Quantification of Cardiac Fat Volume in Humans Using 3D SSFP Imaging

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INTRODUCTION

Cardiac fat signal has been used to measure bulk cardiac motion for real-time navigator gating [1] and retrospective motion correction [2] in coronary MR angiography. This has the advantage of directly measuring motion of peri-coronary tissue without interfering with the water signal of the coronary lumen. The magnitude of signal from this novel motion detection approach depends upon the amount of fat within and around the heart. Though it is known that the epicardial surface of the human heart is covered with fat, quantitative description of the human cardiac fat is lacking. The objective of this study is to estimate the cardiac fat volume using a fast 3D fat-selective pulse sequence.

MATERIALS AND METHODS

Experiments were performed using a 1.5T GE SIGNA CV/i MR system. An ECG-triggered water-suppressed balanced SSFP 3D pulse sequence was used for fat imaging (TR = 3.6 ms, TE = 1.1 ms, flip = 60°, bandwidth = ±62.5 kHz, slice thickness = 10 mm, resolution = 1.6 x 2.5 mm^2, 56 echoes per heartbeat). For magnetization preparation, a fast Kaiser ramp consisting of 6 RF pulses was applied after the water suppression pulse and before the SSFP readout (Fig. 1). The body coil was used for uniform excitation and detection across the 40 cm FOV.

This pulse sequence was calibrated on a fat phantom. To simulate the cardiac fat and the chest wall fat, a 90-ml plastic tube and a plastic bottle were filled with vegetable oil. Imaging was performed on the phantom alone and on the phantom immersed in a 3000-ml water tank.

Human experiments were then performed in 5 healthy volunteers (4 males, 1 female, mean age of 37 ± 9 years, mean body weight of 67 ± 9 kilograms) during a 24-heartbeat breath-hold. The trigger delay time was set such that data acquisition took place during mid-diastole, the period of minimal cardiac contraction. For each slice two cardiac regions-of-interests (ROIs) were drawn: the superior region (from the top of the pulmonary trunk to the coronary ostia) and the inferior region (from the coronary ostia to the cardiac apex).

The number of cardiac fat voxels (including partial ones) was estimated as the sum of signals within the ROIs divided by the mean voxel signal of the subcutaneous pure chest fat on the same slice. The corresponding cardiac fat volumes were calculated by multiplying the estimated number of voxels with the voxel size. The percentage of cardiac volume corresponding to fat was obtained by dividing the number of cardiac fat voxels by the total number of cardiac voxels.

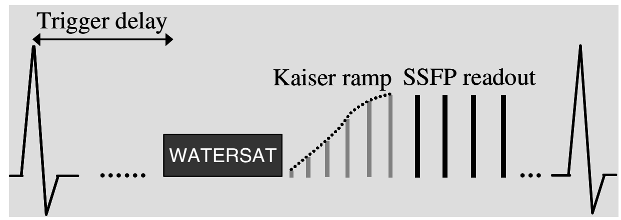

Fig.1. Imaging schematics of the ECG-triggered water-suppressed SSFP 3D pulse sequence. A spectrally selective RF pulse centered on water frequency was used to provide water suppression.

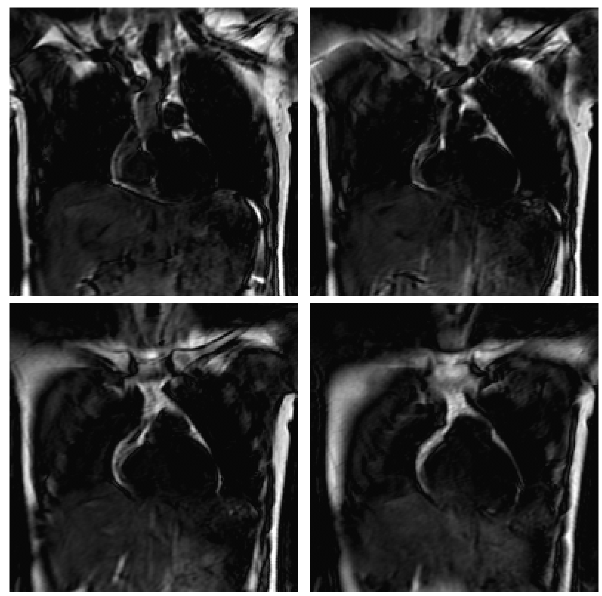

Fig.2. Four contiguous coronal fat images acquired from a 34-year-old healthy male. Both subcutaneous and cardiac fat are well visualized.

RESULTS

On the calibration phantom, the estimated fat volume was 91 ml and 98 ml for measurement without and with water tank, representing a 1% and 9% estimation error, respectively. The increased error was probably caused by the residual water signal due to imperfect water suppression. This error margin was deemed acceptable for our fat measurements.

Human images were obtained successfully from all subjects. Fig. 2 shows four representative coronal fat images acquired from a 34-year-old healthy male (body weight 56 kg). In this subject, the total cardiac fat volume is approximately 10% of the mid-diastolic heart volume, with 60% of the cardiac fat occupying the superior region of the heart and 40% occupying the inferior region. Over the five subjects, the average cardiac fat volume is 115 ± 52 ml, approximately 11 ± 3% of the heart volume (964 ± 192 ml), 55 ± 8% in the superior region and 45 ± 8% in the inferior region. Table 1 summarizes the volume measurements.

Subject	Heart volume [ml]	Cardiac fat volume superior [ml]	inferior [ml]	total [ml]	relative [%]
A	799	47	31	78	10
B	1028	49	63	112	11
C	1173	124	67	191	16
D	1090	70	65	135	12
E	728	30	27	57	8
Mean ± SD	964 ± 192	64 ± 36	50 ± 20	115 ± 52	11 ± 3

Table 1. Heart and cardiac fat volume measurements (n=5).

CONCLUSION Our preliminary data have demonstrated that there is substantial cardiac fat within the human heart volume, which may be sufficient for effective motion tracking. Cardiac fat volume may also be measured using other techniques such as cardiac cine SSFP imaging with IDEAL [3].

REFERENCES 1. Nguyen TD et al. MRM 2003;50:235-241. 2. Stehning C et al. MRM 2005;53:719-723. 3. Reeder SB et al. JMRI 2005;22:44-52.