Comparison of first-pass MRI and arterial spin labeling for quantification of myocardial perfusion in mice

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Introduction: The assessment of myocardial blood flow (MBF) is central to the evaluation of ischemic heart disease. Reduced myocardial perfusion reserve (MPR) is an independent predictor of cardiac mortality in patients with and without obstructive coronary artery disease (CAD). In the latter scenario, the underlying molecular mechanisms are not well understood. Myocardial blood flow (MBF) imaging in gene-modified mice may be used to elucidate molecular mechanisms that underlie coronary vascular function and dysfunction. Perfusion MRI in mice can be assessed using two techniques: first-pass MRI and arterial spin labeling (ASL). The purpose of our study was to compare the repeatability and variability of first-pass MRI and ASL for myocardial perfusion imaging in mice under a variety of conditions including rest, stress and after myocardial infarction.

Methods: C57Bl/6 mice were imaged at rest, with a vasodilator (Regadenoson) and on day 1 after myocardial infarction (MI) using both a first-pass MRI sequence and an ASL sequence. To assess repeatability, the mice were imaged twice using each sequence. The repeated rest and stress imaging sessions were separated by one week and the repeated post-MI sessions were separated by one day. All MRI was performed using a 7T Clinscan system. For first-pass MRI, a previously developed compressed sensing (CS) accelerated dual-contrast saturation-recovery sequence was used[1]. Imaging parameters included: TE/TR = 1.2/2.1 ms, flip angle = 15^0, saturation delay = 15 ms for the arterial input function (AIF) and 57 ms for the tissue function (TF), acceleration rate = 6 for AIF and 4 for TF, and pixel size = 200 x 200 μm^2. ASL was performed using a CS-accelerated spiral Look-Locker sequence based on a previously developed FAIR ASL sequence[2]. Imaging parameters included: acceleration rate = 2, time between inversions = 7 s, number of spiral interleaves for full Nyquist sampling = 87, pixel size = 100 x 100 μm^2, averages = 3 and flip angle = 3^0. Image reconstruction for both sequences was performed using BLOSM[3]. First-pass MR images were analyzed using Fermi function deconvolution and ASL images were analyzed using a previously developed gamma-variate based kinetic ASL model[4] in order to quantify MBF. First-pass MRI and ASL were compared in terms of image quality (score of 1-5, 5 best), between-session coefficient of variability (CV_{bs}), intra-user coefficient of variability ($CV_{intra\text{-}user}$) and inter-user coefficient of variability ($CV_{inter\text{-}user}$). Image acquisition time was 1-2 min for first-pass and approximately 40 min for ASL.

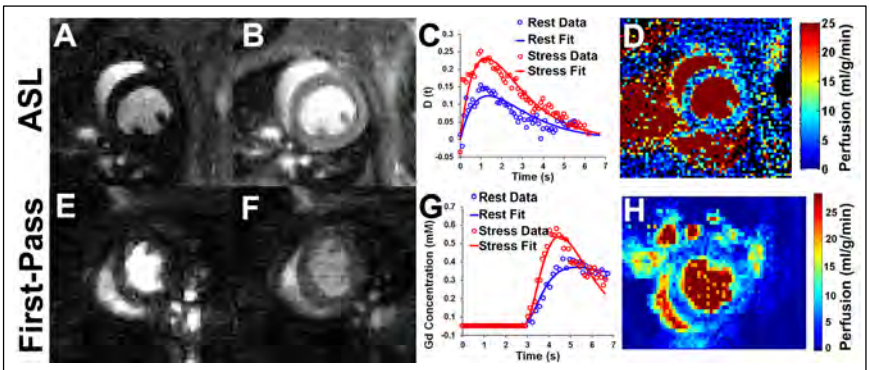

Figure 1: (A-D): Example ASL data obtained from a mouse heart. (E-H): Example first-pass data obtained from a mouse heart.

Results: Example images, kinetic modeling, and perfusion maps obtained from a mouse using both the ASL and first-pass methods are shown in Figure 1. The overall image quality was higher for ASL for all conditions (3.94±0.09 for ASL vs. 2.88±0.10 for first-pass, $p<0.05$). Bland-Altman plots of between-session repeatability for ASL and first-pass are shown in Figure 2. The overall CV_{bs} (including the rest, stress, infarct and remote data) was 22 ± 4% for ASL and 14 ± 2% for first-pass ($p<0.05$). Infarct zone CV_{bs} was significantly lower with first-pass as compared to ASL (17± 3 % with first pass vs. 46± 9% with ASL, $p<0.05$), probably due to higher perfusion sensitivity of first-pass MRI. The overall $CV_{intra\text{-}user}$ was similar for both techniques (10 ± 2% for ASL and 11± 1% for first-pass). However, the stress perfusion $CV_{intra\text{-}user}$ was significantly lower for ASL compared to first pass (3 ± 1% vs. 14 ± 3%, $p<0.05$), probably due to higher image quality of ASL at high heart rates. The overall $CV_{inter\text{-}user}$ was 13.99 ± 2.44% for ASL and 20.50 ± 2.40% for first-pass MRI. $CV_{inter\text{-}user}$ was significantly lower for ASL compared to first-pass MRI at stress (3.69 ± 0.75 vs. 17.16 ± 4.21 vs., $p<0.05$) and it trended lower for all the remaining conditions.

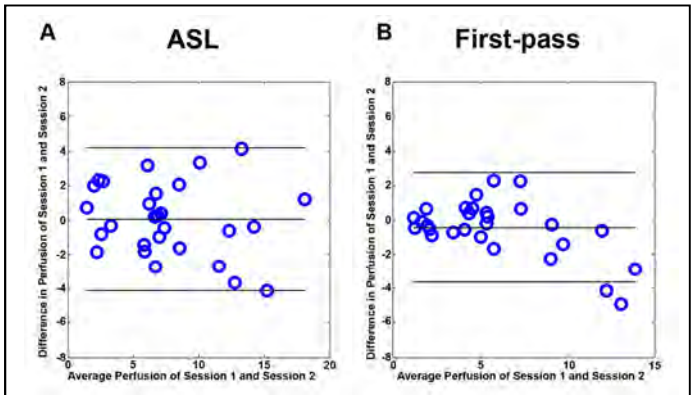

Figure 2: Bland-Altman plots of between-session repeatability for ASL and First-pass under all conditions.

Conclusions: Each technique has its own advantages and disadvantages and depending on the specific application, one technique may perform better than the other. At low MBF conditions such as infarct imaging, our results imply that first-pass MRI is preferred due to its better repeatability and variability. In contrast, at high MBF conditions such as at vasodilation, ASL may be more suitable due to its superior image quality and reduced user variability. In general, due to its speed, first-pass may be easier to use in a comprehensive multiparametric MRI exam for mice. Our results may be useful in planning future studies investigating perfusion in mouse models of heart disease.

References: 1. Naresh NK *et al.*, MRM 2014; DOI: 10.1002/mrm.25238. **2.** Vandsburger MH *et al.*, MRM 2010;63(3):648-657. **3.** Chen X *et al.*, MRM 2013; DOI: 10.1002/mrm.25018. **4.** Epstein FH *et al.* ISMRM 2011;19(216). **Acknowledgements:** NIH R01 EB001763 and NIH R01 HL 115225.