FLASH Proton Density Imaging for Improved Surface Coil Intensity Correction in Quantitative and Semi-Quantitative SSFP Myocardial Perfusion Imaging

Sonia Nielles-Vallespin[1], Peter Kellman[1], Li-Yueh Hsu[1], and Andrew E Arai[1]
[1]*National Institutes of Health, Bethesda, MD, United States*

Target audience: Scientists and clinicians interested in myocardial perfusion imaging.

Background: A low excitation flip angle (α<10°) steady-state free precession (SSFP) proton-density (PD) reference scan is often used to estimate the B_1-field inhomogeneity for surface coil intensity correction (SCIC) of the saturation-recovery (SR) prepared high flip angle (α=40-50°) SSFP myocardial perfusion images[1-7]. The different SSFP off-resonance response for these two flip angles might lead to suboptimal SCIC when there is a spatial variation in the background B_0-field. The low flip angle SSFP-PD frames are more prone to parallel imaging banding artifacts in the presence of off-resonance. The use of FLASH-PD frames would eliminate these sources of error in the presence of off-resonance in the surface coil inhomogeneity estimate and improve homogeneity of semi-quantitative and quantitative perfusion measurements.

Methods: A new sequence was implemented which acquired low flip angle (α = 5°) FLASH PD images followed by SR-prepared high flip angle SSFP perfusion images. Imaging was performed on a 3T Siemens MAGNETOM Skyra (Siemens Healthcare, Erlangen, Germany). All studies were performed under procedures and protocols approved by the Institutional Review Board of the National Institutes of Health (ClinicalTrials.gov identifier NCT00027170). Perfusion scans preceded by both FLASH and SSFP-PD frames from 10 patients with no myocardial infarction and were analyzed semi-quantitatively and quantitatively (rest n=10 and stress n=1). Intra-subject myocardial blood flow (MBF) coefficient of variation (CoV) over the whole left ventricle (LV), as well as intra-subject peak contrast (CE) and upslope (SLP) standard deviation (SD) over 6 LV sectors were investigated.

Results and Discussion: In the 6 out of 10 cases where artifacts were apparent in the LV ROI of the SSFP-PD images, all three variability metrics were statistically significantly better when using the FLASH-PD frames as input for the SCIC ($CoV_{MBF\text{-}FLASH}$=0.3±0.1, $CoV_{MBF\text{-}SSFP}$=0.4±0.1, p=0.03; $SD_{CE\text{-}FLASH}$=10±2, $SD_{CE\text{-}SSFP}$=32±7, p=0.01; $SD_{SLP\text{-}FLASH}$=0.02±0.01, $SD_{SLP\text{-}SSFP}$=0.06±0.02, p=0.03). Example rest and stress data sets (Figure 1) from the patient pool demonstrate that the low flip angle SSFP protocol can exhibit severe ghosting artifacts originating from off-resonance banding artifacts at the edges of the field of view that the GRAPPA[8] parallel imaging was not able to unfold. These artifacts lead to errors in the quantitative perfusion maps and the semi-quantitative perfusion indexes, such as false positives. It is shown that this can be avoided by using FLASH-PD frames as input for the SCIC.

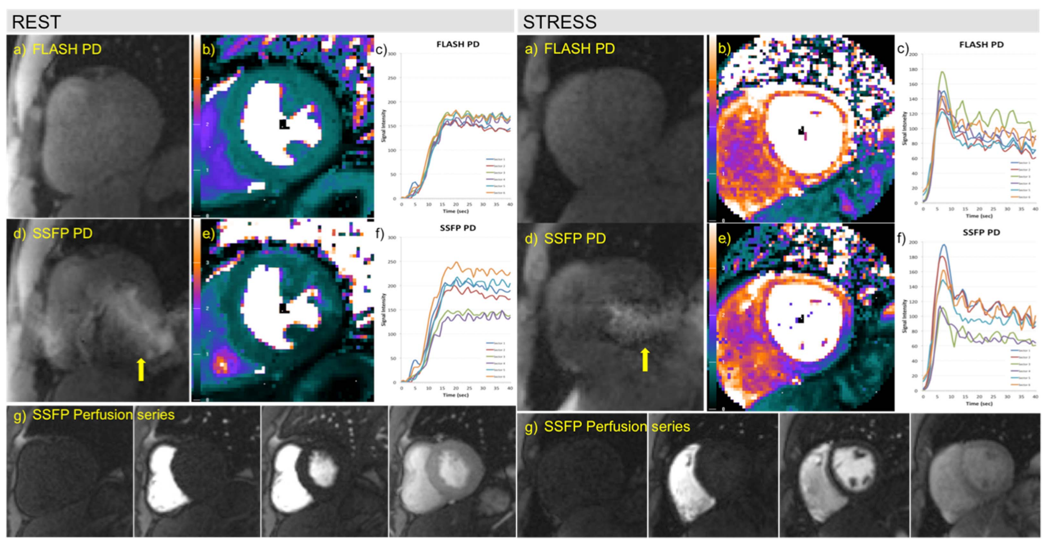

Figure 1. *Example rest and stress scan in two patients with no myocardial infarction. FLASH (a) and low flip angle SSFP PD frames (d) their corresponding quantitative MBF maps (b and e respectively) and regional perfusion signal intensity (SI) curves from 6 sectors of the LV (c and f), as well as some representative frames from the high flip angle perfusion series (g). The low flip angle SSFP PD image (d) shows ghosting artifacts on top of the myocardium (yellow arrows), which lead to overcorrection of the SCIC, causing artefactual lower perfusion values in the inferior and inferolateral walls (e). This affects both the MBF maps and the regional SI curves (f) and could lead to a false positive diagnosis. The FLASH PD frames (a) are unaffected by banding artifacts, which leads to an improved SCIC, a more homogeneous MBF map (b) and better agreement between the regional SI curves (c).*

Conclusion: Low flip angle SSFP PD images can exhibit severe ghosting artifacts originating from off-resonance banding artifacts at the edges of the field of view that parallel imaging is not able to unfold, which are not present in the high flip angle SSFP perfusion acquisition. Using FLASH PD images avoids both SSFP-related artefactual mechanisms in the presence of off-resonance and improves perfusion quantification. Thus, FLASH PD images are recommended for surface coil intensity correction of SSFP perfusion images in place of low flip angle SSFP PD images.

References: **1.** Kellman P, Arai AE; JCMR 2007, 9:525-537. **2.** Hsu LY, Aletras AH, Arai AE; MICCAI Lecture notes in computer science; Berlin. Edited by Ellis R. E. PTM. Springer-Verlag; 2003: 975-976. **3.** Kremers FP, Hofman MB, Groothuis JG, et al.; JMRI 2010, 31:227-233. **4.** Hoffmann MH, Schmid FT, Jeltsch M, et al.; JMRI 2005, 21:310-316. **5.** Murakami JW, Hayes CE, Weinberger E; MRM 1996, 35:585-590. **6.** Jerosch-Herold M, Seethamraju RT, Swingen CM, et al.; JMRI 2004, 19:758-770. **7.** Hsu LY, Rhoads KL, Holly JE, Kellman P, Aletras AH, Arai AE; JMRI 2006, 23:315-322. **8.** Griswold MA, Jakob PM, Heidemann RM, et al.; MRM 2002, 47:1202-1210.