Quantitative Myocardial Perfusion Using Conventional Single-Bolus Contrast Imaging Overestimates Absolute Myocardial Blood Flow Compared with Dual-Bolus or Dual-Sequence Cardiac MR Methods

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Introduction: Estimates of myocardial blood flow (MBF) from first-pass contrast-enhanced cardiac magnetic resonance (CMR) imaging require accurate measurement of the arterial input function (AIF) from the left-ventricular (LV) blood pool. Both dual-bolus [1] and dual-sequence [2,3] CMR methods have been proposed to maintain the linearity of the LV signal during the contrast passage. Several studies have compared quantitative estimates of CMR perfusion using single-bolus and dual-bolus contrast methods [4,5]. These studies used a hybrid echo-planar imaging (EPI) sequence and showed both single-bolus and dual-bolus methods were clinically applicable for quantitative evaluation of coronary artery disease (CAD) in patients. However, it was further shown that myocardial perfusion reserve (MPR) was comparable for both single-bolus and dual-bolus methods [5].

A balanced steady-state free precession (SSFP) sequence can theoretically achieve a higher degree of T1 linearity and SNR compared to the hybrid-EPI sequence [6]. This study is aimed to compare MBF estimates from single-bolus, dual-bolus, and dual-sequence CMR perfusion imaging methods using a SSFP sequence. MBF estimated from CMR perfusion images were compared to microsphere absolute MBF measurements in animals.

Materials and Methods: Both the dual-sequence CMR imaging technique and the dual-bolus contrast method were performed in six canines using a SSFP sequence with saturation recovery magnetization preparation on a 1.5 Tesla Siemens scanner. Microsphere MBF measurements were obtained during intracoronary adenosine infusion. Gd-DTPA at 0.005 mmol/kg and 0.05 mmol/kg were administered during separate breath holds. Typical imaging parameters: 1 RR, 90° composite pulse, 50°read out angle, saturation recovery 90 ms, TR 2.4 ms, TE 1.2 ms, matrix size 128x80. A low TE, low resolution FLASH image (TE 0.6 ms, matrix size 64x48) was acquired during each RR interval.

The AIF was measured within the LV blood pool from the low-dose image series of the dual-bolus single-sequence (DB-SS), the low-resolution image series of the single-bolus dual-sequence (SB-DS), and the conventional image series of the single-bolus single-sequence (SB-SS). Time signal intensity curves of the myocardium on a mid ventricular slice were analyzed based on 8 transmural sectors. A hyperemic sector and a remote sector in each slice were selected for microsphere comparison. CMR derived MBF estimates were calculated separately using the same myocardial curves with the three different AIFs by a model-constrained deconvolution.

Results: Figure-1 shows a qualitative comparison of the AIF measured from three CMR perfusion image series (DB-SS, SB-DS, and SB-SS). There was a significant signal intensity compression of the AIF in the SB-SS image series compared to the DB-SS and SB-DS series. There was no statistical difference in MBF estimates using the AIF from DB-SS and SB-DS image series against the microsphere (MS) measurements (p=NS in both hyperemic and remote sectors, Figure-2a). However, MBF estimates using the AIF from SB-SS image series were significantly higher than the microsphere reference (p<0.01 in both hyperemic and remote sectors, Figure-2a). Figure-2b shows that the MBF ratio (hyperemic/remote) was not statistically different in the three image series compared to the microsphere MBF ratios (p=NS). Figure-3 shows MBF estimates using the AIF obtained from all three image series correlated well with the microspheres reference. However, MBF was overestimated in the SB-SS image series.

Discussion: Using a single bolus, single sequence (SB-SS) derived AIF causes overestimation of myocardial perfusion due to marked underestimation of the AIF amplitude and distortion of the AIF shape. CMR estimates of MBF agreed well with the microsphere MBF measurements in both dual-bolus and dual-sequence experiments. However, perfusion ratio of hyperemic vs. remote MBF estimates from all three image series were comparable to the microsphere MBF ratio. Although this study used a saturation recovery SSFP sequence, these conclusions should extend to other perfusion sequences as well.

References: [1]. Christian, et al., Radiology, 2004, 677-684. [2]. Gatehouse et al., JMRI, 2004, 39-45. [3]. Kim and Axel, JMRI ,2006, 23:81-86. [4]. Utz, et al., MRM, 2008, 1373-1377. [5]. Groothuis, et al., JMRI, 2010, 88-93. [6]. Kellman and Arai, JCMR, 2007, 525-537.
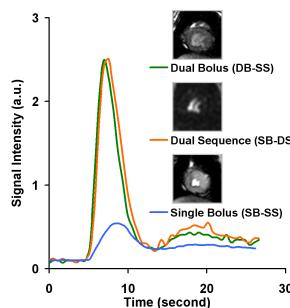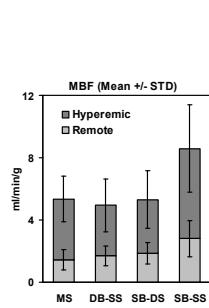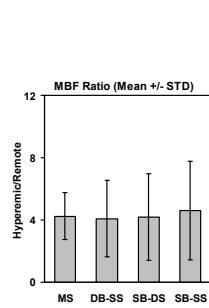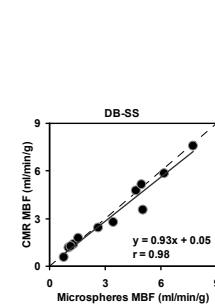

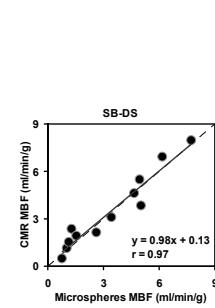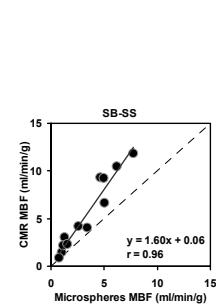Figure-1   Figure-2a   Figure2b   Figure-3a   Figure-3b   Figure-3c