Self-calibrating stack-of-stars (SOS)-CAIPIRINHA for improved parallel imaging

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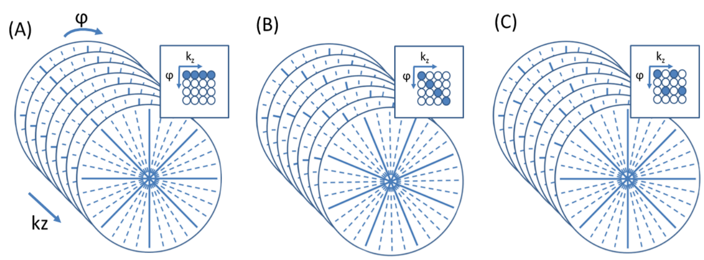
Target audience: Physicists, clinicians.

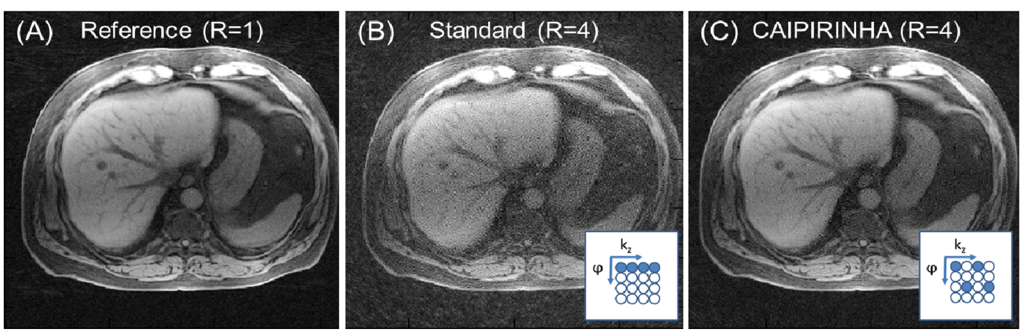
Introduction: 2D radial imaging can be accelerated by parallel imaging (pMRI) without the need for extra coil-calibration scans, since the calibration information can be extracted from the fully sampled k-space center and thus is intrinsically self-calibrated. This allows for robust pMRI reconstruction even in the presence of severe motion during the scan. Unfortunately, non-Cartesian pMRI reconstruction methods are associated with significantly longer processing times since they require either iterative reconstruction algorithms such as e.g CG-SENSE [1] and SPIRIT [2] or the calculation of many reconstruction weights in the case of e.g. GRAPPA [3] and PARS [4]. Recently we demonstrated that the amount of weights required in radial self-calibrated GRAPPA can be significantly reduced by calibrating weights only in a few (12-16) radial and angular k-space segments [3]. In this work we extend this idea to accelerated 3D stack-of-stars (SOS) trajectories where the GRAPPA reconstruction is performed in 3D k-space rather than on a slice by slice basis. We demonstrate that by rotating each undersampled radial plane with respect to each other the concept of CAIPIRINHA (Controlled Aliasing In Parallel Imaging Results IN Higher Acceleration) [5] can be employed allowing for significantly improved pMRI reconstruction since sensitivity variations in all three spatial dimensions can be exploited.

Material and Methods: Volunteer measurements were performed on a 1.5T clinical scanner using 15 channels in total from a spine-body matrix combination. In order to demonstrate the applicability of our approach a fully sampled radial VIBE experiment (TR=4.11ms, FOV = 320x320x) has been acquired with 38 partitions (partial Fourier factor = 0.8) and 304 projections during free breathing. The matrix of the reconstructed images was 320x320x48. This data set was retrospectively undersampled in both the partition and the angular direction mimicking various accelerated standard and CAIPIRINHA-type sampling schemes (see Figure 1). Due to radial sampling in k_x and k_y schemes providing data on each k_z coordinate allow for the auto-calibration approach while schemes leaving gaps at the k_z coordinate require a prescan for calibration.



SOS-CAIPIRINHA using self-calibrating GRAPPA: Similar to previously proposed radial GRAPPA methods operating in 2D [6,7], the accelerated stack-of-stars data is gridded to a low resolution 3D Cartesian k-space (32x32x32) serving as Auto Calibration Signal (ACS) for the following radial 3D GRAPPA algorithm. For any missing point in the undersampled 3D radial k-space a unique non-Cartesian 3D GRAPPA kernel can be specified. For calibration this non-Cartesian GRAPPA kernel can be shifted by Δk_y, Δk_z and Δk_x within the fully sampled 3D ACS region. However, in contrast to the Cartesian case the locations of the source and target points within the ACS region do not fall on a Cartesian grid. However, the correct source and target signals can be derived by degridding (interpolating) the Cartesian ACS data to the required source and target locations. Here, this has been accomplished using simple Fourier interpolation by a factor of 4 in each direction. In order to speed up the reconstruction process the SOS k-space is segmented in both the read-out (4 segments) and the angular (4 segments) as suggested originally by Griswold et al [8] for 2D radial GRAPPA. In contrast to the original radial GRAPPA version where the segments are treated as Cartesian and are calibrated from a fully-sampled radial reference data set, we employ a representative non-Cartesian GRAPPA kernel taken from the center of each segment which is calibrated from the low-resolution ACS data.

Results: Figure 2 shows reconstructions of the (A) fully-sampled reference data and from artificially 4-times accelerated acquisitions following (B) standard radial undersampling only in angular direction and (C) CAIPIRINHA-type undersampling. Both reconstructions where performed using the described autocalibrated 3D GRAPPA approach tailored towards the individual undersampling patterns. The noise enhancement is clearly improved by the SOS CAIPIRINHA approach compared to the reconstructon of the standard radial undersampling. The 4-times accelerated imaging experiments correspond to a total scan-time of less than 12s and thus can be performed within one breath-hold.



Conclusion and Discussion: In this work, the concept of SOS-CAIPIRINHA for improved self-calibrating radial pMRI using GRAPPA and k-space segmentation has been introduced and applied to radial VIBE liver imaging. It is demonstrated that significantly improved image quality with less g-factor related noise enhancement is achieved when the „stars“ are rotated by $\Delta\varphi$ with respect to each other for subsequent k_z phase encoding steps thereby building 2D CAIPIRINHA -like patterns in the k_z-φ plane.

References:

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