Navigator artefact reduction in 3D late gadolinium enhancement imaging

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Purpose: Navigator-gated 3D late gadolinium enhancement (LGE) imaging demonstrates the degree and distribution of atrial scarring both before and after RF ablation of atrial fibrillation (AF).[1,2] While the application of a navigator-restore pulse immediately after the inversion recovery (IR) preparation (Fig 1(a)) enables the navigator to track the diaphragm position, it re-inverts blood which flows into the pulmonary veins (PVs) and atria during the inversion time (TI) and results in a characteristic artefact of high signal intensity which may obscure the right PV ostia. The intensity and extent of this artefact depends on the positioning of the navigator and on the pulmonary vein flow between the IR preparation and data acquisition. While it has been reduced by removing the navigator-restore pulse and using a following navigator for respiratory gating,[2] this precludes the use of prospective tracking or phase ordering techniques. Alternatively, a diaphragmatic slab projection navigator (5cm thick) has been proposed[3] which is implemented without the artefact-forming navigator-restore pulse. However, the sharpness of the navigator edge is reduced by receiving signal from such a large slab (which may compromise the accuracy of the navigator edge detection) and the delay of 100ms which is required following the slab navigator reduces the effectiveness of the respiratory gating. We propose a simple modification to the original sequence which reduces or eliminates the inflow artefact and which allows prospectively gated 3D LGE imaging without these drawbacks.

Methods: A standard crossed-pairs navigator-gated inversion-prepared gradient echo sequence was modified so that the slice-selective navigator-restore pulse may be shifted away from the non-selective IR preparation (Fig 1(b)). The benefit of this is two-fold: (i) it re-inverts less blood (so that the intensity of any artefact is reduced) and (ii) any re-inverted blood has less time to flow into the atria (so that any artefact is shifted away from the PV ostia). Both unmodified and modified 3D acquisitions were performed in 9 patients following standard clinical LGE imaging. Imaging parameters: 24 slices (reconstructed resolution: 1 x 1 x 2mm), single R-wave gating, 48 views per cardiac cycles (acquisition window 140ms), centric ky inside centric kz, left-right phase encoding, nominal acquisition duration (100% respiratory efficiency) 57 cardiac cycles. The inversion time was determined by a scout 2D acquisition prior to each scan. The navigator-restore delay implemented, dR, depended on the TI and the navigator signal-to-noise ratio and was typically 100 – 200ms. *Analysis:* Paired Wilcoxon testing was used to compare the ratio of ostial PV blood signal to that in the descending aorta (on the same image) in the modified and unmodified sequences. Consensus subjective PV image artefact scores (1=severe, 2 = moderate, 3 = mild, 4 = none) were determined from two blinded observers and compared using paired Wilcoxon analysis. Respiratory motion control was also assessed on the same 4-point scale and compared with paired Wilcoxon testing.

Results: One subject had severe respiratory motion artefact (in both sequences) resulting in ghosting across the PVs and was excluded from further analysis. Moderate – severe navigator artefact was present in either the superior or inferior (or both) PVs in 7 of the remaining 8 standard acquisitions and was considerably reduced, or eliminated, when using the modified sequence with a navigator-restore delay of 100 - 200ms (PV blood ratio: 1.8 +/- 0.5 vs 1.1 +/- 0.2, p = 0.008; consensus artefact score: 1.7 vs 4, p = 0.006). Examples are shown in Figure 2. While the SNR in the navigator traces was reduced, the respiratory motion compensation – as determined by the respiratory motion artefact scores - was unaffected (3.6 vs 3.6, p = ns).

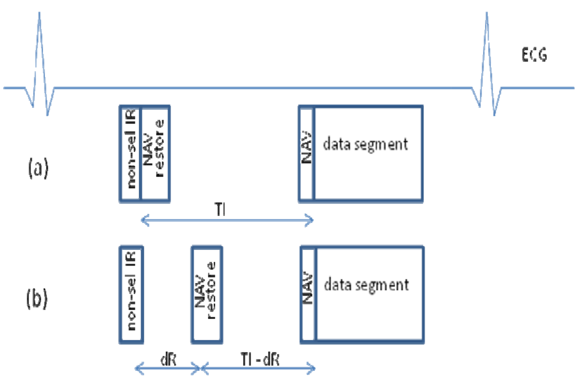

Fig 1: *(a) standard navigator gated sequence with the slice-selective navigator-restore immediately after the non-selective inversion recovery preparation and (b) with a delay, dR. The inversion time (TI) is the same for both, as is the timing of the data acquisition within the RR interval.*

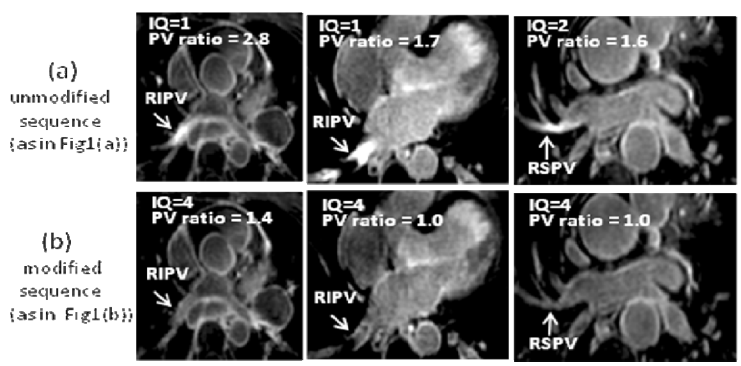

Fig 2: *Example data without (a) and with (b) the introduction of the navigator-restore delay, dR, in 3 example subjects. The subjective image quality scores (IQ) and the PV blood ratios are provided in each case. (RIPV: right inferior pulmonary vein; RSPV: right superior pulmonary vein). Respiratory motion scores were the same for unmodified and modified sequences.*

Discussion and Conclusion: Shifting the navigator-restore pulse reduces or eliminates the navigator artefact. Any residual artefact is shifted away from the right pulmonary vein ostia. The technique is applicable to both crossed-pairs and 2D pencil beam navigator techniques. SNR in the navigator trace is reduced but does not appear to result in a reduction in respiratory motion control. This simple modification improves the image quality of 3D LGE imaging and will improve automatic late enhancement quantification in the atria.

References: [1]Peters et al, Radiology 2007; [2]Oakes et al, Circulation 2009; [3]Moghari et al., Magn Reson Med 2011