Parallel imaging for clinicians

Stefan O. Schönberg, MD, Institute of Clinical Radiology and Nuclear Medicine, University Medical Center Mannheim, Heidelberg University, Germany, www.ikrn.de

The general advantages of parallel acquisition techniques (PAT) for clinical MRI are the possibilities for either a higher spatial resolution or shorter scan times which subsequently allow shorter breath holds or multiple averaging within the same total scan time. Due to the shorter echo-trains, less blurring and image distortion is found in single-shot applications such as HASTE or EPI. Shorter echo times result in less signal decay in tissues with a short T2* such as the lungs. Overall, PAT can be applied to different morphologic and functional imaging techniques in all areas of the human body. In addition, reduction of the applied RF-power by using parallel imaging helps to overcome specific absorption rate (SAR) limitations particularly at 3.0T. Hence, within a reasonable scan time, comprehensive exams become feasible with large anatomic coverage.

For imaging of the lung, the introduction of PAT opened new possibilities for assessment of pulmonary infiltrates with T2-weighted HASTE sequences. Detection of pulmonary abnormalities is almost as good as with CT with a sensitivity, specificity, positive predictive value and negative predictive value of 95%, 88%, 95% and 88%, respectively [1]. For assessment of pulmonary perfusion, both temporal and spatial resolution can be significantly increased by PAT compared with conventional imaging [2]. The combination of fast MR perfusion imaging and high-spatial-resolution MR angiography with PAT enables the differentiation of PPH from CTEPH with a high accuracy of 90% [3]. In addition, quantification of pulmonary perfusion is feasible using PAT [4].

Cardiac imaging has greatly benefited from PAT. One-dimensional acceleration factors up to R = 4 allow accurate SSFP CINE MRI even though CNR is significantly reduced [5]. For evaluation of global and regional cardiac function in patients the acquisition of an entire stack of short-axis Cine SSFP images can be reduced to 2 breath-holds using a TSENSE approach [6]. The application of PAT to SSFP CINE MRI enables the use of higher flip angles at 3.0T hence providing a better blood-myocardium contrast. EDV, ESV, and EF based on TSENSE cine showed excellent correlation to the nonTSENSE cine approach (all r^2=0.99, P<0.001). For assessment of cardiac perfusion, single-heartbeat temporal resolution could be accomplished with spatial coverage of eight slices at heart rates up to 71 bpm, six slices up to 95 bpm, and four slices up to 143 bpm in one study with the implementation of TSENSE [7].

For the liver, PAT allows reduction of acquisition time by approximately 40% without loss of image quality [8]. This facilitates the implementation of motion correction techniques such as respiratory triggering. In addition, PAT drives the use of single-shot black-blood T2-weighted spin-echo EPI sequences with reduced distortion artifacts for improved lesion detection [9].

With the development of multi-channel MRI systems with 32 independent receiver channels, PAT applications can be implemented for whole-body MRI imaging (WB-MRI). A recent study has reported high accuracy for detection of metastases with a sensitivity/specificity of 96%/82% for WB-MRI compared with 82% for PET-CT. Accuracy for correct TNM staging was 96% for PET-CT and 91% for WB-MRI [10]. For detection of bone metastases the accuracy of WB-MRI with PAT appears to be superior to PET-CT [11].

MR Angiography (MRA) has also greatly benefited from PAT with early reports dating already back to the year 2000 [12]. PAT offers the possibility to improve both spatial and temporal resolution while decreasing the acquisition time. High resolution contrast-enhanced (CE) MRA of the renal arteries with sub-millimeter voxel sizes is now feasible in less than 20 s [13]. This allows the quantification of area stenosis on cross-sectional cuts with significantly higher accuracy and inter-observer agreement in comparison with measurements of inplane diameter stenosis. On multi-channel MRI scanners, high-resolution WB CE MRA can be acquired with excellent image quality which allows screening for cardiovascular disease [15]. In combination with techniques such as view-sharing time-resolved CE MRA is possible at a frame-rate of less than 2 seconds [16]. This approach may permit the characterization of tumor vascularity for differential diagnosis of head and neck tumors.

Neuro-imaging and MSK-imaging were traditionally not in the focus of PAT as measurement times were not critical. The combination of dedicated coil technology, higher field strength and functional imaging techniques led to a broader use of PAT. PAT in combination with radial imaging allows to acquire diffusion-weighted images of the brain with almost no geometrical distorsion in every direction [17]. This particularly facilitates detection of small ischemic lesions in the brain-stem and at the base of the brain. Also simply decreasing the acquisition time in spine imaging without loss of diagnostic image quality can be achieved with PAT [18].

One major disadvantage of PAT is the loss of SNR, which decreases by the square root of the acceleration factor, but can be effectively counterbalanced by using higher field strengths and dedicated multi-element coils with higher SNR [19-21]. Current developments in MR scanner technology with increased number of transmitter channels will further broaden the spectrum of clinical applications at 3 Tesla [22, 23].

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