"Breathe In, Breathe Out, Continue Breathing" Towards Full Free-Breathing Abdominal MRI Using Radial Sampling and Compressed Sensing

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Magnetic resonance imaging (MRI) has become an invaluable diagnostic tool due to the excellent soft-tissue contrast, absence of ionizing radiation, and broad spectrum of measurable quantities. However, in clinical practice, its routine application is hampered by high examination costs, long and complex workflows, and high sensitivity to patient motion. The latter poses a significant challenge for imaging body areas that are affected by respiratory motion, such as the abdomen and thorax. With conventional MRI sequences, patients have to hold breath during data acquisition, which can take up to 15-20 secs. Because many patients are unable to suspend respiration for such time period, the failure rate of body MR exams is relatively high, in particular for elderly, sick, and pediatric patients. As consequence, computed tomography (CT) is in many cases still preferred as imaging method.

The motion robustness of MRI can be improved by using non-Cartesian acquisition schemes such as radial k-space sampling [1], which allows for data acquisition during continued shallow respiration. While technically more demanding and difficult to implement, which made routine use infeasible for many years, radial sequences work nowadays with sufficient reliability on existing clinical MR systems [2]. First FDA-approved sequences are commercially available (fat-suppressed stack-of-stars 3D FLASH), and several clinical studies have verified improvements in image quality and diagnostic accuracy [3]. However, not all of the diagnostically needed contrasts can be generated with the available sequences so far.

This talk will first give a brief introduction to radial k-space sampling and illustrate the clinical advantages in the case of fat-suppressed T1-weighted gradient-echo contrast. Afterwards, several technical concepts are presented for providing the missing diagnostic

image contrasts. Combined together, they will allow full free-breathing diagnostic MR examinations that are suited for patients who cannot hold breath and result in a significant simplification of the clinical examination workflow.

GRASP is a novel technique for dynamic contrast-enhanced acquisition (DCE-MRI), which combines radial sampling with the idea of continuous data acquisition [4]. Because radial sampling is less time-efficient, it uses a temporally-constrained Compressed-Sensing reconstruction to achieve the imaging speed needed for DCE-MRI. Furthermore, because GRASP uses the golden-angle scheme [5], it enables retrospective reconstruction with flexible temporal resolution, which can be used to simultaneously extract perfusion information.

For patients who perform severe breathing, it is possible to additionally compensate for motion by incorporating self-navigation into the reconstruction. The self-navigated XD-GRASP method uses motion information extracted from the k-space center to sort the data into motion states and reconstructs parametric frames by applying a Compressed-Sensing reconstruction with constraints along the motion dimension [6]. By displaying the parametric frames from only one motion state, it is then possible to virtually freeze the respiration.

Dixon-RAVE is a new approach for fat/water separation from radial acquisition [7]. It uses a flexible radial multi-echo sequence with blipped readout scheme to acquire T1-weighted data. Fat/water separation is achieved with an iterative model-based reconstruction that directly estimates fat and water maps from the k-space data instead of intermediate images. By including the fat off-resonance frequency into the signal model, the method obtains both sharp water and fat maps without off-resonance blurring that typically arises in non-fat-suppressed radial scans due to the varying readout directions. Dixon-RAVE can be combined both with the GRASP and XD-GRASP principles. Finally, an outlook is given on a radial 3D TSE sequence (Radial SPACE) [8] that is currently under development to provide T2-weighted contrast from free-breathing non-gated abdominal acquisition.

References:

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