To Spoil or To Balance? A Comparison of the White Marker Phenomenon in Gradient Echo Pulse Sequences

Simon Reiß[1], Axel Joachim Krafft[1,2], Klaus Düring[3], Constantin von zur Mühlen[4], and Michael Bock[1]

[1]*Radiology - Medical Physics, University Medical Center Freiburg, Freiburg, Germany,* [2]*German Cancer Consortium (DKTK), Heidelberg, Germany,* [3]*MaRVis Medical GmbH, Hannover, Germany,* [4]*Department of Cardiology and Angiology I, University Heart Center Freiburg, Germany*

Introduction: In MR-guided interventions, active device localization with miniaturized tracking RF coils can cause hazardous RF-induced heating [1], whereas passive tracking with dedicated markers provides an MR-safe delineation of the device with a negative contrast. The white marker phenomenon [2] has been proposed to convert this ambiguous negative contrast into a positive signal around the marker. Therefore, background signals are dephased and the signal in the proximity of the marker is rephased using unbalanced gradient schemes [2]. The white marker phenomenon was combined with spoiled gradient echo imaging (FLASH) [2] and with balanced steady state sequences (bSSFP) [3]. In this work, we compare the white marker signal of FLASH and bSSFP sequences of small paramagnetic platinum markers and an endovascular MR-compatible guidewire with iron oxide markers.

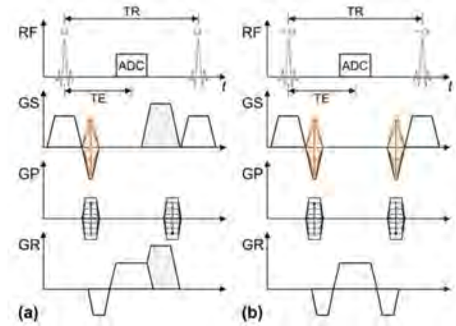

Fig. 1: Diagram of the FLASH (a) and bSSFP (b) sequences with variable SL rephasing (orange).

Material and Methods: White marker sequences were implemented at a 1.5 T whole body MR system (Siemens Symphony). Three different sequences were compared: (i) a FLASH sequence with RF spoiling [4], (ii) a FLASH sequence without RF spoiling, and (iii) a bSSFP (or trueFISP) sequence (Fig. 1). The white marker signal was generated via an unbalanced slice selection (SL) gradient: the gradient moment of the SL rephasing gradient was varied to achieve dephasing of the background signal while preserving the local signal in the proximity of the markers. The dephasing moment ΔM is related to a dephasing length $\Delta z = \gamma\Delta M/(2\pi)$ over which a phase variation of 2π is seen.

Images of two platinum markers (∅: 0.3 mm) of a MR-compatible bioresorbable vascular scaffold (Abbott Vascular, Santa Clara, CA) as well as a 0.014″ MR-compatible guidewire with iron particles (MaRVis Medical GmbH, Hannover, Germany) were acquired in saline solution with each of the 3 sequences and with varying Δz. Sequence parameters were: TR: 20/4.8 ms (platinum markers/guidewire), TE: 10/2.4 ms, BW: 80/910 Hz/px, FOV: 120×120/227×280 mm², slice thickness: 10 mm, matrix: 128×128/104×128, α_{FLASH}: 50°/10°, α_{bSSFP}: 70°, Δz = 0.55-11.03 / 0.77-11.03 mm. For quantitative comparison, the signal-to-background ratio (SBR) was calculated as the ratio of the marker/guidewire signal and the background signal from the saline solution.

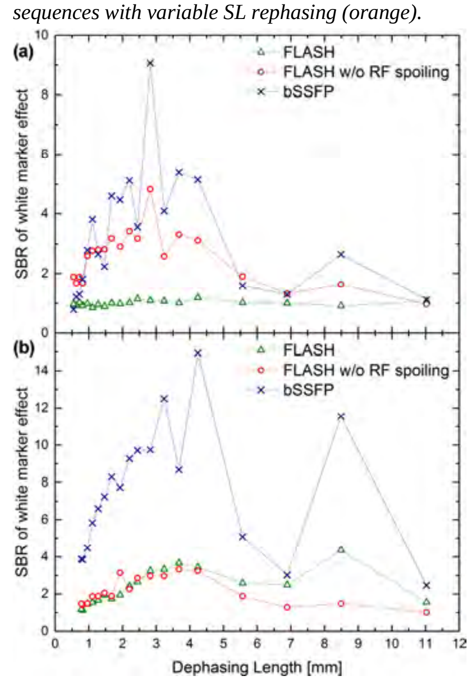

Fig. 2: SBR of white marker effect generated by platinum markers (a) and a guidewire (b) as a function of the dephasing length.

Results and Discussion: Figure 2 shows the SBR of the platinum markers (Fig. 2a) and the guidewire (Fig. 2b) for all three sequences as a function of Δz. Sample images of both objects acquired with various Δz are shown in Figure 3. For the platinum markers, an increased SBR is seen with the FLASH sequence without RF spoiling and the bSSFP sequence with a maximum of SBR = 4.8 and 9.1 at Δz = 2.8 mm respectively. No white marker signal is observed in the FLASH images with RF spoiling. With the guidewire a maximum of the white marker signal enhancement is seen at Δz = 4.2 mm (SBR = 14.9) for the bSSFP sequence and at Δz = 8.5/3.7 mm (SBR = 4.4/3.3) for the FLASH sequences with/without RF spoiling. Note that for the guidewire the RF spoiling improves SBR in the FLASH images at long Δz due to a better background suppression (cf. Fig 3b) as the RF spoiling prevents formation of unwanted coherences of the background signal. As expected, longer echo times (TE $\gtrsim$ 10 ms) were required to generate a white marker signal for the small platinum markers compared to the larger guidewire where a TE of 2.4 ms was already sufficient.

In conclusion, the bSSFP concept provides an improved white marker contrast for both structures. For the guidewire, all 3 sequences yield a good contrast with the SBR of the bSSFP being about 4fold higher than that of the FLASH sequences. However for small paramagnetic objects, our results indicate that FLASH with RF spoiling is not sufficient for a local signal formation. Without RF spoiling the white marker signal is preserved due to local signal coherences. The locally fully-balanced gradient schemes of the bSSFP further amplify the white marker signal by about a factor of 2, and thus, could provide a means to achieve an improved positive contrast even for small objects such as platinum markers at implanted vascular scaffolds.

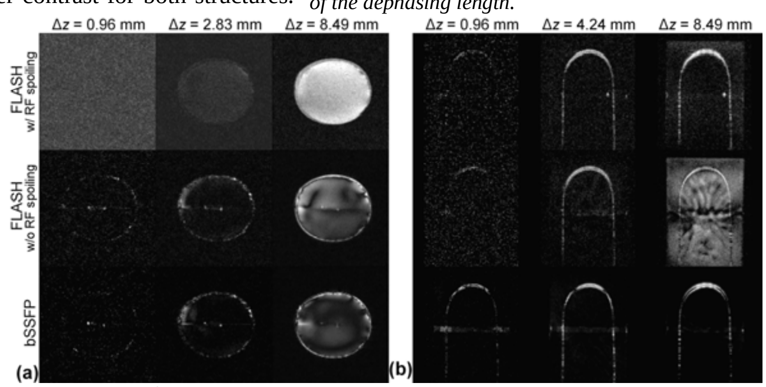

Fig. 3: Images of platinum markers (a) and a guidewire (b) acquired with the three sequences and different dephasing lengths.

References

[1] Konings MK, et al. JMRI 2000, **12**: 79-85
[2] Seppenwoolde JH, et al. MRM 2003, **50**:784-90
[3] Patil S, et al. MRM 2009, **22**: 277-85
[4] Zur Y, et al. MRM 1991, **21**: 251-63