# Referenceless Acquisition of Phase-sensitive Inversion-recovery with Decisive reconstruction (RAPID) for Late Gadolinium Enhancement imaging

Jinnan Wang[1], Peter Börnert[2], Huijun Chen[3], Gregory J Wilson[4], Chun Yuan[4], and Jeffrey H Maki[4]
[1]*Philips Research North America, Briarcliff Manor, NY, United States,* [2]*Philips Research Europe, Hamburg, N.A., Germany,* [3]*Tsinghua University, Beijing, Beijing, China,* [4]*Radiology, University of Washington, Seattle, WA, United States*

**Purpose**

Phase Sensitive Inversion Recovery (PSIR) is now the method of choice for myocardial infarction (MI) detection and quantification[1,2]. Compared to regular IR images, phase sensitive (PS) reconstructed images offer doubled dynamic range ($M_z/M_0$ range increases from [0,1] to [-1,1]), improved contrast and higher flexibility in sequence design[3]. One of the limitations of the PSIR technique is that it relies on a full size reference image to restore the polarity information, which makes the scan time much longer (essentially doubled) and more susceptible to motion artifacts. There have been different techniques proposed to (partially) alleviate the time requirements of PSIR scans. These techniques either still rely on a reference image for PS reconstruction or tend to cause error in regions with abrupt phase changes. In this study, we propose the Referenceless Acquisition of Phase-sensitive Inversion-recovery with Decisive reconstruction (RAPID) that can reliably restore the polarity of the magnetization without relying on the reference image.

**Methods**

<u>RAPID algorithm</u> On inversion recovery based MR images, presumably as a result of the inversion, the magnetization may have different polarities (180º phase differences). The measured signal phase, however, cannot be directly used to differentiate the polarity of the spins because it is a combination of the true and the background phases. Identification and removal of the background phase is the key to phase-sensitive reconstruction.

The RAPID technique is fully automatic and built upon a previously proposed 1-point Dixon technique[4]. As detailed in Fig.1, the RAPID technique contains two steps: 1) Background Phase Estimation: starting from a small homogeneous region of the phase image ($I_p$), it gradually expands itself by assimilating nearby pixels – with the exception that if the new pixel contains an abrupt phase change, it will be flipped 180º degrees (factor of exp(-iπ)) – until the image is complete. The new image, after a certain amount of low-pass filtering, serves as the background phase ($I_{bck}$). 2) General Phase Correction: After subtracting $I_{bck}$ from $I_p$, the true phase image ($I_{tp}$) can be obtained. By combining the original magnitude image and $I_{tp}$, the phase-sensitivity corrected image can be obtained ($I_{cor}$).

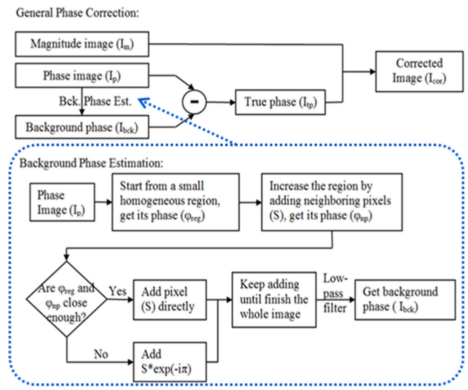


Fig. 1 The details of RAPID implementation. This fully automatic approach contains two separate steps: Background Phase Estimation and General Phase Correction.

<u>MR scan</u> 10 patients referred for myocardial viability scans at our institution were scanned on a 1.5T scanner (Philips Achieva, the Netherlands) using a 5-ch cardiac coil. Local IRB approved this study. After the regular PSIR scan, a regular IR-TFE scan was added for RAPID reconstruction. As the IR-TFE scan does not have to acquire a reference image, its scan efficiency is much improved: 6s/slice compare to PSIR's 11s/slice. The scan parameters for PSIR: 2RR interval, TR/TE 7.5/4.1ms, TI 230-270ms, FOV 360×360mm², resolution 1.5×1.5mm², slice thickness 10mm, scan time: 11s/slice; for RAPID: identical to PSIR except: 1RR interval, TE 4.6ms, TI 30ms less than PSIR, scan time: 6s/slice.

**Results and Discussions**

RAPID algorithm was found to successfully reconstruct phase-sensitive images for nearly all images. As shown in Fig.2, after the background phase ($I_{bck}$) was removed, the corrected phase image ($I_{tp}$) presented much reduced phase variation compared to the original phase image ($I_p$). In $I_{tp}$, only the true phase difference, i.e. the difference caused by the magnetization orientation, can be found in this image. After combining with the magnitude image, the RAPID algorithm was able to restore the magnetization polarity of the original image. Good agreement was found between the RAPID reconstructed image ($I_{cor}$) and the image reconstructed using the PSIR algorithm (acquired in a different acquisition), both of which provide improved visualization of the myocardium and less dependence on chosen TI as compared to the magnitude image.

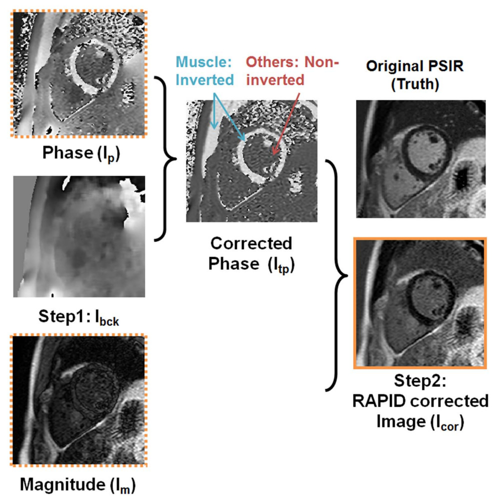


Fig. 2 Paradigm of the RAPID reconstruction algorithm. Good agreement was found between the <u>RAPID (6s/slice)</u> reconstructed and <u>PSIR (11s/slice)</u> reconstructed images.

Contrast difference can be observed between the RAPID and PSIR reconstructed images, caused not by the reconstruction, but rather due to the different TI time and number of RR intervals used during the image acquisition. To demonstrate this, we also attempted the RAPID algorithm on a set of PSIR images without using the reference scans. Nearly identical images were obtained using the two reconstruction methods (Fig. 3).

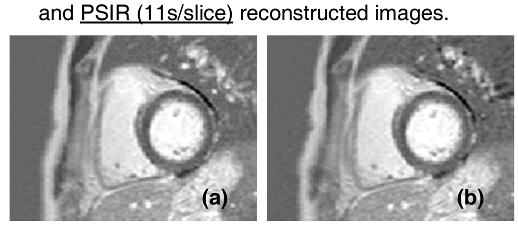


Fig. 3 Comparison PSIR and RAPID on the same dataset. Nearly identical images were obtained by the PSIR (a) and the RAPID (b) algorithms, although no reference images were used in the RAPID reconstruction.

**Conclusion**

In this study, the fully automatic RAPID reconstruction technique was proposed to improve the PSIR acquisition efficiency by removing the phase reference image. While requiring only half the original scan time, RAPID was found to provide very good agreement when compared to the traditional PSIR images. With further development, RAPID has the potential to significantly improve the current viability imaging efficiency and detection accuracy in a clinical environment.

**Reference:**

1. Kim R.J. et al. NEJM 2000, 343:1445. 2. Kino A. et al. AJR 2009, 193:W381. 3. Kellman P et al, 47:372. MRM 2002. 4. Ma J. JMRI 2008, 4:881.