Pericardial fat quantification using respiratory triggered 3D-Dixon pulse sequence

Rami Homsi[1], Alois M. Sprinkart[1,2], Julian Luetkens[1], Juergen Gieseke[1,3], Hans H. Schild[1], Michael Meier-Schroers[1], Daniel Kuetting[1], Darius Dabir[1], and Daniel Thomas[1]

[1]*Radiology, University Hospital Bonn, Bonn, NRW, Germany,* [2]*Institute of Medical Engineering, Ruhr-University Bochum, Bochum, Germany,* [3]*Philips Healthcare, Best, Netherlands*

Target Audience: This study is particularly interesting for scientists and clinicians experimenting with the measurement of pericardial fat, a parameter that is becoming more important in the assessment of cardiovascular risk.

Purpose: The purpose of this study was to introduce a novel method to measure pericardial fat volume (PFV) and to furthermore correlate it with other parameters of cardiovascular risk such as body mass index (BMI), age and pulse wave velocity (PWV) in healthy subjects.

Introduction: Magnetic resonance imaging (MRI) is increasingly used to assess cardiovascular risk. One example is the assessment of aortic stiffness with PWV by velocity-encoded (VE) MRI [1]. Another strong predictor of cardiovascular risk is the PFV which is the fat surrounding the heart [2]. Different methods have been introduced to measure PFV such as transthoracal echocardiography (TTE) [3] or Computed tomography (CT) using the different Hounsfield Units of fat compared to other tissue [2]. Previously MRI has been used to quantify PFV using the modified Simpson method or by simple measurement of the area of fat adjacent to the heart at 4-chamber view by identifying the contours of the adipose tissue with e.g. steady state free precession (SSFP) or T1 weighted black blood sequences[4-5]. Compared to these approaches the 3D-Dixon method may be used to evaluate the PFV more accurately because it allows the acquisition of fat only images[6]. Thus only fat may be used for quantification of PFV. Thus, the purpose of this study was to implement a cardiac and respiratory triggered 3D-Dixon pulse sequence and investigate its suitability for assessment of PFV in healthy individuals and correlate the PFV to other markers of cardiovascular risk, e.g. BMI, age and aortic PWV.

Methods: 33 healthy subjects were examined on a 1.5 Tesla scanner (Ingenia 1.5T, Philips Healthcare, Best, The Netherlands). For aortic PWV an ECG-gated SSFP-cine sequence of the aortic arch was acquired in an oblique-sagittal plane (Field of view [FOV] = 350x350mm²; Repetion time [TR] = 3.12 msec; Echo time [TE]= 1.56 msec; Flip angle [FA]= 60°; Acquired Voxel size [AVS] = 1.68 / 1.77 / 8.00 mm³). A Velocity-encoded (VE) MRI sequence was acquired perpendicular through the aorta ascendens (AA) and descendens (AD) and acquired during free breathing with retrospective ECG-gating (TR = 6.5ms; TE = 2.2; FA = 15°; AVS = 1.7x1.7mm²; reconstructed number of heart phases = 130, FOV = 300x225mm²; maximum VE = 150cm/sec). PWV was calculated by dividing the distance between the section through the AA and through the proximal AD by the transit time, which is the time between the arrival of the velocity waveform at the section AA and the section of the proximal AD, respectively (Figure 2) [1]. Transversal ECG- and respiratory navigator gated Dixon-images were acquired between the split of the pulmonary artery to the most inferior slice of the myocardium, triggered to end-diastole (FOV = 350x302x180mm³; TR = first 1.8 msec / second 4 msec; FA = 60°; AVS = 1.68 / 1.77 / 8.00mm³; Scan duration = 4-5 minutes depending on the heart rate). Dixon Images were analysed offline on a personal computer using in-house software written in MATLAB (The MathWorks, Inc., Natick, MA). PFV was measured in milliliters (ml) within the limits of the heart between the split of the pulmonary artery to the most inferior slice of the myocardium. Measurements were done slice-by-slice with a threshold chosen in each slice on basis of the erector spinae muscles, and only voxels with an intensity above the threshold within each region-of-interest were taken into account.

Results: A total of 33 (22 men and 11 women) subjects were examined. Mean age was 42.8 ± 14.0. Mean BMI was 24.97kg/m² ± 5.23. Mean PWV was 4.4m/s ± 1.4m/s. Mean PFV was 180.1ml ± 91.6. Displaying the results in dependancy of:

a) BMI: compared to subjects with a BMI < 25kg/m² (18 subjects; 10 men; mean age 43 ± 15.04; mean BMI 21.7 ± 2.68), subjects with a BMI > 25 (15 subjects; 12 men; mean age 42.67 ± 15.40; mean BMI 28.7 ± 5.00) had a significantly higher PFV (228.45 ± 93.07 vs. 142.42ml ± 73.53 [$p < 0.01$]). There were no significant differences for Age, BMI or PWV (4.36m/s vs. 4.43m/s).

b) Age: compared to subjects with age < 40 years (17 subjects; 12 men; mean age 31.1 years ± 5.79; mean BMI 25.21 kg/m² ± 6.02), subjects with an age > 40 years (16 subjects; 10 men; mean age 55.31 ± 10.97; mean BMI 24.50kg/m²) had a significantly higher PWV (5.47m/s ± 1.3 vs. 3.44m/s ± 0.6 [$p < 0.01$]) and a significantly higher PFV (211.79ml ± 107.15 vs. 152.06ml ± 66.58 [$p < 0.05$]). There were no significant difference for BMI.

Discussion: This is the first study which uses a 3D-caridac and respiratory navigator gated Dixon fat-saturation technique for measurement of PFV, which in previous studies has been shown to correlate with parameters of cardiovascular risk (e.g. BMI, Dyslipedemia, Hypertension, coronary calcification and Diabetes mellitus)[2]. In this study it could be shown that PFV correlates with age and BMI which is consistent with other studies[7]. There was no difference in PWV between the subjects with a higher BMI compared to a lower BMI, but there was a significant difference in PWV between the older and the younger group, perhaps because arterial stiffness occurs with older age and with cardiovascular diseases[8]. However, there was no significant difference in age between these two groups and all subjects were healthy. MRI has several advantages over other imaging modalities for assessment of PFV such as CT because it does not require the use of radiation or has the disadvantage of having a high interobserver variability such as TTE [2].

Conclusion: Using the implemented 3D-Dixon method PFV can be measured most accurately by only taking fat into account. This approach may be used for future studies of PFV and its role in cardiovascular risk stratification and disease.

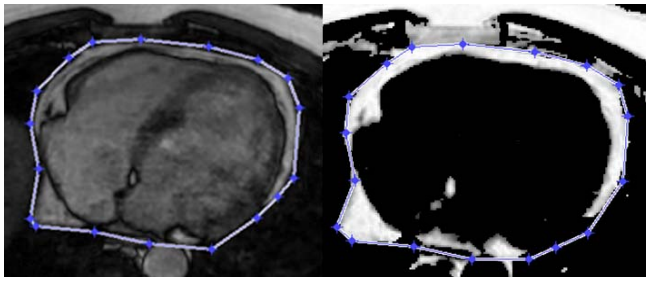

Figure 1: Representative volumetric assessment of pericardial fat volume at the level of the atrioventricular valves in a 50 year old healthy man. Pericardial fat volume was 262,25ml measured within the limits of the heart between the split of the pulmonary artery to the most inferior slice of the myocardium. Left image: opposed phase. Right image: Fat only.

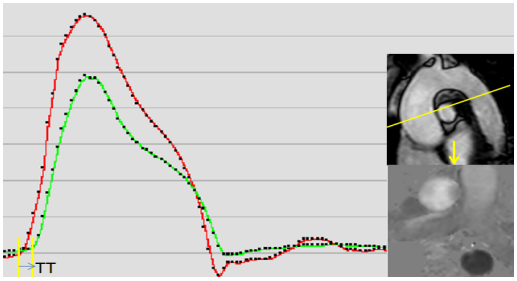

Figure 2: For Aortic pulse wave velocity (PWV) a velocity-encoded (VE) MRI slice was set perpendicular through the aorta ascendens (AA) and decendens (AD) with the distance between AA and AD measured on an oblique-sagittal plane of the aortic arch. The transit time (TT) is the time between the arrival of the velocity waveform at the section AA and the section of proximal AD, respectively. PWV = distance / TT

References: [1] Grotenhuis H.B. et al.: J Magn Reson Imaging, 2009. 30(3): p. 521-6; [2] Dey D. et al.: Atherosclerosis, 2010. 209(1): p. 136-41; [3] Iacobellis G. et al.: Obes Res, 2003. 11(2): p. 304-10; [4] Hua, N. et al. J Cardiovasc Magn Reson, 2014. 16: p. 37; [5] Nelson A.J. et al.: J Cardiovasc Magn Reson, 2009. 11: p. 15; [6] Eggers H. et al. Magn Reson Med, 2011. 65(1): p. 96-107; [7] Rosito G.A. et al.: Circulation, 2008. 117(5): p. 605-13; [8] Laurent S. et al.: Eur Heart J, 2006. 27(21): p. 2588-605.