

New Methods for the Quantification of Myocardial Oxygen Consumption with ^{17}O MRI

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Purpose

PET has been the primary modality for myocardial oxygen consumption rate (MVO_2) measurements, but its use is limited by low spatial resolution, radiation exposure, and lack of broad availability. Preliminary studies using ^{17}O MRI have shown great potential for the quantification of cerebral oxygen consumption in both human and animal subjects [1,2]. We hypothesize that these techniques can be applied in the quantification of MVO_2 . In this initial study, we developed a series of imaging methods and hardware to examine the feasibility of quantifying MVO_2 in a canine model.

Methods

An injectable ^{17}O autologous blood agent was made using the hardware shown in **Figure 1**. The "blood contrast agent" is the artificial blood, Oxyglobin (Biopure Corporation, Cambridge, MA) that is a solution consisting of chemically stabilized hemoglobin in a balanced salt solution. The equipment is essentially a circular loop with a 60-ml syringe to push high-pressured $^{17}\text{O}_2$ gas into the circulating blood. The enrichment can reach up to 98%. We have developed a fast cardiac acquisition method for the quantification of myocardial $T_{1\rho}$ in vivo in order to monitor and quantify myocardial H_2^{17}O concentration [1]. The MRI sequence acquires a series of $T_{1\rho}$ -weighted images at up to 4 different spin-locking (SL) times (denoted TSL) within a breath-hold time.

Four mongrel dogs (wt = 19.5 ± 1.2 kg) were used in this initial feasibility study. A 95% area coronary artery stenosis was created in one dog by an adjustable occluder around the proximal left-anterior descending coronary artery (LAD). All dogs were studied using a variety of doses (10- 50 ml) of ^{17}O -enriched blood or Oxy-17®, administered intravenously. Dobutamine was also infused in the stenotic dog to evaluate elevated MVO_2 . Bolus injections were performed in one normal dog and in the stenotic dog, while a slow infusion was performed in the other two normal dogs to monitor the $T_{1\rho}$ signal changes over 60-120 min. For a comparison, ^{16}O -enriched blood was also injected to the last two normal dogs and the same imaging procedure was followed.

ROI measurements were performed in the entire myocardium in normal dogs and in the anterior stenosis subtended region (ANT) and remote normal perfused posterior region (POT). A simplified method to calculate MVO_2 was adopted from literature [2] for the quantification.

Results

Creation of H_2^{17}O metabolic water reduced $T_{1\rho}$ signals, while H_2^{16}O maintained the baseline signals (**Figure 2**). MVO_2 in **Figure 2** at rest was calculated as $5.3 \mu\text{mol/g/min}$ which agrees well with MVO_2 measured by PET [3]. In the stenotic dog, MVO_2 in the ANT region reduced from 4.2 at rest to $3.6 \mu\text{mol/g/min}$ during dobutamine stress, while MVO_2 in the normal POS region increased from 3.2 at rest to $7.6 \mu\text{mol/g/min}$ during dobutamine stress.

Conclusions

This is the first time that the feasibility of quantifying MVO_2 has been demonstrated using an intravenous injection of ^{17}O -enriched contrast agent.

References

1. Tailor DR, et al. Neuroimage 2004;22:611-618.
2. Fiat D, et al. Neurol Res 2004;26:803-808.
3. McCommis KS, et al, Magn Reson Imaging. 2008;26:11-9.

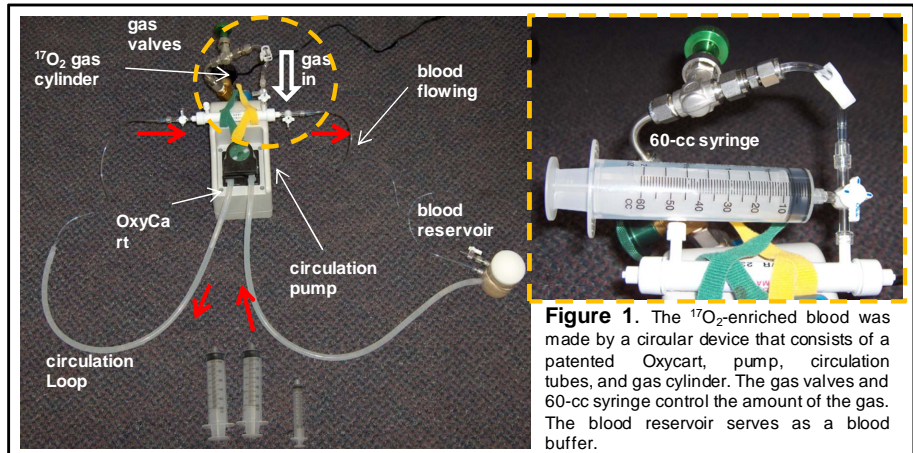


Figure 1. The $^{17}\text{O}_2$ -enriched blood was made by a circular device that consists of a patented OxyCart, pump, circulation tubes, and gas cylinder. The gas valves and 60-cc syringe control the amount of the gas. The blood reservoir serves as a blood buffer.

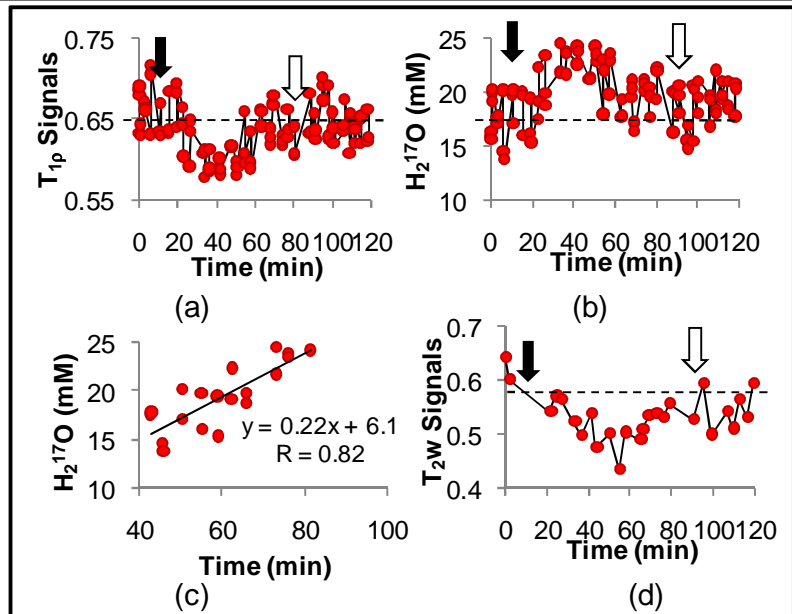


Figure 2 (a) The global myocardial $T_{1\rho}$ signal changes after the infusion of 50-ml $^{17}\text{O}_2$ -enriched blood (black block arrow) and then 40-ml $^{16}\text{O}_2$ -enriched blood (white block arrow). (b) The calculated myocardial concentration of H_2^{17}O . (c) The "zoom" H_2^{17}O concentration vs time when H_2^{17}O concentration was elevated for the calculation of the slope. (d) Concomitant myocardial T_2 -weighted signal changes. The horizontal dashed line indicates the pre-contrast levels.