Black-Blood Preparation Improves Accuracy in Murine Phase-Contrast Cine MRI at Ultra-high Mag-netic Fields

E. Dall'Armellina[1], B. Jung[2], H. Barnes[3], S. Neubauer[1], M. Markl[2], and J. E. Schneider[1]
[1]Cardiovascular Medicine, University of Oxford, Oxford, Oxon, United Kingdom, [2]Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany, [3]University of Oxford, Cardiovascular Medicine, Oxford, Oxon, United Kingdom

Introduction: While *Tissue Phase Mapping* (TPM) is a well-established technique to assess regional cardiac function in humans [e.g. 1,2], only one group has reported in the literature on the application of this technique in mice (e.g. [3-5]), using bright-blood contrast. However, it is well recognized that TPM in humans (at lower magnetic field strength) requires suppression of the dominant blood signal in order to provide an accurate measurement of myocardial velocities [1,6]. Blood suppression has also been shown to improve image appearance in tagging of mouse hearts [7]. Black-blood contrast necessitates the application of dedicated blood suppression techniques (i.e. double inversion or saturation), typically applied at the end or the beginning of the cine-train, which is omitted for bright-blood contrast. Therefore, bright-blood techniques provide extended coverage of the cardiac cycle. We sought to directly compare black-blood versus bright-blood contrast and the impact on measured velocities in phase contrast MRI in murine hearts at 9.4T.

Materials & Methods: TPM experiments were performed in 6 C57BL/6 mice (male, 23.6 ± 1.2 g) on a 9.4T VNMRS DirectDrive MR-system (Varian Inc, USA), equipped with 1 T/ gradient system and a quadrature driven birdcage coil (id 33mm). A mid-ventricular slice in short axis view was acquired using a double-gated multi-frame gradient echo sequence (128x128, FOV 25.6x25.6 mm, α=10°, NAE=2, venc: in-plane – 6 cm/s; through-plane – 8 cm/s). Black-blood contrast was achieved by two 4 mm saturation slices, applied 4.5 mm above and below the imaging slice, followed by a crusher gradient (total duration of the black blood module: 7.5 ms). Bright-blood images were acquired with the black-blood module turned off, but otherwise identical acquisition parameters. Imaging was repeated in 3 additional mice (male, 31 ± 4 g), to assess reproducibility of TPM with black-blood contrast. Data post-processing was performed using customized software programmed in Matlab. After contour segmentation and a correction for translational motion components, the measured in-plane velocities were transformed into an internal polar coordinate system positioned at the center of mass of the left ventricle. Hence, motion parameters are described in terms of radial v_r, rotational v_phi and longitudinal v_z velocities. Correlation coefficients were calculated by correlating mean radial velocities in 24 angular segments with the global velocity time course, which is an important parameter identifying regional myocardial dynamics [8].

Results: Figure 1 shows a plot of the mean velocities averaged over the whole LV segmentation mask obtained from the black blood data for all time frames versus the bright-blood velocities. Linear regression analysis yielded a functional dependency of y=0.80x + 0.049, R=0.97 for v_r, y=0.77x - 0.01, R=0.81, for v_phi, and y=0.84x + 0.06, R=0.87, for v_z, respectively. An identical analysis for black-blood vs. black-blood velocities as a measure of reproducibility of the technique in the three additional mice yielded y=1.06x – 0.03, R=0.99, for v_r, y=0.97x - 0.01, R=0.98, for v_phi, and y=0.99x + 0.02, R=0.97, for v_z. Figure 2 depicts the correlation coefficient plots for the radial velocities for (a) the black-blood and (b) the bright-blood acquisition of a normal mouse. The apparent relative impairment (i.e. greater variability of correlation coefficients) visible in the bright-blood data Fig. 2b is erroneously caused by blood flow rather than by a (patho-) physiological condition.

Figure 1: Linear regression analysis for myocardial velocities obtained from black-blood vs bright-blood TPM-data.

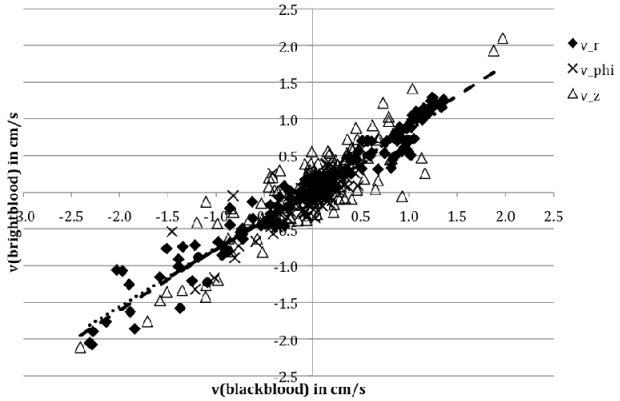
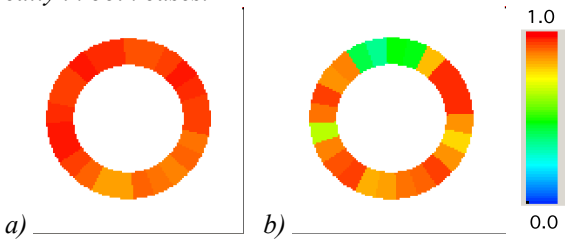


Figure 2: Correlation coefficients of mean radial velocities in 24 angular segments for a) black-blood and b) bright-blood contrast. Phase encoding was applied vertically in both cases.



Discussion: Two out of six mice showed considerable flow-related artefacts in the motion-encoding bright-blood acquisitions, which were not present in the black-black scans. Excluding these two mice from the regression analysis still did not give the same reproducibility in myocardial velocities as the repeated black-blood scans (data not shown). Importantly, bright-blood contrast was found to impact on both, absolute velocities and motion pattern as demonstrated by the correlation coefficient plots. This is of relevance particularly for diseased hearts, which may have less stable heart rates during data acquisition, and may therefore be more prone to these artefacts.

Conclusion: This study therefore suggests that black-blood contrast may yield more stable and reproducible results for regional functional analysis for mouse hearts.

Acknowledgement: This work was funded by the British Heart Foundation and supported by the British Council.

References: [1] Hennig et al. JMRI 1998;868; [2] Jung et al. JMRI 2006;1033; [3] Streif et al. Magn Reson Med. 2003;49(2):315-21; [4] Wiesmann et al. Int J Cardiovasc Imaging. 2004;20(4):289-91; [5] Herold et al. Magn Reson Med. 2006;55(5):1058-64. [6] Drangova et al. JMRI 1997;7:664-668. [7] Berr et al. Magn Reson Med. 2005;53(5):1074-9 [7] Markl et al. JMRI 2002;15:642-53.