Free-breathing DCE-MRI of the Kidney using GRASP

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Challenges in abdominal DCE-MRI

Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is a relevant part of standard renal MRI examination and indispensable for the evaluation of renal pathologies, such as renal masses [1-4]. It also enables the measurement of renal perfusion as well as glomerular filtration rate (GFR), since gadolinium-based contrast agents are excreted almost only by the kidneys [5-11]. However DCE-MRI exams remain challenging and the failure rates are undesirably high. Especially in sick patients unable to hold their breath adequately, respiratory-motion artifacts compromise achievable image quality. Another challenge is the tradeoff between spatial and temporal resolution of DCE-MRI data for measuring perfusion parameters [12, 13]. On the one hand, a high spatial resolution without motion artifacts is beneficial for a diagnostic image quality of morphological images. On the other hand, a high temporal resolution (less than 4 s per volume) is desirable for an accurate calculation of perfusion parameters [13].

Solution approaches

For acceleration of image acquisition, several parallel imaging techniques, such as generalized autocalibrating partially parallel acquisition (GRAPPA) or controlled aliasing in parallel imaging results in higher acceleration (CAIPIRINHA) are available. However, the inverse correlation of the acceleration factor and signal-to-noise ratio (SNR) leads to a loss in SNR. Additionally, several techniques have been introduced to reduce respiratory-motion artifacts and to manage the tradeoff between spatial and temporal resolution such as keyhole [14], k-t broad-use linear acquisition speed-up technique (k-t BLAST) [15] and time-resolved angiography with stochastic trajectories (TWIST) [16].

The GRASP approach

The recent introduction of a new approach, golden-angle radial sparse parallel MRI (GRASP)[1] [17, 18], could potentially address all of the above mentioned issues. By using non-Cartesian acquisition techniques, specifically radial *k*-space sampling, motion-induced ghosting artifacts can be reduced. The radial sampling is performed using the golden-angle radial sampling scheme for a flexible spatiotemporal resolution [18].

To improve the temporal resolution and to suppress undersampling artifacts, iterative reconstruction with through-time total variation regularization is applied. A 2016 study showed that multiphase MRI of the kidney is a suitable candidate for the application of GRASP [17], probably because of the high amount of spatiotemporal data correlations, which is a premise for the application of that technique.

[1] WIP, GRASP is currently under development and is not for sale in the US and in other countries. Its future availability cannot be ensured.

1 Schematic overview of data acquisition with GRASP.

Improved workflow and increased efficiency

As data are acquired continuously with a native phase prior to contrast medium (CM) application (Fig. 1), timing and synchronization errors are no longer possible. Acquiring all information using a single continuous scan instead of several individual scans simplifies workflow even further.

Full flexibility by retrospective choice of temporal resolution

With GRASP, data are acquired continuously during free-breathing. The sampling scheme uses the golden angle as radial increment, which allows that basically any number of radial spokes can be combined into an image providing the possibility to retrospectively decide which temporal resolution should be reconstructed. For morphological images, a poorer temporal resolution (e.g. 55 spokes per image for a temporal resolution of 6.2 seconds) can be reconstructed. For perfusion assessment, images can be reconstructed from the same data set with 13 spokes per image, resulting in a temporal resolution of 1.5 seconds (Fig. 2).

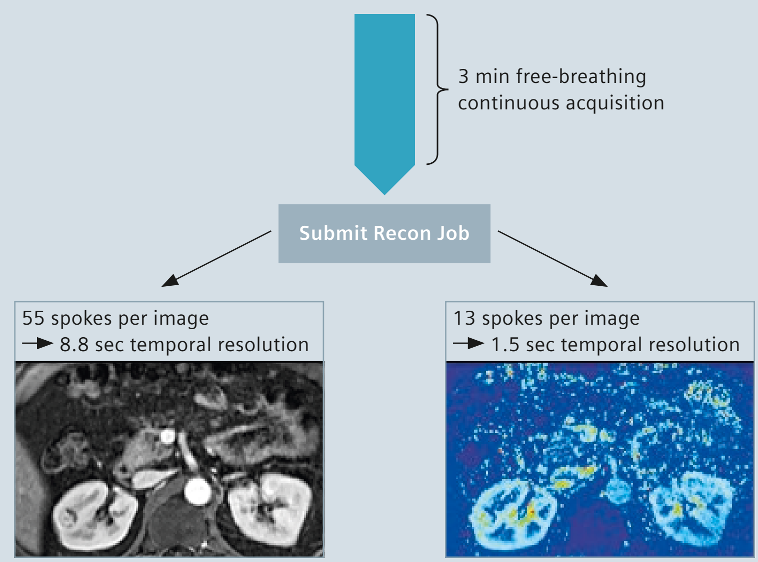
Role model for the combination of morphological and functional imaging

One major strength of MRI is the possibility of acquiring both morphologic and functional information. Perfusion imaging thus represents a cornerstone of functional imaging and is critical for achieving greater diagnostic specificity in terms of lesion characterization and assessment of organ function. The GRASP technique is an excellent example of the combination of morphological and functional imaging and shows considerable potential for overcoming some of the inherent limitations of conventional DCE-MRI. In particular, the technique delivers an overall good image quality and high diagnostic confidence of morphological images (Fig. 3) [17]. Due to use of radial *k*-space sampling, motion-induced ghosting artifacts are minimal although data is acquired during free-breathing.

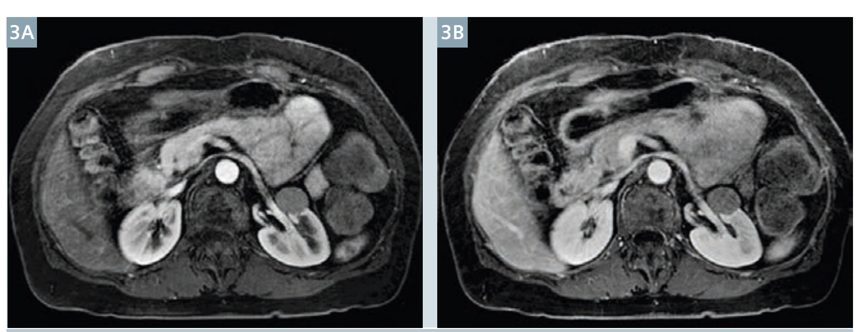
Additionally, the motion insensitive technique has been shown to be a valuable tool to achieve valid and reproducible perfusion parameter maps (Fig. 4) [17].

In conclusion, this technique has the potential to become an integral part of renal MRI. The combination of morphological imaging and functional imaging helps to further entrench MRI as a qualitative and quantitative imaging modality.

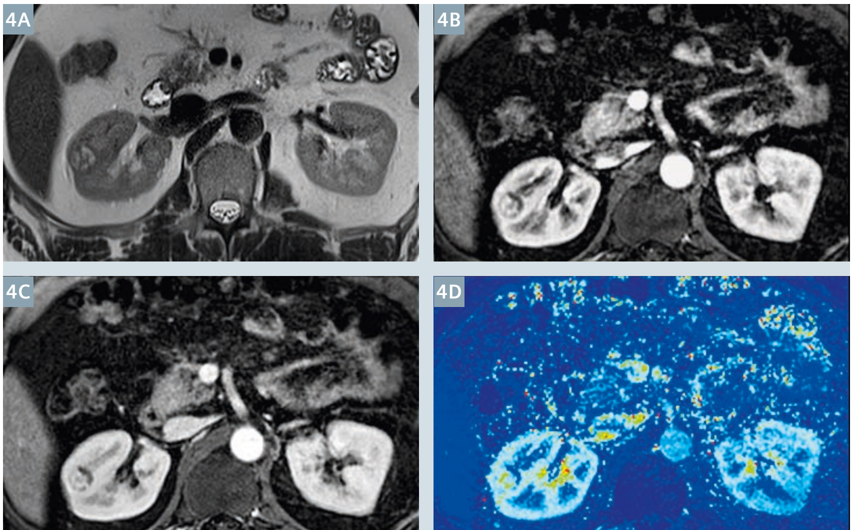
2



2 Example for reconstruction scheme of both morphological images and perfusion parameter maps from one single data set.



3 64-year-old female patient who underwent an examination of the kidneys after contrast administration. Arterial **(3A)** and renal **(3B)** phase of the GRASP reconstruction showing good image quality without respiratory motion artifacts.



4 48-year-old male patient with histologically proven clear cell RCC. T2w HASTE sequence **(4A)**, arterial **(4B)** and renal **(4C)** phase of the GRASP reconstruction, estimated renal plasma flow (RPF) parameter map **(4D)** showing hypervascularity of the lesion.

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