Accuracy of CMR Arterial Spin labeling Method for Detecting Myocardial Ischemia: in Comparison with PET

Jie Zheng[1], David Muccigrosso[1], and Robert J. Gropler[1]
[1]*Washington University, Saint Louis, Missouri, United States*

Purpose

Arterial spin labeling (ASL) has been increasingly used to measure tissue blood flow without using any contrast agent. Recently, a cardiac MR (CMR) ASL method was reported to measure myocardial blood flow (MBF) with single breath-hold [1]. Microsphere validation was also performed in a limited number of subjects. However, the systematic evaluation of CMR ASL for the detection of myocardial ischemia has yet been reported. The purpose of this project was to investigate the accuracy of this CMR ASL in a canine model by using positron emission tomography (PET) as the reference.

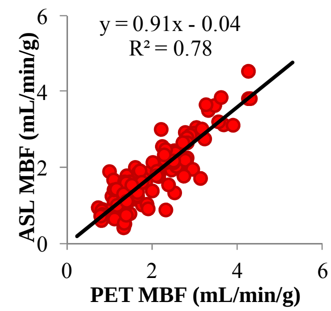

Figure 1 Strong Correlation of MBF measured by ASL and PET imaging.

Methods

Imaging Techniques: Briefly speaking, CMR ASL used following formula to calculate MBF [2]:

$$MBF = \lambda \frac{T_{1,NS}}{T_{1,Blood}} \left(\frac{1}{T_{1,SS}} - \frac{1}{T_{1,NS}} \right) \quad (1)$$

where λ is the constant blood-tissue coefficient of water (λ = 0.92 mL/g); $T_{1,NS}$ and $T_{1,SS}$ are T_1 values of the tissue after nonselective and slice-selective inversion recovery pulse is applied. The 2D CMR ASL sequence was an ECG-trigged, single-shot gradient-echo sequence, prepared by selective and non-selective inversion recovery pulses. The dynamic data acquisition occurred during the mid-diastole after each triggering to acquire T_1-weighted data along the T_1 recovery curve. Other imaging parameters included: TR/TE = 2.4/1.1 msec; flip angle = 5°; FOV = 220 x 110 mm²; matrix = 128 x 53; acquisition = 16 sec.

Table Comparison of MBF (mL/min/g) measurements by CMR ASL and ^{15}O-water PET (n = 14). *P < 0.01 vs PET, MFR = Myocardial Flow Reserve

	CMR ASL		^{15}O-water PET	
	Anterior	Inferior	Anterior	Inferior
Rest	0.97 ± 0.4*	1.23 ± 0.5*	1.27 ± 0.36	1.6 ± 0.59
Hyperemia	1.6 ± 0.37	2.73 ± 0.82	1.73 ± 0.6	2.78 ± 0.27
MFR	1.82 ± 0.58	2.64 ± 2	1.4 ± 0.48	2.08 ± 0.75

PET imaging was performed on a Focus 220 microPET scanner (Concorde Medical Systems, Knoxville, Tenn). A transmission scan was first performed to ensure proper positioning and to correct for photon attenuation. ^{15}O-water was administered intravenously, and dynamic PET data were acquired for 5 minutes. The same pharmacological stressor as used in MRI was then started, followed by the ^{15}O-water stress imaging.

Experiments: 18 normal beagles (mean weight = 9.3 kg) were used and 14/18 dogs were instrumented with varying degree of area stenosis (75-95%) in the left anterior descending coronary artery (LAD) with stenosis clamps [3]. Dipyridamole at a dose of 0.14 mg/min/kg or Dobutamine at an average dose of 20 µg/min/kg was infused to increase MBF. MRI was performed on a 1.5-T Sonata scanner (Siemens Medical Solutions, Erlanger, Germany). A 4-element, phased-array coil placed around the chest was used for signal reception. Single-slice CMR ASL was performed in the middle of short-axis myocardial slice at rest and during the pharmacologically induced hyperemia. PET imaging was performed after CMR experiments. All animals were studied under anesthesia.

Data Analysis: ASL data was analyzed using a home-made software written in Matlab. The source T_1-weighted images were first denoised by hybrid median filters with a window size of 4 x 4 [4]. Based on Eq (1), MBF maps were produced pixel-by-pixel. Four ROIs were drawn in the anterior (ANT), lateral (LAT), inferior (INF), and septal (SEP) myocardial regions of the maps. For PET images, the ROIs matching the MR image ROIs were drawn to generate blood and myocardial time-activity curves. PET MBF was subsequently determined by a previously validated compartmental modeling method [5].

Results

There were 36 pairs of CMR and PET data sets, in which 6 CMR data sets were excluded for analysis due to severe motion artifacts. In addition, 4 more regions were also excluded due to cardiac motion. **Figure 1** shows overall correlation of regional MBF measured by CMR ASL and PET. The correlation is very strong, but ASL MBF was slightly underestimated. **Table** demonstrates averaged regional MBF and myocardial flow reserve (MFR) in 14 stenotic dogs. MBF at rest was significantly underestimated in both ischemic and normal regions. Surprisingly, MFR remained comparable between ASL and PET methods. **Figure 2** shows examples of PET images and MBF maps in a dog with 95% stenosis in LAD. It noted that cardiac motion in the free lateral wall during dobutamine stress caused inaccurate calculation of MBF in the CMR MBF map.

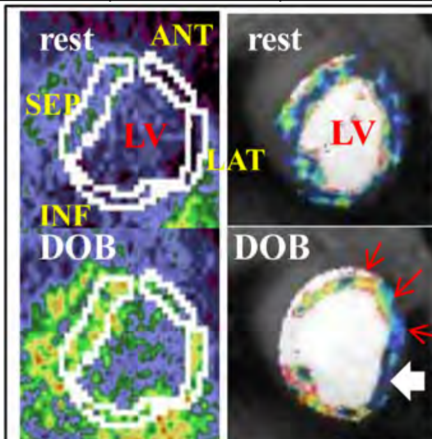

Figure 2. Comparison of PET ^{15}O-water images (left column) and MBF maps (right column) by CMR ASL in a dog with LAD stenosis of 95%. Four ROIs were shown in PET images. Reduced MBF was clearly seen in the anterior region of MBF map (red thin arrows) and PET image during dobutamine stress. Much "reduced MBF" (white arrow) was also observed in the lateral region of CMR MBF map, but was found to be artifacts caused by cardiac motion. DOB = dobutamine

Conclusions

The CMR ASL method can accurately measure MBF during hyperemia, but underestimate resting blood flow. Despite this error, quantitative myocardial flow reserve remains valid for the detection of myocardial ischemia. Future efforts are to minimize motion artifacts and improve SNR.

References [1] Zhang H, et la, MRM, 2005;53: 1135-1142. [2] Belle V, et al, JMRI, 1998; 8:1240-1245. [3] Nohara R, et al, Am Heart J. 1989; 118:1167–1175. [4] Deasy JO, et al, Physics Medicine and Biology, 2000; 45:1765-1779. [5] Bergmann SR, et al, J Am Coll Cardiol. 1989;14:639–652.