Editorial

Parallel and sparse MR imaging: methods and instruments—Part 1

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Magnetic resonance imaging (MRI), capable of providing information on morphology, metabolism and function of living systems non-invasively, has become one of the most important imaging modalities in today's clinical diagnosis and basic biomedical research. However, comparing with other medical imaging methods, such as computed tomography (CT), ultrasound (US), and even the more conventional X-ray radiography, the imaging speed of MRI is low. The slow imaging speed of MRI has significantly limited its capability in some *in vivo* imaging applications. Beating heart, respiratory motion, pulsating cerebrospinal fluid, and involuntary motion could drastically degrade image quality by motion artifacts, particularly in high resolution imaging. This slow imaging acquisition also impacts negatively on the emerging hyperpolarized C-13 MRI where enhanced MR signal intensity rapidly decays (within ~60 seconds for pyruvate). It is critical to have an efficient fast imaging strategy to collect the augmented signals so that the high sensitivity advantages of hyperpolarized C-13 MR can be maximally realized.

Over the past decades, tremendous efforts have been made in developing techniques to accelerate MR imaging acquisition. Methods based on fast sequences, for instance, echo planar imaging (EPI), seem to have reached limits of MR hardware (e.g., max gradient amplitude and slew rate) and physiological effect (e.g., neuromuscular stimulations due to fast gradient switching). Recent advance in parallel imaging with multichannel RF coils has made it possible to reduce imaging time by complementing phase-encoding steps with the RF encodings using the receive coil sensitivity profiles. More recently, a whole new technique, compressed sensing, has emerged as a promising approach to fast MR imaging. With completely different concept over parallel imaging, compressed sensing is able to reconstruct MRI images from much fewer encodings by exploiting the sparsity of the images in an appropriate transform domain. Unlike the conventional fast imaging techniques, the parallel imaging and also the sparse MR accelerate acquisition without significant sacrifice of sensitivity and spatial resolution. These fast imaging techniques are expected to fundamentally change the current MR imaging method. While being promising and successful, these techniques also demonstrate the need for more efficient and advanced RF hardware/instruments and imaging algorithms and also specialized implementation for specific *in vivo* imaging applications, which ultimately facilitate the further development and clinical translation of these robust fast imaging technologies.

With this background, we, along with the editor-in-chief Professor Yi-Xiang Wang and the editorial office of the journal, have organized and assembled two special issues with an emphasis on technical developments of hardware and algorithm for parallel imaging and sparse MR, and their biomedical applications. This first special issue includes eight articles from top MR research and development groups, covering overarching and frontier topics on various aspects in current parallel imaging and sparse MR based fast imaging and its applications.

Apparently techniques integrating parallel imaging and compressed sensing MR could yield a further accelerated imaging approach compared with using each technique alone. Integrating the two techniques is expected to pose technical challenges. In this special issue, Chang *et al*. (1) propose a method by using the reweighted l_1 minimization to improve the quality of compressed sensing MR imaging with multichannel parallel imaging data. Liu and Saloner also describe their accelerated imaging technique with circular Cartesian undersampling and investigate the proposed variable density Cartesian sampling strategy for compressed sensing and parallel imaging (2).

Adopted from the parallel imaging technique, parallel excitation or transmit using multichannel transceiver arrays, rather than receive-only arrays, is able to achieve a fast selective excitation and perform the required RF magnetic field (B_1) shimming and SAR optimization which have been demonstrated to be essential for efficient and safe MRI, especially at ultrahigh magnetic fields. Image inhomogeneity issue is more pronounced in large field-of-view (FOV) applications. The University of Minnesota team presents their unique method using multi-spoke parallel transmit RF pulse to reduce transmit RF magnetic field (B_1+) inhomogeneity in the live imaging at the ultrahigh field of 7T (3).

An overarching issue in parallel imaging hardware is the design of RF coil arrays for MR signal excitation and reception with sufficient element decoupling and efficient B_1 for signal excitation and reception. For the very first time, Pang *et al*., (4) explore the possibility of designing quadrature transmit coil arrays using multiple circularly polarized patch antennas for improving the efficiency of parallel excitation with reduced RF power. In quadrature coil array development, Hu and colleagues (5) utilize the novel common-mode differential mode technique to design quadrature transmit/receive coil arrays and demonstrate its feasibility and advantages in performing parallel imaging effectively. Currently, the RF coil arrays are made by using a set of surface coils which show limitations in imaging coverage, signal-to-noise ratio (SNR) uniformity over FOV, and parallel imaging performance. An attempt to address the issue is the development of volume coil arrays of which the array elements are a set of volume coils (6).

Given the unprecedented SNR gain of hyperpolarized C-13 MR, it is possible to measure tissue metabolic profile *in vivo* by using the highly sensitive hyperpolarized C-13 MR. Fast imaging technique is critical in detecting rapidly decaying C-13 MR signals. Bahrami and team from University of California San Francisco (UCSF) report their study on measuring kinetics of hyperpolarized C-13 pyruvate and C-13 urea in prostate and liver tumors by using compressed sensing dynamic MR spectroscopic imaging, showing the capability of detecting hyperpolarized C-13 signals and measuring the pyruvate to lactate conversion rate (7). In neuro-imaging research, by applying fast parallel imaging to diffusion tensor imaging (DTI), scientists at Yerkes national Primate Research Center, Emory University (8) are able to quantitatively delineate the process of optic nerve aging in monkeys *in vivo*.

We hope this special issue could provide interesting and important information on the current topics and research directions of parallel and sparse MR imaging to the readers of *Quantitative Imaging in Medicine and Surgery* (*QIMS*) and help to facilitate further development and clinical translation of this novel and unconventional fast MR imaging method.

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