Quantitative MRI for in vivo histology from six perspectives

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1096
Educational Course - Half Day (4 hours)
SEC Centre
Room: Alsh

Quantitative MRI is slowly being taken on by the OHBM community, and an increasing number of sequences and software packages become available every year. In order to further these developments, reach consensus, and generate standards, thorough education of brain mappers and a continued dialogue with them are essential. This educational course will be an important milestone in this process. It will summarize the possibilities and challenges that come with quantitative MRI in human brain mapping research and simultaneously provide concrete pointers for how to move forward as a field and as individual researchers.

The half-day course brings together six different perspectives that together provide a broad overview of the field. In the individual sessions, we will explain the promises and current challenges, as well as a vision for the future of quantitative MRI. Martina Callaghan will provide a physicist's perspective and explain what physical properties of the tissue can be mapped with MRI and how. Ashley Stewart will provide a translational perspective and explain how to feasibly bring quantitative MRI into neuroscientific applications. Masaki Fukunaga will provide an anatomical perspective and examples of how quantitative MRI has helped to shape our understanding of brain anatomy. Marina Khodanovich will provide a biological perspective and talk about how to ensure that quantitative MRI markers are biologically interpretable. Susie Huang will provide a clinical perspective and present the challenges and opportunities related to bringing quantitative MRI to clinical trials and clinical practice. Last but not least, Agah Karazuru will present the currently available software tools and BIDS standard for quantitative MRI from a computer science perspective.

Objective

At the end of the symposium, attendees should:

1) understand the basic physical principles underlying quantitative MR and be familiar with various quantitative parameters and what they tell us about brain microstructure.

2) understand the approach of using quantitative MRI to study anatomy and pathology and the challenges regarding biological interpretability and validation of specific markers.

3) come up with ideas for potential applications of quantitative MR to their own research field and have a tool set available to implement these (including available MRI sequences, analysis tools and data organisation).

Target Audience

The symposium is targeted to all scientists interested in the neurobiological properties of brain tissue and in the link between imaging and microstructure in healthy and diseased subjects.

Presentations

Physics for brain mappers: Or how to get your scanner to produce interpretable images

This session will introduce commonly used quantitative MRI parameters and their biophysical origins. Measuring these parameters relies on obtaining images that have sensitivity to specific physical properties of brain tissue, e.g. relaxation rates, susceptibility or magnetisation transfer effects. The images need to be combined with a signal model while accounting for any confounding factors, often introduced by field inhomogeneities or system imperfections. Competing requirements are to have robust measurements that are sensitive to microstructure, with high spatial resolution obtained as fast as possible with minimal confounds. I will provide practical guidance on how to balance these requirements and highlight candidate protocols and software for your data analysis.

Presenter

Martina Callaghan, University College London London, London
United Kingdom

Quantitative imaging for the masses: How to translate cutting-edge methods in quantitative susceptibility mapping to neuroscience applications

While conventional MRI reveals gross morphological and local abnormalities, quantitative MRI techniques such as Quantitative Susceptibility Mapping (QSM) are sensitive to more subtle changes in tissue composition that can be compared across regions and subjects, giving rise to a breadth of new applications. QSM is sensitive to changes in myelin and iron and could therefore be a valuable tool to better understand the human brain in health and disease. However, QSM reconstruction and analysis is a complex process, requiring a range of independent post-processing techniques and software tools applied to gradient-echo MRI data. This presentation explores approaches for translating complex image processing workflows into robust, accessible, and reproducible pipelines that make cutting-edge techniques like QSM available to researchers looking to conduct large-scale clinical studies. I will demonstrate how a combination of software containers, workflow systems and web frameworks can make complex toolchains available for everyone to analyse and interpret quantitative susceptibility information.

Presenter

Ashley Stewart, ARC Training Centre for Innovation in Biomedical Imaging Technology, The University of Queensland Brisbane, AK
Australia

Understanding brain structure and function with quantitative MRI: Magnetic susceptibility and brain microstructure at ultra high fields

With the recent increase of availability for ultra high field MRI (>7T), magnetic susceptibility-based imaging techniques have been attracting attention. Magnetic susceptibility of a material is a measure of whether an applied magnetic field creates a larger or smaller magnetic field in that material. Magnetic susceptibility goes beyond the cerebro-vasculature, reflects the shape of the iron, myelin sheath, and even white matter fibers, providing a wealth of information about brain structure and function. On the other hand, magnetic susceptibility, a quantitative physical parameter, can be calculated from gradient-echo phase images by Quantitative susceptibility mapping (QSM). Myelin and iron have been found to be the main contributors to magnetic susceptibility in brain tissue. An interesting aspect of magnetic susceptibility contrast is that it is sensitive to the fine distribution of iron and myelin, providing the opportunity to extract information at spatial scales much lower than the resolution of MRI. In this presentation, I discuss the main drivers of the subtle magnetic properties of brain tissue and how they affect MRI contrast.

Presenter

Masaki Fukunaga, Division of Cerebral Integration, National Institute for Physiological Sciences Okazaki, Aich, Japan
Japan

Towards biological interpretability through histological validation

Histological validation is one of the most important challenges in demonstrating the feasibility of any non-invasive methodology in preclinical and clinical applications. In this session, the considerations needed to conduct validation research will be outlined. Firstly, appropriate choices of animal models need to be made, taking into account all advantages and limitations of the model of the disease. The next important step is the histological and MR image pre-processing. For histology, this includes making smart choices with regard to the histological marker, appropriate tissue processing and obtaining microscopic data. The processing of MRI data may include registration and elimination of bone and muscle tissue in images. The next step includes measurements of anatomically corresponding MRI and histology data. The question of anatomical correspondence of MR and histological areas on the images is quite rare in publications, which is why this challenge will be particularly emphasized during the session. Another unsettled question is the histological quantification. There is not a “gold” standard, rather, several methods of segmentation are available. I will discuss the advantages and limitations of various approaches in this course. The last step is statistical analysis. I will outline the choice of statistical method depending on the type of validation data.

Presenter

Marina Khodanovich, Tomsk State University Tomsk, Russia
Russian Federation

Quantitative MRI in clinical practice: progress and challenges

I will discuss the opportunities and challenges of translating quantitative MRI techniques from research applications to clinical trials and clinical practice. Quantitative parametric mapping of tissue properties is a key

strength of MRI, yet diagnosis in neurological disease relies primarily on subjective assessments of non-quantitative, contrast-weighted images. I will provide an overview of how quantitative MRI techniques are currently used in clinical trials and practice and discuss future directions for the integration of quantitative MRI techniques into clinical neuroimaging. Continued progress within the field will require improved harmonization, reliability, and efficiency in the acquisition of quantitative MRI markers, and significant logistical and practical issues continue to surround adoption beyond research scenarios. I will describe some techniques that have already been successfully used as biomarkers in clinical trials, and approaches to overcoming the barriers to their translation into clinical practice, including quality control and standardization across vendor platforms.

Presenter

Susie Huang, Harvard Medical School Boston, MA
United States

A 3 ingredients recipe for standardizing quantitative MRI: Vendor-neutral acquisitions, open-source software and community data standards

Our community has made a considerable movement towards developing open-source solutions to improve the reproducibility of quantitative MRI. As of today, there are more than 13 software packages with a particular focus on quantitative MRI, developed in various programming languages. In this course, we will first explore the landscape of open-source quantitative MRI software at the level of data processing. Then, we will dive deeper into the role of vendor-neutral acquisition frameworks in reliable quantitative MRI measurements and take a look at available solutions to develop open-source pulse sequences. Finally, we will discuss how data standards such as ISMRM-RD and BIDS are key to establishing interoperable quantitative MRI workflows that can extend from acquisition to publication.

Presenter

Agah Karakuzu, Polytechnique Montréal Montréal, Canada
Canada