

## Application of Hybrid Through-Time/k-Space Radial GRAPPA Calibration to Real-Time Cardiac Imaging

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**Introduction:** Parallel imaging methods for non-Cartesian trajectories are often complicated by the need for accurate coil sensitivity maps, sensitive parameterization, or iterative reconstructions. The original formulation of radial GRAPPA[1] is based on standard GRAPPA which assumes that segments of the radial k-space can be approximated as Cartesian for the purposes of the parallel imaging reconstruction. This method is advantageous because it does not require a coil sensitivity map and it is computationally efficient. However, for high data reduction factors, this Cartesian approximation breaks down, leading to significant artifacts. It has recently been proposed to acquire several fully-sampled radial images and then perform a *through-time* calibration, where each missing point is reconstructed with an appropriate weight set [2] (see Fig 1).

While the through-time method offers improved image quality, it requires a significant number of fully-sampled calibration time frames. This abstract demonstrates the use of a hybrid through-time/through-k-space radial GRAPPA calibration method for real-time free-breathing, non-gated cardiac imaging which keeps the benefits of the through-time method while employing fewer calibration time frames.

**Materials and Methods:** A total of 300 fully-sampled cardiac radial datasets (TrueFISP, 15-channel cardiac receiver coil, TE=1.35ms, TR =2.7ms, FOV=300mm<sup>2</sup>, base matrix = 128<sup>2</sup>, 128 projections, slice thickness = 6mm, total time=1min46s) were acquired on a healthy volunteer at 1.5T (Siemens Espree). The volunteer was instructed to breathe freely, and no EKG gating was employed. Following the calibration, 100 undersampled (16 projections, R=8) radial datasets were acquired (temporal resolution =43ms/frame, total time=4.3s). The images were reconstructed from the undersampled data off-line using all 300 calibration time frames in order to generate a gold-standard image; the weight set for each missing point was calibrated and applied separately. A second set of images was then reconstructed using only 150 calibration frames and through-time calibration, and the average RMSE of these images calculated. In order to demonstrate that a small bit of through-k-space calibration (as in standard radial GRAPPA) can greatly reduce the number of calibration frames needed, images were reconstructed using only 66 calibration frames, and 1x4 (projection x read) k-space segments; the RMSE of these images was also calculated. As a comparison, undersampled images and images reconstructed using standard radial GRAPPA (32x32 segments) were also generated.

**Results:** The results of the reconstructions are shown in Fig 2. While standard radial GRAPPA (top right) removes some streak artifacts from the undersampled image (top left), many additional artifacts are still present, and the image remains blurry. The through-time radial GRAPPA (bottom left) eliminates these artifacts (yielding a RMSE of 4.85% as compared to the gold-standard 300 calibration frame image), but a total of 150 calibration frames are required. When moving to the hybrid calibration scheme proposed here, involving through-time and k-space repetitions, only 66 calibration frames were used, leading to a RMSE of 4.9%. As can be seen in the figure, this hybrid reconstruction is nearly identical to the purely through-time calibration.

**Discussion:** The hybrid through-time/k-space radial GRAPPA method shown here yields higher-quality images than the standard radial GRAPPA because appropriate GRAPPA weight sets can be calibrated and applied for very small segments in k-space. Unlike the pure through-time calibration, far fewer fully-sampled calibration frames are required. As seen in Figure 2, although the number of calibration frames was reduced by more than a factor of 2, the RMSE of the final image was comparable to that of the through-time method. Thus, the collection of the calibration frames lasted only 23 sec, as opposed to 51 sec in the through-time method. In the cardiac applications shown here, both the calibration and accelerated datasets can be acquired without EKG triggering or breathholding, easing the scan for patients unable to hold their breaths or suffering from cardiac arrhythmia. This method is ideal for dynamic imaging where the time needed for the acquisition of calibration data is less important than capturing motion or temporal contrast changes. We anticipate that this hybrid through-time/k-space radial GRAPPA will also be applicable in other dynamic situations where high acceleration factors are required for extremely rapid data collection.

**References:** [1] Griswold MA, et al. In: Proc. ISMRM 11, 2003, p 2349. [2] Seiberlich N, et al. Proc. 3<sup>rd</sup> Annual International Parallel Imaging Workshop, 2009

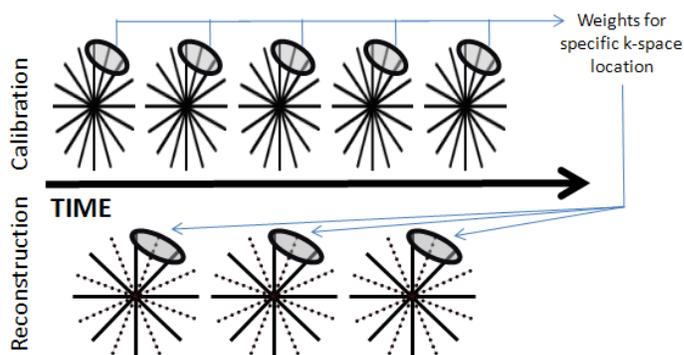


Figure 1: A schematic of the through-time radial GRAPPA method.

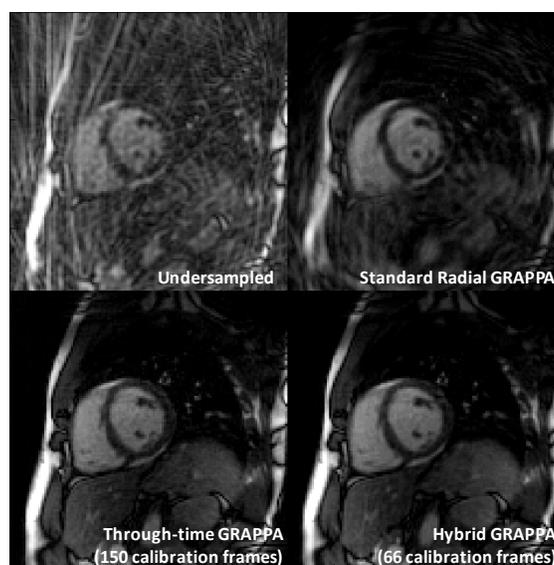


Figure 2: Images generated using 16-projection data (top left), standard radial GRAPPA (top right), through-time radial GRAPPA (bottom left), and hybrid radial GRAPPA (bottom right). The two bottom images are nearly identical, despite the fact that the hybrid image used fewer than half of the calibration frames needed for the through-time image.