Removing the Phase-Sensitive Reconstruction Artifacts in Phase-Sensitive Inversion Recovery (PSIR) Sequence

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Introduction Phase-Sensitive Inversion Recovery (PSIR) has been widely used in cardiac imaging to detect infarcts by providing consistent high contrast between infarcts and normal myocardium [1]. Recently, it has been investigated as an improved intraplaque hemorrhage detection tool with good blood suppression and as a possible MRA tool in carotid atherosclerosis imaging [2]. However, considerable amount of reconstruction artifacts can be found in PSIR sequence acquired short Inversion Time (TI). In this abstract, we analyze the cause of these artifacts and propose a solution.

Phase-Sensitive Reconstruction Artifact The major advantage of the PSIR sequence is its phase-sensitive attribute with positive and negative signals, which provides higher contrast in several applications [1, 2]. In order to acquire phase-sensitive images, background phase caused by imperfection of the MR scanner: non-uniform coil receive patterns, readout gradient delay, B0 inhomogeneity, eddy currents, and more, must be removed. The PSIR sequence uses a reference acquisition *ref* at a different Inversion Time (TI) after the inversion pulse (Fig. 1a) to image the background phase. Then the phase-sensitive reconstruction can be generated as:

$$I = real\left(IR \cdot ref^{*} / \left|ref\right|\right) \qquad (1),$$

where *ref** is the complex conjugate of *ref*.

In this phase-sensitive reconstruction, it is critical that the phase in *ref* is not contaminated by the inversion pulse. If so, there will be artifacts in the phase-sensitive reconstructed images. We tested this theory on the application of suppressing blood signal in carotid atherosclerosis imaging [2]. In this PSIR application, the blood signal should be negative in the phase-sensitive reconstruction. As simulated in Fig.1b, the original sequence with TI=400ms, the blood signal in IR is negative, while in *ref* is positive, the phase-sensitive reconstruction (Eq. 1) will produce correct negative signal for blood. However, if TI=200ms is used (Fig. 1c), the blood signal in *ref* is also negative, Eq. 1 will generate false positive phase-sensitive signal for blood.

Artifact-free PSIR sequence In this study, we propose an artifact-free PSIR sequence by suing separate IR and *ref* scans (Fig. 2a). In this sequence, the *ref* is totally free of influence from the inversion pulse, which means it is free of artifacts in phase-sensitive reconstruction. However, the use of different *IR* and *ref* acquisition protocols also led to background phase differences. These phase differences were addressed under the assumption that they were approximately constant within a small region.

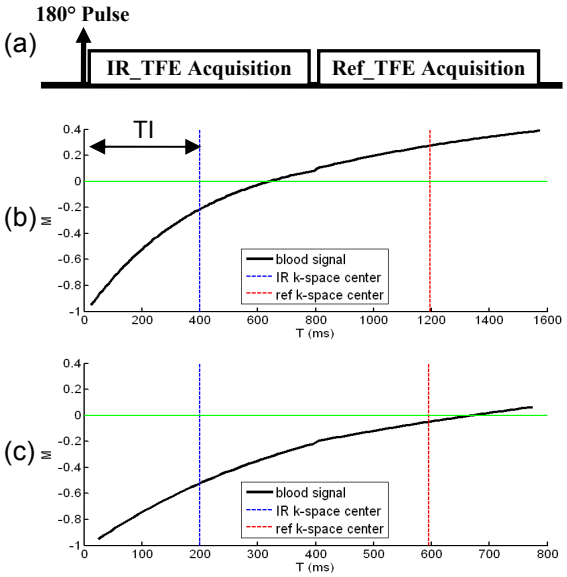

Fig. 1. (a) Diagram of the PSIR sequence. After a inversion pulse, the IR and *ref* images are acquired. (b, c) The simulated blood signal in PSIR [2] with TI=400ms (b) and TI=200ms (c). In (c), the phase in *ref* is contaminated by the inversion pulse due to insufficient relaxation (negative).

Methods The carotid artery of one healthy volunteer was scanned using the traditional PSIR sequence with a short TI (200ms) and proposed artifact-free PSIR sequence and in a whole body 3T scanner (Philips Achieva, the Netherlands) with an custom 8-channel carotid coil. The **PSIR sequence** imaging parameters are: IR_TFE: TR 10ms, FA 11º, FOV 160×160×32mm^3, resolution: 1×1×1mm^3, fatsat, 1 nex. Ref_TFE: TR 10ms, FA 5º. The proposed **artifact-free PSIR sequence** has the same parameters except for the independent IR and *ref* scan.

Results As shown in Fig.3, the proposed artifact-free PSIR sequence can successfully suppress blood signal without any artifact (Fig. 3b). On the other hand, the traditional PSIR sequence produced very severe phase-sensitive reconstruction artifacts inside the carotid lumen.

Discussion and Conclusion In this study, we demonstrated the cause of the artifacts in the phase-sensitive reconstruction of PSIR sequence with short TI. Moreover, we proved that those artifacts can be effectively avoided by removing the influence from the inversion pulse on *ref* using separate IR and *ref* scans. This artifact-free technique overcomes the TI limit of the traditional PSIR sequence, paving the way to obtain better images in many applications. In vascular imaging, it is possible to achieve higher contrast for MRA with shorter TI. Also, in cardiac imaging, the proposed method has the potential to reduce the required breath-hold time by half by fitting each TR inside one cardiac cycle, rather than the usual two cycles [1].

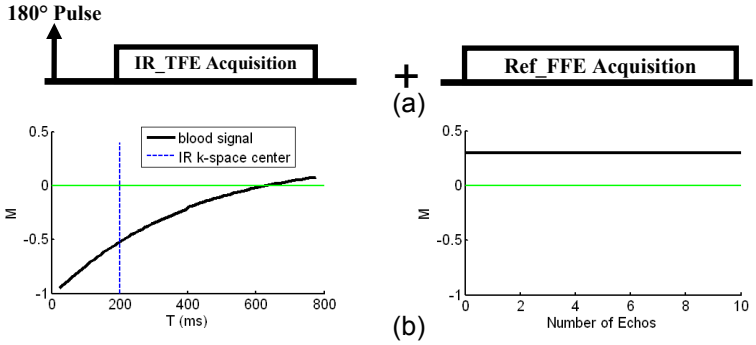

Fig. 2. (a) Diagram of the Artifact-free PSIR sequence, IR and *ref* are acquired at separate sequences. (b) The blood signal simulation: the phase in *ref* is free of contamination from inversion pulse.

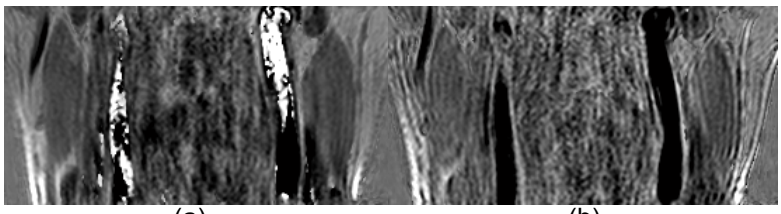

Fig. 3. (a) A phase-sensitive image obtained by traditional PSIR sequence with short TI (200ms) for blood suppression. Severe artifacts can be observed. (b) The phase-sensitive reconstructed image obtained by the proposed artifact-free PSIR sequence with the same short TI (200ms) and a separate reference scan. No obvious artifacts exist.

References:
1. Kellman et al. MRM, 2002, 47: 372-383
2. Wang et al. MRM 2010 64: 1332-1340.