AbstractID: 9760 Title: Parallel Acquisition Methods for Neuroimaging

Parallel Imaging is one of the recent revolutions in Magnetic Resonance Imaging. As conventional gradient encoding is reaching its limits by dB/dt limits, spatial encoding via localized receiver coil sensitivities has brought a dramatic performance boost into the arena of MRI. Essentially, the use of parallel imaging affords less phase encoding steps and hence speeds up data acquisition. Aside from faster imaging, parallel imaging also caused giant leaps in RF receiver array technology development and thus to massive improvements in image quality and improved SNR at similar B0 levels.

For many MRI pulse sequences parallel imaging helps to cut down scan time by factors ranging from 2 to 4, whilst for 3D sequences further speed up factors can be achieved along the second phase encode dimension, pushing the overall scan time reduction ever higher. In this fashion, the scan duration for time-of-flight (TOF) or phase-contrast (PC) angiographic sequences can be considerably shortened and increases patient comfort. Alternatively, larger volumes or better resolved data can be acquired within the same scan time. For contrast-enhanced MRA the faster scanning allows one to minimize the venous overlap in regions with extremely short arterio-venous transit times, such as seen in normal intra and extra-cranial vessels.

In addition to reduce scan time, parallel imaging is also used very often in fast spin echo (FSE) and echo planar imaging (EPI) sequences to reduce geometric distortions and blurring. FSE acquires multiple lines of k-space per repetition interval (TR). During the course of each FSE readout train, the MR signal decays with T2 and impresses a considerable weighting on the k-space, which in turn, leads to noticeable blurring, especially for long FSE trains (e.g. T2-weighted FSE or single-shot FSE/HASTE). By scanning fewer lines in k-space, FSE traverse k-space much faster with parallel imaging and therefore reduces the blurring. In a similar fashion EPI, particularly single-shot EPI, suffers from T2*-weighting of the k-space data. As the T2* decay occurs more rapidly, the blurring in EPI is even more pronounced as with FSE sequences. Faster k-space traversal can again reduce blurring. EPI suffers also from marked geometric distortions that are typically induced by off-resonant spins (e.g., susceptibility differences, B0 inhomogeneities, lipids, eddy currents) and are proportional to how fast one traverse through k-space along the phase encode dimension. Here, parallel imaging helps to reduce these distortions R-fold if it accelerates the EPI readout R-times. The consequences to image quality enhancement are even more important to neuroimaging than overall scan time reduction as single-shot EPI is the backbone sequence for many highly important sequences that are used in clinical practice.

Specifically, diffusion-weighted imaging (DWI), perfusion-weighted imaging (PWI), and functional MRI (fMRI) have benefited the most, thus far. Clearly, distortion correction and resolution enhancement are the driving factors behind that. Whilst better image quality in DWI offers better lesion conspicuity and detection of smaller lesions (which might help to better understand the etiology of a disease, such as stroke), fMRI benefits from better spatial localization and the ability to image regions that would have been otherwise too distorted.

The price that one needs to paid for faster imaging is a loss in SNR that is proportional to the square-root of the acceleration factor and that is also proportional to the so-called geometry factor. The latter takes into account the size, number, and orientation of the individual receiver coils, which ultimately determine the conditioning of the inverse reconstruction problem.

In summary, parallel imaging has led to a considerable boom in neuroimaging. By making acquisitions faster and less distorted patient comfort and motion artifacts could be reduced. Moreover, one can achieve spatial resolutions that would have been unthinkable before with regular gradient encoding.
The field of parallel imaging is still growing at a very fast pace and is now paralleled by similar developments on the RF transmit side, for example, to shorten complex RF pulses and for advanced B1+ shimming methods.