# Dynamic Volumetric MRI using Golden-Angle Variable Density Spiral Acquisition with Sparse Parallel Imaging Reconstruction

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**Target audience:** Researchers and clinicians who are interested in high resolution dynamic volumetric MRI.

**Purpose:** High resolution time-resolved imaging is crucial for the accurate clinical diagnosis, which can detect small lesions and all critical phases. There have been some studies about data acquisition and image reconstruction strategies to achieve high temporal and spatial resolution for dynamic volumetric imaging, such as fast 3D contrast enhanced MRI of the liver using Temporal Resolution Acceleration with Constrained Evolution Reconstruction (TRACER) [1] and Golden-Angle Radial Sparse Parallel MRI (GRASP) [2]. In TRACER, golden angle variable density spiral (VDS) is used, which ensures the data acquisition efficiency and motion insensitivity, but it still requires breath hold because of the highly undersampled data and the reconstruction method. In GRASP, data are acquired with golden angle radial trajectories and reconstructed using the joint of compressed sensing and parallel imaging. GRASP is extremely insensitive to motion so that it is suitable for free breathing acquisitions. However, the data acquisition with radial trajectories is much slower than spiral. In this study, we aim to combine the GRASP reconstruction method with golden angle VDS trajectories to improve the motion insensitivity as well as acquisition efficiency in dynamic volumetric MRI.

**Methods:** Experiments were performed on a GE 3T MR750 scanner (GE Healthcare, Waukesha, WI) with an 8 channel coil. A 3D stack of golden angle VDS was used to acquire k-space data. The scan parameters were TR/TE=6.1ms/0.6ms, FOV=420×420×150mm$^3$, in-plane resolution=1.64×1.64mm$^2$, slice thickness=5mm, interleaf number for each slice=288, total scan time=64sec. The subject was required to hold breath when scanning, but he deeply breathed once in the middle of the scan because of the long scan time. The reconstruction method of GRASP, combining compressed sensing with parallel imaging, was used for the spiral data reconstruction. We used 4 interleaves to reconstruct one frame. The fully sampled k-space consisted of 48 interleaves. With such an undersampling rate, the temporal resolution was about 888ms, corresponding to an acceleration factor of 12. TRACER was also used to reconstruct the images for comparison.

**Results:** Three representative frames are selected to compare the reconstruction algorithms of TRACER and GRASP for the golden angle VDS data. Frame 20 was acquired before the deep breath of the subject, frame 40 was acquired when breathing, and frame 56 was acquired after breathing (Fig. 1). Motion artifacts are very severe during deep breathing in TRACER, however, they are suppressed to a great extent in GRASP reconstruction. In frame 20 and 56 when the subject held breath well, the image quality of TRACER seems reasonable, but the results of GRASP are sharper and the background noise level is lower. For this dataset, a small ROI in abdominal aorta was manually chosen to evaluate the signal dynamics (Fig. 2). The curve of the GRASP images is smoother than that of TRACER, which reflects the temporal blurring resulting from GRASP reconstruction.

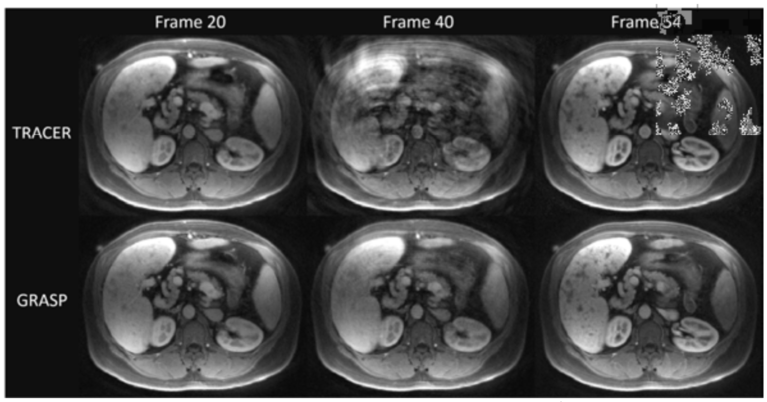


*Fig. 1 Three frames selected from the image series. The 20$^{th}$ frame is before deep breathing, the 40$^{th}$ is during deep breathing and the 56$^{th}$ is after deep breathing. Results of the two reconstruction algorithms are presented respectively.*

**Discussion:** TRACER reconstructs each frame by enforcing data fidelity to the sampled k-space data and imposing strong consistency with the previous image frames to achieve high temporal and spatial resolution. However, when considerable motion exists between consecutive frames, consistency constraint can lead to severe motion artifacts because the k-space data used for one frame are extremely insufficient. To improve the data efficiency and motion insensitivity, compressed sensing is introduced to GRASP. Thus, when reconstructing one frame, all k-space data contributes to it which results in improved image quality. On the other hand, compressed sensing will make the image series blurred in the temporal dimension as a tradeoff for great image quality. Our experiments demonstrate that golden angle VDS is a superior trajectory for the reconstruction algorithm in GRASP, although it is originally designed for radial trajectory.

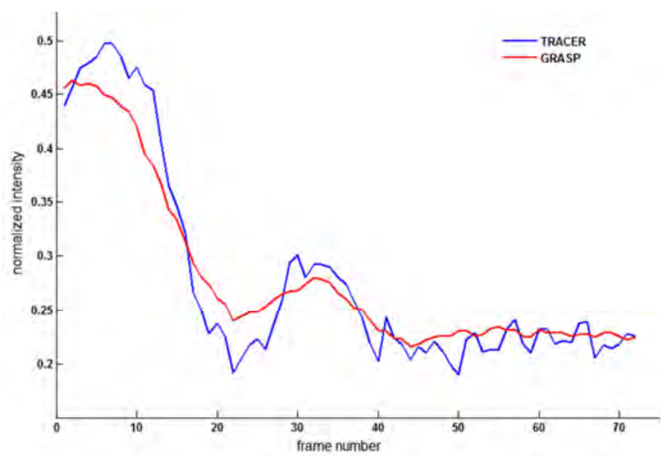


*Fig. 2 Signal-intensity curves were calculated along the temporal dimension respectively. A small ROI was chosen manually in the abdominal aorta.*

**Conclusion:** A new dynamic volumetric imaging method is investigated which combines golden angle VDS and the reconstruction algorithm of GRASP. This technique is highly motion insensitive and acquisition efficient so that it is very promising to achieve high temporal and spatial resolution imaging without breath hold in clinical applications.

**Reference:**

1. Bo Xu, et al. MRM, 2013; 69:370–381.
2. Li Feng, et al. MRM, 2014; 72:707–717.