Assessment and Validation of Cardiac MR Oximetry in Obesity

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Purpose

Obesity is an independent risk factor to cardiovascular disease, including coronary heart disease and heart failure. Animal studies and few studies in humans indicate myocardial metabolic alternations precede and contribute to cardiac remodeling and dysfunction in obesity [1]. Positron Emission tomography (PET) can measure myocardial perfusion and oxygen metabolism rate. However, non-radiation nature of MRI could allow for serial monitoring of obese patients with cardiac remodeling. We have developed a MRI acquisition and modeling method to assess global myocardial oxygenation. The aims of this study were to validate and evaluate this MRI method by PET in a group of obese patients and volunteers.

Table 1 Imaging sequence parameters

	T2prep-GRE	TurboFLASH
Echo #	5	1
TEs (ms)	24,36,48,60,72	TR/TE=2.1 /1.2
Flip Angle	15	18
Segment #	31	1
Scan Time	20 sec	1 min

Methods

This ongoing study recruited 5 previously obese patients (5F) who underwent gastric bypass surgery (a surgery in abdominal to cause malabsorption, i.e., decreased ability to absorb calories and nutrients from food, for losing weight) and PET scans for the measurements of myocardial blood flow (MBF) and oxygen consumption rate (MVO_2) at rest only. All obese participants underwent CMR study in about one year from their PET scans, at rest and then during the adenosine vasodilation. In addition, 5 Body-mass index or BMI matched normal volunteers (2F) were also recruited for control study. The MRI scanner is 1.5T Siemens Avanto or Sonata system. The adenosine was infused intravenously at a constant rate of 0.14 mg/kg/min. CMR methods included a new bright-blood T_2-prep-gradient-echo (**T2prep-GRE**) sequence for acquiring a series of T_2-weighted images of coronary sinus with breath-holding. Myocardial perfusion was also measured using a **TurboFLASH** sequence to collect 80-100 dynamic images of short-axis myocardium, after a bolus injection of 0.02 mmol/kg Multihance (Bracco Diagnostic, Princeton, NJ). **Table 1** lists the imaging parameters for each sequence.

Table 2 OEF and MVO_2 (μmol/g/min) of global myocardium in obese

Obese Pts	BMI (PET)	BMI (MRI)	Resting PET		Resting MRI		Adenosine MRI	
			OEF	MVO_2	OEF	MVO_2	OEF	MVO_2
1	26.2	26.7	0.65	6.25	0.61	-	0.5	-
2	25.2	26.3	0.67	5.17	0.61	5.23	0.45	9.58
3	30.6	32.9	0.59	5.46	0.57	5.36	0.43	10.58
4	29.7	29.1	0.78	4.78	0.75	4.56	0.41	8.5
5	**37.7**	**43.1**	0.78	5.64	0.72	**6.31**	**0.62**	12.9
Mean (1-4) (std)	27.9 (2.6)	28.8 (3)	0.67 (0.08)	5.4 (0.6)	0.64 (0.08)	5.1 (0.4)	0.45 (0.04)	9.6 (1.0)
5 Normal Volunteers	-	26 (3)	-	-	0.74 (0.03)	5.6 (1.9)	0.38 (0.06)	9.5 (2.7)

Using a newly developed multi-variable regression algorithm, global myocardial oxygen extraction fraction (OEF) was determined in the coronary sinus, at rest and during the adenosine vasodilation. Absolute MBF was determined using a newly developed model-independent algorithm [2] in a unit of ml/g/min in the short-axis myocardial images. Global MVO_2 was then calculated using Fick's law: $MVO_2 \propto OEF \times MBF$. **Figure** shows one set of MBF maps and PET image from one volunteer.

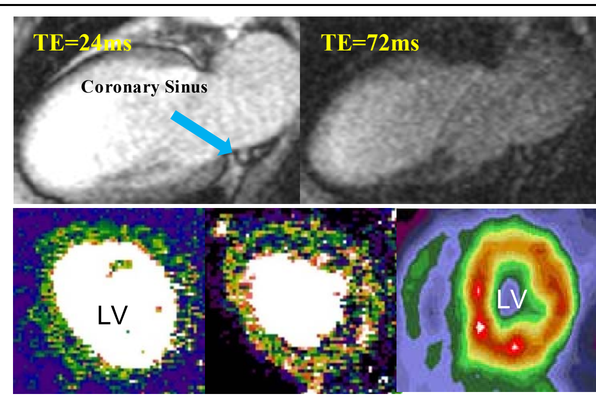

Figure. Top row: two T_2-weighted images of coronary sinus (blue arrow). Bottom row: (left to right) resting MBF map, adenosine MBF map, PET ^{11}C-Acetate map

Results

In obese patients, average resting MBF in obese patients was 0.88 ± 0.15 ml/g/min (PET), vs. 0.87 ± 0.19 ml/g/min (by MRI, p = NS). Adenosine MBF increased to 2.41 ± 0.22 ml/g/min (MRI only). Myocardial OEF and MVO_2 results by PET and MRI were listed in **Table 2** for obese patients, except MVO_2 data in the first patient due to severe cardiac motion in perfusion imaging. For comparison, average values of OEF and MVO_2 in normal volunteers were listed as well. There are excellent correlations between PET and MRI for OEF (r^2 = 0.94) and MVO_2 (r^2 = 0.87). Obese patient #1-4 maintains the similar BMI between PET and MRI scans, and their physiology parameters were similar to those of normal volunteers. However, **patient #5** (bold) shows significantly increased BMI, leading to elevated MVO_2 at rest with normal resting OEF. Interestingly, the adenosine OEF of the patient #5 reduced much less than other patients, while both resting and adenosine MBF were similar to others (not shown here).

Conclusions

This is the first study to evaluate cardiac oxygen metabolism at rest and during the stress in overweight and obese patients. Our CMR approach for the quantification of myocardial OEF and MVO_2 was validated by PET at rest. Obese patients after gastric bypass surgery appear to have normal MBF and OEF at rest and during the stress by comparing with literature values and normal volunteers. However, elevated BMI seems to cause elevated stress OEF with normal resting and stress MBF. This may indicated alternation of oxygen metabolism precede abnormal microcirculation and future cardiac remodeling. Future serial studies are warranted for elucidating the mechanism of cardiac metabolism and remodeling in obese patients for early intervention.

References [1]. Mittendorfer B, et al. Drug Discov Today Ther Strateg. 2008;5:53-61. [2] Goldstein TA, et al, MRM. 2008;59:1394-1400.