Free Breathing Independent Respiratory Navigator-Gated Imaging: Concurrent PSIR and T2-Weighted 3D Imaging of the Left Ventricle

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INTRODUCTION: The distribution of viable and infarcted myocardium is typically visualized using inversion recovery (IR) late gadolinium enhancement (1) or phasesensitive inversion recovery (PSIR) sequences (2). Transitioning PSIR from breath-hold 2D to respiratory navigator-gated 3D imaging promises higher SNR and CNR, and whole heart coverage (3-5). However, the optimal method for motion compensation with 3D PSIR is undetermined. With standard PSIR, the IR-prepared volume (first heartbeat) is corrected with the phase from the reference volume (second heartbeat), (Fig 1a). Current implementations of respiratory navigated 3D PSIR accept data for the reference based solely on navigator NAV1, which takes place over a heartbeat in advance. Respiratory motion occurring between NAV1 and the reference volume acquisition potentially corrupts the reference image quality and may compromise the PSIR image. We propose an independently navigated PSIR (INPSIR) sequence with a separate navigator, NAV2, dedicated to motion compensation of the reference volume (Fig 1b). By increasing the image quality of the reference images, it is possible to apply additional contrast mechanisms to facilitate tissue differentiation. For example, in addition to the myocardial infarction (MI)-normal myocardium (MYO) contrast from PSIR, MI-left ventricular blood (LVB) contrast can be increased with the addition of T₂Prep to the phase reference

METHODS: All imaging was performed on a 3T Philips system (Philips Healthcare, Best, The Netherlands) using a 32-channel cardiac phased array (InVivo, Gainsville FL). Independent navigator gating was implemented for pulse sequences that acquire 2 and 3 sequential volumes. Each navigator is trained (calibrated) independently and motion is tracked from each separately, removing possible residual effects of changing liver signal intensities due to T1-relaxation post. *Moving phantom:* To demonstrate the effects of motion on reference and PSIR image quality, a set of agar gel phantoms with varying T₁ values was placed on a pneumatic motor that oscillated in the superiorinferior direction 20 mm every 1s.

Animal Experiments: Swine (N=4): Under a ACUC-approved protocol, swine underwent 2 hr LAD occlusion. Imaging took place 4-25 weeks post MI and 10-35 min post double-dose injection of Magnevist. A 3D GRE sequence with 1.25x1.25x4mm³ resolution and 2.5min scan time (100% efficiency) was typically used. Additionally, for the quantification of relative SNRs and CNRs, lower resolution ~2x2x8 mm³ images were acquired: 5-15 min post infusion standard PSIR (Fig 1a) followed by INPSIR (1b); 25-35 min post infusion INPSIR (1b) followed by INSPIR+T2prep (1c); INPSIR was repeated twice to minimize effects of contrast kinetics on tissue signal intensities. Relative SNRs and CNRs were quantified using ROIs on healthy (remote) myocardium (MYO), infarction (MI) and the left ventricular blood pool (LVB). Noise was measured without the presence of RF or gradients. Data was normalized per animal to the

signal intensity of LVB during non-contrast studies. Acquisition time for the high resolution images was ~ 6 min assuming 100% navigator efficiency. No parallel imaging was used.

RESULTS: Figure 2 (a-b) images from moving agar gels demonstrate possible artifacts when no motion compensation is used for the reference images. Short-axis images from an infarcted swine model including reference image magnitude, single-coil phase and phase-sensitive reconstruction are shown. The phase reference image was improved with INPSIR (asterisk) and navigator efficiency was not affected. In the phase sensitive images, the liver-lung border motion artifact was reduced in the reference image of INPSIR compared to the standard PSIR. Fig 2 (g,h) show the phase sensitive reconstruction (top) and reference (bottom) images acquired with INPSIR+T2Prep. MYO-LVB and MYO-MI contrast is improved in the reference images. Figure 3 displays relative SNR and CNRs obtained as part of the comparison of standard PSIR, INPSIR, and INPSIR+T2Prep. There were no significant differences between PSIR and INPSIR acquisitions, though some variation was expected due to contrast kinetics. However, the addition of T2Prep to INPSIR (bottom row) increased all contrast in the reference image at the expense of some contrast in the phase sensitive image.

DISCUSSION AND CONCLUSIONS: We have presented independent navigators to produce high spatial resolution 3D PSIR images of the left ventricle during free-breathing with the possibility of adding a T_2 -weighted imaging volume. Independent navigators allow for higher quality imaging reference volumes, uncorrupted by respiratory motion, during multi-heartbeat acquisitions. A combined INPSIR and T_2 -weighted imaging pulse sequence produced a registered set of T_1 and T_2 -weighted images, yielding clearer distinction between MI, normal myocardium and blood though the benefits of INSPIR on the PSIR images has yet to be quantified. The use of such a pulse sequence to distinguish between chronic infarcts, acute infarcts, edema, and ablation sites has yet to be fully investigated.

REFERENCES: [1] Kim RJ et al, N Engl Jour Med 2000; 343:1445;[2] Kellman P, et al. MRM 2002;47(2):372. [3] Kino A et al. AJR Am J Roentgenol. 2009 Nov; 193(5):W381-8. [4] Peukert D et al. Acad Radiol 2007;14(7):788. [5] Wang Y et al. Radiology 1996;198(1):5. [6] Kellman P JMRI 2005;22(5):605



Figure 1: Standard ECG-gated PSIR sequence and proposed independently navigated PSIR sequences. Current implementations of 3D PSIR sequences do not perform any motion compensation on the reference volume (a). Here, we use independent navigator for reference image compensation (b), and apply T2Prep to the reference image for additional contrast (c).



Figure 2: PSIR of moving agar gel phantoms (**a**) without and (**b**) with independent navigators (IN). Magnitude short-axis swine phase reference images taken from the second heartbeat in a PSIR pulse sequence (**c**) without and (**d**) with IN. Notice the reduction of motion artifacts at lung-liver boundary (asterisk). Phase for a reference image taken from a single receiver channel (**e**) without and (**f**) with IN. Note phase disturbances in (**e**). (**g**) PSIR and (**h**) reference images taken with INPSIR+T2Prep. The addition of T2-weighting onto the reference images increases contrast between the MYO and LVB, and between MYO and MI, making previously confounded tissues apparent (arrows).

