Kristopher Vigen¹, Huanzhou Yu¹, Chris J. Francois¹, Ann Shimakawa², Scott B. Reeder¹,³*

¹Radiology, University of Wisconsin-Madison, Madison, WI, United States; ²Applied Science Lab, GE Healthcare, Menlo Park, CA, United States; ³Medical Physics, University of Wisconsin-Madison, Madison, WI, United States

T2* mapping has previously been investigated in cardiac imaging for iron overload assessment and detection of myocardial BOLD effects. Advanced T2* measurement techniques have been previously demonstrated with chemical shift-based fat-water separation techniques in applications such as iron- and fat-content measurement in the liver, and chemical shift-based fat-water decomposition methods have been used to separate fat and water in cardiac imaging. In this work, the feasibility of T2* mapping with chemical shift-based fat-water decomposition in cardiac imaging is demonstrated.
Determination of Body Compartments at 1.5 and 3 Tesla, Combining Three Volume Estimation Methods

Tania Buehler¹, Nicolas Ramseier¹, Juergen Machann², Nina Schwenzer², Chris Boesch¹
¹Dept. of Clinical Research, University of Bern, Bern, Switzerland; ²Dept. of Diagnostic Radiology, Eberhard-Karls-University of Tübingen, Tübingen, Germany

Insulin resistance and the metabolic syndrome are cardiovascular risk factors with enormous consequences for the individual patient and the health care system. They can be linked with whole body fat (WBF), visceral adipose tissue (VAT), lean body volume (LBV), and whole body volume (WBV) imaged with MRI. In this study, a method is proposed and tested that uses point counting algorithms to determine the above mentioned body compartments in two groups of age-, weight-, height-, and BMI-matched volunteers at 1.5 and 3 Tesla.

Autocalibrating Correction of Spatially Variant Eddy Currents for Three-Point Dixon Imaging

Holger Eggers¹, Adri Duymdan²
¹Philips Research, Hamburg, Germany; ²Philips Healthcare, Best, Netherlands

The use of bipolar readout gradients in three-point Dixon imaging increases scan efficiency and separation robustness, but eddy currents lead to phase variations that do not adhere to the assumed linear evolution over echo time. In first approximation, these phase variations are limited to one spatial direction and are easily removed prior to the separation. For large volumes, however, this approximation becomes inaccurate. A correction of these phase variations in all directions that requires no additional calibration data is proposed in this work and demonstrated to substantially improve the fat suppression over large volumes in three-point Dixon imaging.

Three Echo Dixon Water-Fat Separation for Cardiac Black Blood Turbo Spin Echo Imaging

Peter Koken¹, Holger Eggers¹, Tobias Schaeffter², Peter Börnert¹
¹Philips Research Europe, Hamburg, Germany; ²Division of Imaging Sciences, King's College, London, United Kingdom

Turbo spin echo (TSE) sequences with black blood and fat suppression preparation pulses are widely used in cardiac MRI. In the presence of B₀ inhomogeneity the common prepulse fat suppression techniques often fail. Furthermore, it was recently shown, that the amount and the distribution of fat in the heart could be of diagnostic value. We propose the combination of black blood TSE with a three echo GRASE-like readout and an iterative water fat separation reconstruction without restrictions to the inter echo time. Data were acquired ECG-triggered during breath-hold at both polarities of the readout gradient and combined with accelerated parallel imaging. The combination of TSE with the three point Dixon method could be an interesting new tool in cardiac MRI.

Water Fat Separation with Undersampled TSE BLADE Based on Three Point Dixon

Qiang He¹,², Dehe Weng¹,², Xiaodong Zhou¹,², Marc Beckmann¹, Cheng Ni¹,²
¹Siemens Mindit Magnetic Resonance Co. Ltd., Shenzhen, Guangdong, China; ²Life Science and Technology School, Tongji University, Shanghai, China; ³Beijing MRI Center for Brain Research, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China

By the method of integrating the total variation regularized iterative reconstruction and water fat separation calculation, the water and fat images with robust and high quality is reconstructed from the undersampled TSE BLADE three point Dixon with less scanning time comparing with full coverage of BLADE k-space trajectory. The final fat and water images have less streaking artifacts comparing with conventional regridding reconstruction methods followed by water-fat separation. Meanwhile, inheriting the benefits of the BLADE scanning, the present method is less sensitive to the motions comparing with Cartesian sampling.

CS-Dixon: Compressed Sensing for Water-Fat Dixon Reconstruction

Mariya Doneva¹, Peter Börnert¹, Holger Eggers¹, Alfred Mertins¹, John Pauly¹, Michael Lustig³,⁴
¹Institute for Signal Processing, University of Lübeck, Lübeck, Germany; ²Philips Research Europe, Hamburg, Germany; ³Electrical Engineering, Stanford University, CA, United States; ⁴Electrical Engineering, UC Berkeley, CA, United States

An integrated Compressed Sensing-Dixon algorithm is proposed, which applies a sparsity constraint on the water and fat images and jointly estimates water, fat and field map images. The method allows scan time reduction of above 3 in 3D MRI, fully compensating for the additional time necessary to acquire the chemical shift encoded data.

Accelerated Robust Fat/Water Separation at 7T

Sreenath Narayan¹, Fangping Huang¹, David Johnson¹, Christopher Flask¹,³, Guo-Qiang Zhang¹, David Wilson¹
¹Case Western Reserve University, Cleveland, OH, United States; ³Ohio State University, Columbus, OH, United States; ²University Hospitals, Cleveland, OH, United States

VARPRO-ICM was previously introduced as a Dixon processing formulation that was able to handle the very large field inhomogeneities seen at 7T. However, long processing times have prevented this formulation from achieving practical use. In this abstract, we present image processing improvements that decrease the processing times required to solve the VARPRO-ICM formulation by a factor of about 70.
2921. Consistent Region-Growing Based Dixon Water and Fat Separation for Images with
Disconnected Objects
Hua Ai¹, Jingfei Ma²
¹The University of Texas M.D. Anderson Cancer Center, Houston, TX, United States

Consistent water and fat separation in images with disconnected objects is difficult for a region-growing based Dixon method. Here, we propose to monitor and record the quality index of a recently-proposed algorithm for region-growing at each step. The quality index is then used to automatically segment the disconnected objects into separate sub-images. Finally, the sub-images are consistently recombined on the basis of water and fat spectral asymmetry and slice-to-slice phase correlation. The proposed method was tested on a total of 1106 axial in vivo leg images and was shown to reduce the number of inconsistent slices from 203 to 6.

2922. Optimized Single-Acquisition Lipid- And Water-Selective Imaging at High Field
William M. Spees¹, Tsang-Wei Tu¹, Sheng-Kwei Song¹, Joel Garbow²
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Side-lobe spatial-spectral excitation and frequency-selective saturation with a binomial-series RF pulse scheme were evaluated for application at high field. Both methods yield separate water- or lipid-selective images in a single acquisition. In most circumstances, the performance of the binomial saturation approach proves to be more robust. A strategy is described for overcoming unwanted artifacts arising from magnetic susceptibility mismatch in small-animal imaging.

2923. Chemical Shift Based Water-Fat Separation with an Undersampled Acquisition
Catherine J. Moran¹, Ethan K. Brodsky, ¹, Tzu-Hsin Hwang¹, Shengzhou Yu¹, Scott B. Reeder, ¹, Richard X. Kijowski², Walter F. Block³
¹Medical Physics, University of Wisconsin, Madison, WI, United States; ²Radiology, University of Wisconsin, Madison, WI, United States; ³Global Applied Sciences Lab, GE Healthcare, Menlo Park, CA, United States; ⁴Biomedical Engineering, University of Wisconsin, Madison, WI, United States

The chemical shift based IDEAL decomposition method generally requires redundant sampling at multiple time points. A unique undersampled radial k-space trajectory at each echo time provides a means to accelerate data acquisition while still allowing for robust chemical species decomposition. In this work we present a dual-pass dual-half-echo radial acquisition which utilizes undersampled source images with IDEAL to achieve bSSFP images with high isotropic resolution and robust fat-water separation in the breast and knee.

2924. Influence and Compensation of Fat Signal Dephasing and Decay in Two-Point Dixon Imaging
Holger Eggers¹
¹Philips Research, Hamburg, Germany

Fat has a complex spectral composition, which causes its signal to dephase and decay noticeably even over short intervals. The influence of these effects on the extent of fat suppression reached in two-point Dixon imaging is evaluated in this work and is found to strongly depend on the choice of echo times. Moreover, it is shown how more complex spectral models of fat may be incorporated into a generalized two-point Dixon method, with which a more uniform degree of fat suppression is achieved across a range of relevant echo times.

2925. Water Fat Separation with TSE BLADE Based on Three Points Dixon Technique
Dehe Weng¹,², Marc Beckmann¹
¹Siemens Mindit Magnetic Resonance Ltd, Shenzhen, Guangdong, China; ²Beijing MRI Center for Brain Research, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China

Three points Dixon method for water and fat separation based on TSE BLADE is proposed. New phase correction using the in-phase image blades is introduced for the reconstruction of the two out-of-phase images in order to keep the water fat chemical shift information so that the water and fat can be separated after the reconstruction. Result shows that water and fat can be separated correctly, furthermore, the method enjoys the advantage of blade, it's less vulnerable to rigid body motion and pulsation etc.

2926. Robust Field Map Estimation Using Both Global and Local Minimia
Hojin Kim¹,², Kyung Sung³, Brian Andrew Hargreaves¹
¹Department of Radiology, Stanford University, Stanford, CA, United States; ²Electrical Engineering, Stanford University, Stanford, CA, United States

In the least-squares fat/water separation techniques, the residual or cost function that is minimized contains exactly one or two local minimum, depending on the relative amount of fat and water, and water-fat phase difference. Separation algorithms attempt to find which minimum provides true field-map, but may converge to the incorrect local minimum. Based on this principle, this work proposes a robust field-map estimation technique by tracking two minima at each pixel through region growing process and suggesting more secure way of determining an initial seed for region growing.
Optimization of Flip Angle to Allow Tradeoffs in T1 Bias and SNR Performance for Fat Quantification

Catherine D. G. Hines¹, Takeshi Yokoo², Mark Bydder², Claude B. Sirlin², Scott B. Reeder¹,³
¹Biomedical Engineering, University of Wisconsin-Madison, Madison, WI, United States; ²Radiology, University of California-San Diego, San Diego, CA, United States; ³Radiology, University of Wisconsin-Madison, Madison, WI, United States

Chemical shift based water-fat separation methods used to quantify fat in tissue are usually based on rapid 2D or 3D spoiled gradient echo methods. In order to avoid bias from differences in T1 between water and fat, a low flip angle is typically used to minimize this source bias. Reducing the flip angle reduces SNR performance, however. In this work, we present an algorithm to maximize the flip angle (to maximize SNR) while maintaining a user-defined allowable error in fat-fraction from T1 related bias. Experimental validation is also shown.

Volumetric Adiposity Imaging Over the Entire Abdomen and Pelvis in a Single Breath-Hold Using IDEAL at 3.0T

Aziz Hatim Poonawalla¹, Ann Shimakawa², Huanzhou Yu³, Charles McKenzie³, Jean Brittain³, Scott Reeder¹,⁴
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We have demonstrated the capability to acquire high-spatial resolution 3D volumetric images of the entire abdomen and pelvis, using a highly-accelerated chemical-shift-based water-fat separation technique and a 32-channel coil at 3.0T. The high-quality fat and fat-fraction images obtained by this technique provide unprecedented visualization and delineation of the adipose depot boundaries, with sufficient spatial resolution to allow 3D reformatting for optimal segmentation. This new technique will greatly facilitate rapid quantitative assessment of visceral adipose tissue volume, VAT/SCAT ratio, and total adipose volume within a single-breath-hold acquisition without the need for ionizing radiation.

Preliminary Results of IDEAL Fat/water Separation at 9.4T

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IDEAL has emerged as a promising method for rapid fat/water separation. Here we present our first results on the feasibility of this method on ex-vivo rat images at 9.4T.

Dynamic MR, Superresolution, Off-Resonance & Tissue Orientation

Hall B Thursday 13:30-15:30

System Dynamics Estimation for Kalman Filtering with Radial Acquisition

Mahdi Salmani Rahimi¹, Steve R. Kecskemeti², Walter F. Block¹,³, Orhan Unal³
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A novel method has been proposed to use adaptive Kalman filtering and causal DCF based tornado filtering together to reconstruct undersampled MR images for dynamic and time resolved applications. Existing Kalman method uses an initialization scan or a sliding window to estimate system dynamics. In this work, we used tornado filter to infer motion maps for the Kalman process. This helps us to have a better estimation of image changes at every time frame and therefore a more accurate reconstruction. Simulations have been done on a cardiac phantom using radial projections and results were compared to existing techniques.

Deterministic Comparisons of Nonlinear Acceleration Methods Using a Realistic Digital Phantom

Leah Christine Henze¹, Catherine J. Moran², Matthew R. Smith², Frederick Kelez³, Dan Xu¹, Kevin F. King², Alexey Samsonov³, Walter F. Block¹,¹²
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Several different accelerated imaging methods exist that can improve the acquisition of dynamic data. Clinical adoption of many of these methods has been slow, partially due to the difficulty in conclusively proving the extent to which a specific method provides additional diagnostic information that would not otherwise have been available. We have created a realistic digital phantom from which k-space data for a DCE exam can be simulated and reconstructed by both Cartesian and non Cartesian acceleration methods. We use the phantom to quantitatively analyze and compare the performance of multiple accelerated imaging methods.
3D contrast-enhanced MR Angiography frequently uses a pre-contrast (tissue) acquisition as a subtraction reference (mask) to improve the output image quality and contrast-to-noise ratio. We discuss the appropriate application of this technique to the case of 3D time-resolved view-shared reconstructions, including at what stage in the reconstruction process the subtraction is performed and the selection of effective mask data to suppress magnetization history effects.

Many of Parallel MRI techniques are based on a time-interleaved acquisition scheme and allow dynamic imaging with high frame rates. In addition, in order to improve the SNR, the temporal average (also referred to as direct current, DC) is subtracted from the raw data so that only the dynamics of the object is reconstructed. In this work we demonstrate that DC subtraction may lead to temporal filtering effects in form of signal nulls in the temporal frequency spectra of the reconstructed images. We propose to correct the DC by an additional GRAPPA reconstruction prior to subtraction from the raw data.

Super-resolution is a method of generating images beyond the limit of the resolution. Recently, a method by which to realize super-resolution by a technique that performs registration by a sub-pixel unit from several pieces of an image has been reported. Gerchberg-Papoulis (GP) method is known to realize super-resolution from a single image and signal, however, spatial resolution will not be improved well when it is based on the Fourier transform. On the other hand, GP method involving convolution integral can expand the resolution on the image space with reference to the scaling parameter of FREBAS transform. Improvement of resolution with reference to the scaling parameter of FREBAS transform is examined.

Introduction: We extend the model-based reconstruction method with a physically based linear-phase model that can account for gadolinium field distortions. Methods: Both constant- and linear-phase models were used in reconstructing two 4D breast DCE k-space acquisitions, retrospectively undersampled at R-factors of 1, 4, and 8. Results: Image reconstruction errors correlate spatially with dynamic image phase estimation errors. The errors of the constant-phase model grow fastest as R increases. Conclusion: The new extension can reduce most of the error from phase. The reconstructions have full spatial resolution without the blurring, ghosting, and ringing spatial artifacts typically associated with aggressive undersampling.
clearly visible with high contrast using IRON. A seed localization algorithm to process IRON images demonstrates the potential of this imaging technique for seed localization and dosimetry.

2938. A Positive Contrast Method for MR-Lymphography Using Superparamagnetic Iron Oxide Nanoparticles
Haitao Zhu1, Kazuyuki Demachi
1Department of Nuclear Engineering, The University of Tokyo, Tokyo, Japan

The objective of this work is to apply a post-processing method in MR-lymphography with superparamagnetic iron oxide nanoparticle (SPION) enhancement to achieve positive contrast in the image. The method analyzes the echo position shift caused by susceptibility gradient and uses this criterion to enhance region with large gradient caused by SPIONs. Both phantom and animal experiments are performed to test the method. Results show that this positive contrast method can generate enhanced signal at the region targeted by SPIONs and might provide additional information in MR-lymphography.

2939. Reconstruction Method for Non-Homogeneous Magnetic Fields Using the Fractional Fourier Transform
Vicente Parot1,2, Carlos Sing-Long1,2, Carlos Lizama3, Sergio Uribe,2,4, Cristian Tejos1,2, Pablo Irarrazaval1,2
1Department of Electrical Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile; 2Biomedical Imaging Center, Pontificia Universidad Catolica de Chile, Santiago, Chile; 3Department of Mathematics and Computer Science, Universidad de Santiago de Chile, Santiago, Chile; 4Department of Radiology, Pontificia Universidad Catolica de Chile, Santiago, Chile

In Magnetic Resonance Imaging (MRI) field inhomogeneities produce severe distortions, especially with long acquisition sequences, e.g. EPI. Shimming or post-processing strategies are usually applied to correct those distortions. However, those approaches require additional hardware or long processing times. We propose an alternative reconstruction method based on the Fractional Fourier Transform (FrFT) assuming spatially-varying quadratic fields. We tested our method in phantoms and in vivo acquisitions. Results demonstrate the ability of our reconstruction scheme to correct the geometric distortions that appear in standard Fourier Transform reconstructions under non homogeneous fields.

2940. Geometrically Accurate Positive Contrast of Field Disturbances Using Radial Sampling with Off-Resonance Reconstruction (RASOR)
Hendrik de Leeuw1, Peter R. Seevinck1, Clemens Bos2, Gerrit H. van de Maat1, Chris J.G. Bakker1
1Image Sciences Institute, Utrecht, Netherlands; 2Philips healthcare

With the advent of short-TE acquisitions, such as UTE and SWIFT, center out radial acquisition schemes to fill k-space are gaining interest. Although these short TE acquisitions minimize signal dephasing, they still suffer from field inhomogeneities in terms of geometric distortion. Still geometrically accurate depiction and localization of local field disturbers can be achieved by a 3D center-out radial acquisition by using off-resonance acquisition or reconstruction (RASOR). The advantage of RASOR reconstruction is a more precise determination of shape and location of the field disturbance, while retaining the original image.

2941. Spiral Off-Resonance Distortion Correction for Tagged MRI Using Spectral Peak Matching and HARP Refinement
Harsh K. Agarwal1, Xiaofeng Liu1, Khaled Z. Abd-Elmoniem2, Jerry L. Prince1
1Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore, MD, United States; 2National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD, United States

Off-resonance due to magnetic field inhomogeneity causes geometric distortion in tagged images acquired using a segmented spiral k-space data acquisition. This causes erroneous alignment of horizontal and vertical tag acquisitions and inaccurate displacement estimation. A technique based on fast marching HARP refinement is proposed to estimate and correct for the distortion. Improved motion estimation is demonstrated on an in vivo data set.

2942. Multi-GPU Implementation for Iterative MR Image Reconstruction with Field Correction
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1Bioengineering, University of Illinois at Urbana-Champaign, Urbana, IL, United States; 2Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, United States

Nowadays Graphics Processing Units (GPU) leads high computation performance in science and engineering application. We propose a multi-GPU implementation for iterative MR image reconstruction with magnetic field inhomogeneity compensation. The imaging model includes the physics of field inhomogeneity map and its gradients, and thus can compensate for both geometric distortion and signal loss. The iterative reconstruction algorithm is realized on C-language based on Compute Unified Device Architecture (CUDA). Result shows the performance of multi-GPU gains significant speedup by two orders of magnitude. Therefore, the fast implementation make the clinical and cognitive science requirements are achievable for accurate MRI reconstruction.
Recent publications suggest a relationship between white matter fiber orientation and $T2^*$ contrast at higher field strengths. In this study the relationship between fiber orientation and $B_0$ for normal and tilted head position was examined in the whole human brain at 3T. As previously shown by Wiggins et al. for the cingulum and corpus callosum, WM signal intensity in the whole brain changed when the head was tilted. Blood vessels following the fiber tracts could explain the relationship found between $B_0$ and relaxation rate, while a magic angle effect cannot explain the measured relationship.

**Sensitivity of MRI Resonance Frequency to the Orientation of Brain Tissue**

**Microstructure**

Jongho Lee$^1$, Karin Shmueli$^1$, Masaki Fukunaga$^1$, Peter van Gelderen$^1$, Hellmut Merkle$^1$, Afonso C. Silva$^2$, Jeff H. Duyn$^1$

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Here we demonstrate microstructural orientation affects the MRI resonance frequency. The experiment was designed to avoid macroscopic susceptibility effect to identify true microstructural effect. We suggest an origin related to anisotropic susceptibility.

**Wide-Range T1 Mapping Using Two Variable Flip Angle Acquisitions**

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Variable flip angle (VFA) methods using two optimized flip angles have become popular for in-vivo T1 mapping within a limited range of a specific T1 of interest. The range limitation in this approach is generally due to bias against long T1s in the signal-dynamic range product used for flip angle optimization. This study presents a new strategy for flip angle pair selection that mitigates this bias to provide highly uniform accuracy and precision across the biological T1 range. In using only two flip angle acquisitions, this method represents a rapid approach to wide-range VFA T1 mapping.

**Fast T$_{1}$ Mapping of Mouse Brain at 7 T with Time-Optimized Partial Inversion**

Naoharu Kobayashi$^1$, Hironaka Igarashi$^1$, Tsutomu Nakada$^1$

$^1$Center for Integrated Human Brain Science, Brain Research Institute, University of Niigata, Niigata, Japan

We present a new method for measuring a longitudinal relaxation time, $T_1$, for a surface coil application utilizing adiabatic saturation pulses, referred to here as time-optimized partial inversion recovery (TOPIR). The recovery delays before and after the inversion pulse were optimized to sample data points such that the total sequence time was minimized under a specified dynamic range of the recovery curve. Accuracy of the method was validated by comparing the values obtained utilizing optimal inversion recovery sequence. The method enabled a two dimensional $T_1$ mapping of a mouse brain using a 6 point recovery curve in 20–36 s.

**The Effect of Heart Rate in Look-Locker Cardiac T$_{1}$ Mapping**

Glenn S. Slavin$^1$, Ting Song$^1$, Jeffrey A. Stainsby$^1$

$^1$Applied Science Laboratory, GE Healthcare, Bethesda, MD, United States; $^2$Applied Science Laboratory, GE Healthcare, Toronto, ON, Canada

Because inversion times in cardiac Look-Locker acquisitions are a function of heart rate, $T_1$ measurements can be incorrect. Pulse sequence modifications to account for heart rate variability and its effect on the magnetization recovery curve can significantly improve $T_1$ accuracy.

**Demonstrating the Influence of Magnetisation Transfer on Putative T$_{1}$ Relaxation**

Times: A Simulation Study

Miriam Rabea Kubach$^1$, Kaveh Vahedipour$^2$, Ana Maria Oros-Peusquens$^2$, Tony Stoecker$^3$, N. Jon Shah$^{1,2}$

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$T_1$ is an MRI parameter very sensitive to pathological changes. Proper $T_1$-mapping is therefore vital for many MRI applications, but the variability of $T_1$ values within different methods is larger than within a group of volunteers measured with the same method. The accuracy of the $T_1$ determination is affected by a number of rectifiable parameters but also influenced by MT in ways, which are strongly method-dependent and usually not quantified. We present numerical simulations, based on an existing software package...
JEMRIS, which allow one to simulate MR sequences considering MT effects. We investigate changes in the T1 relaxation of the observable water component due to the presence of and exchange with a bound proton pool. A simple pulse-acquire sequence is used for simulations, which can be the elementary building block of more realistic MR imaging sequences.

**2949. Fast T1/B1 Mapping Using Multiple Dual TR RF-Spoiled Steady-State Gradient-Echo Sequences**

Tobias Voigt1, Stefanie Remmele2, Ulrich Katscher3, Olaf Doessel4
1Institute of Biomedical Engineering, University of Karlsruhe, Karlsruhe, Germany; 2Philips Research Europe, Hamburg, Germany

Efficient and accurate baseline T1 and B1 quantification is a pre-requisite for standardized and clinical Dynamic Contrast-Enhanced MRI (DCE-MRI). This study investigates a new approach called “Multiple TR B1/T1 Mapping” (MTM), capable of fast, simultaneous B1 and T1 mapping. In this work, MTM is analysed with respect to its T1 mapping performance in comparison with an inversion recovery reference sequence and in due consideration of the limited time allowed in a clinical set-up. In calibrated phantom measurements, MTM T1 mapping was found to be more accurate than IR-TSE, inter alia due to its intrinsic B1 correction mechanism.

**2950. Fast T1 Mapping at 7T Using Look-Locker TFEPI**

Emma Louise Hall1, Ali M. Al-Radaideh1, Su Y. Lim2, Susan T. Francis1, Penny A. Gowland3
1Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom; 2Clinical Neurology, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Ultra high field has the benefit of increased SNR to facilitate high resolution imaging. However, the lengthened relaxation time requires long scan times to produce high resolution T1 maps due to the need to allow the system to return to equilibrium. Here we present a Look-Locker TFEPI sequence that allows the acquisition of high resolution, 1.25mm isotropic, T1 maps with large volume coverage at 7T in less than 6 minutes.

**2951. Accelerated Mapping of T1 Relaxation Times Using TAPIR**

Klaus Möllenhoff1, N.Jon Shah1,2, Eberhard D. Pracht1, Tony Stöcker1
1Institute of Neuroscience and Medicine – 4, Medical Imaging Physics, Forschungszentrum Juelich GmbH, Juelich, Germany; 2Faculty of Medicine, Department of Neurology, RWTH Aachen University, JARA, Aachen, Germany

TAPIR is an extremely flexible Look-Locker sequence that allows choices to be made regarding coverage and number of time points acquired on the recovery curve. We are using AFP inversion pulses to be more accurate and a segmented EPI readout together with parallel imaging to reduce the total acquisition time.

**2952. Rapid 3D Relaxation Time and Proton Density Quantification Using a Modified Radial IR TrueFisp Sequence**

Philipp Ehses1, Vikas Gulani2, Peter Michael Jakob1, Mark A. Griswold2, Felix A. Breuer3
1Dept. of Experimental Physics 5, Universität Würzburg, Würzburg, Germany; 2Department of Radiology, Case Western Reserve University and University Hospitals of Cleveland, Cleveland, OH, United States; 3Research Center Magnetic Resonance Bavaria (MRB), Würzburg, Germany

The IR TrueFISP sequence has been shown to be a promising approach for the simultaneous quantification of proton density, T1 and T2 maps. However, delays between individual segments are required in order to allow the magnetization to recover, resulting in relatively long scan times. Recently, a modified IR TrueFISP method has been proposed, which does not necessitate relaxation delays. This method was combined with a radial stack-of-stars acquisition with golden-ratio based profile order, in order to rapidly obtain a full set of parameter maps of the brain in three dimensions.

**2953. The Influence of Finite Long Pulse Correction on DESPOT2**

Hendrik Joseph Alphons Crooijmans1, Klaus Scheffler1, Oliver Bieri1
1Division of Radiological Physics, Department of Medical Radiology, University of Basel Hospital, Basel, Switzerland

The DESPOT2 theory is based on the assumption of instantaneous RF pulses. However, this is a pure theoretical assumption and it can never be met in practice, only approached with short pulse durations. Explicitly in cases where MT effect reduction is desired, long RF pulses are applied and the assumption is not met leading to deviation of calculated T2 from true T2 values. The implementation of a correction for finite pulse effects in the DESPOT2 theory makes the method independent of RF pulse duration and marginal deviations of around 1% of the true T2 are obtained for the calculated T2.

**2954. Quantification of Transversal Relaxation Time T2 Using an Iterative Regularized Parallel Imaging Reconstruction**

Markus Kraiger1, Florian Knoll1, Christian Clason2, Rudolf Stollberger1
1Institute of Medical Engineering, Graz University of Technology, Graz, Austria; 2Institute for Mathematics and Scientific Computing, University of Graz, Graz, Austria

Nonlinear parallel imaging reconstruction using an iterative regularized Gauss Newton method has shown its potential in several applications. This technique determines both the coil sensitivities and the image from undersampled multi-coil data. It enables high
For the variation in MWF, and that exchange between T2 components may be limited by the apparent diffusivity of myelin water.

In-vivo experiments confirm a bias in the MWF within rat spinal cord. Numerical studies further suggest that exchange can account for the variation in MWF, and that exchange between T2 components may be limited by the apparent diffusivity of myelin water.

The myelin water fraction (MWF) estimated from multi-exponential T2 analysis is an effective marker of myelin in tissue, but there is evidence that the MWF is underestimated due to the exchange of water between myelin and other tissue compartments. In this work, in-vivo experiments confirm a bias in the MWF within rat spinal cord. Numerical studies further suggest that exchange can account for the variation in MWF, and that exchange between T2 components may be limited by the apparent diffusivity of myelin water.

The most frequent method for accurate T2 quantification uses multi-echo spin-echo (MESE incorporating multiple refocusing pulses in each repetition time following the CPMG sequence. To cover a wide range of T2 values, the number of spin echoes and corresponding RF pulses needs to be relatively large, resulting in increased TR, long scan durations, and a high SAR. Recently, a fast T2 mapping method, reducing the total number of phase encoding steps of a MESE sequence without sacrificing spatial resolution nor the dynamic range of T2 values, was proposed and evaluated in simulations and pre-clinical experiments. In this work, the accuracy of this acceleration technique for T2 mapping in the human brain was assessed in a larger group of volunteers.

T2 measurements provide important information about the mobility and chemical environment of water in the tissue of interest. The most frequent method for accurate T2 quantification uses multi-echo spin-echo (MESE incorporating multiple refocusing pulses in each repetition time following the CPMG sequence. To cover a wide range of T2 values, the number of spin echoes and corresponding RF pulses needs to be relatively large, resulting in increased TR, long scan durations, and a high SAR. Recently, a fast T2 mapping method, reducing the total number of phase encoding steps of a MESE sequence without sacrificing spatial resolution nor the dynamic range of T2 values, was proposed and evaluated in simulations and pre-clinical experiments. In this work, the accuracy of this acceleration technique for T2 mapping in the human brain was assessed in a larger group of volunteers.

Only recently a fast method for quantitative T2 mapping was introduced based on partially RF spoiled SSFP sequences (T2-pSSFP). It has been shown that for large flip angles, estimation of T2 is independent on T1 but becomes sensitive for low to moderate excitation angles. We will show that a correction of T2-pSSFP with T1 is possible and yields accurate T2 values for flip angles down to 30°. This offers the possibility for acquisitions with higher SNR, but requires prior knowledge of T1.

Myocardial T2 measurements usually require multiple breath hold acquisitions, leading to patient discomfort and misregistrations between images. We present a new method allowing free breathing T2 quantification that combines respiratory motion estimation, motion compensated reconstruction and T2 calculation. It has been validated on five healthy volunteers and has shown no significant difference compared to the standard breath hold technique. A morphological proton density weighted image is also obtained, allowing accurate examination of heart structures. Such technique could be used for cardiac iron overload assessment or detection of early rejection of heart transplant, even in non cooperative patients such as children.

Magnetic resonance images are formed typically by taking the magnitude of reconstructed complex values. The magnitude operation changes the noise distribution from Gaussian to Rician. This operation causes artifacts in T2 distributions calculated using the non-negative least squares algorithm. The artifacts caused by non-Gaussian noise distributions are becoming more relevant as scientists begin to identify tissue compartments with small intensity long T2 decays. Here we propose, and examine, a temporal phase correction method allowing T2 distributions to be created from complex quantitative T2 data.

In this study, we analyze the effect of flip angles and choice of T2Prep times in T2 quantification using Magnetization prepared balanced SSFP sequence.
2961. Making High Resolution T2 and T2* Maps Through the Use of Accelerated Gradient-Echo Asymmetric Spin-Echo (GREASE) Pulse Sequences
Daniel Lee Shefchik1, Andrew Scott Nencka1, Andrzej Jesmanowicz1, James S. Hyde1
1Biophysics, Medical College of Wisconsin, Milwaukee, WI, United States

The gradient-echo asymmetric spin-echo pulse sequence (GREASE) allows for the production of T2 and T2* maps. In order to obtain high resolution maps, while maintaining signal, the GREASE sequence was modified to accelerate the acquisition of the images three different ways. The modifications included partial k-space GREASE [2], generalized autocalibrating partially parallel acquisitions (GRAPPA) Grease [3], and partial k-space GRAPPA GREASE. The sequences are implemented and compared to the original GREASE sequence to determine the best technique to obtain quality T2 and T2* maps.

2962. R2/R2* Estimation Errors in Combined Gradient- And Spin-Echo EPI Sequences Due to Slice-Profile Differences Between RF Pulses
Heiko Schmiedeskamp1, Matus Straka1, Roland Bammer1
1Lucas Center, Department of Radiology, Stanford University, Stanford, CA, United States

There is an increased interest in combined gradient-echo and spin-echo pulse sequences for applications in PWI and fMRI, facilitated by the differences in signal decay of gradient echoes and spin echoes depending on the mean vessel size within a voxel. This abstract deals with issues of mismatched slice profiles in such pulse sequences between the 90° excitation pulse and the 180° refocusing pulse, and it introduces a scaling factor for improved T1-independent R2 and R2* quantification.

2963. Multi Echo Spiral Imaging : Optimized K-Space Trajectories for T2*
Nicolas Pannetier1,2, Mohamed Tachrount1,2, Christoph Segebarth1,2, Emmanuel Louis Barbierr2, Lauretan Lamalle3
1Inserm, U836, Grenoble, France; 2Université Joseph Fourier, Grenoble Institut des Neurosciences, UMR-S836, Grenoble, France; 3IFR n°1, INSERM, Grenoble, France

Effective and theoretical k-space trajectories differ due to eddy currents or gradient hardware imperfections. In this study we propose a fast two steps approach to optimized k-space trajectories in multi-echo spiral imaging. Once optimized, images were acquired on rat brain and T2* map was estimated.

2964. T2* Mapping at 7 T
Kai Zhong1, Ralf Deichmann2, Weiqiang Dou1, Oliver Speck1
1Biomedical Magnetic Resonance, Otto-von-Guericke University, Magdeburg, Saxon-Anhalt, Germany; 2Brain Imaging Center, University Frankfurt, Frankfurt, Germany

Previous studies at 7 T have related T2* maps to the iron deposition in brain tissue. However, the field inhomogeneity and susceptibility distortion at 7 T are significantly higher compared to lower field. This potentially distorts the true T2* values and could lead to false estimation of the tissue iron content. In this study, T2* correction based on the susceptibility gradients was applied to 7 T and can improve the resulting T2* maps. This method therefore should help to improve the accurate determination of T2* at 7 T for clinical studies. On the other hand, stronger dephasing is encountered, so thinner slices should be chosen than at lower fields to avoid systematic errors.

2965. R2* Reference Phantoms for Longitudinal Research Studies
Matthew T. Latourette1, James E. Siebert1
1Radiology, Michigan State University, East Lansing, MI, United States

In longitudinal research studies that employ R2*/T2* quantitation, reference phantoms can serve to improve the sensitivity and reproducibility of R2* measurements through detection and correction of bias and reduction of the variance of pooled study data. Stable phantoms comprised of agarose and carageenan gel doped with SPIO, NiCl2, and methylisothiazolinone were developed, enabling reliable R2* measurements that are adequately insensitive to temperature variations near room temperature. The phantoms’ R2* dependence on B0 was evaluated at field strengths of 0.35T, 0.7T, 1.5T, 3.0T. Chemical stability has been evaluated since phantom construction in April 2009.

2966. Transverse Relaxation of Water in Ferritin Gel: Relative Contributions of Iron and Gel
Nobuhiro Takaya1, Hidehiro Watanabe1, Fumiyuki Mitsumori1
1National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan

Transverse relaxation of tissue water in human brain was explained with a linear combination of contributions from ferritin iron and the macromolecular mass fraction defined as 1-water fraction. This work examined whether the same scheme is applicable to relaxation of a model system composed of ferritin and agarose gel. The result of multiple regression analysis on the system showed that transverse relaxation in the system was described in the same manner as in human brain. B0 dependence of R2 demonstrated that the relaxation mechanism due to iron in gel samples is identical to that reported for a ferritin solution.
The IR TrueFISP sequence has been shown to be a promising approach for the simultaneous quantification of proton density, T1 and T2. A fast 3D T2 mapping technique based on two partially Spoiled Steady State Free Precession (pSSFP) acquisitions has recently been presented. For most human soft tissues, accurate T2 measurements can only be obtained for high flip angle (FA) leading to SAR issues especially at high field. In this work we proposed an analytical expression derived from pSSFP theory which allowed us to introduce a more flexible T2 mapping technique. By doubling data collection, T1 map can also be extracted. The method has been validated on a phantom comparing pSSFP results with standard T1 and T2 measurements.

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The IR TrueFISP sequence has been shown to be a promising approach for the simultaneous quantification of proton density, T1 and T2; maps. For accurate quantification, segmentation is usually necessary, leading to an increase in scan time. In this work, a full set of parameter maps was obtained in a single-shot by combining the IR TrueFISP sequence with a golden-ratio based radial trajectory and using extensive view-sharing. The effects of both magnetization transfer and the violated instantaneous RF assumption on parameter quantification were further analyzed by prolonging the RF pulses and TR (thereby reducing RF power and thus MT).

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The relaxation properties T1 and T2 of MRI images are important parameters in assessment of pathology. Many musculoskeletal (MSK) tissues (cortical bone, tendon, ligaments, etc) have very short transverse relaxation times. UTE imaging of MSK tissues can pose unique challenges for the quantification of the longitudinal or transverse relaxation. We describe these challenges and offer simple solutions to help overcome them.

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Comparison of Magnetic Field Correlation in Brain at 1.5 and 3 Tesla

Caixia Hu, Jens H. Jensen, Casian Monaco, Kathleen Williams, Joseph A. Helpern

1Radiology, New York University School of Medicine, New York, NY, United States; 2Center for Advanced Brain Imaging, Nathan S. Kline Institute, Orangeburg, NY, United States

The magnetic field correlation is theoretically predicted to scale as the square of the applied field. This was verified experimentally in brain for two subjects by scanning them at 1.5T and 3T. The magnetic field correlation was estimated by using a recently proposed MRI method based on asymmetric spin echoes. The consistency of the experimental results with the theoretical prediction constitutes an important validation for the imaging method and helps to justify its application at clinical field levels. Magnetic field correlation can be of interest for studying brain iron changes associated with neuropathologies, such as Alzheimer’s disease and multiple sclerosis.

Ultra Short TE

Hall B Tuesday 13:30-15:30

Ultra-Short Echo-Time (UTE) Imaging for Early Diagnosis of Dental Demineralization

Anna-Katinka Bracher, Christian Hofmann, Said Boujraf, Axel Bornstedt, Erich Hell, Johannes Ulrici, Axel Spahr, Volker Rasche

1Department of Internal Medicine II, University Hospital of Ulm, Ulm, Baden-Württemberg, Germany; 2Department of Operative Dentistry, Periodontology and Pedodontics, University Hospital of Ulm, Ulm, Germany; 3Department of Internal Medicine II, University Hospital of Ulm, Ulm, Baden-Württemberg, Germany; 4Department of Biophysics and Clinical MRI Methods, Faculty of Medicine and Pharmacy, University of Fez, Morocco; 5Sirona Dental Systems GmbH, Bensheim, Germany

Due to the high mineral content, the concentration of free protons is extremely low causing only weak magnetization and due to the susceptibility interfaces in the mineral structures, the spin-spin relaxation rates result below 1ms for dentin and below 250µs for enamel. During caries lesion formation, some increase in liquid content resulting from the production of acid or caused by water penetrating into the lesion through the porous demineralized enamel layer is expected. The performance of ultra-short echo time (UTE) MRI for early assessment of lesion formation was investigated and compared to X-ray imaging.

Theoretical Sensitivities of SWIFT and the Ideal Sequence (Delta Pulse-Acquire) for Ultra-Short T2

Robert Daniel O'Connell, Steen Moeller, Djaudat Idiyatullin, Curt Corum, Michael Garwood

1Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

A comparison is made between infinitely short RF pulses (delta), hard pulses and SWIFT using the Ernst energy equation and Bloch simulations. Simulation results are reported for each pulse sequence for on- and off-resonance systems at T1=T2. The SWIFT, delta pulse, and long T1,2 on-resonance hard-pulse sequences are described by the Ernst equations. On-resonance hard pulses have signal energy loss for short T1,2. Off-resonance hard pulses are not described by the Ernst equations. In addition to being unaffected by resonance offsets, for any flip angle the SWIFT sequence results in having a signal energy peak at shorter T1,2 than the other sequences.

3D Ultrashort Echo Time (UTE) Imaging in the Brain at 7T

Peder E. Z. Larson, Duan Xu, Daniel B. Vigneron

1Radiology and Biomedical Imaging, University of California - San Francisco, San Francisco, CA, United States

Ultrashort echo time (UTE) imaging of the brain has the potential for direct detection of myelin, calcifications and other short-T2 components that are altered in neurodegenerative diseases and other neurological pathologies. Ultra high-field MRI at 7T offers improved SNR for detection of these components which generally have low signal intensity. In this project, we have developed a 3D radial UTE acquisition for 7T brain imaging providing full head coverage in just over 5 mins. Both dual-echo subtraction and off-resonant saturation pulses were applied yielding good contrast of connective tissues and white matter short-T2 components.

Single Point Sequences with Shortest Possible TE – GOSPEL

David Manuel Grodzki, Michael Deimling, Björn Heismann, Hans-Peter Fautz, Peter Jakob

1Magnetic Resonance, Siemens Healthcare, Erlangen, Bavaria, Germany; 2Center of Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

We present a novel single point sequence, GOSPEL (Gradient Optimised Single Point Imaging with Echo-time Leveraging). Based on a RASP / SPRITE sequence, it uses the shortest possible echo-time for each acquired k-space point. Especially for clinical scanners with limited gradient strength, the reduction of the echo-time enables an improved measurement of tissues with short T2 times. We present an image of a human hand, depicting both the bone structure and tendons. The results indicate that GOSPEL can be used for bone and tendon imaging or MR-PET attenuation correction.
Imaging of Renal Stones in Vitro with UTE MRI

Aya Yassin1, Ivan Pedrosa1, Michael Kearney1, Elizabeth Genega3, Neil M. Rofsky1, Robert E. Lenkinski1
1Radiology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States; 2Urology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States; 3Pathology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States

Renal stones have short T2 values and are therefore difficult to demonstrate when using conventional MR sequences. We utilized the UTE MR sequence to characterize renal stones in vitro. Thirty-six stones from patients were scanned, and T1 and T2 values were calculated for every stone. The results were correlated with the composition. The 21/36 visualized stones showed high signal on UTE images. Having demonstrated the feasibility of the UTE sequence for imaging renal stones we anticipate employing this technique on a wider scale to patients suspected of having renal stones, especially to those in whom it is desirable to avoid ionizing radiation exposure such as children, women of child bearing age and pregnant females.

MRI Signal Delay: A Potential Probing Mechanism for Cellular Imaging in the Brain

Yongxain Qian1, Fernando E. Boada1
1MR Research Center, Radiology, University of Pittsburgh, Pittsburgh, PA, United States

This work presents new observations of the delay of MRI signal in human brain on 3T MRI scanner with ultrashort echo time (UTE) acquisitions. The MRI signal delay was related, by our hypotheses, to those parameters such as ion concentration and T2* relaxation time, that characterize cellular micro environment inside/outside a cell as well as cell membrane. An electromagnetic (EM) interaction between RF pulse and mobile ions in tissue was employed to illuminate the delay of MRI signals.

Detection of Short T2 Component in Brain by SWIFT

Lauri Juhani Lehto1, Djaudat Idiyatullin2, Curtis Andrew Corum3, Michael Garwood2, Olli Heikki Gröhn1
1A. I. Virtanen Institute for Molecular Medicine, University of Kuopio, Kuopio, Eastern Finland, Finland; 2Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

The aim of this work was to directly detect signal from the short T2 component in the brain using the SWIFT sequence that allows almost simultaneous excitation and detection. To detect the short T2 component, the overwhelming long T2 component signal was suppressed either by using long adiabatic inversion pulses or by suppressing the short T2 component and subtracting that from a normal SWIFT image. Results show relative enhancement of white matter structures in the brain. The contrast in the latter approach is interpreted to have a contribution also from MTC and thus represents combined direct and indirect detection of the short T2 pool.

Magnetization Transfer & CEST

Hall B Wednesday 13:30-15:30

Pulsed CEST for the Quantification of pH

Kimberly Lara Desmond1, Greg J. Stanisz1,2
1Medical Biophysics, University of Toronto, Toronto, Ontario, Canada; 2Imaging Research, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada

We present a method for the quantification of pH using a pulsed chemical exchange saturation transfer (CEST) method. Experimental data is from a phantom model consisting of 1M ammonium chloride in 10mM citric acid buffer for the modification of pH. This data is fit using a two-compartment Bloch equation model of exchange in the presence of off-resonance excitation. A linear relationship is observed between the log of the fitted exchange rate and the true pH of the phantom.

Ytterbium (Yb)-Based PARACEST Agent: Feasibility of CEST Imaging on a Clinical 3.0 T Scanner

Yukihisa Takayama1, Akihiro Nishie1, Takashi Yoshiura1, Tomohiro Nakayama1, Eiki Nagao1, Naoki Kato2, Satoshi Yoshise2, Shutaro Saiki2, Dirk Burdinski3, Holger Grull3, Jochen Keupp3, Hiroshi Honda1
1Department of Clinical Radiology, Graduate School of Medical Sciences, Kyushu University, Fukuoka, Japan; 2Philips Electronics Japan, Tokyo, Japan; 3Philips Research Europe, Hamburg, Germany

Chemical Exchange-dependent Saturation Transfer (CEST) is a novel contrast mechanism for magnetic resonance (MR) imaging, but it is not yet common in clinical practice. We investigated the feasibility of CEST imaging on a clinical MR scanner by in vitro study using a ytterbium complex of paramagnetic CEST agents. The CEST effect could be observed at specific offset frequencies. In addition, it increased and decreased depending on the degrees of concentration, pH or solution. We showed the clinical potential of CEST imaging using these agents, but further modifications, such as optimized presaturation RF pulse, imaging protocols or other techniques, remain necessary.
Magnetic Resonance Imaging of the Neurotransmitter GABA in-Vivo

Kejia Cai1, Mohammad Haris1, Anup Singh1, Feliks Kogan1, Prianka Waghray1, Walter Witschey1, Hari Hartharan1, John A. Detre1, Ravinder Reddy1
1CMROI, Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States; 1Department of Biology, Wake Forest University, Winston-Salem, NC, United States; 1Department of Neurology, and Center for Functional Neuroimaging, University of Pennsylvania, Philadelphia, PA, United States

Gamma-aminobutyric acid (GABA) is the major inhibitory neurotransmitter of the brain and plays a critical role in multiple central nervous system diseases. The objective of this study was to characterize the chemical exchange saturation transfer (CEST) effect of the -NH2 protons of GABA and to demonstrate GABA imaging in the human brain at 7T. The Z-spectrum of GABA showed a pH sensitive asymmetry around ~2.75 ppm downfield to the water resonance. CEST imaging of healthy human volunteers clearly showed the distribution of GABA CEST contrast in different regions of the brain with negligible contrast from cerebrospinal fluid.

CEST and Sodium Imaging of Glycosaminoglycans In-Vivo on the 3T: Preliminary Results

Elena Vinogradov1, Alexander Ivanishev1, Aaron K. Grant1, Ron N. Alkalay2, David B. Hackney1, Robert E. Lenkinski1
1Department of Radiology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States; 2Department of Orthopedic Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States

Quantitative assessment of Glycosaminoglycans (GAGs) in the clinical environment can assist with characterization of disorders associated with cartilage degradation and loss. Sodium imaging and Chemical Exchange Saturation Transfer for GAG detection (gagCEST) are two of the several methods for GAG assessment. Both methods rely on the endogenous effects. However, sodium imaging suffers from low sensitivity and requires specialized hardware. GagCEST is a new method still in the validation phase. Both methods were implemented on the clinical 3T scanner for the purpose of the validation of the techniques and the correlation between GAG state in-vivo as assessed using the two methods.

Detection of Glycosaminoglycans Using Positive CEST Approach

Elena Vinogradov1, Robert E. Lenkinski1
1Department of Radiology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States

Chemical Exchange Saturation Contrast utilizes selective presaturation of a small pool of exchanging protons and is manifested in the decrease of the free water signal. Recently, CEST method has been applied successfully to detect glycosaminoglycans (GAG) in cartilage. CEST contrast is negative, resulting in decreased signal from areas with high agent (GAG) concentration. An alternative scheme, positive CEST (pCEST), results in the background suppression and positive contrast when signal is increased due to the presence of the exchanging agent. Here we evaluate application of the pCEST to detect GAG in solutions and ex-vivo samples.

Improving Amide Proton Transfer Imaging with Dual Echo B0 Mapping for Field Inhomogeneity Correction at 3T

Wenbo Wei1, Guang Jia1, Steffen Sammet2, Peter Wassenaar1, Jinyuan Zhou2, Michael Knopp1
1Department of Radiology, The Ohio State University, Columbus, OH, United States; 2Department of Radiology, Johns Hopkins University, Baltimore, MD, United States

In this study, dual echo B0 mapping was used in Amide Proton Transfer (APT) imaging for correcting B0 inhomogeneity with fewer data points which will lead to approximately one third of the current scan time and thus higher resolution. CEST spectrum, MTRasym curve and MTRasym (3.5ppm) encoded color maps of the proposed APT method were compared to a conventional method. The proposed method offers a more accurate MTRasym curve shape and a better determination of the water resonance frequency which allows a better MTRasym calculation.

Optimization of RF Saturation to Minimize B0 Inhomogeneity Effects in Pulsed Amide Proton Transfer Imaging

Rachel Scheidgger1,2, Elena Vinogradov1,3, David C. Alsop1,3
1Radiology, Beth Israel Deaconess Medical Center, Boston, MA, United States; 2Health Sciences and Technology, Harvard-MIT, Cambridge, MA, United States; 3Radiology, Harvard Medical School, Boston, MA, United States

Off-resonance errors due to magnetic field inhomogeneity are a major challenge for amide proton transfer imaging. Two-pool Bloch equation simulations were used to optimize the timing for pulsed APT imaging with two different subtraction methods. Simulations indicate that the pulse width and interpulse delay as well as the subtraction method used are key factors in optimizing APT for insensitivity to magnetic field inhomogeneity.
An Echo-planar imaging (EPI) pulse sequence was developed to detect CEST paramagnetic contrast. The EPI PARACEST sequence included a 2.5s CEST saturation pulse, followed by a ~28ms echo-train. Signal to noise ratio (SNR), CEST effect, and CEST efficiency for EPI CEST sequence were compared to fast spin-echo (FSE) CEST and fast low angle shot (FLASH) CEST in a phantom containing 10 mM Eu³⁺-DOTAM-Gly-Phe. EPI CEST, provided high temporal resolution and SNR while fully maintaining CEST effect due to the short readout times. Decreasing readout bandwidth had no significant impact on acquisition time or CEST contrast but increased image SNR.

Paramagnetic chemical exchange saturation transfer (PARACEST) contrast agents are being developed for in-vivo MRI. In this study, an accurate in-vivo MRI simulator was developed and used to optimize a time-course Echo-Planar Imaging (EPI) scheme. An 8-shot EPI sequence was simulated for the detection of 100μM and 1mM solutions of Dy³⁺-DOTAM-GlyLys in vivo. A dynamic EPI scheme, which alternates between a PARACEST EPI sequence that saturates on the bound water pool and a control sequence, was optimized to minimize the SNR requirements for detection. It was determined that EPI schemes may be feasible for PARACEST detection in-vivo.

If CEST imaging is employed in clinical MR systems hardware restrictions and SAR regulations exclude the possibility to generate a steady-state for saturation through CW irradiation. Pulsed saturation, which is used instead, holds disadvantages in preparation time and frequency coverage compared to CW. A narrow frequency coverage while maintaining SAR boundaries as well as short scan times are essential for clinical CEST imaging. We propose an effective pulsed saturation scheme which meets both requirements. The scheme is based on simulations and its effectiveness was verified experimentally.

Currently, CEST compounds are detected using radiofrequency (RF) based saturation transfer followed by asymmetry analysis of the magnetization transfer spectrum. We report an approach that, instead of saturation transfer, employs a series of so-called label-transfer modules (LTMs), in which frequency labeling and consecutive transfer of labeled protons to water is achieved. No asymmetry analysis is needed and exchangeable protons at multiple frequencies can be detected simultaneously through the water proton signal, while maintaining specific frequency information of the individual solute protons. As a first example, the method is applied to a DNA modules (LTMs), in which frequency labeling and consecutive transfer of labeled protons to water is achieved. No asymmetry analysis is needed for saturation through CW irradiation. Pulsed saturation, which is used instead, holds disadvantages in preparation time and frequency coverage compared to CW. A narrow frequency coverage while maintaining SAR boundaries as well as short scan times are essential for clinical CEST imaging. We propose an effective pulsed saturation scheme which meets both requirements. The scheme is based on simulations and its effectiveness was verified experimentally.

Balanced SSFP shows a pronounced magnetization transfer (MT) contrast, which allows for quantitative MT imaging. However, very accurate shimming is needed to cope with offresonances particularly at prolonged TR. A novel approach based on offset averaging of SSFP images with a linear frequency response is investigated. It presents a robust means for MT SSFP imaging with prolonged TR. This approach may be appealing in anatomic regions where susceptibilities cannot be addressed by shimming alone.

This work shows a quantitative analysis of magnetization transfer contrast (MTC) enhancement due to intermolecular multiple quantum coherences (iMQC). Therefore a measurement over a wide range of offset frequencies of the MT pulses was performed for different orders of iMQCs. This data was analyzed by fitting both the standard MT 2 Pool model and a modified model including the order of coherence of the iMQCs. Moreover the tissue dependency of the contrast enhancement was investigated.
2994. **Theoretical Study of a New Saturation Technique for Magnetization Transfer Experiments**

*Moritz Wilhelm Zaiss*, *Benjamin Schmitt*, *Bram Stieltjes*, *Peter Bachert*

1Medical Physics in Radiology, DKFZ, Heidelberg, Germany

The best method to evaluate magnetization transfer and chemical exchange transfer are saturation transfer experiments with constant saturation power. Our approach is a varying saturation power depending on the saturation offset. Hereby, the solution of the Bloch-McConnell equations changes fundamentally. Theoretical studies show that off-resonant pools can be isolated from the water resonance while the intensity of the transfer effect remains unchanged. Numerical simulations with pulsed saturation returned similar results. So, the application on clinical scanners with pulsed saturation promises a more robust way of measuring and evaluating z-spectra than common z-spectrum asymmetry analysis.

2995. **Preliminary Investigation of the Use of Parallel RF Transmission in MTR**

*Rebecca Sara Samson*, *Matthew Clemence*, *Xavier G. Golay*, *Claudia A M Wheeler-Kingshott*

1NMR Unit, Department of Neuroinflammation, UCL Institute of Neurology, London, United Kingdom; 2Philips Clinical Science Group, Philips Healthcare, Guildford, United Kingdom; 3NMR Unit, Department of Brain Repair and Rehabilitation, UCL Institute of Neurology, London, United Kingdom

RF B1 transmit field non-uniformity, caused primarily by skin depth and dielectric resonance effects, is a large source of error in quantitative MR measurements made at 3.0T. We investigated the possibility that B1 errors could be reduced using dual transmission by measuring the MTR and B1 with and without dual transmission. We present preliminary data acquired on three healthy subjects indicating that it may be possible to reduce inter-subject variation in MTR histogram peak locations via the use of dual transmission at 3.0T. This could be an important consideration when designing future long-term clinical studies using quantitative MRI outcome measures.

2996. **Orientation Dependence of Magnetization Transfer in Human White Matter.**

*Dirk K. Müller*, *André Pampel*, *Harald E. Möller*

1Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

We present an investigation of the dependence of quantitative magnetization transfer (qMT) on fibre orientation. QMT parameters obtained from experiments using pulsed off-resonance irradiation were correlated to the orientation of the diffusion tensor obtained from DTI data. In particular, we observed a correlation between the fiber orientation with respect to B0 and the transverse relaxation rate of the semi-solid pool ($T_2b$).

2997. **Quantification of the Magnetization Transfer Phenomenon in the Human Head at 7T**

*Olivier E. Mougin*, *Penny A. Gowland*

1Sir Peter Mansfield Magnetic Resonance Centre, School of Physics & Astronomy, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Magnetization Transfer and related effects such as CEST are important sources of contrast in MRI. Sensitivity and increase spectral resolution make possible the measurement of MT effects at 7T in vivo. We used pulsed saturation with Turbo Field Echo readout with a range of saturation offset frequencies on the approach to steady-state, providing data that can be used to measure MT parameters at 7T in a reasonable imaging time at a resolution of 1.25mm isotropic.

2998. **A Simple Iterative Reduction Method for Optimization of Quantitative Magnetization Transfer Imaging**

*Ives R. Levesque*, *John G. Sled*, *G Bruce Pike*

1Montreal Neurological Institute, McGill University, Montreal, Quebec, Canada; 2Mouse Imaging Centre, Hospital For Sick Children, Toronto, Ontario, Canada

A method is presented for the selection of an optimal acquisition scheme for quantitative magnetization transfer imaging using pulsed off-resonance saturation. This method is based on the iterative reduction of a discrete sampling of the Z-spectrum. In vivo results demonstrate that optimized sampling improves parameter map quality and longitudinal reproducibility. The reduction method avoids clustering and repeated points, an attractive feature for the purpose of MT model validation. The optimal number of MT weightings is also investigated.

2999. **Measuring Scan-Rescan Reliability in Quantitative Brain Imaging Reveals Instability in an Apparently Healthy Imager and Improves Statistical Power in a Clinical Study.**

*Becky Ilana Haynes*, *Nick G. Dowell*, *Paul S. Tofts*

1Clinical Imaging Sciences Centre, Brighton and Sussex Medical School, Brighton, United Kingdom

Repeatability of MTR and ADC brain histograms of healthy volunteers in our centre showed disturbingly large differences, even though the scanner was producing high quality images. Such instrumental variation could mask small between-group differences in a
cross-sectional study, and increase the number of participants needed to see an effect. Repeat scans in phantoms and healthy controls highlighted the variability and showed when the problem had been fixed. Our current normal standard deviations are at the lower end of the published range. Ongoing QA for quantitative studies should include explicit measurement of short- and long-term repeatability in controls.

**3000. Reconstruction of Bound Pool Fraction Maps from Subsets of Cross-Relaxation Imaging Data at 3.0 T: Accuracy, Time-Efficiency and Error Analysis**

*Hunter R. Underhill*, *Chun Yuan*, *Vasily L. Yarnykh*

1Radiology, University of Washington, Seattle, WA, United States; 2Bioengineering, University of Washington, Seattle, WA, United States

In this study, we compare strategies for the time-efficient acquisition of the bound pool fraction in the in vivo human brain at 3.0 T. The bound pool fraction can be accurately estimated using only two off-resonant magnetization transfer data points by applying appropriate, field-strength specific constraints to the transfer rate constant and transverse relaxation parameters. In so doing, whole-brain, three-dimensional, high-resolution $f$-maps can be obtained in a clinically acceptable scan time. Simulations demonstrate that the effects of parameter constraints induce minimal error in determining $f$ in grey matter, white matter and multiple sclerosis lesions.

**3001. Five-Site Modeling of Protons Chemical Exchange Processes for in Vivo CEST-Based Molecular Imaging**

*Julien Flamant*, *Benjamin Marty*, *Céline Giraudeau*, *Sébastien Mériaux*, *Julien Valette*, *Christelle Médina*, *Caroline Robic*, *Marc Port*, *Franck Lethimonnier*, *Gilles Bloch*, *Denis Le Bihan*, *Fawzi Boumezbeur*

1NeuroSpin, FBM, Commissariat à l’Energie Atomique, Gif-sur-Yvette, France; 2Guerbet, Research Division, Roissy-Charles de Gaulle, France

LipoCEST are a new class of contrast agents for CEST-MRI which provide a tremendous amplification factor but suffer from a quite small chemical shift (2-28 ppm) compared to paramagnetic complexes. Consequently, their detection in vivo is hampered by endogenous Magnetization Transfer contrast. It is therefore important to separate specific LipoCEST signal from endogenous background coming from macromolecules. Thus in this study, we propose to characterize water exchange processes using a five-site model by measuring and fitting the Z-spectrum of each tissular compartment of mouse brain in order to achieve quantitative CEST imaging with LipoCEST contrast agents.

**3002. Detection of Proton Chemical Exchange Between Metabolites and Water Using T1ρ MRI**

*Feliks Kogan*, *Walter Witschey*, *Keijia Cai*, *Mohammad Haris*, *Ravinder Reddy*

1Center for Magnetic Resonance and Optical Imaging, Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

Imaging of chemical exchange processes is important as it allows for quantification of specific metabolites. In this study, we developed a new method based on T1ρ MRI to create image contrast and quantify the exchange of protons between metabolites and water. We showed that this method is responsive to changes in concentration as well as pH. The sensitivity of this technique scales quadratically with static magnetic field and becomes much more valuable as high field magnets become more widely available clinically.

**3003. Comparison of Chemical Exchange Saturation Transfer (CEST) and T1ρ MRI for Measurement of Proton Chemical Exchange Between Metabolites and Water at 7T**

*Feliks Kogan*, *Walter Witschey*, *Keijia Cai*, *Mohammad Haris*, *Ravinder Reddy*

1Center for Magnetic Resonance and Optical Imaging, Department of Radiology, University of Pennsylvania, Philadelphia, PA, United States

Recent work on imaging chemical exchange processes has been focused on exploiting chemical exchange saturation transfer (CEST). T1ρ imaging is another imaging technique which depends on chemical exchange which can be used to image metabolites based on their proton exchange properties. In this study, we compared the sensitivities of these two techniques for measuring metabolites based on proton exchange. We observed that at 7T, T1ρ imaging has a higher sensitivity to exchanges processes compared to that of CEST.

**3004. Study of Chemical Exchange in the Intermediate Exchange Regime: A Comparison of Spin-Locking and CEST Techniques**

*Joonas Arttu Autio*, *Tao Jin*, *S-G Kim*, *Takayuki Obata*

1Department of Biophysics, National Institute of Radiological Sciences, Chiba, Japan; 2Department of Neurobiology, University of Kuopio, Kuopio, Finland; 3Department of Radiology, University of Pittsburgh, Pittsburgh, PA, United States; 4Department of Neurobiology, University of Pittsburgh, Pittsburgh, PA, United States

Previous study has demonstrated an indirect MRI detection of hydroxyl protons of small metabolites via chemical exchange saturation transfer. We used an on-resonance spin-locking (SL) pulse to detect proton exchange for hydroxyl-, amide- and amine-phantoms, and a protein sample. Analysis of spin-lattice relaxation rate in the rotating frame dispersion over a range of SL B1 fields, resulted in robust estimates for intermediate proton exchange rates and exchangeable proton site populations. Our results suggest that SL technique with on-resonance irradiation is not sensitive to very slow exchange, but may be more suited for quantitative study in the intermediate exchange regime.
A pulse sequence based on gradient echo design was modified to include four hyperbolic secant pulses, following by a signal acquisition. This was repeated four times to obtain a $T_1\rho$ weighted signal intensity curve with incrementally increasing spin-lock time for single phase encoding step. $T_1\rho$ relaxation times were compared between developed method and spin echo readout with a $T_1\rho$ preparation pulse train in mice brains. Similar $T_1\rho$ values were obtained with both methods. The developed method allows acquisition of several incremented spin-lock times within one repetition time enabling faster quantization of $T_1\rho$ and/or decreased specific absorption rates.

In the present work we investigate the different sensitivity to exchange processes generated at 4T by a variety of preparation pulses. To this aim, we quantitatively analyzed images from the human brain acquired by preparing magnetization with an off-resonance hard pulse, to exploit the so-called magnetization-transfer effect, or by preparing magnetization with a series of adiabatic pulses with different modulation functions, to exploit adiabatic rotating frame relaxation mechanisms. Results demonstrate that the two approaches are sensitive to completely different regimes of exchange, thus providing complimentary information to characterize the tissue.

The purpose of this study is to determine the ability of magnetic resonance (MR) imaging to assess regional pH levels. Both phantom and mouse models were used to evaluate pH sensitive changes in $T_1\rho$ imaging. A linear relationship was observed between $T_1\rho$ time and pH. In the mouse model, widespread increases in $T_1\rho$ times during CO$_2$ inhalation were found consistent with the expected acidosis, whereas reduced $T_1\rho$ times during HCO$_3^-$ injection were found to be consistent with the expected alkalosis.

Magnetization transfer (MT) effects in the human brain occur when there is magnetization transfer between the free and bound water pools associated with gray and white matter. These MT effects can become significant, particular when longer excite pulses are used, for example, to induce uniform tip angles in the presence of non-uniform RF fields. Therefore, we developed a simulation program written in Matlab to calculate these MT effects, and to simulate the 3D MPRAGE experiment. The simulations show that the MT effects must be taken into account when longer excite pulses are used in the 3D MPRAGE experiment.

Phase images generated using gradient echo techniques at high field show excellent contrast related to variation of magnetic susceptibility across brain tissues. Calculating susceptibility maps from phase data is made difficult by the ill-posed nature of the deconvolution problem which must be solved. Careful conditioning is therefore required. Here, we compare the performance of three conditioning strategies ((i) combination of data acquired at multiple orientations; (ii) k-space thresholding of data acquired at a single orientation; (iii) incorporation of structural information using corresponding modulus data) in the calculation of susceptibility maps from high-resolution phase images of the brain and a phantom.
Basis for Contrast Enhanced T1-Weighted Imaging Using SE at High Field
Niravkumar Darji1, Michel Ramni1, Oliver Speck1
1Department Biomedical Magnetic Resonance, Institute for Experimental Physics, Otto-von-Guericke University Magdeburg, Magdeburg, Germany

Aim of this study was to reduce fat signal without using fat saturation pulse. This task was achieved by modification of RF pulse in SE sequence. Different bandwidth of the refocusing pulse allows suppression of fat signal without increased SAR in high resolution SE imaging. The reduced fat signal with longer refocusing pulse duration is evident from in-vivo experiments.

Adiabatic Magnetization Preparation Pulse for T2-Contrast at 7 Tesla
Priti Balchandani1, Daniel Spielman1
1Radiology, Stanford University, Stanford, CA, United States

T2-weighted sequences such as Fast Spin Echo are highly susceptible to the B1-inhomogeneity and are SAR-intensive at 7T. We present an alternative method to obtain T2-contrast at 7T which utilizes an adiabatic magnetization preparation (AMP) pulse. The AMP pulse is a 0° BIR-4 pulse with delays inserted between segments to introduce T2-decay. Phantom and in vivo experiments show that the AMP pulse provides more uniform SNR and T2-contrast over the excited slice. The AMP pulse is suitable for use in a volumetric fast gradient echo sequence.

Comparison of Reduced FOV Techniques for High Resolution Imaging at 7T
Christopher Joseph Wargo1, Marcin Jankiewicz1, John C. Gore1
1Vanderbilt University Institute of Imaging Science, Nashville, TN, United States

High-resolution MR imaging benefits from ultra-high field strength such as at 7T due to improvement in signal, but requires acquisition of a large number of voxels. This increases the scan duration, and thus field and time dependent artifacts, and reduces temporal resolution for functional studies. Reduction of the FOV enables scan times to be shortened, but introduces tradeoffs between SNR, scan efficiency, SAR, and image artifacts. In this abstract, we compare a subset of selective excitation approaches including STEAM, PRESS, OVS, and spectral spatial pulses, for reduced-FOV resolution improvement in phantoms using a human 7T system.

Towards the Accurate and Precise Assessment of SNR in Vivo at 7T
Josef Habib1,2, Dorothee P. Auer1, Richard W. Bowtell1
1Academic Radiology, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom; 2Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

The Signal-to-Noise ratio (SNR) is a fundamental and critical data quality measure in MRI, with several investigations dedicated to devising and validating optimized measurement techniques. While the introduction of higher field strength MRI systems is expected to impact attainable SNR levels, this study shows that the prevalent technique for measuring SNR in vivo performs sub-optimally at 7 Tesla, due to artifacts presumably caused by the increased sensitivity to subject or physiological motion. Here we propose the use of an alternative measurement technique for increased robustness, after quantitatively evaluating its precision and accuracy.

A Fast Spin-Echo Multi Gradient-Echo Sequence to Reduce Distortions on T2-Weighted Images at High Field
Ludovic de Rochefort1, Martine Guillermier1, Diane Houitte1, Marion Chaigneau1, Philippe Hantraye1, Vincent Lebon1
1MIRCen, I2BM, DSV, CEA, Fontenay-aux-Roses, France

Susceptibility-induced magnetic field and chemical shift increase image distortion at high field. In a 2D FSE sequence, increasing the bandwidth to limit these artifacts implies degrading SNR by reducing the ratio of the observation time (TO) per unit time rapidly reaching SAR and gradient duty cycle limitations. We propose to replace the readout within the 180 pulses by a train of gradient echoes with a larger bandwidth and the same TO. It is shown in vivo on rat brain that susceptibility induced distortions are suppressed by this approach while preserving SNR and contrast.

Phase Imaging

Monday 14:00-16:00

Removing Air-Tissue Artifacts in Phase Images by Modulating the Air Susceptibility
José P. Marques1,2, Rolf Gruetter1,3
1Centre d’Imagerie BioMédicale, EPFL, Lausanne, Vaud, Switzerland; 2Department of Radiology, University of Lausanne, Lausanne, Vaud, Switzerland; 3Department of Radiology, Universities of Lausanne and Geneva, Switzerland

In this work, the susceptibility of air was varied by changing its oxygen fraction. Such a variation of the air susceptibility allowed to exclusively map the contribution from oxygen towards the measured frequency shift maps in phantoms and volunteers. This allowed removal of a significant part of the observed frequency shift around air-water interfaces, making the frequency shift maps more specific to their rich tissue contrast.
Myelin as a Primary Source of Phase Contrast Demonstrated in Vivo in the Mouse Brain

Nicoleta Baxan¹, Laura-Adela Harsan¹, Iulius Dragonu¹, Annette Merkle¹, Juergen Hennig², Dominik von Elverfeldt¹

¹Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany

While most of MRI studies are focused on the magnitude data, the phase contrast has only recently proved its ability to improve the contrast to noise in high-resolution images at high-field strength. The origin of phase contrast between white matter (WM) and gray matter (GM) has been widely discussed; several sources were suggested including paramagnetic blood deoxyhemoglobin, tissue iron concentrations, water-macromolecules exchange or tissue myelin content. In the present study we examine the contribution of tissue myelin content to the phase contrast by exploiting the frequency shift variation in a chronic model of cuprizone induced demyelination.

Phase Imaging: A Novel Tool for Myelin Quantification.

Gregory A. Ladyginsky¹, Rajika Maddage², Alexandra Chatagner³, Petra S. Hüppi³, José Pedro Marques³, Stephane V. Sizonenko³, Rolf Gruetter²

¹Pediatrics, Pediatric and Neonatal ICU, University of Geneva, Geneva 14, Switzerland; ²Laboratory for Functional and Metabolic Imaging, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland; ³Pediatrics, Division of Child Growth & Development, University of Geneva, Geneva, Switzerland

Phase imaging may allow fast and accurate myelin quantification at high resolution. A quantitative MRI-histology study of myelination on the developing rat brain.

Chemically Selective Asymmetric Spin-Echo EPI Phase Imaging for Internally Referenced MR Thermometry

Markus Nikola Streicher¹, Andreas Schäfer¹, Bibek Dhital¹, Dirk Müller¹, Robin Martin Heidemann¹, Andre Pampel¹, Dino Ivanov¹, Robert Turner¹

¹Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

We implemented a novel spin-echo EPI sequence that can acquire phase images of different chemically-shifted protons at the same slice positions. Chemical selection was achieved by applying different slice-select gradient amplitudes for excitation and refocusing RF pulses, and phase sensitivity was obtained using an asymmetric EPI readout. MR Thermometry was then performed on a mixture of water and dimethyl sulfoxide (DMSO), which has a proton chemical shift of -2 ppm from water. The two compounds were then imaged alternately, water for temperature sensitivity and DMSO to monitor field changes. Fat can also be selectively imaged as a reference compound.

A Novel Method of Increasing the Contrast to Noise Ratio of Phase Images Using Balanced SSFP

Jongho Lee¹, Masaki Fukunaga¹, Jeff H. Duyn¹

¹Advanced MRI/LFMI/NINDS, National Institutes of Health, Bethesda, MD, United States

A new method of generating phase contrast is proposed. Using balanced SSFP sequence a significant contrast to noise ratio improvement was achieved. Using this method, the line of Genari in the visual cortex was shown at 3 T in a high resolution.

SSFP

Hall B Tuesday 13:30-15:30

Balanced Binomial-Pulse Steady-State Free Precession (BP-SSFP) for Fast, Inherently Fat Suppressed, Non-Contrast Enhanced Angiography

Garry Liu¹, Venkat Ramanan¹, Graham Wright¹

¹University of Toronto, Toronto, ON, Canada; ²Sunnybrook Health Sciences Centre, Toronto, ON, Canada

Fat signal suppression is essential for MR angiography. In this work, we present a generalized design of a 1-2-1 binomial pulse SSFP (BP-SSFP) sequence, and the trade-off between TR reduction, water SNR, and water/fat CNR. We apply our method to achieve a short scan time, provide steady-state fat suppression, maintain high SNR, and restrict banding artifacts for peripheral MR angiograms.

Balanced SSFP Profile Asymmetries Reflect Frequency Distribution Asymmetries: Evidence from Chemical Shift Imaging (CSI)

Way Cherng Chen¹, Rob H Tijssen¹, Christopher T Rodgers², Jamie Near¹, Karla L Miller¹

¹FMRIB, University of Oxford, Oxford, United Kingdom; ²OCMR, University of Oxford, Oxford, United Kingdom

Steady-state free precession (SSFP) is characterized by strong signal dependence on resonance frequency often described by the SSFP frequency profile. This profile has a well known symmetric shape in a homogeneous voxel but it becomes asymmetric in an inhomogeneous voxel. The SSFP profile can be modeled as the convolution of the homogeneous profile with the frequency distribution. In this study, CSI lineshape from normal white matter tracts was convolved with the homogeneous profile obtain a
predicted SSFP asymmetry profile. The predicted SSFP asymmetry profile was found to be in good agreement with the measured SSFP asymmetry profile. The ability of SSFP profile to amplify small frequency shifts makes it a promising contrast mechanism for probing tissue microstructures.

3022. Off-Resonance Banding Maps with Low Flip Angle Balanced Steady-State Free Precession

Abbas Nasiraei Moghaddam1,2, J Paul Finn1, Daniel B. Ennis3
1Radiology, UCLA, Los Angeles, CA, United States; 2Bioengineering, Caltech, Pasadena, CA, United States

Balanced steady-state free precession (bSSFP) is widely used for clinical exams. The off-resonance sensitivity, in particular, limits the use of bSSFP for clinical exams at field strengths greater than 1.5T. Herein we highlight the signal characteristics of the bSSFP pulse sequence for high and low flip angles in regions that are on- and off-resonance. Low flip angle bSSFP can be used to map off-resonance bands with bright image contrast. This is useful for discriminating image features that have low bSSFP signal intensity when high flip angles are employed and regions of off-resonance.

3023. Radio Frequency (B1) Field Mapping at 7T Using 3D SE/STE EPI Technique

Antoine Lutti1, Chloe Hutton1, Jorg Stadler2, Oliver Josephs3, Oliver Speck2, Claus Tempelmann1, Johannes Bernarding3, Nikolaus Weiskopf1
1Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, London, United Kingdom; 2Special Lab Non-Invasive Brain Imaging, Leibniz Institute for Neurobiology, Magdeburg, Germany; 3Dept. Biomedical Magnetic Resonance, Institute for Experimental Physics, Otto-von-Guericke University, Magdeburg, Germany; 4Department of Neurology, Otto-von-Guericke University, Magdeburg, Germany; 5Institute for Biometry and Medical Informatics, Faculty of Medicine, Otto-von-Guericke-University, Magdeburg, Germany

Spatial inhomogeneities in the radio-frequency (RF) field (B1) increase with field strength affecting quantification and image contrast. Fast and robust whole-brain B1 mapping methods are therefore essential to correct for B1 inhomogeneities at ultra-high fields. Here we optimize a SE/STE 3D EPI method for rapid B1 mapping at 7T, addressing severe off resonance effects and reducing sensitivity to transverse coherence effects. We demonstrate the robustness of this B1 mapping technique and illustrate its accuracy by correcting for B1 inhomogeneities in T1 maps.

3024. Transient Balanced SSFP Imaging with Increased Signal by Variable Flip Angles

Pauline W. Worters1, Brian A. Hargreaves1
1Stanford University, Stanford, CA, United States

This work presents a method for calculating variable flip angles for balanced (or fully refocused) steady state free precession (bSSFP) acquisition to generate echoes at predefined amplitudes. The main advantage is to allow for transient stage imaging with minimal artifacts and with increased signal. The variable flip angle calculation was applied to provide temporally uniform echo amplitudes. A non-contrast enhanced MRA acquisition, inflow inversion recovery (IFIR) bSSFP, was used to demonstrate the method; the resulting angiograms show improved signal and small vessel depiction.

3025. Analysis of the Transient Phase of Balanced SSFP with Non-Continuous RF for Cardiac Imaging

Glenn S. Slavin1
1Applied Science Laboratory, GE Healthcare, Bethesda, MD, United States

An analytical expression for the transient phase of a segmented, ECG-gated, non-continuous-RF, balanced SSFP sequence is presented. The results provide a means for true quantification of T1 and T2 for Look-Locker-based cardiac acquisitions.

3026. Region-Growing Reconstruction for Large-Angle Multiple-Acquisition BSSFP

Brady Quist1, Brian A. Hargreaves2, Glen R. Morrell1, Garry E. Gold2, Neal K. Bangerter1
1Department of Electrical & Computer Engineering, Brigham Young University, Provo, UT, United States; 2Department of Radiology, Stanford University, Stanford, CA, United States; 3Department of Radiology, University of Utah, Salt Lake City, UT, United States

A novel method for simultaneously suppressing fat and reducing bSSFP banding artifacts in the presence of field inhomogeneity was recently presented, called large-angle multiple-acquisition (LAMA) bSSFP. LAMA bSSFP requires the acquisition of two phase-cycled SSFP acquisitions and a field map, although previous work has suggested that an intelligent region-growing algorithm could replace field-map acquisition. In this work, we present such a region-growing algorithm, and demonstrate that LAMA bSSFP can perform effectively without the acquisition of a field map. Results are presented in the lower leg of a normal volunteer.

3027. High-Resolution 3D Isotropic Black-Blood Imaging with T2prep Inversion Recovery: Comparison Between FSE and SSFP

Keigo Kawaji1, Thanh D. Nguyen1, Beatriu Reig2, Pascal Spincemaille3, Priscilla A. Winchester4, Martin R. Prince5, Yi Wang1,2
1Biomedical Engineering, Cornell University, Ithaca, NY, United States; 2Radiology, Weill Cornell Medical College, New York, NY, United States

T2prep Inversion Recovery (T2IR) is a magnetization preparation technique that combines two preparations: T2prep and Inversion Recovery, in order to provide both T1 and T2 contrasts. Subsequently, T2IR provides flow-insensitive global black-blood suppression
suited for slow flow at the expense of SNR, being suitable for 3D volumetric black-blood imaging of vessel walls where slow blood flow is observed. In this study, we examined the performance of using a T2IR preparation in both FSE and SSFP sequences to image a large 3D coronal volume (20cm x 20cm x 5.2cm) at a submillimeter isotropic spatial resolution of 0.8mm.

3028. **Dark Blood BSSFP Cardiac MRI Using HEFEWEIZEN**

Karan Dara1, Jamal J. Derakhshan1, Jeffrey L. Duerk1, Jeffrey L. Sunshine2, Mark A. Griswold2

1Department of Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States; 2Department of Radiology, University Hospitals of Cleveland, Cleveland, OH, United States

T2-weighted dark blood prepared TSE sequences are commonly used to image cardiac pathology. These methods often suffer from motion artifacts due to their long acquisition times. Here we apply a new, fast, high SNR, dark blood prepared segmented TrueFISP sequence (HEFEWEIZEN) for cardiac imaging in which some TR blocks are replaced by spatially selective saturation pulses for out-of-slice signals. This directionally suppresses bright blood flow (>65%) in the cardiac ventricles with some stationary tissue signal suppression offering a potential application to cardiac imaging.

3029. **Banding Artifact Reduction in 2D CINE Balanced SSFP at 3.0 T Using Phase-cycling and k-T BLAST**

Ute Kremer1, Fabian Hezel2, Gabriele A. Krombach1, Thoralf Niendorf2,3

1Department of Diagnostic Radiology, University Hospital, RWTH Aachen, Aachen, Germany; 2Berlin Ultrahigh Field Facility, Max-Delbrueck Center for Molecular Medicine (MDC), Berlin, Germany; 3Charité, University Medicine, Berlin, Germany

This work proposes to combine phase-cycled bSSFP with k-t BLAST to overcome the scan time penalty of multiple-acquisition bSSFP while still eliminating off-resonance induced banding artifacts at 3.0 T. Acquisitions were conducted using four-fold accelerated k-t BLAST and three phase-cycles. For comparison conventional bSSFP was obtained and endocardial border sharpness (EBS) assessment was performed. In theory omitting one of the four standard phase-cycles disturbs the off-resonance profile's flatness, however for in vivo imaging it yielded excellent banding reduction and improved the mean EBS. Accelerated, phase-cycled bSSFP imaging promises to extend the capabilities of routine CINE imaging at (ultra)high fields.

Rare & Turbo Spin Echo

**Hall B Wednesday 13:30-15:30**

3030. **Reduced SAR with Combined Acquisition Technique (CAT) Hybrid Imaging Sequence at 7 Tesla**

Morwan Choli1, Felix A. Breuer1, Daniel Neumann2, Michael Bock2, Claudia M. Hillenbrand1, Ralf B. Loeffler1, Peter M. Jakob2,3

1Research Center Magnetic Resonance Bavaria e.V (MRB), Wuerzburg, Germany; 2Dept. of Experimental Physiks 5, University of Wurzburg, Wuerzburg, Germany; 3Department of Medical Physics in Radiology, German Cancer Research Center (dkfz), Heidelberg, Germany; 4Department of Radiological Sciences, Division of Translational Imaging Research, Memphis, TN, United States; 5Research Center Magnetic Resonance Bavaria e.V (MRB), Wuerzburg, Germany

Higher field strength comes along with increase of the deposited SAR energy. Important imaging sequences like TSE with numerous refocusing pulses are only exercisable with limitations of the parameters at the expense of image quality to protect patients. In this work it is shown that it is possible to obtain high resolution in vivo images on a 7T scanner with an almost equal signal behavior in a combined acquisition technique (CAT) hybrid sequence consisting of a TSE module and an EPI module with SAR saving of 27%.

3031. "Spin-Echo Like T1 Contrast" Volumetric Black-Blood Images Using 3D LOWRAT: Low Refocusing Flip Angle TSE.

Masami Yoneyama1, Masanobu Nakamura1, Takashi Tabuchi1, Atsushi Takemura2, Junko Ogura1

1Medical Satellite Yaesu Clinic, Chuo-ku, Tokyo, Japan; 2Philips Electronics Japan, Ltd., Minato-ku, Tokyo, Japan

T1 weighted 3D VRFA-TSE sequence is decreasing flow artifacts by sequence-endogenous flow-void enhancement. But, T1 contrast becomes sub-optimal with the long echo train and pseudo steady-state effects. We propose a new scheme of more T1-optimized black-blood 3D TSE pulse sequence with low refocusing flip angles. Volunteer experiments were acquired in 3D low refocusing flip angle TSE (LOWRAT) using a 3.0T imager. The optimal parameter for T1-optimized black-blood imaging was low excitation flip angles, low refocusing flip angles, NPHA pseudo steady-state preparation, short ETL, best echo number for K-space center=2nd echo, and shortest TR. Contrast behavior of 3D LOWRAT T1W was similar to that of 2D SE. This optimal sequences can be used for 3D volumetric T1 weighted black-blood imaging.
Rapid Optimization of Acquisition Parameters for Fast Spin Echo Imaging in RF Power Constrained Regimes
Robert Marc Lebel1, Alan W. Wilman1
1Biomedical Engineering, University of Alberta, Edmonton, Alberta, Canada

At high field strengths, fast spin echo is a SAR constrained procedure; parameter concessions are required to enable its use. Typical modifications include elongated RF pulses and reduced refocusing angles. We present an SNR analysis investigating the effects of reduced angles (lower signal) and longer RF pulses (less readout time) and present a reliable method for rapidly selecting these parameters to optimize the SNR for a given target power level.

Reduced SAR with BASE Sequence at 7 Tesla
Daniel Neumann1, Morwan Choli2, Martin Blaimer2, Michael Bock3, Felix Breuer2, Peter M. Jakob4
1Experimental Physics 5, University of Würzburg, Würzburg, Germany; 2Experimental Physics 5, Research Center Magnetic Resonance Bavaria (MRB), Würzburg, Germany; 3Department of Medical Physics in Radiology, German Cancer Research Center (dkfz), Heidelberg, Germany; 4Experimental Physics 5, University of Würzburg, Bavaria, Germany

The step towards higher magnetic fields on the one hand provides a stronger NMR signal while on the other hand SAR is significantly increased in comparison with standard clinical scanners. Therefore the application of sequences using many refocusing pulses such as TSE can be difficult.

In this work we examine the potential of the BASE sequence to obtain high resolution images at 7 T. BASE is a combination of BURST and multiple refocusing pulses. However, compared to TSE, there are a lower number of pulses and therefore SAR could be reduced by a factor of four.

Whole-Brain FLAIR Using 3D TSE with Variable Flip Angle Readouts Optimized for 7 Tesla
John W. Grinstead1, Oliver Speck2, Dominik Paul, Lisa Silbert3, Louis Perkins3, William Rooney3
1Siemens Healthcare, Portland, OR, United States; 2Biomedical Magnetic Resonance, Otto-von-Guericke-University, Magdeburg, Germany; 3Oregon Health and Science University

Routine FLAIR uses a 2D inversion-recovery turbo spin echo pulse sequence having many high-SAR RF pulses, allowing only a few slices to be acquired at 7 Tesla. Recent work demonstrated the feasibility of using 3D IR-TSE with a T2-prepared IR and a reduced flip angle readout of 70 degrees to perform whole brain FLAIR at 7 Tesla for the first time. The present work extends this approach with a variable flip angle readout optimized for the T1 and T2 values of brain tissues at 7 Tesla to further improve the SAR, contrast, and SNR performance.

Inversion of a Non-CPMG Fast Spin Echo Train.
Patrick H. Le Roux1
1Applied Science Lab, GE Healthcare, Palaiseau, IDF, France

The non-CPMG sequence permits to acquire MR signal in the Fast Spin Echo mode even when the CPMG (Carr Purcell Meiboom Gill) phase conditions cannot be fulfilled. It consists in a quadratic phase modulation of the refocusing pulses train, preceded by a suitable preparation period. It turns out that this sequence of RF pulses can be readily inverted permitting a perfect Driven Equilibrium scheme to be applied.

Verse-Space
Guobin Li1, Christoph Sauerbier2, Dominik Paul1, Weijun Zhang1, Qiang He1, Marc Beckmann1, Lars Lauer2
1Siemens Mindit Magnetic Resonance Ltd., Shenzhen, Guang Dong, China; 2Hochschule Furtwangen University, Germany; 3Siemens Medical Solutions, Erlangen, Germany

Slab selection by the dual echo-spacing technique in SPACE with non-selective refocusing pulses needs averaging with phase cycling ans is sensitive to chemical shift artifacts during excitation. A new technique, VERSE-SPACE is presented in this abstract to provide faster acquisition speed and better slab profile than the previous technique.

Multi-Slab SPACE
Guobin Li1, Dominik Paul2, Weijun Zhang1, Tallal Charles Mamisch3, Qiang He1, Marc Beckmann1, Lars Lauer2
1Siemens Mindit Magnetic Resonance Ltd., Shenzhen, Guang Dong, China; 2Siemens Medical Solutions, Erlangen, Germany; 3Department of Orthopaedic Surgery, Inselspital, University of Berne, Bern, Switzerland

In Single Slab SPACE, relative short TR and long echo train have to be used to reduce the total acquisition time into clinical acceptable range at the cost of the degradation in contrast purity and SNR, especially in PDw imaging. A new Multi-Slab SPACE is presented here to further increase the sampling efficiency, and then provides more flexibility to use longer TR and shorter echo train acquisition compared to Single Slab SPACE.
Fast Spin-Echo Imaging of Inner Field-Of-Views Using 2D-Selective RF Excitations

Jürgen Finsterbusch

1Department of Systems Neuroscience, University Medical Center Hamburg-Eppendorf, Hamburg, Germany; 2Neuroimage Nord, University Medical Centers Hamburg-Kiel-Lübeck, Hamburg-Kiel-Lübeck, Germany

Fast spin-echo imaging suffers from image blurring if a large number of echoes per excitation (turbo factor) is used and, in particular at higher magnetic fields, from SAR limitations. Focussing the field-of-view to a small inner volume reduces the number of required echoes considerably and thus ameliorates blurring and RF deposition. This is demonstrated in phantoms and the human brain at 3T using blipped-planar 2D-selective RF excitations. Thereby, the unwanted side excitations were positioned in the dead corner between the slice stack and the image section in order to minimize the duration of the 2DRF excitations without saturating neighbored sections.

Echo Planar Imaging: New Acquisition Approaches

Hall B Thursday 13:30-15:30

An Effective Method to Increase Temporal or Spatial Resolution in Interleaved Echo Planar Imaging

Thomas Sushil John, Dwight George Nishimura, John Mark Pauly

1Electrical Engineering, Stanford University, Stanford, CA, United States; 2Electrical Engineering, Stanford University, Stanford, CA, United States

A common solution to correct for ghosting in interleaved echo planar imaging (EPI) is to employ echo time shifting (ETS). Although ETS corrects for ghosting in a robust, non-iterative, and automatic manner, it does so at the expense of increasing total scan time. In this work, a simple, yet effective scheme to increase the efficiency of ETS is proposed. Using the proposed technique, shorter scan times are possible when the in-plane resolution is fixed. Alternatively, the proposed scheme can acquire higher resolution images when total scan time is fixed.

Non-Uniform Density EPI Acquisition Improves the SNR of Smoothed MR Images

Lars Kasper, S. Johanna Vannesjö, Maximilian Häberlin, Christoph Barmet, Klaas Enno Stephan, Klaas Paul Prüssmann

1University and ETH Zurich, Institute for Biomedical Engineering, Zurich, Switzerland; 2Institute for Empirical Research in Economics, University of Zurich, Laboratory for Social and Neural Systems Research, Zurich, Switzerland; 3Institute of Neurology, University College London, Wellcome Trust Centre for Neuroimaging, London, United Kingdom

Smoothing MR-images is a common preprocessing step in areas like functional MRI to improve signal as well as noise characteristics of the images and facilitate inter-subject comparison. We present how an EPI-acquisition scheme (1.5 mm resolution) whose density is specifically tailored to match an image smoothing kernel improves the SNR of the finally smoothed images. Furthermore, this shows the opportunity to assign differing spatial properties to signal and noise contributions within an MR image. Because these non-uniform trajectories differ from common MR gradient demands, we relied on actually measured trajectories for our reconstructions, using an NMR field monitoring setup.

Reducing the Effective Point Spread Function in Echo Planar Imaging Through the Use of Partial Fourier Asymmetric Spin Echo Pulse Sequences

Andrew Scott Nencka, Daniel L. Shefchik, Eric S. Paulson, Andrzej Jesmanowicz, James S. Hyde

1Department of Biophysics, Medical College of Wisconsin, Milwaukee, WI, United States; 2Department of Radiation Oncology, Medical College of Wisconsin, Milwaukee, WI, United States

Pulse sequences which acquire trains of echoes face an inherent limit in resolution due to intra-acquisition decay. In gradient echo sequences, often used in functional studies, T2* decay leads to an increased point spread function in the phase encoding direction due to the lower effective bandwidth in that direction during data acquisition. In this abstract, we illustrate that the desirable T2* weighting associated with gradient echo sequences may be preserved with an asymmetric spin echo, and that acquisitions on the ascending edge of the spin echo yield point spread functions which are reduced in the phase encoding direction. This effect comes from the competing T2* rephrasing and T2 decay leading up to the formation of the spin echo. Matching the effective echo time on the ascending and descending sides of the spin echo can yield varying image contrast in vivo due to true T2 decay, thereby affecting the perceived smoothness of the reconstructed image.
Optimized, Unequal Pulse Spacing in Multiple Echo Sequences Improves Refocusing in Magnetic Resonance

Warren S. Warren¹, Rosa Tamara Branca²
¹Chemistry/CMBI, Duke University, Durham, NC, United States; ²Chemistry, Duke University, Durham, NC, United States

A recent quantum computing paper analytically derived optimal pulse spacings for a multiple spin echo sequence which differ dramatically from the conventional, equal pulse spacing of a Carr-Purcell-Meiboom-Gill (CPMG) sequence. Here we show that this “UDD sequence” has advantages for MR of tissue, where diffusion in microstructured environments leads to fluctuating fields on a range of different timescales. Both in excised tissue and in a live mouse tumor model, optimal UDD sequences produce different contrast than do CPMG sequences, with substantial enhancements in most regions. This provides a new source of endogenous contrast and enhances sequences which are currently T2-limited.

T2-Prepared Segmented 3D-Gradient-Echo as Alternative to T2-Weighted TSE for Fast High-Resolution Three-Dimensional Imaging

Jian Zhu¹,², Axel Bornstedt¹, Vinzenz Hombach¹, Alexander Oberhuber¹, Genshan Ma², Naifeng Liu², Volker Rasche³
¹Department of Internal Medicine II, University Hospital of Ulm, Ulm, Germany; ²Department of Cardiology, Zhongda Hospital, Southeast University, Nanjing, China; ³Department of Thorax and Vascular Surgery, University Hospital Ulm, Ulm

Spin-echo and multi-spin echo sequences are still the gold standard for generation of a T2 – weighted image contrast. A major drawback of this technique rises from the long repetition times required for achieving sufficient recovery of the longitudinal magnetization, which cause long acquisition times especially in high-resolution volumetric imaging. In this study, the use of a fast gradient echo sequence with T2 preparation is investigated for generating a T2 weighted image contrast similar to a multi-spin-echo approach, but with an up to 8-fold reduction of the acquisition time.

Differential Subsampling with Cartesian Ordering (DISCO): A Novel K-Space Ordering Scheme for Dynamic MRI

Dan Rettmann¹, Manojkumar Saranathan¹, James Glockner²
¹Applied Science Lab, GE Healthcare, Rochester, MN, United States; ²Radiology, Mayo Clinic, Rochester, MN, United States

Dynamic contrast enhanced MRI (DCEMRI) and MR angiography (MRA) are both beset by the conflicting requirements of spatial and temporal resolution. Various schemes have been proposed and evaluated for high spatio-temporal resolution MR imaging which incorporate combinations of partial Fourier imaging, sub-sampling, view sharing and parallel imaging to effect acceleration. We propose DISCO (DIfferential Subsampling with Cartesian Ordering), a flexible k-space segmentation scheme that minimizes sensitivity to eddy currents and motion for dynamic imaging while dispersing artifacts and residual ghosting and demonstrate its use in first pass contrast enhanced liver imaging.

Advancements in Contact-Free Respiration Monitoring Using RF Pick-Up Coils

Ingmar Graesslin¹, Giel Mens¹, Alexander Guillaume¹, Henry Stahl¹, Peter Koken¹, Peter Vernickel¹, Paul Harvey², Jouke Smink², Kay Nehrke¹, Peter Boernert¹
¹Philips Research Europe, Hamburg, Germany; ²Philips Healthcare, Best, Netherlands; ³FH Westküste, Heide, Germany

Advanced methods of motion detection and motion artifact reduction help to improve diagnostic image quality. The use of conventional navigators requires additional planning and adversely influences the steady state, which can result in image artifacts. A new approach was presented that uses the detection of changes of RF coil loading induced by the respiratory motion of the patient. This paper describes the application of a real-time self-navigated respiration monitoring approach using dedicated RF monitoring pulses instead the RF excitations of the imaging sequence. RF amplifier drift is analyzed, and a compensation scheme is proposed to overcome this problem.
Correction of motion artifacts is an ongoing and very important task in MRI. This motion, most often introduced by patients that suffer from a medical condition, which makes it difficult to remain motionless during MRI acquisitions, can significantly corrupt the resulting images and their diagnostic value. In this study we show first in-vivo results of our prospective optical motion correction system applied to three-dimensional time of flight (3D TOF) angiography. Results show that compared to the non-motion corrected case the real-time motion correction is able to dramatically improve image quality of 3D TOF angiograms.

In this work we investigate the potential to characterise rigid-body head motion by monitoring free induction decay (FID) changes over time in coil arrays. The technique makes use of the fact that FID signals detected by local coil elements change as a function of object distance. Assuming a sufficient coverage of the scanned object with local coil elements, the inverse problem of back-calculation of the rigid motion parameters may be solvable. In this investigation, a framework to derive these motion parameters is developed and first results are shown from phantom and human scans using a 32-channel head coil array.

Motion during data acquisition can seriously degrade image quality. Motion compensated reconstruction can restore image quality if the motion is measured with suitable navigator signals. We present a new scheme for motion compensated reconstruction which can be applied to segmented Cartesian acquisitions (e.g. TSE, TFE). It can be combined with parallel imaging and is fast because it works mainly in the spatial domain avoiding many Fourier-transforms between k-space and image space. The motion is detected and quantified by adding an orbital navigator echo in front of the imaging echoes.

Motion estimation helps sparsifying the residues effectively. Recent literatures suggest improved baseline estimation using adaptive regularization or motion estimation (ME) and compensation (MC). While the suitability of these methods on other dynamic images has not been investigated.

A simple method of respiratory monitoring using the phase of the DC term of k-space collected with a spiral k-space trajectory is presented and compared with the measurement from the respiratory bellows. The method presented is shown to be in excellent agreement with the measurement from the respiratory bellows and reveal even cardiac pulsatility. In this work the method is used to gate a spiral-trajectory scan of the liver. The image reconstructed with the DC phase used for gating was qualitatively similar to the one reconstructed using conventional gating. Since the image data is used for gating no additional navigators must be acquired.

In functional MRI, subject motion during the acquisition of an image series can confound results and is generally corrected for using a variety of methods. Because statistical models for performing complex-valued fMRI analysis are available which can provide some benefits beyond the standard magnitude-only technique, investigation of a signal resulting from direct neuronal current involves complex-valued analysis, and recent reports have indicated potentially valuable functionally related phase signal, performing motion...
correction on complex-valued time series is of interest. This work identifies the problems facing motion correction of complex-valued images and proposes a solution for properly applying the correction.

**3052. Compensation for Nonrigid Motion Using B-Spline Image Registration in Simultaneous MR-PET**

Se Young Chun¹, Sanghee Cho², Tim G. Reese³, Bastien Guérin⁴, Xuping Zhu⁵, Jinsong Ouyang², Ciprian Catana⁶, Georges El Fakhri⁷

¹Division of Nuclear Medicine & Molecular Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States; ²Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States; ³Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States

This abstract reports preliminary results of motion corrected MR-PET reconstruction based on B-spline nonrigid image registration and compares it with HARP based motion compensation. With a breathing phantom, we collected MR and PET data simultaneously using BrainPET prototype PET scanner operating in the bore of a 3T TIM Trio scanner. Then we estimate the motion of a phantom using HARP and proposed B-spline based image registration with a novel invertibility penalty. These estimated motions were used in motion compensated iterative PET reconstruction. This preliminary result shows significant improvement of PET images for large motions.

**3053. Respiratory Motion Correction of PET Using Simultaneously Acquired Tagged MRI**

Timothy Gordon Reese¹, Bastien Guérin², Sanghee Cho², Se Young Chun², Jinsong Ouyang², Xuping Zhu², Ciprian Catana², Georges El Fakhri²

¹Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States; ²Division of Nuclear Medicine & Molecular Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States; ³Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Boston, MA, United States

As the spatial resolution of PET scanners improves, the deleterious effects of patient motion become an ever increasing limitation in PET studies. We present our first results with incorporating clinically relevant motion information derived from MR into the PET reconstruction process. We describe our current methods for tracking non-rigid periodic motion over the entire FOV of the MR-PET scanner, during the PET acquisition. All PET coincidences were reconstructed in a single frame while correcting the data for motion using MRI, demonstrating feasibility on an actual MR-PET system and a significant improvement in PET image quality.

**3054. DCE-MRI Non-Rigid Kidney Registration**

Michael Hafer¹, Steven Keeling¹, Gernot Reishofer¹, Michael Riccabona¹, Manuela Aschauer¹, Rudolf Stollberger²

¹Institute of Medical Engineering, Graz University of Technology, Graz, Austria; ²Institute for Mathematics and Scientific Computing, University of Graz, Graz, Austria

Dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) is a very promising method for noninvasive assessment of renal function. To remove the influence of motion artifacts like breathing, a novel registration approach is proposed which derives a template image series with the underlying signal time course. This results in an independency from signal changes due to contrast media uptake. The original dynamic time series (source images) is then registered by elastic registration to this virtual template. This results in an independency from signal changes due to contrast media uptake. The original dynamic time series (source images) is then registered by elastic registration to this virtual template. The algorithm successfully reduces motion artifacts. Comparisons between pre and post registration underlines the importance of image registration in DCE-MRI examinations.

**3055. Flow Compensation in Frequency-Encode Direction for the Fast Spin Echo Triple-Echo Dixon (FTED) Sequence**

Kaining Shi¹, Russell Low¹, Shanglian Bao¹, Jingfei Ma²

¹Beijing City Key Lab of Medical Physics and Engineering, Beijing University, Beijing, China; ²Imaging Physics, University of Texas MD Anderson Cancer Center, Houston, TX, United States

The triple echo readout in the FTED sequence presents a challenge to achieve flow-compensation along the frequency-encode direction. In this work, two flow-compensation methods were proposed. In the first method, gradient moments are nulled at every RF locations so that the CPMG condition is always maintained. In the second method, the spin echo component of the signal is nulled at the 1st and 3rd echo locations and the stimulated component is minimized at different echo locations. The effectiveness of both methods in reducing the flow-induced artifacts was examined with a numerical calculation and demonstrated in a phantom testing.

**3056. On the Optimization of Parallel Imaging for Ghost Reduction: A Blood Flow Example**

Feng Huang¹, Wei Lin¹, Yu Li¹, Arne Reykowski¹

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A parallel imaging based technique, CONvolution and Combination OperAtion (COCOA), has been proposed recently to efficiently remove ghost artifacts due to non-rigid motion. COCOA has two steps: a convolution step for a synthetic k-space with redistributed error, and a combination step for the final reconstructed k-space with reduced error. In this work, by using blood flow artifact as an example, the optimization schemes for these two steps are introduced to improve the ability for ghost suppression.
A method for reconstructing multiple high-resolution respiratory phases from free-breathing 3D-MRI is presented. The proposed method combines an undersampled self-gating acquisition with a non-rigid image registration scheme. This approach uses all the acquired data to reconstruct a single high spatial resolution (HSR) phase at the most visited respiratory position and multiple respiratory resolved (RR) images at the remaining phases followed by an improving of image quality for all RR images (suffering from remained aliasing artifacts) using a registration procedure. This aligns the features of HSR with the remaining RR phases, leading to a sequence of time-resolved high resolution respiratory phases.

We present a novel motion correction method using coil arrays (MOCCA). In MOCCA, the elements of a coil array are used as individual motion "sensors" which detect the motion-induced signal variations that are modulated by coil sensitivity maps. The inclusion of multiple coils by stacking multi-coil data into a column vector increased the accuracy of motion detection compared to existing methods based on projections. We evaluate the accuracy of MOCCA in a phantom and demonstrated the application of MOCCA on healthy volunteers for bulk motion correction in brain imaging and for respiratory and cardiac self-gating in cardiac cine imaging.

In general, the minimum number of K-Space samples required to produce good results in sparse reconstruction is approximately four times the number of sparse coefficients. Patient motion that is neither periodic nor smooth will reduce sparsity in the temporal direction and degrade the success of the sparse reconstruction. It is therefore beneficial to detect and correct as much patient motion as possible to maximize temporal sparsity and thus reduce the total number of K-Space samples required. This is accomplished using a hybrid Radial-Cartesian sampling technique called. This sequence has an inherent ability to correct bulk patient motion and is well suited to non-linear sparse reconstruction.

With the combination of Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) into a single combined system, a novel imaging modality has become available. Previous approaches to patient motion tracking for PET data correction are difficult to use in the combined MR-PET environment. Thus, alternative methods for motion tracking have to be developed. Here, a novel approach for MR-PET motion correction using the Lissajous navigator is presented.

Conventional MRI reconstruction techniques are susceptible to artifacts when imaging moving organs. In this paper, a reconstruction algorithm is developed that accommodates motion instead of altering the scanning protocol. The maximum a posteriori (MAP) algorithm uses the raw time-stamped data to reconstruct the images and estimate deformations in anatomy simultaneously. The algorithm eliminates artifacts by avoiding gating processes and increases signal-to-noise ratio (SNR) by using all of the collected data. The algorithm is tested in a simulated torso phantom and is shown to increase image quality by dramatically reducing motion artifacts.

DWI leads to patient table vibration that may affect image quality, as has been demonstrated previously in phantom and brain. We therefore investigated the impact of mechanical vibration during abdominal DWI on diffusion parameter estimation. Diffusion scans were performed on three subjects that were once in direct contact with the MR-system, thus experiencing vibration, and once without contact to the MR-System. The results demonstrate that the impact of vibration on diffusion parameter estimation, including micro-perfusion estimation, and also on the image intensity is only small. This holds true for standard measurement parameters.
data can detect the diaphragm position accurately even when the data have a fuzzy magnitude edge or noisy phase in the lung.

phase information to detect the diaphragm position. Our results show that the edge detection based on the magnitude-weighted phase navigator trajectory and its application to motion compensated reconstruction.

estimated motion derived from the navigator signal. We present a fast, robust and precise algorithm to evaluate data from an orbital interpolation algorithm to reduce these artifacts without introducing significant motion blurring. In-vivo results are presented to compare the algorithm with other motion artifact reduction techniques.

unstable in the lung, and wrong position can be detected accordingly. We present a hybrid algorithm utilizing both magnitude and profile of navigator enables the navigator gated imaging even with the saturation effect. However, the phase profile is sometimes unstable in the lung, and wrong position can be detected accordingly. We present a hybrid algorithm utilizing both magnitude and phase information. Cardiac pulsations induce phase gradients that can shift the local low-frequency information into the unacquired part of k-space. The associated signal voids are therefore irretrievable by any PF reconstruction method. Thus, PF DW imaging should generally be avoided or used solely with cardiac gating.

Image artifacts induced by subject motion during multi-channel MRI were simulated for different sensitivity map profiles and different amounts of abrupt random motion. More localized maps resulted in stronger artifacts in the images. Two procedures for retrospective motion correction, k-space signal correction and sensitivity map correction were applied during an iterative non-Cartesian SENSE reconstruction. The signal correction evidently reduced the artifacts. The sensitivity map correction further improved image quality for strong motion and highly localized maps, at the cost of a longer computation time. For small motion and less localized maps, sensitivity map correction can be avoided since no improvement was visible.

Any object movement during or between MRI acquisition readouts leads to data inconsistency artifacts in the images. The manifestation of these artifacts depends on the k-space sampling trajectory. For example, in echo-planar imaging they appear as “ghosting” artifacts, and in spiral imaging they manifest as “swirling” artifacts. Dynamic imaging, which attempts to capture body or physiological motion through continuous acquisitions, is vulnerable to these artifacts. In this work, we present an adaptive polynomial interpolation algorithm to reduce these artifacts without introducing significant motion blurring. In-vivo results are presented to compare the algorithm with other motion artifact reduction techniques.

Image artifacts induced by subject motion during multi-channel MRI were simulated for different sensitivity map profiles and different amounts of abrupt random motion. More localized maps resulted in stronger artifacts in the images. Two procedures for retrospective motion correction, k-space signal correction and sensitivity map correction were applied during an iterative non-Cartesian SENSE reconstruction. The signal correction evidently reduced the artifacts. The sensitivity map correction further improved image quality for strong motion and highly localized maps, at the cost of a longer computation time. For small motion and less localized maps, sensitivity map correction can be avoided since no improvement was visible.

Dynamic Imaging Motion Artifact Reduction Using Adaptive K-Space Polynomial Interpolation

Dynamic Imaging Motion Artifact Reduction Using Adaptive K-Space Polynomial Interpolation

Magnitude-Weighted Phase Based Edge Detection for Navigator Gated Imaging

Irretrievable Signal Loss in Partial-Fourier Acquired Diffusion-Weighted Images

Robust and Fast Evaluation of Orbital Navigator Data for Rigid Body Motion Estimation
GE EPI is a widely used imaging technique, but is very sensitive to B₀ field inhomogeneities. To correct for temporal changes of B₀, real-time measuring methods are necessary, such as estimating gradient maps of B₀ from raw EPI data. Here a filter scheme is presented to calculate local B₀ gradients. The local gradient in the readout direction is estimated independently from the gradient in the phase encoding direction by finding the contour lines of the gradients. The method is compared with previously introduced raw data based techniques and shown to perform better or equally well.

**3070. Rapid Retrospective Non-Rigid Motion Correction for Free-Breathing MRI**

Yoshihiro Tomoda¹, Yui Iwadate², Tetsuji Tsukamoto³, Yoshikazu Ikezaki²

¹MR Engineering, GE Healthcare Japan, Hino, Tokyo, Japan; ²MR Applied Science Laboratory, GE Healthcare Japan, Hino, Tokyo, Japan

We proposed a new framework that enables not only non-rigid motion correction with 100% acceptance rate but also rapid reconstruction. As the first investigation, we implemented the 1D non-rigid motion correction, called 1D MMFK, and confirmed the effectiveness with the simple linear expansion model by numerical simulation and volunteer scan.

**3071. Correction of Motion Artifacts Using a Genetic Algorithm**

Stephan Witoszynskyj¹, Alexander Rauscher²

¹Department of Radiology, Medical University of Vienna, Vienna, Austria; ²UBC MRI Research Centre, University of British Columbia, Vancouver, BC, Canada

We present a genetic algorithm for correction of motion artifacts in MRI. Two types of genetic algorithms were investigated: the first used only "non-sexual" multiplication and the second allowed "cross-over" between solutions. The algorithm corrects for translations by estimating correction factors for each k-space line. Four different image metrics were studied: entropy, normalized-gradient-squared (NGS), signal in the background and local coherence in the background. The best results were obtained by using the simple algorithm and NGS and entropy as metric. Since genetic algorithms are inherently parallelizable our approach could benefit greatly from being implemented on computer clusters and GPUs.

**3072. Less Can Be More: Reduction of Motion Artifacts by Ignoring Parts of the Acquired Dataset**

Tim Nielsen¹, Jinnan Wang²,³, Peter Boernert¹

¹Philips Research Europe, Hamburg, Germany; ²Philips Research North America, Briarcliff Manor, NY, United States; ³University of Washington, Seattle, WA, United States

High resolution MR imaging of the carotids is an interesting technique for plaque characterization but image quality can be compromised by motion artifacts. Effects of breathing and pulsation can be reduced by gated acquisition. Coping with non-periodic motion (e.g. swallowing) is still often required in clinical practice and is considered as a major factor that contributes to the overall 20% failure rate in clinical scans. We present a method to reduce the effects of sudden, non-periodic motion by exploiting data redundancy which is usually present in parallel imaging with multiple receive coils. The method can be applied retrospectively without any navigator information.

**3073. Fast Phase Based Registration for Robust Quantitative MRI**

Anders Eklund¹,², Marcel Warntjes, ²³, Mats Andersson¹,², Hans Knutsson¹,²

¹Division of Medical Informatics, Department of Biomedical Engineering, Linköping University, Sweden; ²Center for Medical Image Science And Visualization (CMIV), Linköping University, Sweden; ³Division of Clinical Physiology, Department of Medicine and Health, Linköping University, Sweden

Quantitative magnetic resonance imaging has the major advantage that it handles absolute measurements of physical parameters. Quantitative MRI can for example be used to estimate the amount of different tissue types in the brain, but other applications are possible. When quantitative MRI is performed, a number of volumes are collected from the MR scanner. In order for the tissue quantification to work properly, the volumes have to be perfectly aligned. The problem with the volumes is that they differ significantly in intensity. We present a method for fast registration of such volumes and prove that it is more robust than the statistical parametric mapping (SPM) software.

**3074. Navigator-Based Elliptical K-Space Reordering for Aortic 4D-Flow Imaging**

Ashley Gould Anderson III¹, Sebastian Gruhlke², Oliver Wieben¹,³, Michael Markl²,⁴

¹Medical Physics, University of Wisconsin, Madison, WI, United States; ²Medical Physics, University Hospital Freiburg, Freiburg, Germany; ³Radiology, University of Wisconsin, Madison, WI, United States; ⁴Diagnostic Radiology, University Hospital Freiburg, Freiburg, Germany

Respiratory motion causes significant artifacts during 4D-Flow imaging in the torso due to long scan time requirements. Respiratory gating based on navigator signals or external measurements with bellows have been shown to reduce phase-related motion artifacts in long two- and three-dimensional free breathing acquisitions. Moreover, real-time adaptive k-space reordering, i.e. phase encoding based on the current position in the respiration cycle, can considerably improve navigator efficiency and thus reduce overall scan time. This work builds on proven respiratory gating and compensation methods by extending them to include reordering in the 3D slice-select direction in addition to the phase-encoding direction.
3075. **Background Phase Correction Using K-Space Filters in Phase Contrast Velocity**

**Encoded MRI**

* Martin Uppman¹, Michael Markl², Bruce S. Spottiswoode³,⁴

¹Lund Institute of Technology, Lund, Sweden; ²Diagnostic Radiology, Medical Physics, Albert-Ludwigs Universität, Freiburg, Germany; ³MRC/UCT Medical Imaging Research Unit, Department of Human Biology, University of Cape Town, South Africa; ⁴Department of Radiology, Stellenbosch University, South Africa

This work evaluates k-space high-pass filtering as a post-processing background phase correction technique for 2D phase contrast velocity encoded MRI. Results are compared to an established technique which involves estimating the phase variation in stationary tissue and subtracting a fitted polynomial surface. Phantom and in-vivo studies show that k-space filtering with a large kernel performs equally as well as a high order polynomial surface subtraction.

3076. **Intrinsic Detection of Corrupted Data**

* Jason K. Mendes¹, Dennis L. Parker¹

¹UCAIR, University of Utah, Salt Lake City, UT, United States

Correlations between adjacent K-Space lines can be used to detect non-rigid body motion or motion that occurs out of plane. The cross correlation between two adjacent sets of equally spaced K-Space lines is a set of equally spaced delta functions convolved with an error function. The error function is a result of correlation errors between adjacent sets of lines. These errors are present even when there is no motion of any kind, however, as the amount of data corruption increases the error function broadens. As a result, a measure of the relative sharpness of the error function provides a measure of data corruption.

3077. **SPI Motion Correction Using In-Plane Estimates**

* Ryan Keith Robison¹, Kenneth Otho Johnson¹, James Grant Pipe¹

¹Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, AZ, United States

Spiral Projection Imaging (SPI) allows for intrinsic estimation of rigid-body patient motion through the comparison of data between spiral planes that correspond to different time points but similar k-space locations. The in-plane estimation scheme produces 2D estimates of motion for each spiral plane. Full 3D motion estimates can be obtained for each plane by combining the 2D estimates of spatially orthogonal, sequential triplets of spiral planes. In-vivo images and quantitative estimation results are presented for simulated and in-vivo motion affected data.

3078. **Reconstruction Exploiting Phase-Correlation Motion Estimation and Motion Compensation Methods for Cine Cardiac Imaging**

* Mei-Lan Chu¹, Jia-Shuo Hsu¹, Hsiao-Wen Chung¹

¹Graduate Institute of Biomedical Electronics and Bioinformatics, National Taiwan University, Taipei, Taiwan

Motion estimation (ME) and motion compensation (MC) are successfully exploited by dynamic MRI as baseline estimation for enhancing reconstruction. However, ME and MC have not been exploited as a standalone approach for direct dynamic MRI reconstruction, since the absence of full-resolution frames. A robust reconstruction technique was proposed in this work to address this issue, based solely on phase-correlation ME and MC methods without incorporating extra reconstruction routine. Cine cardiac images are tested with the proposed method, and the results indicate that the proposed method can achieve improved temporal resolution even from substantially down-sampled k-space data.

**Image Correction: Gradients & Frequency**

Hall B Wednesday 13:30-15:30

3079. **Compressive Slice Encoding for Metal Artifact Correction**

* Wenmiao Lu¹, Kim Butts Pauly², Garry Evan Gold³, John Mark Pauly⁴, Brian Andrew Hargreaves²

¹Electrical & Electronic Engr., Nanyang Tech. University, Singapore, Singapore; ²Radiology, Stanford University, Stanford, CA, United States; ³Electrical Engr., Stanford University, Stanford, CA, United States

Metal artifacts in MRI can be completely corrected by Slice Encoding for Metal Artifact Correction (SEMAC), which nonetheless incurs prolonged scan times due to the additional phase encoding along slice-select direction. Here we incorporate SEMAC with compressed sensing to vastly reduce the number of phase encoding steps required to resolve metal artifacts. The new technique, referred to as Compressive SEMAC, can greatly reduce scan times, while producing high-quality distortion correction and SNR comparable to SEMAC with full sampling.

3080. **Noise Reduction in Slice Encoding for Metal Artifact Correction Using Singular Value Decomposition**

* Wenmiao Lu¹, Kim Butts Pauly², Garry Evan Gold³, John Mark Pauly⁴, Brian Andrew Hargreaves²

¹Electrical & Electronic Engr., Nanyang Tech. University, Singapore, Singapore; ²Radiology, Stanford University, Stanford, CA, United States; ³Electrical Engr., Stanford University, Stanford, CA, United States

To obtain distortion-free MR images near metallic implants, SEMAC (slice encoding for metal artifact correction) resolves metal artifacts with additional z-phase encoding, and corrects metal artifacts by combining multiple SEMAC-encoded slices. However,
many of the resolved voxels contain only noise rather than signals, which degrades signal-to-noise ratio (SNR) in the corrected images. Here the SEMAC reconstruction is modified to perform denoising using singular value decomposition, which exploits the redundancy in the SEMAC-encoded data received from multiple coils. We demonstrate the efficacy of the proposed technique in several important imaging scenarios where SEMAC-corrected images are liable to relatively low SNR.

### 3081. Imaging Near Metals with Phase Cycled SSFP

*Michael Nicholas Hoff*, Jordin D. Green, *Qing-San Xiang*

1Department of Physics & Astronomy, University of British Columbia, Vancouver, British Columbia, Canada; 2Siemens Healthcare, Calgary, Alberta, Canada; 3Department of Radiology, University of British Columbia, Vancouver, British Columbia, Canada

A fast bSSFP technique is devised for removing imaging artifacts near metals. 3D phase cycled TrueFISP provides comprehensive artifact reduction using powerful gradients, two dimensions of phase encoding, short TR, and thorough refocusing of magnetization. Problematic banding artifacts are eliminated using a technique which formulates expressions for each voxel’s modulated magnetization, and then analytically solves the system with a simple Cross-Solution (XS) to obtain the demodulated magnetization. Application to a phantom consisting of a hip prosthesis within a Lego structure confirms that 3D imaging with XS-SSFP is simple, efficient, and robust in artifact reduction.

### 3082. B₁ Effects When Imaging Near Metal Implants at 3T

*Kevin M. Koch*, Kevin F. King, Graeme C. McKinnon

1Applied Science Laboratory, GE Healthcare, Waukesha, WI, United States

Recently developed techniques have enabled low susceptibility-artifact imaging near metal implants using conventional spin-echo acquisition strategies. Previous demonstrations of these techniques have been presented at 1.5T. While the susceptibility artifact mitigation of these techniques remains sufficient at 3T, here we address the effects of reduced B₁ wavelength applied at 3T. These effects introduce increased B₁ artifacts near metal implants, particularly those with long axes oriented collinear with B₀. Finite element simulations and phantom images are presented to demonstrate and discuss these effects.

### 3083. Adaptive Slice Encoding for Metal Artifact Correction

*Brian A. Hargreaves*, Garry E. Gold, John M. Pauly, Kim Butts Pauly

1Radiology, Stanford University, Stanford, CA, United States; 2Electrical Engineering, Stanford University, Stanford, CA, United States

Slice encoding for metal artifact correction (SEMAC) excites 2D slices, then uses a 3D encoding to resolve the distortion of slices due to large metal-induced susceptibility shifts. The addition of a simple, fast spectral prescan easily estimates the extent of this distortion, allowing the slab width and encoded field-of-view to be adapted to the subject. This, allows the total number of excited slices to be greatly reduced without diminishing final image quality, thus offering a substantial reduction in SEMAC scan time.

### 3084. Fat-Suppressed and Distortion-Corrected MRI Near Metallic Implants

*Brian A. Hargreaves*, Wenmiao Lu, Kim Butts Pauly, John M. Pauly, Garry E. Gold

1Radiology, Stanford University, Stanford, CA, United States; 2Electrical & Electronic Engineering, Nanyang Tech University, Singapore, Singapore; 3Electrical Engineering, Stanford University, Stanford, CA, United States

Fluid-sensitive volumetric imaging of patients with metallic implants is potentially an important diagnostic tool to assess for infection, implant loosening, or other complications. Recent MR techniques use spin echoes combined with additional encoding to substantially reduce distortion and signal loss artifacts. Here we demonstrate the use of these sequences with short TI inversion recovery (STIR) to provide reliable fat suppression near metallic implants, which is particularly important in assessment of many disorders.

### 3085. Spiral Chemical Shift Imaging in the Presence of Metal Artifacts

*Atsushi M. Takahashi*

1Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States

MRI in the presence of metal in the body is complicated by B₀ field perturbations and by the shortening of the T₂* relaxation times. With a multi-interleave, short readout, spiral k-space trajectory, chemical shift imaging method, we can image in the presence of metal. Here we describe a method which can be used in-vitro to visualize the field maps surrounding metal implants.

### 3086. Evaluation of MR Image Artifacts of Stent Implants at 3 Tesla Using a Phantom Filled with Mineral Oil Compared to CuSO₄

*A Koenig*, Frank Reintke, Gerrit Schönwald, Gregor Schaefers

1University of applied Science Gelsenkirchen, Gelsenkirchen, NRW, Germany; 2MR Safety Testing Laboratory, MRcomp GmbH, Gelsenkirchen, Germany; 3University Witten/Herdecke

The ASTM-Standard F2119-07 is used to evaluate artifacts of implants. According to the test method a phantom with CuSO₄ is used. By replacing the solution by mineral oil it is desired to avoid standing waves in images. We tested both fluids in two sequences (SE/GRE) with 2 test devices, a Nitinol stent and an acryl reference tube. We compared a visual, a statistically and a manual analysis. We noticed non-significant results with one exception. Under certain conditions the standard CuSO₄ can be exchanged with mineral oil allowing better and precise artifact analysis at higher field strengths > 3 T.
The increased SNR of ultra-high-field MR scanners allows high resolution functional and diffusion studies to be performed. Because chemical-shift artifact suppression is essential for SE EPI images, we evaluated the performance of different fat suppression techniques. Conventional methods using additional radiofrequency (RF) and gradient pulses provide suboptimal results owing to increased B0 and B1 inhomogeneity at higher fields. They also increase RF power deposition. A recently developed method using different slice-select gradient strengths during the excitation and refocussing pulses was demonstrated to be most robust, and delivered best chemical shift selection.

Binomial water excitation is useful in low field MR system (<0.5T) for fat suppression, but it is vulnerable to main magnetic field instability. Dynamic magnetic field measurement is introduced in this method. The initial phase of the RF pulses except the first RF pulse in the binomial RF train is modified afterward in order to improve the performance of fat suppression. Result shows that lipid signal was suppressed well while water signal is enhanced in volunteer images.

Well-established methods for estimation of background field contributions were quantitatively analyzed based on a realistic numerical whole-body model. The results indicate that interpretability of phase data strongly depends on chosen filter-type, filter-parameter, and region of interest.

MR images are known to suffer from geometric distortion from a variety of sources. Boundaries between fat- and water-based tissues lead to discontinuities in the distortion field and result in hyper- and hypo-intense regions which cannot be corrected using standard distortion correction procedures. We propose a number of pre-processing steps which separate the image into fat and water components and shift the fat portion of the image prior to distortion correction. The technique was successfully demonstrated on phantom images and work is underway to evolve and apply the technique to more complex in-vivo images.

Methods of correcting the effects resulting from magnetic field inhomogeneities and off-resonance that have proven to be most effective in recovering homogenous image intensity, recovering signal dropout and providing optimal image unwarping often involve inverting a matrix kernel constructed with prior knowledge of the magnetic field. Field maps estimated using echo-planar images are very convenient to acquire, but are not compatible with the mentioned group of algorithms due to their “warped” space coordinates. A straightforward method is presented providing a connection between echo-planar based maps and optimal correction schemes leveraging both the convenience and performance of the combination.
High resolution, high contrast MRI scans can be used in neurophysiology research on nonhuman primates to plan invasive procedures that target deep brain structures. With procedures involving chronic, plastic head implants, susceptibility artifacts may severely distort the measurement of the projected entry trajectory. Geometric distortion correction based on field mapping is found both necessary and adequate to address this issue.

**3094. Computationally Efficient Removal of Inhomogeneities at the Cortical Surface in MR Phase Images.**

Amanda Ng, Jingxi Zhang, John Ashburner, Chloë Hutton

Department of Electrical and Computer Systems Engineering, Monash University, Melbourne, Australia; Department of Electrical and Electronic Engineering, University of Melbourne, Melbourne, Australia; Centre for Neuroscience, University of Melbourne, Melbourne, Australia; Department of Electrical and Electronic Engineering & NICTA Victorian Research Laboratory, University of Melbourne, Melbourne, Australia

Phase images in MRI are subject to inhomogeneities at the cortical surface due to susceptibility artefacts induced by air/tissue interfaces and insufficient filtering at foreground/background borders. We present a computationally efficient method of removing these inhomogeneities from phase unwrapped images using spatially dependent filters and omission of background voxels from the filtering calculations. The method is shown to successfully reveal structural detail in the cortical surface that is otherwise obscured in traditional filtering methods.

**3095. Correction of RF Inhomogeneities in FLASH-Based T1 Mapping Using Unified Segmentation**

Nikolaus Weiskopf, Antoine Lutti, Gunther Helms, John Ashburner, Chloë Hutton

Wellcome Trust Centre for Neuroimaging, UCL Institute of Neurology, University College London, London, United Kingdom; MR-Research in Neurology and Psychiatry, University Medical Center, Göttingen, Germany

Quantitative T1 mapping based on variable flip angle acquisitions requires precise knowledge of the local flip angle and is therefore usually combined with RF transmit mapping methods. RF transmit mapping is not readily available and requires extra scan time. We propose a method to correct for RF inhomogeneities that does not require measured RF maps. The method uses the unified segmentation and bias correction approach implemented in SPM8 to simultaneously estimate and correct for the RF inhomogeneities from the T1 maps. The model-based approach is shown to reduce the bias in T1 maps by more than 50%.

**3096. Improved Contrast and Image Homogeneity with BIR4 Pulses in Magnetization Prepared Flair at 7 Tesla**

Jacqueline M. Zwanenburg, Friedy Visser, Vincent O. Boer, Wybe JM van der Kemp, Dennis W. Klomp, Peter R. Luijten

Radiology, University Medical Center Utrecht, Utrecht, Netherlands; Philips Healthcare, Best, Netherlands

It is shown that using BIR4 pulses for excitation and magnetization prepared inversion, can considerably improve the image homogeneity and contrast of FLAIR images at 7 Tesla, in areas with inhomogeneous B1+ fields.

**3097. Distance Weighted B1 Uniformity Correction for Multiple Channel Image Reconstruction**

Fred J. Frigo, Brian W. Thomsen, Joshua V. Marso, Jason M. Darby, Stephen A. Verdi, Chad A. Rowland

GE Healthcare, Waukesha, WI, United States; Marquette University, Milwaukee, WI, United States

Conventional multiple channel image reconstruction benefits from increased signal-to-noise ratios however hyper-intensity near coil elements can lead to difficulties in the evaluation of images. We present a novel approach for multiple-channel magnetic resonance image reconstruction with pixel intensity corrections for B1 non-uniformity. Coil sensitivity maps are generated from the actual data acquired during a scan, so this is a self-referencing technique. The coil sensitivity maps for each channel are generated based on the Euclidean distance of pixels from each individual coil image to the coil elements.

**3098. Non Uniformity Correction Using Cosine Functions and Total Variation Constraint in Musculoskeletal NMR Imaging**

Noura Azzabou, Paulo Loureiro de Sousa, Pierre G. Carlier

NMR Laboratory, Institute of Myology, Paris, France; NMR Laboratory, CEA, I2BM, MIRCen, IdM, Paris, France

We introduced here a new technique for non homogeneity correction that does not rely on prior knowledge about all the tissues in the image. To estimate the non uniformity field, we assumed that it can be modelled as a finite sum of cosine functions. To compute the parameters of the model, we minimised the variance of the image in the subcutaneous fat region under the constraint that the total variation of the field is minimum. The later constraint is the main contribution of this paper. Experimental results, on phantom, healthy subjects and pathological cases showed the efficiency of our model.
Phase Correction in Bipolar Multi-Echo Water-Fat Separation for Off-Isocenter Imaging

Hojin Kim1,2, Kyung Sung1, Misung Han1,2, Marcus Alley1, Wenmiao Lu3, Brian Andrew Hargreaves1
1Department of Radiology, Stanford University, Stanford, CA, United States; 2Department of Electrical Engineering, Stanford University, Stanford, CA, United States; 3School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore

Bipolar multi-echo sequence benefits from reducing scan time as well as motion artifacts at the cost of several sources of phase discrepancy due to the polarity reversal in the readout gradient. To address phase correction in bipolar sequences, this work proposes the use of simple reference scan with baseline projections, which corrects linear and constant phase errors. Significantly, this proposed method is applied for off-isocenter imaging, so that accurate water-fat separation in bipolar sequence is capable at any scan location.

Correcting Hardware Imperfections

Hall B Thursday 13:30-15:30

An Efficient Correction Technique for Constant, Linear and ‘Oblique’ Phase Errors in EPI-PROPELLER

Novena Rangwala1,2, Xiaohong Joe Zhou1,3
1Center for Magnetic Resonance Research, University of Illinois Medical Center, Chicago, IL, United States; 2Department of Bioengineering, University of Illinois at Chicago, Chicago, IL, United States; 3Departments of Radiology, Neurosurgery and Bioengineering, University of Illinois Medical Center, Chicago, IL, United States

A new technique for phase correction of individual blades for EPI-PROPELLER sequences is proposed. Constant, linear, and ‘oblique’ phase corrections are performed by synthesizing the reference scans for arbitrary blade orientations, using only two reference scans acquired in orthogonal directions. This technique was found to decrease the Nyquist ghost by at least 75%, yielding images comparable to those obtained by using time-consuming, blade-specific reference scans.

Anisotropic Gradient Time Delay Correction for Oblique Radial Readouts Used in Ultrashort TE (UTE) Imaging

Atsushi M. Takahashi1
1Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States

Gradient delays in MRI system are typically anisotropic and yield artifacts that are especially noticeable in ramp sampled, center-out, radial k-space trajectories. We have developed a calibration procedure and a mathematical formulation for correcting artifacts from anisotropic gradient delays.

Correcting for Gradient Imperfections in Ultra-Short Echo Time Imaging

Jeremy F. Magland1, Hamidreza Saligheh-Rad2, Felix W. Wehrli2
1Department of Radiology, University of Pennsylvania Medical Center, Philadelphia, PA, United States

Imperfections in readout gradients can cause scanner-specific problems in ultra-short echo time (UTE) imaging sequences. In addition to slight gradient delays, the shape of the readout gradient waveform may not be trapezoidal. Here we describe a simple technique for mapping the k-space trajectory of the initial readout ramp in a UTE pulse sequence. The method uses data from a short calibration scan in which two dimensions of spatial encoding is applied prior to readout. After correcting for B0 inhomogeneity, the method provides a very accurate measurement of the k-space trajectory during the ramp, which can be used as input to a gridding-based reconstruction algorithm.

Scaling in Readout Direction: A Vibration-Induced Distortion of Diffusion-Weighted Images and Its Retrospective Correction by Affine Registration

Siawoosh Mohammadi1, Michael Deppe1, Harald E. Moller2
1Department of Neurology, University of Muenster, Muenster, NRW, Germany; 2Magnetic Resonance Unit, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Sachsen, Germany

The strong lobes of the diffusion gradients cause different kinds of MR artifacts, like eddy-current (EC) and vibration effects. While EC effects could significantly be reduced using a twice-refocused spin-echo (TRSE) sequence for DTI acquisition, the vibration effects become more evident when the TRSE sequence is used. We showed that the vibration-induced motion leads to an affine scaling effect in x and y-direction that could be retrospectively corrected. While the y scaling is also subject to EC effects, the x scaling seems to correct solely vibration effects and might thus be usable for comparing vibration effects of different data sets.
Rapid Concomitant Field Correction for 2D Spiral Imaging

Ajit Devaraj1, Payal Bhavsar1, James G. Pipe1
1Keller Center for Imaging Innovation, Barrow Neurological Institute, Phoenix, AZ, United States

Concomitant fields are a source of artifact for non-axial spiral images. The resulting artifacts are similar to B0 in-homogeneity blurring, hence challenging to account for. This work presents a rapid approach based on separable de-blur kernels. The efficacy of the proposed approach is demonstrated on both simulated and phantom sagittal images.

Efficient Off-Resonance Corrected Reconstruction of Rosette Trajectories by Deformed Interpolation Kernels

Marco Reisert1, Jürgen Hennig1, Thimo Grotz1, Benjamin Zahneisen1
1Medical Physics, University Hospital Freiburg, Freiburg, Baden-Wuerttemberg, Germany

Using a 3D rosette trajectory and iterative, regularized reconstruction a 643 volume can be acquired in less than 30ms. Single shot trajectories suffer from off-resonance effects because of their long readout times. Common off-resonance correction methods approximate the phase map by a time segmentation to correct for these effects but slow down the reconstruction. We therefore have developed an off-resonance correction, which uses an approximation in space rather than in time by deforming k-space interpolation kernels leading to a speed up of a factor of 10 at comparable reconstruction quality.

MR Gradient Estimation Using a Linear Time Invariant Model

Nii Okai Ady1, Holden H. Wu1, Dwight G. Nishimura1
1Electrical Engineering, Stanford University, Stanford, CA, United States; 2Cardiovascular Medicine, Stanford University, Stanford, CA, United States

MR system imperfections limit the accuracy with which gradient waveforms of fast imaging trajectories such as spirals and 3D cones, are generated on the scanner. This mainly results in a delay of achieved k-space trajectories from the theoretical case. It is possible to measure the system delays for each axis and manually adjust the timing of the gradients to improve image reconstruction. However, a range of delay values can be observed on a single axis. This work models the gradient system with a linear time invariant model for accurate estimation of a range of gradient waveforms generated on the scanner.

Reference Coils Signal Combinations Removes Gradient Switching Artefacts in Physiological Recordings During MRI

Roki Viidik2,3, Simon Bergstrand2, Tomas Karlsson3, Göran Ståhr2,4
1Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden; 2Department of Medical Physics and Biomedical Engineering, Sahlgrenska University Hospital, Göteborg, Sweden; 3Institute of Neuroscience and Physiology, Sahlgrenska University Hospital, Göteborg, Sweden; 4Department of Radiation Physics, University of Gothenburg, Göteborg, Sweden

Physiological registrations simultaneously with MR scanning usually require the removal of a huge gradient switching artefact from the weak physiological signal. We investigated a concept with pickup coils for simultaneous gradient switching registration for artefact removal. Adapted combinations of three reference signals recorded at the rear of the magnet could minimize the gradient artefact in all signal recordings at different positions in front of the magnet. The presented method works with any pulse sequence and any position and geometry of electrode leads loop.

Fast Field Inhomogeneity and Concomitant Gradient Field Correction in Spiral Cardiac Imaging

Joseph Titan Cheng1, Juan M. Santos1, John M. Pauly1
1Electrical Engineering, Stanford University, Stanford, CA, United States; 2HeartVista, Inc., Los Altos, CA, United States

Off-resonance blurring from main field inhomogeneities and concomitant gradient fields degrade the quality of spiral imaging. For cardiac imaging, off-isocenter acquisitions are unavoidable resulting in significant artifacts from these effects. We present the importance of correcting both the field inhomogeneity and the concomitant gradient field using two fast and accurate algorithms. The advantages of our algorithms are demonstrated in cardiac imaging: their computation speed in a real-time study and their accuracy in a high-resolution study.

One Step Real-Time Image Correction with GUSTO (Gradient Warp and UnderSampled Transform Operator)

Matthew Ethan MacDonald1, Randall Brooke Stafford, Michel Louis Lauzon, Richard Frayne
1Electrical and Biomedical Engineering, University of Calgary, Calgary, Alberta, Canada; 2Seaman Family MR Research Centre, Calgary, Alberta, Canada; 3Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada; 4Radiology and Clinical Neurosciences, University of Calgary, Calgary, Alberta, Canada

Real time imaging requires fast acquisition and low latency reconstruction algorithms. We propose the Gradient warp and UnderSampling Transform Operator (GUSTO) algorithm as a fast method for correction of aliasing and gradient warped images using a single matrix transformation. Proof of concept is shown with low resolution (64 x 64) phantom images.
3110. **Real-Time Gradient Warp Correction with OpenGL NURBS Surfaces**

Randall Brooke Stafford, Matthew Ethan MacDonald, Richard Frayne

1Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada; 2Seaman Family MR Research Centre, Foothills Medical Centre, Calgary, AB, Canada; 3Department of Electrical Engineering, University of Calgary, Calgary, AB, Canada; 4Departments of Radiology and Clinical Neurosciences, University of Calgary, Calgary, AB, Canada

Gradient warp correction is computationally intensive, and therefore not always practical for real-time imaging. OpenGL (Open Graphics Language) is a graphics display library with mathematical graphics functions called non-uniform rational B-splines (NURBS) that can project a 2D texture onto a 3D surface within the fast display framework. In this study, we test collected raw data in real-time and projected the resulting uncorrected image onto the NURBS surface for display. The NURBS-corrected images were then qualitatively compared to product-sequence gradient warp corrected images. Our results support our hypothesis that NURBS surfaces have the capacity for real-time non-linear gradient warp correction.

**Simulation in MR Teaching & Research**

Hall B Monday 14:00-16:00

3111. **Utility of Hand-On Scanning for Assimilating MRI Concepts** (www.learnmri.org)

Michelle Castro Cerilles, Martin R. Prince, Mitch Cooper, Bo Xu, Cynthia Wisnieff, Robert Zubkoff, Satre Stuelke

1Radiology, Weill Cornell Medical College, New York, NY, United States

Effectiveness of learning basic MRI principles by following hands-on workbook exercises as demonstrated by 11 students/residents/fellows. The workbook exercises teach MRI concepts such as MRI safety and patient screening, optimizing resolution, SNR and CNR on a phantom, optimizing T1 and T2 weighting in the volunteer brain, creating, identifying and eliminating various artifacts, adapting scanning parameters to match varying anatomy in the volunteer knee and abdomen, and implementing various approaches to minimizing respiratory motion effects.

3112. **Generalized Formalism of the Extended Phase Diagram and Computational Applications Including an MRI Simulator**

Giuseppe Palma, Marco Comerci, Anna Prinster, Mario Quarantelli, Bruno Alfano

1ESAOTE s.p.a., Naples, Italy; 2Biostructure and Bioimaging Institute, National Research Council, Naples, Italy; 3“S.D.N.” Foundation, Naples, Italy

We have built and generalized a rigorous formalism of the Extended Phase Diagram algorithm, in order to coherently include within a computational framework also non-trivial dephasing effects arising from static magnetic field inhomogeneities. Computational applications are presented providing both analytical and numerical outputs, including programs evolving the state populations according to virtually any pulse sequence provided by the user. Presented examples include tools to derive in a fully automated way the analytic signal equations (developed in Mathematica®) and to simulate MR Image formation process (developed in MATLAB®).

3113. **Magnetic Resonance Parameter Mapping Using Computer Simulation**

Yo Taniguchi, Suguru Yokosawa, Yoshitaka Bito

1Central Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo, Japan

In MR parameter mapping, parameters are estimated from images obtained with various acquisition parameters. For the estimation, the intensity function, which defines the relationship of image intensity to acquisition and MR parameters, needs to be formulated analytically in a simple form. A method to formulate the intensity function numerically by computer simulation based on Bloch equations is proposed. Intensity functions of arbitrary pulse sequences are formulated using this method so that rapid imaging is applied for the mapping. The intensity function for RF-spoiled gradient echo was formulated numerically, and we confirmed that a T1 map was successfully estimated from images obtained in a phantom experiment.

3114. **Simplified Signal Equations for Spoiled Gradient Echo MRI**

James Grant Pipe, Ryan K. Robison

1Neuroimaging Research, Barrow Neurological Institute, Phoenix, AZ, United States

This work presents simplified signal equations for spoiled gradient echo (SPGR) imaging. The framework introduces an exponential time constant T1, which reflects magnetization loss from the rf pulse. This framework is then used for to consider image SNR and T1 contrast.
Advanced Images Algebra (ADIMA): A Novel Method for Lesion Heterogeneity Enhancement in Multiple Sclerosis

Marios C. Yiannakas1, Daniel J. Tozer1, Klaus Schmierer1, Declan T. Chard1, Valerie M. Anderson1, David H. Miller1, Claudia A.M Wheeler-Kingshott1
1UCL - Institute of Neurology, London, United Kingdom

Multiple Sclerosis lesions are known to be pathologically heterogeneous but this is not well depicted on conventional MRI. In this work a new MR analysis method is presented which utilizes conventional FSE dual echo data sets with the use of advanced images algebra (ADIMA). The method is an extension to a previously described technique and involves image subtraction and normalisation in order to enhance the dynamic range in the image with a consequent enhancement of lesional heterogeneity in MS lesions. The method is shown to permit classification of T2 hyper-intense lesions into “bright” and “dark” regions in a reproducible way.

Normalised Double Inversion Recovery for Quantification of Cerebral Tissue Proportional Density

Sha Zhao1, Simon J. P. Meara2, Geoff J. M. Parker1,3
1ISBE, The University of Manchester, Manchester, England, United Kingdom; 2Physics Department, Clatterbridge Centre for Oncology, Merseyside, England, United Kingdom; 3Biomedical Imaging Institute, The University of Manchester, Manchester, England, United Kingdom

We propose a method for obtaining 3D proportional density maps for each major brain tissue component. Using double inversion recovery (DIR), we acquire images of grey matter, white matter, CSF and proton density. Each DIR image is divided by proton density, then an optimised correction factor is calculated for each so that the sum of these ratio images is unity for all voxels, thereby correcting for inter-tissue relaxation time, and coil sensitivity confounds. These proportional density images are potentially useful for studies of brain morphology and atrophy, as demonstrated in a cohort of healthy volunteers of different ages.

Method for Constructing Rapid Prototyping from MR Data

Cristobal Arrieta1,2, Sergio Uribe,2,3, Carlos Sing-Long2, Jorge Ramos4, Alex Vargas5, Pablo Irrazaval1,2
1Department of Electrical Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile; 2Biomedical Imaging Center, Pontificia Universidad Catolica de Chile, Santiago, Chile; 3Department of Radiology, Pontificia Universidad Catolica de Chile, Santiago, Chile; 4Department of Mechanical Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile; 5Department of Surgery, Pontificia Universidad Catolica de Chile, Santiago, Chile

Rapid Prototyping (RP) allows building realistic replicas of biological structures. The building process consists of acquiring imaging data, segmenting the structures of interest, triangulating the segmentation and printing. When RPs of soft tissues are built, segmentation becomes an important issue because of the low contrast between structures. Therefore, threshold, region-growing or edge-detection based segmentation tend to fail, making this process extremely tedious as important human assistance is required. We propose the use of an implicit Active Contour technique to facilitate the segmentation process. We evaluated our method by constructing an RP of a pathological heart scanned with a standard CMR.

Segmentation of the Rat Hippocampal Mossy Fiber Network from MEMRI Under Inhomogenous B1 Field

Way Cherng Chen1, Kai-Hsiang Chuang1
1Singapore Bioimaging Consortium, A*STAR, Singapore, Singapore

A method of segmenting the rat hippocampal mossy fiber network from MEMRI under inhomogenous B1 field was introduced. High-pass filtering was used to correct the intensity inhomogeneity, followed by multi-level Otsu thresholding and removal of clusters with 10 or less pixels to obtain final segmented image. High-pass filtering corrected for intensity inhomogeneity and enhanced the edges of the network making it preferable to N3 correction. Comparison with manual segmentation on 5 data sets yielded a t-value of 0.390>0.05 and a true positive rate of 91.8%.

Automatic Segmentation of MR Images for Long-Bone Cross-Sectional Image Analysis

Shing Chun Benny Lam1, Hamidreza Salilgehe Radv, Jeremy Magland1, Felix W. Wehrli1
1Radiology, University of Pennsylvania, Philadelphia, PA, United States

A software program has been developed to automatically segment cortical bone region from cross-sectional MR image of long bones such as the tibial shaft and extract geometric and parametric information from the segmented region. Our results show that the parameters obtained from the automatic segmentation software are in good agreement with those obtained from manual segmentation. With these parameters, the mechanical properties of the cortical bone can be quantified and analyzed over subject groups at different stages.
3120. Assessing the Accuracy of Detecting Mouse Brain Structure Changes from MRI
Using Simulated Deformations
Matthijs Christiaan van Eede1, R Mark Henkelman1, Jason P. Lerch1
1Mouse Imaging Centre, Toronto, Ontario, Canada

The use of image registration to investigate shape differences in mouse brain MRIs have become a significant area of interest. It is unknown how accurately structural changes can be detected or whether this sensitivity varies with structure shape. We present a novel method to simulate deformation fields with known structural tissue change and subsequently attempt to recover the induced changes in 21 structures. We demonstrate that image based registration algorithms can reliably detect structural shape differences down to 5% in the structures with a lower surface to volume ratio, and reliably down to 10% in all others.

Mark Andrew Horsfield1, Stefania Sala2, Mohit Neema1, Martin Absinta3, Anshika Bakshi3, Maria Pia Sormani4, Mara Rocca2, Rohit Bakshi5, Massimo Filippi2
1Cardiovascular Sciences, University of Leicester, Leicester, United Kingdom; 2Neuroimaging Research Unit, Ospedale San Raffaele, Milan, Italy; 3Laboratory for Neuroimaging Research, Harvard Medical School, Boston, MA, United States; 4Department of Health Sciences (DISSAL), University of Genoa, Genoa, Italy

A new semi-automatic method for rapid segmentation of the spinal cord from MR images is presented, based on an active surface (AS) model of the cord surface with intrinsic smoothness constraints. The intra- and inter-observer reproducibilities of cord area measures were evaluated, and compared favorably with an existing segmentation cord method. Correlations between cord area and clinical disability scores confirmed the relevance of the new method in measuring cord atrophy. A novel form of cord visualization is shown, in which the straightened cord center-line forms one coordinate axis of a new image, allowing simple visualization of the cord structure.

3122. Semi-Automated Microbleed Identification on Susceptibility Weighted Images
Samuel Barnes1,2, E. Mark Haacke2
1Wayne State University, Detroit, MI, United States; 2Loma Linda University, Loma Linda, CA, United States

A method to detect microbleeds in the brain in a semi-automated fashion is presented. The goal of this technique is to reduce the processing time of quantifying microbleeds. The semi-automated method compares favorably with manual counting achieving approximately 80% sensitivity and 100% specificity while reducing processing time to under an hour.

3123. Segmentation and Volume Estimation on a Sub-Voxel Basis Using Quantitative MR: A Validation Study
Janne West1,2, Jan B. Warntjes, 23, Peter Lundberg3
1Department of Medical and Health Sciences, Division of Radiation Physics, Linköping, Östergötland, Sweden; 2Center for Medical Imaging Science and Visualization, Linköping, Östergötland, Sweden; 3Department of Medicine and Health, Division of Clinical Physiology, Linköping, Östergötland, Sweden

Using an MR quantification sequence; specific brain-tissues typically exhibit a narrow range of R1, R2 and PD values, and thus the tissues in the brain can be identified as clusters in the three dimensional R1-R2-PD space. In partial volume voxels (voxels containing two or more tissue types) the R1-R2-PD values are a combination of the values from the contributing tissues. By using a partial volume model a segmentation method to assess fractional brain-tissue volumes of white matter (WM), grey matter (GM) and CSF for the complete brain on a sub-voxel basis was created and validated on 7 normal subjects.

3124. Brain Extraction Algorithm Using 3D Level Set and Refinement
Jinyoung Hwang1, HyunWook Park1
1Department of Electrical Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Korea, Republic of

Skull-stripping methods have been proposed widely, but they usually provide coarse segmentation results. For example, in superior and inferior slices, their results could serve incorrect result. Thus, we present a brain extraction algorithm using 3D level set and refinement process. First, 3D level set function is applied to whole brain volume, to find coarse brain region. The refinement process is then applied to the result of 3D level set function, which improves the accuracy of the final segmentation results. We evaluated the proposed method to normal brain data acquired from BrainWeb, IBSR, 1.5T, and 3T data.

3125. Symmetric and Multi-Scale Features for Automatic Segmentation of Multiple Sclerosis Lesions Using Pattern Classification
Marco Battaglini1, Nicola De Stefano1, Mark Jenkinson2
1Quantitative Neuroimaging Laboratory, University of Siena, Siena, Italy; 2Clinical Neurology, FMRIB Centre, University of Oxford, Oxford, Oxon, United Kingdom

In order to develop a fully automated segmentation tool for MS lesions we explore using novel input features with two pattern classification methods (Neural Networks and Random Forests). Results show a statistically significant improvement in DICE by using the novel multi-scale and symmetry features with both classifiers. To be useful for clinical trials we use multi-centre real clinical data, segmented by different manual raters, which makes this challenging. Nonetheless, we still achieve DICE results consistent with.
state-of-the-art methods, without requiring costly pruning of the Neural Networks, complicated post-processing, or having to apply any exclusion criteria to the images.

3126. Development of Partial Volume Segmentation of Brain Tissue Based on Diffusion Tensor Imaging (DTI)

Seiji Kumazawa1, Takashi Yoshiura2, Hiroshi Honda3, Fukai Toyofuku1, Yoshiharu Higashida1

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To study the cortical/subcortical diffusivity in neurological diseases, brain tissue segmentation methods based on DTI data have been proposed. However, a partial volume effect might complicate the segmentation. We present a brain tissue segmentation method based on DTI data. The features of our method include the conducting of the segmentation in DTI space without any registration, and the estimation of the partial volume fractions of each tissue type within a voxel using a maximum a posteriori probability principle. The results of the digital phantom experiment and human DTI data demonstrate that our method was able to perform a reasonable segmentation for brain tissue on DTI data.

3127. Characterization of Local Field Disturbances Through Phase Derivative Mapping

Hendrik de Leeuw1, Mandy Conijn1, Peter R. Seevinck1, Jeroen Hendrikse2, Gerrit H. van de Maat1, Chris J.G. Bakker1

1Image Sciences Institute, Utrecht, Netherlands; 2Radiology, University Medical Center Utrecht, Utrecht, Netherlands

In MRI studies, magnitude images are often used as the only source of information. Especially in the presence of local field distortions, this might be considered suboptimal, since information on the local magnetic field is encoded in the signal phase. Studies that use signal dephasing only, do not allow discrimination between paramagnetic and diamagnetic disturbances, since signal dephasing is independent of the sign of the field. We will show, by analysis of microbleeds and calcifications in the brain, that by using the phase derivative, local field disturbances can be detected and analyzed in terms of positive or negative susceptibility deviations.

3128. Detection of Abnormal Human Brain Structure from MRI Using Symmetry Features

Chi-Hsuan Tsou1, Tun Jao1,2, Jiunn-Shing Jeng3, Jyh-Horng Chen1,4

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Brain magnetic resonance images (MRI) is crucial in modern medical diagnoses. However, there is usually a time delay between images acquisition and interpretation of radiologists and/or doctors who prescribe the images, which may contribute to clinical exacerbation of the patients. In this preliminary study, we use symmetry index to discriminate between normal brain structures and intracranial pathologies, and to provide a foundation for images auto-alarm system in the future. Experimental results of the proposed algorithm on 24 MR images (11 pathological, 13 healthy), show that the symmetric index can help differentiate the normal and abnormal brain structures with promising performance.

3129. Automatic Detection of the Anterior and Posterior Commissures from T1-Weighted Images

Islem Rekik1,2, Linda Marrakchi-Kacem1,2, Jean-François Mangin1,3, Denis Le Bihan1,3, Cyril Poupon1,3, Fabrice Poupon1,3

1NeuroSpin, CEA, Saclay, France; 2ESIEE, Noisy-le-Grand, France; 3ESIEE, Noisy-le-Grand, France; 4IFR49, Paris, France

Frame-based interventional MRI and multi-subject image analysis often rely on the manual selection of the Anterior Commissure (AC) and the Posterior Commissure (PC) that are used to define the standard referential of Talairach. We developed a fast and fully automatic identification of the AC and PC points from T1-weighted MR images, thus leading to an automation of the image processing step during the neurosurgery planning.

3130. Objective Assessment of T2-Based Liver Lesion Classifiers

Christian Graff1, Eric W. Clarkson2, Maria J. Altbach3

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Classification of lesions as benign or malignant is an important imaging task. In liver, transverse relaxation time (T2) can be used as a classifier. Recently a radial fast spin-echo technique has been developed to obtain T2 estimates within a single breath-hold during which under-sampled radial k-space lines are acquired. The degree of under-sampling in this technique motivated the development of various post-processing techniques that attempt to enforce prior information to compensate for data under-sampling. In this work we evaluate these proposed algorithms through the use of a receiver-operating-characteristic (ROC) based metric which directly measures the classification performance of each algorithm.
**3131. Bladder Wall Extraction and Mapping for MR Cystography**
Jerome Zhengrong Liang\(^1,2\), Chaijie Duan\(^1\), Xianfeng Gu\(^3\), Mark E. Wagshul\(^1\), Hongbin Zhu\(^1\), Yi Fan\(^1\), Hongbing Lu\(^3\)
\(^1\)Radiology, Stony Brook University, Stony Brook, NY, United States; \(^2\)Computer Science, Stony Brook University, Stony Brook, NY, United States; \(^3\)Biomedical Engineering, Fourth Military Medical University, Xian, China

MRI-based virtual cystoscopy, MR cystography, T1-weighted imaging, bladder cancer, tumor recurrence, image segmentation, conformal mapping, 3-D to 2-D flattening

**3132. Effects of Treatment on Brain Tissue Classification with Serial MRI-Based ISODATA Cluster Analysis in an Experimental Subarachnoid Hemorrhage Model**
Mark J.R.J. Bouts\(^1\), Ivo A.C.W. Tiebosch\(^1\), René Zwartbol\(^1\), Ona Wu\(^2\), Rick M. Dijkhuizen\(^1\)
\(^1\)Image Sciences Institute, University Medical Center Utrecht, Utrecht, Netherlands; \(^2\)Athinoula A. Martinos center for biomedical imaging, Massachusetts General Hospital, Charlestown, MA, United States

Voxel-wise clustering of multiparametric MRI data enables classification of heterogeneous ischemic lesions into distinct categories. Previously, we have introduced a lesion clustering approach that incorporates temporal T2 and diffusion dynamics for tissue characterization. In the current study we extend this approach in an experimental subarachnoid hemorrhage model, to evaluate lesion characteristics in a treatment and control group based on temporal changes in T2, diffusion, and perfusion parameters. Five distinct signatures with different characteristics of cerebrovascular injury were identified and signature distribution revealed a different prevalence in Interferon-β treated animals compared to controls.

**3133. A Multi-Anatomy System for Computing and Centering Field of View from Localizer Images**
Vivek Prabhakar Vaidya\(^1\), Maggie M. Fung\(^2\), Rakesh Mullick\(^1\), Robert D. Darrow\(^3\)
\(^1\)GE Global Research, Bangalore, Karnataka, India; \(^2\)GE Healthcare, Waukesha, WI, United States; \(^3\)GE Global Research, Niskayuana, NY, United States

A system is demonstrated for automatically deriving and centering oblique scan extents/fields of view (FOV) from localizer scans. Our method differs from prior work in the field by being marker-less and allowing for automated acquisitions oblique to the input localizer. By constraining acquisition to the precise anatomy being sought acquisition time is reduced. This acquisition time reduction is particularly valuable in cardiac and abdominal imaging: given the need for breath-held scanning. Furthermore, by prescribing an optimal field of view we can also reduce potential wrapping artifacts and improve the consistency of image representation.

**3134. Automated Volume of Interest Evaluation for Sequence Development**
Ying Wu\(^1,2\), Hongyan Du\(^1\), Fiona Malone\(^1\), Shawn Sidharthan\(^1\), Ann Ragin\(^7\), Robert Edelman\(^1,5\)
\(^1\)Radiology, NorthShore University HealthSystem, Evanston, IL, United States; \(^2\)Radiology, University of Chicago; \(^3\)NorthShore University HealthSystem Research Institute, IL, United States; \(^4\)Radiology, Northwestern University; \(^5\)Radiology, University of Chicago

This investigation compared the standard manual region of interest approach with a volume-of-interest analysis based on automated brain segmentation. Analysis based on automated VOI successfully detected subtle changes in tissue contrast and was consistently informative for MR sequence optimization. Results based on the standard ROI approach were ambiguous in different brain regions and individuals, and failed to document changes in image quality when scanning parameters were alternated in MR sequence optimization. These findings demonstrate the potential benefit of integrating advanced quantitative image analysis into sequence development routines to improve efficiency and accuracy.

**Registration & Image Analysis**
**Hall B Wednesday 13:30-15:30**

**3135. Combining Variational and Model Based Techniques to Register MR Finger Images and PET Hand Data**
Derek Magee\(^1\), Steven Frederick Tanner\(^2\), Michael Waller\(^5\), Ai-Lyn Tan\(^4\), Dennis McGonagle\(^4\), Alan Jeavons\(^5\)
\(^1\)School of Computing, University of Leeds, Leeds, W-Yorkshire, United Kingdom; \(^2\)Division of Medical Physics, University of Leeds, Leeds, W-Yorkshire, United Kingdom; \(^3\)Medical Physics, St James University Hospital, Leeds, United Kingdom; \(^4\)Academic Section of Musculoskeletal Disease, Chapel Allerton Hospital, Leeds, W-Yorkshire, United Kingdom

A non-rigid image registration method for co-registering high-resolution PET data and MR images of the hand is described and evaluated. Employing this protocol to register synthetic data indicated a the mean registration error of less than approximately 1.5 mm. Measurements made in images acquired from patients with osteoarthritis show that the registration errors are consistent with those made in the study using synthetic data.
We propose a faster automated scan plane planning method for the brain using 2D multi-slice orthogonal three-plane scout images. Our algorithm based method, uses 2D scout images, which can be acquired rapidly. Furthermore, our algorithm can prescribe scan plane faster than other method that use 3D data due to the smaller 2D data size. We applied our proposed method to healthy volunteers, and compared automatically defined scan plane position with those manually defined. The results showed that our method prescribed scan planes quickly and with acceptable accuracy in clinical practice.

We present the Moore-Rayleigh (MR) test as nonparametric statistical test for longitudinal brain MRI deformation based morphometry: A group of male mice (n=10) was followed during exposure to the stress hormone corticosterone for 2 weeks and a recovery period of 1 week. The results of the MR test are comparable to volumetric based morphometry, but it enriches the analysis with its ability to detect also localized shape changes, which are still significant under Bonferroni correction.

The increasing use of genetically modified mice has highlighted the need for effective phenotyping methods. Propagation-based morphometry (PBM) is an emerging technique enabling non-invasive and rapid acquisition of volumetric data using an average population atlas for morphometric analysis. Thus, PBM shows promise towards the broad applicability of this technique for phenotyping mutant mouse models.

When working with mouse brain models it becomes apparent, that anatomically detailed, three dimensional atlases are not readily available. On one hand, histological atlases are two dimensional, whereas three dimensional MRI atlases might only define 40 brain structures.
Our aim is to create a digital atlas using high resolution images produced by a 16.4 T MRI scanner, complemented by histological data. A higher grade of segmentation, for example 45 structures in the cerebellum and 35 in the hippocampus, will enable the researcher to compare normal mouse brain anatomy to pathological anatomical changes in models of disease.

3141. Developmental Changes in the Shape of Hippocampus in Children Aged from 6 to 9 Years Old
Muqing Lin¹, Lutfi Tugan Mustuler¹, Ke Nie¹, Kevin Head¹, Claudia Buss², Elysa Poggi Davis², Curt A. Sandman², Orhan Nalcioglu¹, Min-Ying Lydia Su¹
¹Tu & Yuen Center for Functional Onco-Imaging, University of California, Irvine, Irvine, CA, United States; ²Department of Psychiatry and Human Behavior, University of California, Irvine, Irvine, CA, United States

The shape analysis of hippocampus was commonly applied to evaluate the progression of atrophy pattern in elderly patients, and in this study it was applied to evaluate the changes in developmental brain in 48 children. The distance from the hippocampal surface to the central line was mapped to a 2D grid for statistical analysis. The Permutation and t-test was applied to compare two age groups (6-7 vs. 8-9 y/o), and the regression analysis with age was also performed. Significant differences were found in small areas of CA1 and subiculum; however, overall there is not a strong age dependence.

3142. Comparison of Normalized DTI Analytical Methods II: Detection Powers of Voxel- Based, Atlas Based, and Sub-Atlas Based Analysis
KOJI SAKAI¹, Susumu Mori², Kenichi Oishi², Andreia Faria², Naozo Sugimoto
¹Kyoto University, Kyoto, Japan; ²Johns Hopkins University

The VBA is one of the most effectual assessment methods of the entire white matter of brain. However, the VBA often suffers from high false discovery rate which caused by embedded noise in voxels and imperfect registration. On the other hand, 3D whole brain WM atlas (ABA: atlas-based analysis) was proposed to achieve statistical power on the examination of the WM analysis. We also have proposed alternative way to analyse WM by sub-atlas based analysis (SBA). In this paper, we attempted to ascertain the statistical detection power and the features of VBA, ABA, and SBA.

3143. Accelerating the Image Registration of MRI Volumes by Modern GPGPU Parallel Computation
Shiu-Ying Ju¹, Yu-Wei Tang¹, Teng-Yi Huang¹
¹Department of Electrical Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan

Image registration has been an important topic in the MRI applications, such as longitudinal follow-up studies, brain-normalization for group statistics and motion correction for fMRI studies. However, the automatic registration requires a lot of iteration loops and a huge amount computation for linear transformations and thus it is generally very time-consuming task. In our study, we proposed to use the parallel computing on recently advanced general-purpose computation on graphic processing units (GPGPU) to accelerate the registration calculations, especially for the popular SPM system. We got about 23-fold acceleration of the computation process on our datasets.

Sebastian Kurtek¹, Eric Klassen², Anuj Srivastava³, Zhaohua Ding³, Sandra W. Jacobson³, Joseph L. Jacobson³, Malcolm J. Avison³,⁴
¹Department of Statistics, Florida State University, Tallahassee, FL, United States; ²Department of Mathematics, Florida State University, Tallahassee, FL, United States; ³Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States; ⁴Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States; ²Department of Psychiatry and Behavioral Neurosciences, Wayne State University School of Medicine, Detroit, MI, United States

Shape analysis of anatomical structures is central to medical diagnosis, especially when using MRI data. We propose a novel Riemannian framework for analyzing shapes of 3D brain substructures (e.g. putamen). This framework provides metrics that are invariant to rigid motion, scaling and most importantly parameterizations of surfaces (placements of meshes). The metric is evaluated by a gradient-based alignment of meshes for the surfaces being compared. Consequently, the distance between identical surfaces with different meshes is zero. We present results of this methodology applied to comparisons of left putamens across subjects and to classification of subjects with prenatal exposure to alcohol.
An anatomically labeled DTI atlas of the adult Sprague Dawley brain is proposed. The atlas is constructed using a population based atlas construction approach to create a template which represents the average anatomy. Further, a bias to a single subject is minimized. During the construction, a non-rigid coregistration technique is used to avoid local misalignment inaccuracies due to intersubject differences. The delineation of brain structures was performed on high resolution ex-vivo scans and the resulting parcellation maps were non-linearly warped into the in-vivo atlas space afterwards. The atlas is perfectly suited for automated ROI analysis and more standardized VBA studies.

**3146. Comprehensive Digital 3D Monkey Brain MRI Atlas**

*Tina Jeon¹, Takashi Yoshioka¹, Steven Hsiao², Stewart Hendry², Hao Huang¹*

¹Advanced Imaging Research Center, University of Texas Southwestern Medical Center, Dallas, TX, United States; ²Mind and Brain Institute, Johns Hopkins University, Baltimore, MD, United States

Due to their close relationship to the human brain, animal models of primates have been unique and irreplaceable in neurobiological studies. In these studies, atlases have played central roles as anatomical references. However, few atlases are 3D, digital, or have comprehensive gray and white matter labeling. In this abstract, we show the digital atlas with complete labeling of cortical gyri, subcortical nuclei and white matter tracts with high resolution DTI. The digital format of the atlas makes it possible to map the labeling information of the atlas to the experimental monkey brain with image registration.

**3147. Arterial Input Function Correction and Its Impact on Quantitative DCE-MRI: A Comparison with DCE-CT**

*Lauren Jean Bains¹², Josephine H. Naish¹², David L. Buckley³*

¹Imaging Science and Biomedical Engineering, School of Cancer and Imaging Sciences, University of Manchester, Manchester, Greater Manchester, United Kingdom; ²University of Manchester Biomedical Imaging Institute, University of Manchester, Manchester, Greater Manchester, United Kingdom; ³Division of Medical Physics, University of Leeds, Leeds, United Kingdom

Quantitative DCE-MRI benefits from the use of individual patient AIFs, however, accurate MRI-based AIF measurements are complicated by partial volume and inflow effects. We tested two methods of AIF correction based on cardiac output, and evaluated their effects on DCE-MRI tracer kinetic parameter estimates by comparing these estimates with DCE-CT, a modality which is unaffected by many of the artefacts that are problematic in DCE-MRI. Our results show that the use of cardiac output to correct DCE-MRI produces parameter estimates which are significantly closer to DCE-CT with reduced variance; the use of such corrections may significantly benefit DCE-MRI analyses.

**3148. A Novel Method for Automatic Estimation of M0 Used by ASL CBF Quantification**

*Ognjen Zivojnovic¹, Greg Zaharchuk², Ajit Shankaranarayan³*

¹Stanford University, Stanford, CA, United States; ²Department of Radiology, Stanford University, Stanford, CA, United States; ³Applied Sciences Laboratory - West, GE Healthcare, Menlo Park, CA, United States

Calculating quantitative CBF values based on ASL images requires knowledge of M0. Two models exist for estimating its value, a blood based model that depends on the M0 of CSF, and a tissue based model that requires the re-imaging of the entire volume. This abstract presents a novel method for automatically estimating M0 based on the blood model in order to take advantage of its faster scan times compared to the tissue based model, as well as to remove human inconsistencies in selecting the area from which the estimate is made.

**3149. Haemal Supplies Correlation Based Hepatic Nodules Identification from Dynamic Contrast-Enhanced MR Images**

*Min Sun¹², Xuedong Yang¹, Dongjiao Lv¹, Mingyuan Xie¹, Ling Yang², Chengbo Wang³, Xiaoying Wang¹³, Yue Zhang¹³, Jie Fang¹³*

¹Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China; ²Dept. of Electronic Engineering, Chengdu University of Information Technology, Chengdu, Sichuan, China; ³Dept. of Radiology, Peking University First Hospital, Beijing, China

Early detection of liver nodular lesions is critical in improving patient’s survival rate. Previous studies have shown that for dynamic contrast-enhanced MR imaging of liver nodules, there exists correlation between nodules’ blood supplies and MR signal changes. In this retrospective study, haemal supplies correlation based strategy was introduced to identify the suspected hepatic nodules, including DN, RN and SHCC from dynamic contrast-enhanced MR Images, and the analysis results were in consistence with the clinical diagnosis under double-blind test. The proposed computer aided identification approach could be helpful to provide valuable information for the detection of hepatic nodules.
**3150. Performance and Accuracy of a Morphological MR Marker Localization at Reduced Spatial Resolutions: Results from Simulated and Real Marker Images**  
Gregor Thörmer1, Nikita Garnov1, Jurgen Haase1, Thomas Kahn1, Michael Moche1, Harald Busse1  
1Diagnostic and Interventional Radiology, Leipzig University Hospital, Leipzig, Germany; 2Physics and Geosciences Department, Leipzig University, Leipzig, Germany

MR-visible markers have many potential applications such as an automated mapping of coordinate systems (image/patient registration), stereotactic planning/monitoring of procedures, and the localization/tracking of devices inside the magnet. In this work, precision, accuracy and update rates of a fully automatic marker localization based on morphologic image processing have been studied experimentally as well as theoretically (simulation) as a function of the underlying pixel size. The moderate 3D errors (≤0.1 mm) observed for the fastest sequence (pixel dimension 4.7 mm) clearly demonstrate that the presented technique does not necessarily require highly resolved images of the markers (physical dimension ≤34 mm).

**3151. Automatic MRI Acquisition Parameters Optimization Using Perceptual Criteria**  
Javier Jacobsen2, Sergio Uribe,2, Cristian Tejas2, Carlos Sing-Long2, Pablo Irarrazaval1,2  
1Department of Electrical Engineering, Pontificia Universidad Catolica de Chile, Santiago, Chile; 2Biomedical Imaging Center, Pontificia Universidad Catolica de Chile, Santiago, Chile; 3Department of Radiology, Pontificia Universidad Catolica de Chile, Santiago, Chile

The visualization of structures in MRI highly depends on many user defined scan parameters. The selection of them is always done heuristically and requires a vast experience from the operator. We propose a methodology based on an automatic optimization to find the MRI acquisition parameters that maximize the visibility of a desired structure. The objective function of our optimization is computed from Visibility Maps (VM) that are designed to measure the visibility of structures according a perceptual criteria. The method was tested on brain MRI experiments and the optimal parameters found by our method are in excellent agreement with those found by experienced radiologists.

**3152. A Stochastic Framework for Improving the Accuracy of PIESNO**  
Cheng Guan Koay1, Evren Ozarslan1, Carlo Pierpaoli1, Peter J. Basser1  
1NIH, Bethesda, MD, United States

Probabilistic Identification and Estimation of Noise (PIESNO) is a recent technique capable of identifying noise-only pixels in magnitude-reconstructed MR images. The identification criterion and the estimation method used in PIESNO were chosen and constructed for expediency in terms of computational efficiency and theoretical simplicity rather than for accuracy. Although a strictly theoretical approach to determine the exact level of bias in the estimate of noise level through PIESNO seems to be intractable, it is still worthwhile to use stochastic framework for determining the level of bias. Here, we present one such framework for improving the accuracy of PIESNO.

**3153. Comparison of SNR Calculation Methods for in Vivo Imaging**  
Bing Wu1, Chunsheng Wang, Yong Pang1, Xiaoliang Zhang1  
1Radiology & Biomedical Imaging, University of California, San Francisco, San Francisco, CA, United States; 2UCSF/UC Berkeley Joint Group Program in Bioengineering, CA, United States

Local and global SNR of in vivo MR images are often measured to evaluate the image quality. Due to the density variation of in vivo images, the motion during the acquisition and other aspects, the SNR measurement of the in vivo image, especially at high field MRI, is much more complicated. The purpose of this work is to evaluate and compare SNR calculation methods to provide the reference or guidance for in vivo image SNR measurements.

**3154. Consistency Assessment for R2* Measurements Obtained with Different Techniques at 7 Tesla**  
Xiangyu Yang1, Petra Schmalbrock1, Michael V. Knopp1  
1Department of Radiology, The Ohio State University, Columbus, OH, United States

At high and ultrahigh field, R2* measurement can be dependent on the technique used due to non-exponential FID distortions caused by various factors. In this study, we compared R2* measurements obtained with three different techniques in a group of four healthy volunteers at 7 Tesla to assess their consistency. Our results demonstrate that R2* values measured with a 2D imaging technique is only comparable with those from a 3D technique when appropriate correction for the background field inhomogeneity effect is applied.

**3155. Analysis of Abdominal Fat Tissue Images Acquired with Continuously Moving Table MRI**  
Stathis Hadjidemetriou1, Juergen Hennig1, Florian Klausmann1, Ute Ludwig1  
1Department of Diagnostic Radiology, University Hospital Freiburg, Freiburg, Germany

The risk for hypertension and diabetes is correlated closely to the amount of visceral fat. In this work, the abdominal fat is imaged with a continuously moving table whole body MRI technique. A method is presented for the repeatable, general, and reliable differentiation of lipids into subcutaneous and visceral. The data is restored for intensity uniformity. The corrected image is processed to segment the body region with the graph cuts algorithm operating on level sets. Then, the contour separating the subcutaneous and visceral fat regions is identified with a combination of the random walks algorithm and graph cuts.
**3156. Fast Fat/Water Decomposition Using GPU Computation and Newton's Method**

*David Johnson, Sreenath Narayan, Chris Flask, David Wilson*

1Heart and Lung Research Institute, Ohio State University, Columbus, OH, United States; 2Biomedical Engineering, Case Western Reserve University, Cleveland, OH, United States; 3Radiology, University Hospitals of Cleveland, Cleveland, OH, United States

An improved fat/water estimation technique was developed using Iterative Decomposition of Water and Fat with Echo Asymmetry and Least-squares estimation method and Graphics Computational Units (IDEAL-GPU). The IDEAL-GPU technique produced robust fat and water images quickly and efficiently using a vectorized equation implemented on graphics cards. In addition, our implementation used binary weighted planar extrapolation for robust estimation in the face of large field variations on a high field, small animal scanner. Fast computation will become even more significant as the trend towards high resolution, whole body mouse and human scanning continues.

**3157. Case-PDM Optimized Compressed Sensing Sampling for Fat-Water Separation**

*Sreenath Narayan, Jun Miao, Fangping Huang, David Johnson, Guo-Qiang Zhang, David Wilson*

1Case Western Reserve University, Cleveland, OH, United States; 2Ohio State University, Columbus, OH, United States

Compressed Sensing for 3 point Dixon method source image reconstruction has not yet been optimized for perceptual performance. In this abstract, we determine how to densely to sample each of the source images to achieve a given global sampling ratio.

**3158. Comparison of Compressed Sensing and Keyhole Methods for Fat-Water Separation**

*Sreenath Narayan, Jun Miao, Fangping Huang, David Johnson, Guo-Qiang Zhang, David Wilson*

1Case Western Reserve University, Cleveland, OH, United States; 2Ohio State University, Columbus, OH, United States

Dixon-type methods require multiple scans with different chemical shift weights. Keyhole methods have previously been used to reduce scan time. In this abstract, we compare keyhole methods and Compressed Sensing for quantitative studies.

**Brain Image Analysis**

**Hall B Thursday 13:30-15:30**

**3159. Methodology for the Estimation of the Extension of a White Matter Tract Into and Through Associated Grey Matter**

*Daniel J. Tozer, Declan Chard, Olga Ciccarelli, Benedetta Bodini, David H. Miller, Alan J. Thompson, Claudia Angela Michela Wheeler-Kingshott*

1NMR Unit, Department of Neuroinflammation, UCL Institute of Neurology, London, United Kingdom; 2Brain Repair and Rehabilitation, UCL Institute of Neurology, London, United Kingdom

The definition of areas of grey matter (GM) that are associated with specific white matter tracts is important for studies investigating the spatio-temporal relationship between the two. The work proposes a method for extending a white matter tract calculated from diffusion MRI through the GM using a geometrical extension of those pixels on the tract edge, which are in or about GM, to the nearest point on the outer GM boundary. It was found that running the extension in 3 orthogonal 2D planes included more tissue than running the process in 3D, which may be preferable in many cases.

**3160. New Invariant Indexes to Quantify Water Anomalous Diffusion in Brain**

*Silvia De Santis, Silvia Capuani, Andrea Gabrielli, Bruno Maraviglia*

1Physics department, Sapienza University, Rome, Italy; 2INFN-CNR SOFT, Sapienza University, Rome, Italy; 3SMC - CNR/INFN, Sapienza University, Rome, Italy; 4ISC - CNR, Rome, Italy; 5Neuroimaging Laboratory, S. Lucia Foundation, Rome, Italy

We propose a new procedure to detect the deviation from the mono-exponentiality of water diffusion in brain. The stretched-exponential model has been extended to three-dimensional space to obtain new scalar invariants. The potentiality of this methodology has been evaluated on young healthy subjects. Statistical analysis on selected ROIs from different cerebral tissues underlined a different contrast compared to conventional DTI one. In particular, GM and WM can be discriminated on the basis of their microstructural complexity, underlying a chance for investigating subtle changes of the water diffusive motion in tissues which are not detected by conventional MD and FA indexes.
3161. **Spatial Normalization of Diffusion Spectrum Imaging Using Large Deformation Diffeomorphic Metric Mapping**

Yung-Chin Hsu¹, Ching-Han Hsu², Wen-Yih Tseng³

¹National Tsing Hua University, Hsin-Chu, Taiwan; ²National Tsing Hua University, Taiwan; ³Center for Optoelectronic Biomedicine and Department of Medical Imaging

Problems of image registration has been well studied in the neuroimaging field. However, the registration of the diffusion MRI data, especially to align the fiber orientations among different brains, is not readily applicable using current available packages. We generalized the conventional 3D registration to the 6D scenario by implementing LDDMM algorithm. The results demonstrate the proposed method is applicable for the registration between DSI datasets.

3162. **Cortical Shape Analysis Using Spherical Wavelet Decomposition of Curvature**

Kim Mouridsen¹ ², Rudolph Pienaar³ ⁴

¹Neuroradiology, Center for Functionally Integrative Neuroscience, Aarhus, Denmark; ²Radiology, Massachusetts General Hospital, Boston, MA, United States; ³Radiology, Childrens Hospital Boston, Boston, MA, United States; ⁴Radiology, Harvard Medical School, Boston, MA, United States

We present a method to analyze cortical shapes based on wavelet decomposition of curvature functions. Using spherical harmonics as effective encoding, we show that groups of healthy controls and patients suffering from polymicrogyria may be identified using automated classification techniques.

3163. **Is Quantitative T2 Sensitive to Tumor Cell Infiltration?**

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Quantitative analysis of multi-echo T2 relaxation has been used to examine micro compartmental structures in rat glioblastoma tumors. The infiltrative nature of malignant gliomas poses a major clinical challenge in rendering tumors incurable by conventional techniques. Recently, brain tumor initiating cells (BTIC) have been hypothesized to represent the cell of origin for these tumors. We analyzed 5 mouse brains in vivo inoculated with BTIC to characterize the changes in T2 distributions for each heterogeneous tumor. Based on the qualitative comparison between segmented geometric mean T2 map and histology staining, 4 regions were identified that corresponded to varying tumor cell densities.