

Multislice Single Shot Spin Echo EPI Perfusion Imaging with Zone-Selection and Parallel Imaging

P. Ferreira¹, P. Gatehouse², D. Firmin¹, C. Bucciarelli-Ducci¹, and R. Wage²

¹Imperial College, London, United Kingdom, ²Royal Brompton Hospital, United Kingdom

Aim

To reduce subendocardial dark rim artifacts by providing a very quick image acquisition time, and also nulling the signal in the Left Ventricle (LV) blood pool.

Introduction

There is a growing interest in the study of Myocardial Perfusion (MP) by using MRI during the first pass of a paramagnetic contrast agent through the heart as an alternative to Nuclear Medicine. However, MP images are often affected by the subendocardial dark rim artifact (DRA), which appears in the subendocardium during the bright LV first-pass of a Contrast Agent (CA) and is sometimes difficult to distinguish from a mild perfusion defect. Several causes have been suggested: motion [1]; Gibbs truncation [2]; non-uniform k-space weighting [3]; and susceptibility associated with the peak LV bolus CA concentration [4-6].

The sequences currently used for MP (saturation-recovery FLASH, bSSFP, segmented-EPI) all give a bright blood signal, which can be acquired separately if quantitative analysis is required [7]. The DRA is worsened by the large step from bright LV blood to darker myocardium; therefore this work is aimed to darken the LV blood. Cardiac motion during the image acquisition is another source of DRA, so this work also aimed to use the shortest possible image acquisition time. Saturation-recovery single-shot EPI offers one approach to these requirements [8].

Methods

Aiming for greater robustness against cardiac motion and also against B0-distortion (especially during CA first-pass), we applied two methods for reducing the EPI image acquisition time. First, we reduced the echo-train length (ETL) by using a zone-selection (inner-volume) to enable a small phase-encode FOV limited to the region of interest only [9-11]. The refocusing pulse selection gradient was applied along the phase-encode axis. This is compatible with multislice imaging in each cardiac cycle because of the non-selective saturation applied before each perfusion image. Second, we applied temporal parallel imaging (TSENSE) which further halved the ETL [12]. The sequence consisted of a single-shot Spin-Echo Echo Planar Imaging (SE-EPI) with zonal excitation and TSENSE R=2, chemical-shift fat saturation, TE of 21ms; read FOV = 350mm; phase FOV = 132mm; voxel size 2.7x2.7x10mm; bandwidth 2230 Hz/pixel, total acquisition time of 40 ms. Large through-plane velocity sensitivity was added aiming to dephase Mxy in moving blood; the varying and sometimes very short blood T1 during the first-pass was therefore irrelevant. For perfusion, non-selective saturation (TI=100ms) ran before each single-shot EPI.

Initial studies in normal volunteers without CA, and 2 patients during CA first-pass (0.1mmol/kg, 5ml/s antecubital) evaluated the effects of cardiac motion and main-field distortion, the efficacy of blood-suppression, and the SNR available with zonal and parallel imaging methods combined. Without CA and saturation, only a single short-axis slice was acquired per cycle. With saturation, 3 short-axis slices were acquired in each of 50 cardiac cycles during the CA first-pass.

Results and Discussion

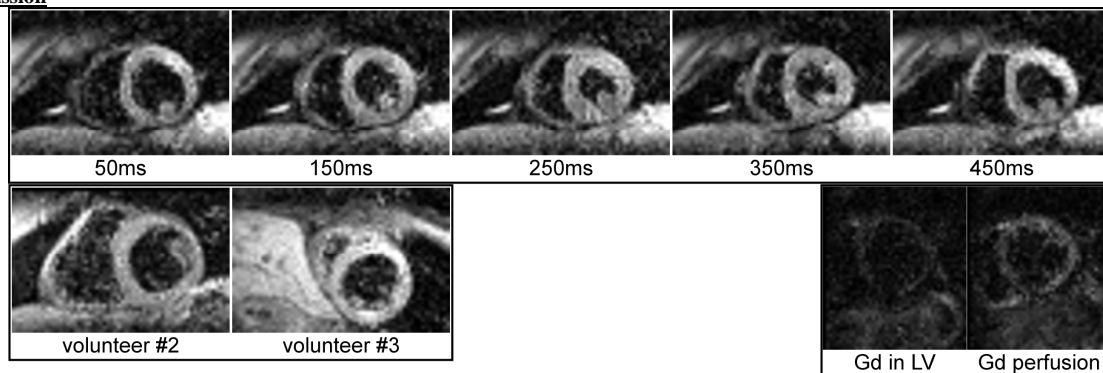


Figure 1: Top: Scans of volunteer #1 during different triggering times without CA and saturation. Bottom left: Two other volunteer scans, also without CA and saturation. Bottom right: Volunteer with saturation recovery and injection of CA (Gd-DTPA): first when CA arrives in the LV blood pool; and next when CA perfuses into the myocardium.

Without saturation (Figure 1 Top and Bottom left), all myocardial segments remained visible at all cardiac phases, showing no evidence of myocardial dephasing or distortion by cardiac motion, or by B0-nonuniformity. With saturation (Figure 1 Bottom right), images often contain parallel imaging artifacts and it is currently unclear whether a suboptimal TSENSE setup also added more random noise. Crucially, the myocardium remained undistorted by the peak LV bolus (Figure 1 Bottom right (Gd in LV)) and was enhanced by CA arrival later (Figure 1 Bottom right (Gd perfusion)). The blood suppression procedure appeared reliable at all cardiac phases and this would be useful in removing DRA. Figure 1 Top and Bottom left shows the myocardial SNR at approximately 1s recovery time at its native T1 of 900ms. During first-pass perfusion, at TI=100ms and estimated peak perfusion myocardial T1 of 250ms, the SNR is likely to drop by another factor of approx 2 compared to the volunteers without contrast agent. As with any perfusion sequence, there is a lower SNR when used with saturation recovery, and this may challenge parallel imaging by adding noise to the coil sensitivity maps, which are already weakened by the narrow phase-encode FOV of zonal imaging. Further work must determine the correct programming of TSENSE for zone-selective applications, perhaps by a separate coil-sensitivity prescan and a different zone-selection technique which does not require saturation for multislice operation [13].

Conclusion

The fast zonal TSENSE EPI acquisition succeeded in avoiding motion and B0-distortion artifacts. Currently this work is inconclusive on whether 1.5T SNR can support zonal-acquisition and parallel imaging for saturation-recovery perfusion.

References

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