Improved ASL Imaging with 3D GRASE PROPELLER

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Introduction: Arterial Spin Labeling (ASL) uses blood water as an endogenous tracer to non-invasively measure cerebral blood flow. In a previous study, Günther et al. (1) has shown a near 3-fold improvement in perfusion signal-to-noise ratio (SNR) with single-shot 3D GRASE compared to conventional 2D EPI. However, a limitation of 3D GRASE is through-plane blurring caused by T2 decay. Reducing through-plane blurring may be accomplished by reducing the Echo Train Length (ETL) of each partition. In this study, we show that a PROPELLER (2) trajectory in combination with 3D GRASE reduces the ETL of each partition and subsequently through-plane blurring. In addition, 3D GRASE PROPELLER improves the overall image quality and spatial resolution of ASL perfusion images without sacrificing the perfusion SNR or increasing scan time.

Materials and Methods: 3D GRASE PROPELLER samples k-space with a series of rectangular 3D volumes, known as “bricks,” rotating about the central kz-axis. Each brick is acquired with a single-shot 3D GRASE readout. The k-space trajectory and 3D GRASE pulse diagram are shown in Figure 1. Since the final resolution of PROPELLER images depends on the frequency encoding readout length rather than the blade width (ie. the number of phase encoding steps), the in-plane image resolution can be maintained while shortening the effective ETL per partition. In addition, a reduced ETL reduces susceptibility artifacts and minimizes signal loss from through plane dephasing, both of which impact image quality and perfusion sensitivity. For image reconstruction, a 1D FFT is applied along the slice dimension after zero padding the raw data for spatial encoding. A self referenced Nyquist ghost correction technique is then applied to individual bricks, followed by the PROPELLER bulk motion correction. The corrected k-space data is regridded with an appropriate density compensation function and then a 2D-FFT is applied to transform the data to image space.

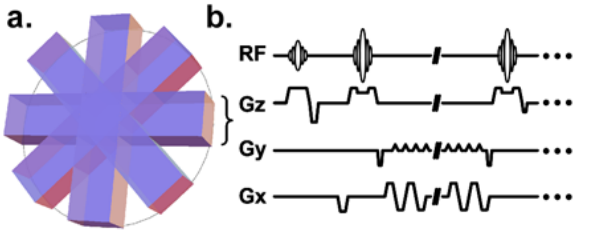

Figure 1. PROPELLER k-space trajectory (a) and 3D GRASE pulse diagram (b)

A Q2TIPS (3) – FAIR (4) sequence with background suppression pulses (5) was implemented as the ASL tagging sequence. All experiments were carried out on a 1.5T GE scanner (Twinspeed, GE Medical Systems, Milwaukee, WI). An 8-channel phased array head coil was used for data collection. Two healthy volunteers (27 year old male and 30 year old female) were scanned with informed consent. The tagging parameters include: TI$_1$ = 700ms, TI$_{1s}$ = 900ms and TI$_2$ = 1500ms. The acquisition parameters include: frequency encoding = 96, phase encoding = 20, 13 acquired partitions with a kz center out encoding, FOV = 28.8x28.8x90cm yielding a voxel resolution of 3x3x5mm^3, 16 blades acquired per image, TE = 17.5ms and 3 minute total scan time. The perfusion weighted image is computed by subtracting the final label image from the control image. An M$_0$ weighted PROPELLER image with 4 blades was acquired in a separate scan for perfusion quantification. 3D GRASE perfusion images were acquired for comparison with identical parameters except TE= 41.2ms and ETL=64.

Results: Three slices of the CBF maps (inferior, middle and superior) out of a total of 18 from one subject is shown in Fig. 2 with 3D GRASE PROPELLER (a) and 3D GRASE (b). Severe blurring artifacts can be observed in the 3D GRASE acquisition, especially in the superior and inferior slices. With 3D GRASE PROPELLER, fewer artifacts were observed and anatomical details such as gyrus in the cortex could be better identified. The mean gray matter perfusion values for the two subjects are 87 and 80 (ml/100gram/min) for 3D GRASE PROPELLER, 84 and 90 (ml/100gram/min) for 3D GRASE.

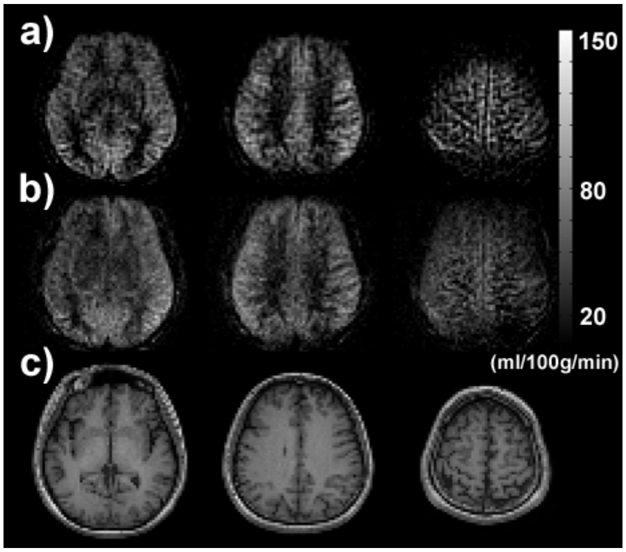

Figure 2. Quantitative CBF maps acquired with (a) 3D GRASE PROPELLER and (b) 3D GRASE. (c) Anatomical images acquired with 3D SPGR.

Discussion & Conclusion: We have shown here that the PROPELLER trajectory can be used to reduce through-plane blurring in the 3D GRASE acquisition. In addition, PROPELLER is less susceptible to off-resonance effects due to a shorter ETL and robust against motion artifacts, providing a promising alternative strategy for ASL acquisitions. Future work aims to further improve image quality by correcting residual distortions in each “brick” resulted from field inhomogeneities. This sequence has strong potential to offer superior image quality for perfusion imaging at high resolution at high field strengths.

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