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Quantitative Brain MRI

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This issue of *Topics in Magnetic Resonance Imaging* (MRI) is about "Quantitative Brain MRI." What do we mean by "quantitative" MRI? In the context of imaging studies, the term *quantitative* is often used when numeric values of signal intensities are measured in addition to performing the conventional "qualitative" visual inspection of the images. For example, a region of interest analysis or tissue segmentation and classification based on relative signal intensities are often referred to as "quantitative." Here, we consider a more stringent definition of the term quantitative. We regard an MRI study to be quantitative when we obtain maps of meaningful physical or chemical variables that can be measured in physical units and compared between tissue regions and among subjects.

By this definition, most clinical MRI acquisitions are not quantitative. Traditionally, clinical MRI relies on the acquisition of so-called *weighted images*, whose image contrast is affected by a combination of different factors, some intrinsic to the tissue and some dependent on the specifics of the experiment. The diagnostic utility of conventional MRI in many neurological disorders is unquestionable; however, the domain of conventional MRI is limited to revealing either gross morphological abnormalities or focal abnormalities resulting in regional differences in signal intensities within a given brain. To detect pathology, conventional MRI relies on differences in contrast between areas that are "supposedly" affected and areas that are "supposedly" normal. Conventional MRI is intrinsically insensitive to subtle global changes that may affect the entire brain.

There is no doubt that a more widespread use of quantitative MRI methods is desirable. They will increase the sensitivity of clinical brain MRI by allowing the comparison of measurements in a single subject with normative values acquired in a healthy population and will provide the foundations for monitoring subtle changes caused by the progression or remission of disease.

Another limitation of conventional MRI techniques is their lack of biological specificity; that is, different physiological and pathological substrates can produce similar changes in image contrast. For example, hyperintensity in T2-weighted images can originate from a number of factors such as edema, demyelination, dysmyelination, axonal loss, and necrosis. Although quantification per se does not ensure biological specificity, it represents an important component of any metric that is an imaging "biomarker" candidate.

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Given that the advantages of more quantitative approaches in neuroimaging seem obvious, why does clinical neuroradiology still rely almost completely on qualitative techniques? In this edition of *Topics in Magnetic Resonance Imaging*, we asked experts of several MRI techniques used in neuroimaging studies to discuss quantification issues in their respective fields by providing a balanced report not only on recent progress and future promises but also on standing obstacles. All authors are well known for having provided fundamental theoretical and scientific contributions and also for working extensively on the dissemination and clinical implementation of their respective techniques. They cover (1) perfusion MRI using arterial spin labeling (Jiongjiong Wang et al), (2) perfusion MRI using dynamic-susceptibility contrast (Fernando Calamante), (3) diffusion MRI (Derek Jones), (4) MRI proton relaxometry (Sean Deoni), and (5) proton magnetic resonance spectroscopy and spectroscopic imaging (Jeffry Alger). In addition to these technique-specific contributions, in the closing paper of this issue, Ona Wu et al discuss the use of multiparametric MRI techniques for the characterization and clinical investigation of brain disorders. Although, given time constraints, multiparametric assessment is usually done using “qualitative” signal measurements, the ability to perform a meaningful analysis of multiparametric data is an important and promising aspect of quantitative MRI.

We hope that this issue will provide clinical researchers with information helpful to evaluate the feasibility of using quantitative neuroimaging approaches in their work. It seems that, with recent technological improvements, several neurological conditions could be investigated using quantitative MRI techniques if carefully designed time-efficient scanning protocols are developed.