European Journal of Radiology 85 (2016) 936–942

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

3D-Dixon cardiac magnetic resonance detects an increased epicardial fat volume in hypertensive men with myocardial infarction

Rami Homsi[a,*], Alois M. Sprinkart[a,b], Juergen Gieseke[a,c], Seyrani Yuecel[d], Michael Meier-Schroers[a], Julian Luetkens[a], Darius Dabir[a], Daniel Kuetting[a], Christian Marx[a], Jennifer Nadal[e], Hans H. Schild[a], Daniel Thomas[a]

[a] University of Bonn, Department of Radiology, Sigmund-Freud-Str. 25, 53127 Bonn, Germany
[b] Institute of Medical Engineering, Ruhr-University Bochum, Germany
[c] Philips Research, Hamburg, Germany
[d] Gemeinschaftskrankenhaus Bonn, St. Petrus, Department of Cardiology, Bonner Talweg 4-6, 53113 Bonn, Germany
[e] Institute for Medical Biometry, Informatics and Epidemiology, University of Bonn, Germany

ARTICLE INFO

Article history:
Received 22 September 2015
Received in revised form 5 February 2016
Accepted 16 February 2016

Keywords:
CMR
Epicardial fat
Pericardial fat
Dixon
Hypertension
Myocardial infarction

ABSTRACT

Purpose: Using a three-dimensional ECG- and respiratory navigator gated magnetization prepared mDixon-sequence (3D-Dixon) we quantified *epi*- and pericardial fat volumes (EFV, PFV) in hypertensive men compared to a healthy control group and related the amount of fat volumes in hypertensive men to the presence of coronary artery disease (CAD) and myocardial infarction (MI).

Materials and methods: 55 hypertensive men (mean age 63.02 ± 10.73 years [y]) with MI (n = 22; mean age 61.55 ± 10.50y) and without MI (n = 33; mean age 63.17 ± 10.93y), and a group of ten healthy men (mean age 59.00 ± 8.41y) underwent a comprehensive cardiomagnetic resonance (CMR) examination on a 1.5 T MR system (Ingenia, Philips). Hypertensive men without MI consisted of patients with CAD (n = 15) and without CAD (n = 18).

EFV and PFV were assessed using 3D-Dixon. Fat only images were reconstructed online at the scanner, and the segmentation of fat volumes was performed based on fat fraction maps. EFV and PFV were normalized to the body surface area (ml/m^2).

Results: Mean EFV and PFV in all hypertensive men (81.8 ± 33.90 and 194.86 ± 83.51) as well as in hypertensive men with no CAD (74.53 ± 26.40 and 174.60 ± 65.70) were significantly higher than in the healthy controls (52.98 ± 19.81 and 115.50 ± 53.57; P < 0.05, each). EFV and PFV in hypertensive men with MI (94.14 ± 43.16 and 224.26 ± 100.79) were significantly higher than in hypertensive men with no MI (73.57 ± 23.27 and 175.26 ± 63.07; P < 0.05, each). There were no significant differences in age, BMI or heart rate between the groups.

Conclusion: 3D-Dixon measurements revealed significantly higher *epi*- and pericardial fat volumes in hypertensive men with myocardial infarction compared to hypertensive men without MI. This finding underscores the role of cardiac fatty tissue as a proinflammatory and metabolically active organ. Non-invasive CMR-based whole volume measurement of *epi*- and pericardial fat may play a relevant future role in cardiovascular risk stratification and disease management.

1. Introduction

Recently, a cardiac magnetic resonance (CMR) method using a three-dimensional ECG- and respiratory navigator gated magnetization prepared modified Dixon-sequence (3D-Dixon) was introduced and validated [1]. It allows for an accurate volumetric quantification of pericardial fat (which refers to the whole mediastinal fat around the heart including epicardial fat) and epicardial fat (which is located around the heart, covered by the pericardium). Its assessment has gained an increased interest in the last years and associations with cardiovascular risk and disease have been described. Unfavorable metabolically and proinflammatory activities are ascribed to this tissue [2,3].

Its utility for the detection and quantification of these fat volumes in patients with increased cardiovascular risk, such as hypertension, has not been investigated yet. Previous studies based

* Corresponding author. Tel.: +49 228 28715960.
E-mail address: homsi@uni-bonn.de (R. Homsi).

http://dx.doi.org/10.1016/j.ejrad.2016.02.016
0720-048X/

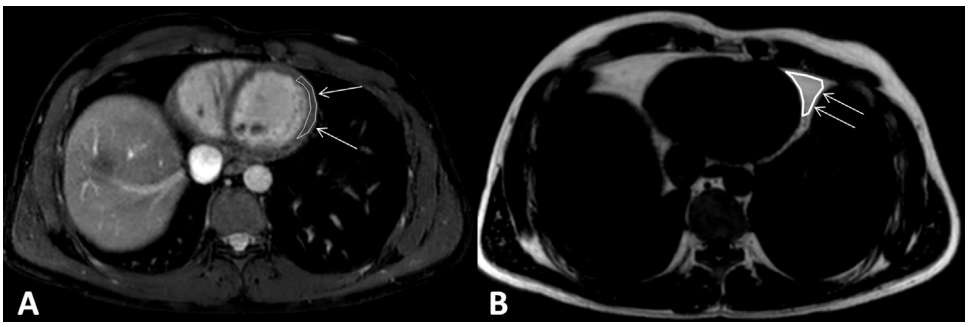

Fig. 1. Determination of an appropriate threshold (thres) [1]: for the segmentation of fat volumes based on the fat fraction map (FF = F/F + W) an appropriate threshold accounting for relaxation effects is determined by drawing two ROIs, one in pure fat (A), one in myocard (B) yielding the signal intensities Sfat and Smyo. The threshold for identification of voxels predominantely containing fat is then set to FFthres = Sfat/(Smyo + Sfat).

Table 1
Baseline patient characteristics (n = 55).

Myocardial infarction	22 (40%)
No myocardial infarction	33 (60%)
Coronary artery disease	15 (27.3%)
1-Vessel disease	6 (10.9%)
2-Vessel disease	6 (10.9%)
3-Vessel disease	3 (5.5%)
Medication	
Beta-inhibitors	37 (67.3%)
Antiplatelet drugs (acetylsalicylic acid)	37 (67.3%)
Statins	38 (69.1)
Calcium-channel inhibitors	14 (25.5%)
Angiotensive-converting-enzyme inhibitors	43 (78.2%)
Creatinine [mg/dl]	1.06±0.33
Cholesterine [mg/dl]	175.31±69.20
Low-density lipoprotein [mg/dl]	100.33±34.67
High-density lipoprotein [mg/dl]	55.85±25.49
Triglyceride [mg/dl]	186.79±71.72

on computed tomography (CT) and transthoracic echocardiography (TTE) reported a relationship with the presence of hypertension [4,5], which is one of the most important risk factors for adverse cardiovascular outcomes such as myocardial infarction [6]. However, studies trying to link coronary artery disease in general to the amount of *epi*- or pericardial fat yield equivocal results [7–9].

So the purpose of our study was first, to quantify total *epi*- and pericardial fat volumes (EFV and PFV) using 3D-Dixon MRI in hypertensive men and to compare the volumes to a healthy control group and second, to relate the amount of fat volumes to the presence of coronary artery disease (CAD) and myocardial infarction (MI).

2. Materials and methods

Our Institutional Review Board (equivalent to the European Medical Ethical committee in some countries), approved the protocol for this prospective observational study. All scans were performed on a 1.5 Tesla (T) MR system (Ingenia 1.5T, Philips Healthcare, Best, The Netherlands) with a maximum gradient strength of 45 mT/m and a maximum slew rate of 120 mT/m/ms. A 32 channel torso coil with digital interface was used for signal reception.

2.1. Study population

Hypertensive men (n = 55) and a gender and age matched healthy control group (n = 10) were recruited for this study. Hypertensive men were referred to the Department of Radiology for clinically indicated CMR evaluation. According to clinical history and CMR findings hypertensive men consisted of patients with MI (n = 22) and patients without MI (n = 33). Hypertensive men without MI consisted of patients with CAD (n = 15) and patients without CAD (n = 18). Exclusion criteria included general contraindications for CMR (e.g., pacemaker, claustrophobia) and arrhythmias, such as atrial fibrillation. Written informed consent was obtained from all study subjects prior to CMR.

2.2. MRI imaging

2.2.1. Functional imaging and late gadolinium enhancement

ECG-gated SSFP-cine images were obtained in breath-hold in the horizontal long axis (HLA), the vertical long axis (VLA), left ventricular outflow tract (LVOT), and short axis (SA) for assessment of wall motion and functional analysis. For detection of myocardial infarction late gadolinium enhancement (LGE) was assessed using a 3D-segmented inversion-recovery gradient-echo sequence in SA, VLA, and HLA orientation [10].

2.2.2. Dixon water/fat imaging:

For assessment of *epi*- and pericardial fat volumes, a 3D transversal (transaxial) ECG- and respiratory navigator gated magnetization prepared mDixon-sequence (modified Dixon-sequence) was acquired [1,11,12]. The "gate and track" option of the scanner software was used, i.e., navigator gating was combined with prospective motion correction [13]. The following sequence parameters were used: FOV = $350 \times 302 \times 180\,mm^3$; voxel size = $1.5 \times 1.5 \times 3.0\,mm^3$ (120 overcontiguous slices), reconstructed voxel size = $1.0 \times 1.0 \times 1.5\,mm^3$, TR = 5.4 ms, TE_1/TE_2 = 1.8 ms/4.0 ms; $\alpha = 20^\circ$, parallel imaging factor (SENSE) = 1.5 in both phase encoding directions, water fat shift = 0.16 pixel, arrhythmia rejection was applied, T2 preparation = 50 ms. Trigger delay was set to end-diastole and the acquisition window was 100–156 ms (selected based on cine MRI data). Net scan duration was 3–5 min. With an assumed navigator efficiency of 40–50%, the average total scan duration time was about 7.5 min. In-phase (IP), opposed-phase (OP), water only (W), and fat only (F) images were reconstructed online at the scanner console [12].

2.3. Image analysis

Measurements were performed by an investigator with more than 5 years of experience in CMR. Left ventricular end systolic and end diastolic volume (LVESV and LVEDV), left ventricular function (LVEF), interventricular septal diameter (IVSD) and the presence of myocardial infarction (ischemic LGE-pattern) were determined offline using dedicated software (ViewForum, Philips Healthcare).

Dixon Image analysis was performed offline using in-house software written in MATLAB (The MathWorks, Inc., Natick, MA) as previously described [1]. Briefly, *epi*- and pericardial fat volumes