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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

The relationship between location-specific epicardial adipose tissue volume and coronary atherosclerotic plaque burden in type 2 diabetic patients

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Abstract

Background and aim: Epicardial adipose tissue (EAT) is a metabolically active visceral fat depot that plays an important role in the pathogenesis of coronary atherosclerosis. Due to its asymmetrical distribution, the relation between location-specific EAT measurements and coronary atherosclerosis remains unclear. Our study investigated the relationship between location-specific EAT volume and coronary atherosclerotic plaque burden that was detected by coronary computed tomography angiography (CCTA) in type 2 diabetic patients without coronary artery disease (CAD) history.

Methods: A total of 157 consecutive diabetic patients who had undergone CCTA were included retrospectively. After evaluation of the CCTA images, the study population was divided into two groups according to the presence of coronary atherosclerosis. In both groups, total and left atrioventricular groove EAT volumes were measured.

Results: Total and left atrioventricular groove EAT volumes were significantly associated with coronary atherosclerosis, but only left atrioventricular groove EAT volumes were an independent predictor for CAD. Also, total and left atrioventricular groove EAT volumes were positively correlated with C-reactive protein values ($p = 0.0001$/$p = 0.0001$) and the number of coronary atherosclerotic segments ($p = 0.0001$/$p = 0.0001$).

Conclusions: Left atrioventricular groove EAT volume is an independent predictor of CAD in type 2 diabetic patients without CAD history. Left atrioventricular groove EAT volume may be used to identify type 2 diabetic patients who may require early CAD intervention because of the potential risk of coronary atherosclerosis.

Key words: epicardial adipose tissue, coronary artery disease, type 2 diabetes mellitus

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INTRODUCTION

Type 2 diabetes mellitus (DM) is an important risk factor for cardiovascular disease (CVD). New biomarkers and diagnostic strategies are required for the early detection of cardiovascular disease in patients with DM.

Epicardial adipose tissue (EAT) is defined as the adipose tissue between the myocardium and the visceral layer of the pericardium. It has been suggested that excessive EAT deposit plays a major role in the development of coronary artery atherosclerosis through paracrine or endocrine mechanism by exerting inflammatory mediators such as tumour necrosis factor-alpha, interleukin-6, adipocytokines, and leptin.

Epicardial adipose tissue can be measured noninvasively by echocardiography, cardiac magnetic resonance imaging (MRI), or multidetector computed tomography (MDCT). MDCT can provide more accurate measurements than other techniques because of its high temporal resolution [1], and MDCT measurements are reproducible [2, 3]. It has also been shown that MDCT volumetric measurements are more reliable than echocardiographic thickness measurements [4].

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Recent studies give importance to location-specific EAT measurement at the left atrioventricular (AV) groove as a potentially new biomarker associated with cardiometabolic risks by using MDCT or MRI measurement. In this study, we aimed to evaluate the relation between location-specific EAT volume and coronary atherosclerotic plaque burden, which may serve as a reliable predictor and improve coronary artery disease (CAD) risk stratification in the future.

METHODS

Patient selection

This single-centre retrospective and cross-sectional study was carried out at a tertiary heart care centre. A total of 157 consecutive patients with type 2 DM, who underwent coronary computed tomography angiography (CCTA) between 2012 and 2014 were included. Atypical chest pain, 15–50% pre-test probability ratio according to Bayesian approach, inconclusive or uninterpretable stress test results, evaluation for CAD before non-coronary cardiac surgery, and suspected coronary anomalies were the indications for CCTA.

The exclusion criteria were: previous diagnosis of CAD, coronary revascularisation procedures, heart failure, valvular heart disease, aortic aneurysms, peripheral arterial atherosclerosis, type 1 DM, renal dysfunction, hepatitis B or C infection, other known liver diseases, haemolytic disorders, acute/chronic inflammatory conditions, neoplastic diseases, metformin use within the previous week, and missing laboratory parameters or uninterpretable CCTA results.

After evaluation of the CCTA images, the study population was divided into two groups (a CAD group and a non-CAD group) according to presence of coronary atherosclerosis. Demographic information and cardiovascular risk factors (age, family history, smoking habits, hyperlipidaemia, hypertension, and DM) were obtained after a systematic review of the patients' hospital records. Missing variables were obtained by telephone interviews with the patients and/or their relatives. Verbal and written informed consent was obtained from each study participant and the study protocol was approved by the Local Ethics Committee.

Definitions

The patients provided data on their daily smoking habits. Past smokers were included in the smoker category. Hypertension was defined as systolic arterial pressure exceeded 140 mm Hg and/or diastolic arterial pressure exceeded 90 mm Hg, or the patient was using antihypertensive drugs [5]. DM was defined as fasting glucose levels exceeded 126 mg/dL or the patient used prescribed glucose-lowering agents [6]. Hyperlipidaemia was defined as total serum cholesterol levels greater than 240 mg/dL, low-density lipoprotein (LDL) cholesterol more than 130 mg/dL, or serum triglycerides exceeding 180 mg/dL, or if the patient used lipid lowering agents [7].

CCTA

Coronary computed tomography angiography was performed using a dual-source CT system (Definition Flash; Siemens Medical Solution, Forchheim, Germany) with 280 ms of rotation time, 2 × 128 slices, a pitch of 3.4, and a 60% R-R interval. The tube current for the protocol was set at 180–300 mAs and 0.6 mm slice collimation was used. Non-ionic contrast reagent (Iomeron 400 mgI/mL; Bracco, Milan, Italy) was administered at a rate of 5 mL/s (80–100 mL total) through an 18-G needle positioned in the antecubital vein using a dual-head power injector. Images were obtained during a single six-second interval in which the patients held their breath using the bolus tracking technique.

Image analysis

Two experienced radiologists, blinded to the clinical data of the patients, analysed the scans on a three-dimensional (3D) workstation (Syngo; Siemens Healthcare, Erlangen, Germany); a consensus diagnosis was achieved using MDCT. The radiologists analysed the characteristics of the stenosis and the number of coronary plaques/segments on the basis of the modified American Heart Association classification [8]. Plaques were defined as 1-mm^2 structures within or adjacent to a vessel lumen that could be clearly distinguished from the lumen and the surrounding pericardial tissue. The plaque burden was calculated as the sum of the atherosclerotic segments (one point for each) in the coronary arteries, which were divided into 15 segments [8].

Adipose tissue between the surface of the myocardium and visceral pericardium was defined as EAT. EAT was quantified by manually tracing the pericardium on 10 to 18 axial CCTA sections. Manual quantification of EAT was performed according to the CCTA data set by volumetric software (Syngo via; Siemens Healthcare, Forchheim, Germany). To obtain total EAT volume, starting from the right pulmonary artery mid-level to cardiac apex, by using 0.75 mm thickness of axial sections, external cardiac borders were drawn manually for every 16 sections (Fig. 1). For left AV groove EAT volume, borders were drawn manually from the left main coronary artery ostium level to the end of the left ventricule basis (Fig. 2). The number of slices had to be traced manually, ranging from five to nine in each patient. The computer software then automatically interpolated and traced the epicardium in all the slices interposed between the manually traced slices. EAT was semi-automatically reconstructed by software into a 3D region of interest, which was controlled visually and was adjusted manually, if deemed necessary. Within this region of interest delineated by the pericardium, contiguous 3D voxels between limits of −250 HU and −30 HU were defined as fat voxels. This resulted in a measurement of left AV groove EAT in cubic centimetres (cm^3).

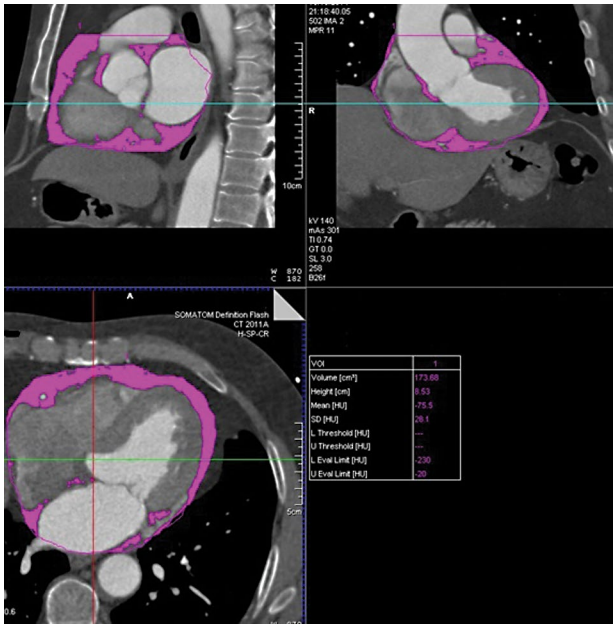

Figure 1. Computed tomography slice shows how the total epicardial adipose tissue volume was measured in sagittal, coronal, and axial views, and the table shows the numeric values

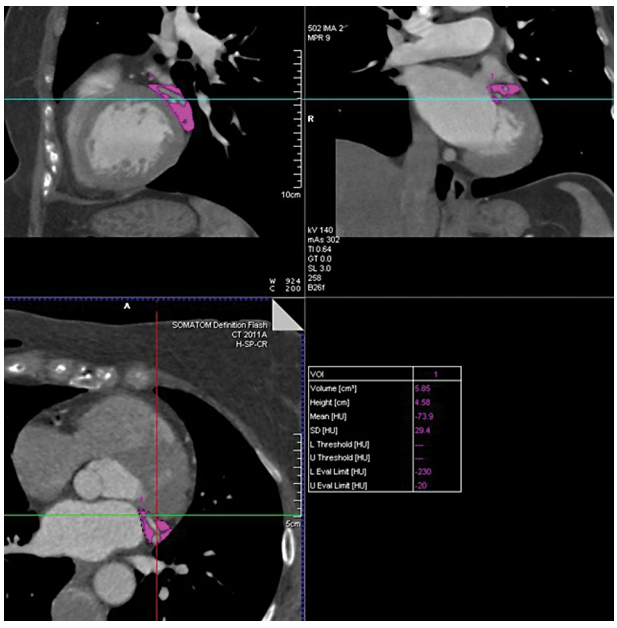

Figure 2. Computed tomography slice shows how the left atrioventricular groove epicardial adipose tissue volume was measured in sagittal, coronal, and axial views, and the table shows the numeric values

Laboratory analyses

All laboratory values were obtained retrospectively from patients' hospital records. After they had undergone a 12-h fast, venous blood samples were drawn from the patients to determine levels of haemoglobin A1c (HbA1c), C-reactive protein (CRP), serum creatinine, and glucose (Cobas C501 Autoanalyzer; Roche Diagnostics, Mannheim, Germany). An Abbott Aeroset Autoanalyzer (Abbott Laboratories, Abbott Park, Illinois, USA) was used to measure triglycerides, high-density lipoprotein (HDL), and total cholesterol in blood serum samples. The Friedewald equation was used to calculate LDL levels.

Statistical analysis

Descriptive statistics were expressed as numbers (%) for categorical variables and as means ± standard deviation for numerical variables. The normal distribution of continuous variables was checked using the Kolmogorov-Smirnov test. The differences between the patients and controls were evaluated using two-sample t-tests and the Mann-Whitney U-test, as appropriate. An χ^2-test was used to compare independent categorical variables. The relationships between the numerical variables were identified using Spearman correlation tests, and a receiver operator characteristic (ROC) curve analysis was carried out to determine the total and left AV groove EAT cutoff values for the diagnosis of coronary atherosclerosis. In addition, stepwise multivariate logistic regression analyses, which included variables with p-values less than 0.10 in the univariate analysis, were carried out to identify the independent predictors of coronary atherosclerosis; a p-value less than 0.05 was considered significant. The Spearman correlation test was used to assess the inter- and intra-observer variability. Data was analysed using the Statistical Package for the Social Sciences, version 16.0 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

The present study included 101 patients (mean age, 56.68 ± 8.26 years; 50.5% men) with coronary atherosclerosis and 56 patients with normal coronary arteries (mean age, 52.29 ± 7.62 years; 28.57% men). The mean duration of DM history of the study population was 7.4 ± 5.8 years. 106 patients used oral antidiabetic drugs and 51 patients were on insulin therapy. The baseline demographics and clinical and laboratory characteristics of the study groups are summarised in Table 1. When compared with the non-CAD group, the CAD group included older ($p = 0.001$), smoking ($p = 0.027$), male ($p = 0.008$) patients than the non-CAD group.

An evaluation of the biochemical parameters showed that, compared with the non-CAD group, the plasma creatinine ($p = 0.008$), CRP ($p = 0.0001$), glucose ($p = 0.022$), and HbA1c ($p = 0.021$) levels were significantly higher in the CAD group. The total cholesterol ($p = 0.031$), LDL ($p = 0.005$) and triglyceride ($p = 0.009$) levels were also higher in the CAD group than in the non-CAD group, and HDL levels were significantly lower in the CAD group ($p = 0.001$).

Table 1. Baseline demographic, clinical, and laboratory characteristics of the study groups

	Non-CAD (n = 56)	CAD (n = 101)	p
Age [years]	52.2 ± 7.6	56.6 ± 8.2	0.001
Sex: female/male	71.4%/28.5%	49.5%/50.5%	0.008
Hypertension	69.6%	68.3%	0.864
Smoker	41.0%	59.4%	0.027
Glucose [mg/dL]	150.8 ± 38.6	174 ± 68.6	0.022
HbA1c [%]	7.2 ± 1.1	7.7 ± 1.4	0.021
Creatinine [mg/dL]	0.6 ± 0.1	0.7 ± 0.2	0.008
Total cholesterol [mg/dL]	178.8 ± 46.3	194.8 ± 42.8	0.031
LDL [mg/dL]	100.7 ± 38.9	118.6 ± 37.1	0.005
HDL [mg/dL]	50.2 ± 12.1	41.8 ± 7.2	0.0001
Triglyceride [mg/dL]	143 ± 64.9	186.7 ± 113.4	0.009
CRP [mg/L]	1.1 ± 0.3	1.8 ± 0.8	0.0001
Total EAT volume [mL]	95.8 ± 27.3	131.3 ± 53.6	0.0001
Left AV groove EAT volume [mL]	4.8 ± 2	6.9 ± 3.1	0.0001

Data are presented as percentage or mean ± standard deviation. AV — atrioventricular; CAD — coronary artery disease; CRP — C-reactive protein; EAT — epicardial adipose tissue; HbA1c — haemoglobin A1c; HDL — high-density lipoprotein; LDL — low-density lipoprotein

Table 2. Univariate regression analysis for predictors of coronary atherosclerosis

	Univariate analysis		
	p	OR	95% CI
Age	0.002	1.071	1.026–1.119
Sex	0.009	0.392	0.195–0.789
Hypertension	0.894	1.064	0.525–2.158
Smoker	0.029	0.476	0.245–0.925
HbA1c	0.025	1.393	1.043–1.860
Creatinine	0.011	11.66	1.775–76.586
Total cholesterol	0.033	1.009	1.001–1.017
CRP	0.0001	6.126	2.915–12.874
Total EAT volume	0.0001	1.024	1.012–1.036
Left AV groove EAT volume	0.0001	1.462	1.219–1.753

CI — confidence interval; OR — odds ratio; other abbreviations as in Table 1

After evaluation of EAT volumes, both total EAT (131.36 ± 53.66/95.84 ± 27.38, p = 0.0001) and left AV groove EAT (6.9 ± 3.18/4.85 ± 2.03, p = 0001) volumes were found to be significantly higher in the CAD group.

In a univariate regression analysis age, male sex, smoking, CRP, total cholesterol, creatinine, HbA1c, and total and left AV groove EAT volumes were associated significantly with coronary atherosclerosis (Table 2).

According to the multivariate regression analysis (Tables 3, 4), left AV groove EAT volumes (p = 0.041; OR: 1.263; 95% CI 1.009–1.581) were significant independent predictors of coronary atherosclerosis after adjusting for other risk factors in patients with type 2 DM, but total EAT volumes were not. Also age, male sex, CRP, and HbA1c were found to be significant independent predictors of coronary atherosclerosis.

To investigate the predictive value of left AV groove EAT volumes for coronary atherosclerosis in patients with DM, an ROC curve was generated for sensitivity and specificity using the respective areas under the curve (Fig. 3). The analysis indicated that left AV groove EAT volumes of more than 5.74 mL had a 60.4% sensitivity and a 76.79% specificity for predicting coronary atherosclerosis in the DM patients (area under the curve: 0.718; 95% CI 0.641–0.787);

Table 3. Multivariate regression analysis for independent predictors of coronary atherosclerosis including total epicardial adipose tissue volumes

	Multivariate analysis		
	p	OR	95% CI
Age	0.022	1.064	1.009–1.122
Sex	0.025	0.335	0.129–0.870
Smoker	0.504	0.745	0.315–1.765
HbA1c	0.034	1.509	1.032–2.206
Creatinine	0.528	2.003	0.231–17.338
Total cholesterol	0.354	1.005	0.995–1.015
CRP	0.002	3.875	1.668–9.002
Total EAT volume	0.075	1.013	0.999–1.027

CI — confidence interval; OR — odds ratio; other abbreviations as in Table 1

Table 4. Multivariate regression analysis for independent predictors of coronary atherosclerosis including left atrioventricular groove epicardial adipose tissue volumes

	Multivariate		
	p	OR	95% CI
Age	0.024	1.063	1.008–1.121
Sex	0.025	0.336	0.129–0.873
Smoker	0.517	0.753	0.319–1.777
HbA1c	0.035	1.506	1.030–2.203
Creatinine	0.468	2.255	0.250–20.313
Total cholesterol	0.223	1.006	0.996–1.170
CRP	0.001	3.955	1.735–9.018
Left AV groove EAT volume	0.041	1.263	1.009–1.581

CI — confidence interval; OR — odds ratio; other abbreviations as in Table 1

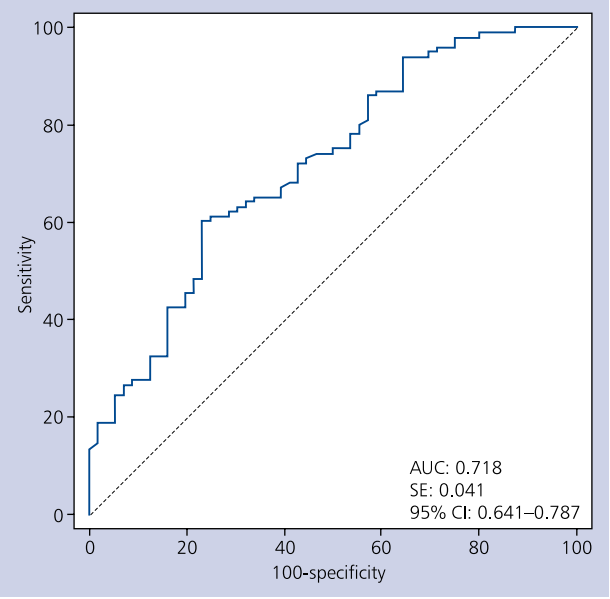

Figure 3. Receiver operator characteristic curve for left atrioventricular groove epicardial adipose tissue volumes; AUC — area under curve; CI — confidence interval; SE — standard error

its positive and negative predictive values were 82.4% and 51.8%, respectively.

In the Spearman-Pearson correlation analysis, both total and left AV groove EAT volumes were correlated positively with CRP and the number of coronary atherosclerotic segments (Table 5), and the inter- and intra-observer variability showed high agreement (Table 6).

DISCUSSION

The main findings of our study were:

— left AV groove EAT volumes were significant independent predictors of coronary atherosclerotic burden in patients with type 2 DM without CAD history. Left AV groove EAT volumes of more than 5.74 mL had a 60.4% sensitivity and a 76.79% specificity for predicting coronary atherosclerosis;

— additionally, age, male sex, HbA1c, and CRP were significant independent predictors of coronary atherosclerotic burden for our study population;

— total and left AV groove EAT volumes correlated with coronary atherosclerotic plaque burden.

Many risk factors play an important role in the development and the progression of atherosclerosis. EAT, which is the

Table 5. Correlation analysis between epicardial adipose tissue volumes and other variables

	Total EAT volume	Left AV groove EAT volume
Age		
r	0.155	0.112
p	0.052	0.161
HbA1c		
r	0.094	0.133
p	0.242	0.097
Creatinine		
r	0.157	0.109
p	0.05	0.174
Total cholesterol		
r	0.129	0.105
p	0.107	0.19
LDL		
r	0.085	0.069
p	0.29	0.389
HDL		
r	–0.112	–0.092
p	0.161	0.254
Triglyceride		
r	0.145	0.121
p	0.07	0.13
CRP		
r	0.563	0.539
p	0.0001	0.0001
CA segment number		
r	0.368	0.334
p	0.0001	0.0001

CA — coronary atherosclerotic; other abbreviations as in Table 1

Table 6. Correlation analysis for intra- and inter-observer variability

	Intra--observer	Inter--observer
Total EAT volume		
r	0.96	0.95
p	0.0001	0.0001
Left AV groove EAT volume		
r	0.96	0.94
p	0.0001	0.0001

Abbreviations as in Table 1

equivalent of the visceral adipose tissue, is like an endocrine and inflammatory organ, which locally effects the cardiac morphology and function via secreting proatherogen and proinflammatory cytokines.

First, Iacobellis et al. [9] showed the correlation between excessive EAT amount and metabolic syndrome parameters. Then it was proven that EAT thickness measured by echocardiography is correlated with CAD detected by conventional angiography [10–12]. But the major limitations of these studies were different EAT measurement techniques and low resolution of echocardiography. Not only atherosclerosis but also ventricular premature beats are found to be related to EAT due to its effect on cardiac morphology and function [13].

Nowadays MDCT is preferred to echocardiography because volumetric EAT measurement by MDCT is found to be more reliable than echocardiographic thickness measurement [4]. Previous studies showed a strong correlation between EAT volume measured by MDCT and cardiometabolic risk factors [14], coronary calcium score [15], and CAD [16–18]. In a study by Konishi et al. [19], 171 patients' EAT volumes measured by 64 MDCT showed that EAT volumes were higher in patients who had obstructive or non-obstructive CAD than non-CAD patients. Also, this study showed a stronger relation between EAT and early CAD than anthropometric measurements [19]. A similar study designed by Sarin et al. [17] reported strong correlation between EAT volume, measured by MDCT, and CAD [18]. In the studies, which were carried out by MDCT [20], it was found that there was a strong relationship between EAT mass and the CAD severity. Mazurek et al. [21] showed the correlation between EAT and the plaque burden and plaque type in acute coronary syndrome without persistent ST-segment elevation patients. In our study we investigated coronary atherosclerotic plaque burden, not severity, and we found significant correlation between both total and left AV groove EAT volumes and coronary atherosclerotic plaque burden.

Due to asymmetrical distribution of EAT, many different studies investigated which location of EAT is more capable to predict metabolic syndrome and CAD. Chung et al. [22] found that EAT volume measured by MDCT at the level of the left main coronary artery was the most reliable location, which was related to metabolic syndrome. Eventhough Wang et al. [23] measured the thickest EAT at the right AV groove, they found that left AV groove EAT measurements were significantly related with CAD and metabolic syndrome [24]. In our study we also found that left AV groove EAT volumes were significant independent predictors of coronary atherosclerosis. There are several possible explanations to define the correlation between the left AV groove EAT volume and coronary atherosclerosis [23].

First, it was proven that by direct diffusion of its bioactive molecules into the intima–media layer of the vessel wall, perivas-

cular fat tissue plays an important role in the development of atherogenesis. According to this, EAT's location-specific metabolic activity differences can be a reasonable cause, but this hypothesis has not been proven yet. Second, coronary veins are also surrounded by EAT, like coronary arteries. Therefore, thin-walled veins may generate greater systemic effects by direct diffusion of metabolically active molecules to blood circulation. There is no coronary vein in the right AV groove. The great cardiac vein occupies the left AV groove. Third, several studies have shown that there is a relationship between the amount of EAT and cardiometabolic risk factors and intra-abdominal obesity [2, 14, 25]. Wang et al. [24] showed that a relationship between the left AV groove EAT amount and cardiometabolic risk [24]. According to this, EAT may be considered as a predictor of atherogenic risk. Therefore, it may reflect atherogenic risk and indirectly be related to the development of coronary atherosclerosis.

Limitations of the study

Our study has some limitations. First, this study was designed retrospectively and involved a single centre and a small study population. Second, follow-up data describing future cardiovascular events is absent. Third, our study evaluated coronary atherosclerotic plaque burden, not plaque type or severity.

CONCLUSIONS

In our study, left AV groove EAT volumes were significant independent predictors of coronary atherosclerotic burden in patients with type 2 DM without CAD history. Additionally, age, male sex, HbA1c, and CRP were found to be significant independent predictors for our study population. Although total EAT volume is related to coronary atherosclerosis, it is not an independent predictor. Total and left AV groove EAT volumes were correlated with coronary atherosclerotic plaque burden. Left AV groove EAT volume may help to identify early CAD intervention requirement because of the potential risk of coronary atherosclerosis in type 2 DM patients.

Conflict of interest: *none declared*

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Związek między objętością tkanki tłuszczowej o określonej lokalizacji a nasileniem zmian miażdżycowych w tętnicach wieńcowych u chorych na cukrzycę typu 2

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Streszczenie

Wstęp i cel: Nasierdziowa tkanka tłuszczowa (EAT) to metabolicznie aktywny magazyn tkanki tłuszczowej trzewnej odgrywający istotną rolę w patogenezie miażdżycy tętnic wieńcowych. Ze względu na niesymetryczne rozmieszczenie EAT korelacje między pomiarami jej grubości a chorobą wieńcową pozostają niejasne. W niniejszym badaniu oceniono zależność między objętością EAT o określonej lokalizacji a nasileniem zmian miażdżycowych w angiografii metodą tomografii komputerowej tętnic wieńcowych (CCTA) u pacjentów z cukrzycą typu 2 bez choroby wieńcowej (CAD) w wywiadzie.

Metody: Do badania włączono retrospektywnie 157 kolejnych chorych na cukrzycę poddanych CCTA. Po ocenie obrazów uzyskanych w CCTA uczestników badania podzielono na dwie grupy w zależności od występowania zmian miażdżycowych w tętnicach wieńcowych. W obu grupach zmierzono objętość EAT, zarówno całkowitą, jak i objętość tkanki tłuszczowej w bruździe przedsionkowo-komorowej lewej.

Wyniki: Objętość całkowita EAT i objętość EAT w bruździe przedsionkowo-komorowej lewej były istotnie związane z miażdżycą tętnic wieńcowych, ale tylko objętość EAT w bruździe przedsionkowo-komorowej lewej była niezależnym czynnikiem predykcyjnym CAD. Ponadto stwierdzono dodatnią korelację między obiema powyższymi objętościami EAT a stężeniem białka C-reaktywnego ($p = 0{,}0001/p = 0{,}0001$) i liczbą odcinków tętnic wieńcowych zmienionych miażdżycowo ($p = 0{,}0001/p = 0{,}0001$).

Wnioski: Objętość EAT w bruździe przedsionkowo-komorowej lewej jest niezależnym czynnikiem predykcyjnym CAD u pacjentów z cukrzycą typu 2 bez CAD w wywiadzie. Pomiar objętości EAT w bruździe przedsionkowo-komorowej lewej może być stosowany w celu identyfikacji chorych na cukrzycę typu 2 wymagających wczesnego wdrożenia prewencji CAD ze względu na ryzyko miażdżycy tętnic wieńcowych.

Słowa kluczowe: nasierdziowa tkanka tłuszczowa, choroba wieńcowa, cukrzyca typu 2

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