ECG–triggering improves blood suppression in abdominal aortic imaging using the quadruple inversion recovery sequence.

S. A. Peel[1], T. Hussain[1], M. Cecelja[2], A. Abbas[3], G. Greil[1], and R. M. Botnar[1]
[1]Division of Imaging Sciences and Biomedical Engineering, King's College London, London, London, United Kingdom, [2]NIHR Comprehensive Biomedical Research Centre, Guy's and St Thomas' NHS Foundation Trust / King's College London, United Kingdom, [3]Academic Department of Surgery, Cardiovascular Division, King's College London, United Kingdom

Introduction: The double inversion recovery (DIR) pre-pulse relies on the correct inversion time (TI) to achieve blood suppression which varies substantially pre and post contrast administration.[1] In contrast, the quadruple inversion recovery (QIR) pre-pulse allows black blood imaging pre and post contrast with identical TI delay times. It was originally developed for carotid vessel wall imaging without cardiac triggering.[2] As aortic blood flow varies considerably during the cardiac cycle, we hypothesize that ECG-triggering may improve QIR blood suppression in the aorta. Furthermore, to reduce scan time, we combined the DIR and QIR sequences with a small field-of-view (FOV) 'zoom' technique.

Methods: *Simulations:* The Mz of blood in the QIR sequence (Mz_b) was simulated with the effective TR (TReff) set to the RR-interval for heart rates 45-120bpm at 5bpm intervals. For each heart rate, the optimal values of TI1 and TI2 were calculated by minimizing the integral of Mz_b for T1 values between 100ms and 1400ms.
Phantom studies: Assuming complete blood exchange, the blood will only experience non-selective inversion pulses. To examine the blood signal characteristics, a T1 phantom was imaged at 1.5T using the body coil with a pre-pulse consisting of: a non-selective pulse, TI1, a non-selective pulse, followed by TI2. To minimize the effect of the imaging sequence, a TFE read-out was used with TFE factor=2 and FA=25˚. Other imaging parameters included: spatial resolution=2x2x15mm, TR/TE=4.3/2.1ms and optimized TI1 and TI2 delays for simulated heart rates between 45 and 105bpm.
ECG-triggering: As QIR blood suppression requires complete blood exchange within the TI2 delay, we programmed the clinical QIR sequence (fig.1) with TReff=1RR and shortest trigger delay aiming to time TI2 with maximum systolic flow.

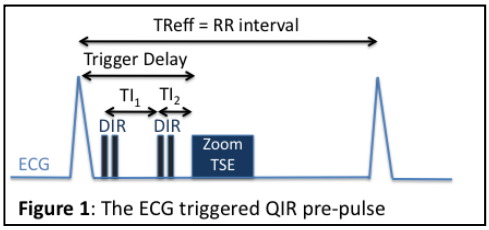

Figure 1: The ECG triggered QIR pre-pulse

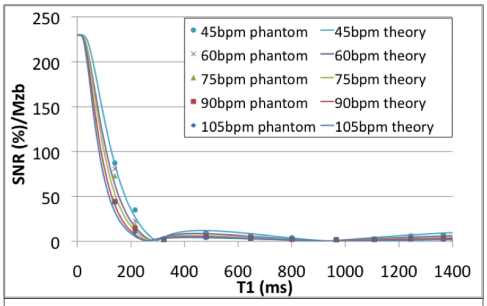

Figure 2: Normalized Mz_b simulations and SNR values from phantom experiments to examine QIR blood suppression.

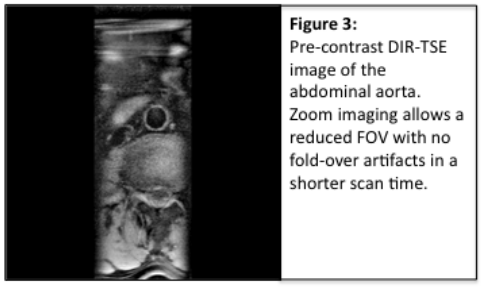
Figure 3: Pre-contrast DIR-TSE image of the abdominal aorta. Zoom imaging allows a reduced FOV with no fold-over artifacts in a shorter scan time.

Volunteer studies: 7 volunteers were imaged at 1.5T using a 32-channel coil. Firstly pre-contrast images were acquired of the abdominal aorta using a zoom multi-slice DIR-TSE scan (33 slices, FOV=79x201mm, spatial resolution=1x1x5mm, TE=5ms, TReff=1RR, TI=chosen to null pre-contrast blood using the Fleckenstein formula[3]). Five slices were then imaged with the DIR pre-pulse replaced by the QIR pre-pulse with imaging parameters maintained. 10-15 minutes after administration of a double dose of Gadovist, the DIR-TSE scan was repeated (firstly with TI set as for the pre-contrast scan and then set according to a preceding Look locker scan.) The ECG-triggered QIR-TSE sequence was then performed and repeated with the same TReff but no ECG-triggering.

Results: Simulations and phantom measurements show that the QIR sequence suppresses Mz_b in a wide T1 range (fig.2). Volunteer images (fig.3.) show that zoom imaging enables a reduced FOV without fold-over artifacts in a shorter scan-time (8 heartbeats per slice compared to 28 heartbeats per slice for a full FOV.) The DIR-TSE sequence nulls the blood pre-contrast (fig.4a) but TI must be shortened to suppress blood post-contrast (figs.4c and 4d). ECG-triggered QIR-TSE images (fig.4b and 4e) achieve blood suppression both before and after contrast administration with identical imaging parameters. Blood suppression is clearly superior to un-triggered QIR scans (fig.4f). In 4 patients QIR blood suppression was further improved by using TReff=2RR and TD=1RR+300ms to ensure adequate blood exchange during TI2.

Conclusions: The QIR pre-pulse was successfully combined with ECG-triggering and zoom imaging thereby allowing a reduced total scan time. Volunteer images show that ECG-triggering improves blood suppression and image quality when using the sequence in the abdominal aorta.

References: 1. Kramer, CM et al, Circ 2004 109(8):p1016, **2.** Yarnykh, VL et al MRM, 2002 48(5):p899, **3.** Fleckenstein, JL et al, Radiology, 1991 179(2):p499

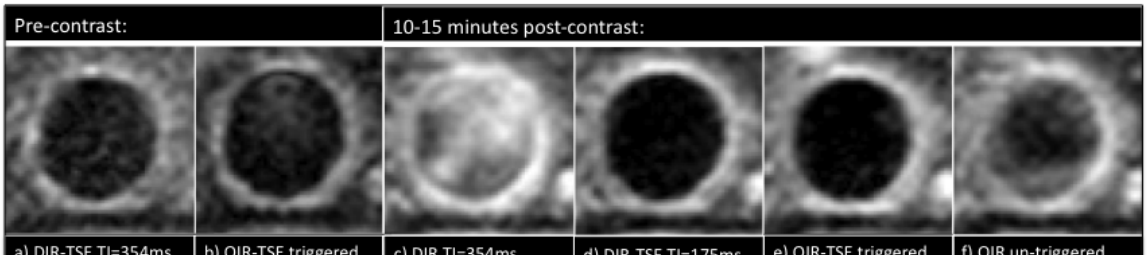

Figure 4: Abdominal aorta images in a volunteer pre-contrast (a-b) and post-contrast (c-f).