In-vivo validation of a novel 3-echo SSFP phase-contrast sequence

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Introduction: Steady-state free precession (SSFP) sequences have high SNR efficiency, and when combined with phase-contrast (PC) imaging, can provide increased precision and/or reduced acquisition times compared to conventional GRE PC imaging [1-3]. Recently, a novel 3-echo SSFP sequence for rapid PC imaging was proposed [4-5]. We present an in-vivo validation of this technique applied to the imaging of aortic outflow. The accuracy and precision of this method is established using GRE and SSFP 3-echo techniques, and a conventional GRE-PC technique.

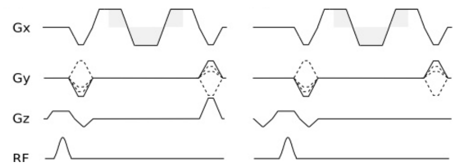
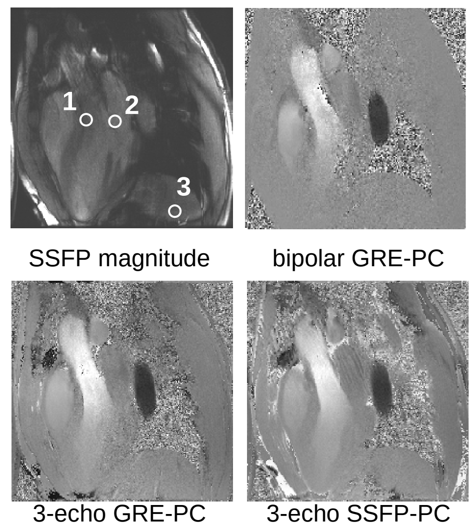


Fig.1: *3-echo phase-contrast sequences, (left) GRE, (right) SSFP.*

Methods: Experiments were performed on a GE Signa 3T EXCITE HD system (40 mT/m gradient amplitude; 150 T/m/s slew rate). Three different PC pulse sequences were compared in healthy volunteers: conventional GRE-PC imaging using bipolar velocity-encoding gradients (not shown), a 3-echo GRE-PC sequence (Fig. 1, left), and a 3-echo SSFP-PC sequence (Fig. 1, right). CINE scans were breath-held (**20 R-R intervals** for the 3-echo sequences; **25 R-R intervals** for conventional GRE-PC) and prospectively ECG-gated, with a 20 cm FOV, 1x1x7 mm voxel size. The temporal resolution was **70 ms** for conventional PC (4.4 ms TR), and **54 ms** for three-echo PC (5.4 ms TR). 3-echo PC maps were calculated according to Ref. [4], with linear and DC offsets subtracted based on a linear fit to manually selected static regions in the PC map.

Results: Fig. 2 shows magnitude and PC maps of the left ventricular outflow tract (LVOT) in one representative study. Three regions of interest were analyzed (white circles). The table lists the SNR of the 3-echo SSFP-PC values inside each ROI for two volunteers, relative to 3-echo GRE-PC. Note that the SNR is based on a measurement of the standard deviation within each ROI, which reflects not only PC noise, but also true changes in the PC values across the ROI. Fig. 3 shows velocity-time curves for each ROI. The plotted values are the average value inside the ROI.



Subject	Aorta	Left atrium	static tissue
1	157%	100%	133%
2	133%	94%	179%

Fig.2: *(top) Cardiac three-chamber view, healthy volunteer. (bottom) SNR of 3-echo SSFP-PC maps (relative to 3-echo GRE).*

Discussion: The 3-echo SSFP magnitude images exhibit 'streaking' artifacts near the root of the aorta at time-points with high blood velocities, which may be caused by flow variations during the breath-hold. Even in the presence of such magnitude fluctuations, the phase-contrast maps were accurate compared to conventional PC. One drawback of the 3-echo approach is the relatively long TR compared to conventional SSFP imaging sequences, which may limit its application to 3T cardiac imaging.

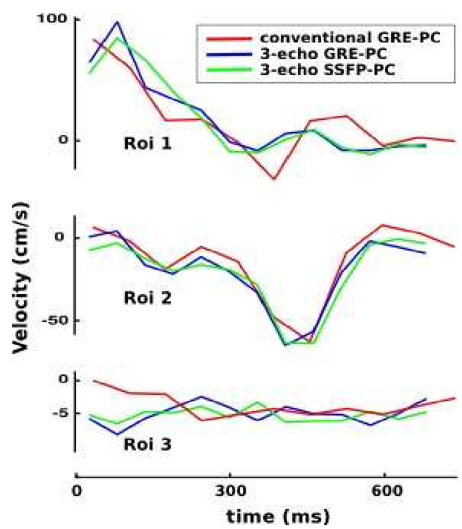


Fig.3: *(a) Velocity-time curves inside regions of interest.*

Conclusion: 3-echo phase-contrast imaging provides rapid in-plane velocity measurements, and our preliminary analysis indicates good agreement with a conventional bipolar GRE-PC sequence. When executed as a balanced SSFP sequence, 3-echo PC imaging provides accurate velocity measurements with improved SNR in-vivo.

References: [1] Overall et al, MRM 2002;48:890-898. [2] Markl et al, MRM 2003;49:945-952. [3] Grinstead et al, MRM 2005;54:138-145. [4] Nielsen et al, ISMRM 2006, #879. [5] Pai et al, SCMR 2006.