Original Article

Relationship between different clinical characteristics and pericoronary adipose tissue attenuation values quantified from coronary computed tomographic angiography (CCTA) in patients without coronary heart disease (CHD)

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Background: Pericoronary adipose tissue (PCAT) is a sensor of vascular inflammation. Elevated PCAT attenuation values indicate the presence of coronary inflammation in patients. However, it is unclear which clinical characteristics are associated with increased PCAT attenuation values in patients without coronary heart disease (CHD). The study aims to investigate the relationship between increased PCAT attenuation values and clinical characteristics of patients without CHD.

Methods: We recruited 785 eligible patients without CHD who underwent coronary computed tomographic angiography (CCTA). Clinical data were recorded for each patient, and PCAT attenuation values for the left anterior descending branch (LAD_{PCAT}), left circumflex branch (LCX_{PCAT}), and right coronary artery (RCA_{PCAT}) were quantified by CCTA using fully automated software. Univariate and multivariate analyses were performed to identify the associations between different clinical characteristics and elevated LAD_{PCAT}, LCX_{PCAT}, and RCA_{PCAT}.

Results: Univariate analysis showed body mass index (BMI) to be positively associated with LAD_{PCAT} (rs=0.109), LCX_{PCAT} (rs=0.076), and RCA_{PCAT} (rs=0.083). Moreover, the duration of smoking, and drinking was positively associated with LAD_{PCAT} (rs=0.099, 0.165). Hyperlipidemia was positively associated with LAD_{PCAT} (rs=0.089) and RCA_{PCAT} (rs=0.334), while statin use was negatively associated with RCA_{PCAT} (rs=−0.145). Multivariate analysis showed that the significant determinants of LAD_{PCAT} were BMI (β=0.359, P=0.001), duration of smoking (β=2.612, P=0.002), drinking (β=4.106, P<0.001), and hyperlipidemia (β=1.664, P=0.027). LCX_{PCAT} was associated with BMI (β=0.218, P=0.024), while RCA_{PCAT} was associated with hyperlipidemia (β=6.110, P<0.001) and statin use (β=−3.338, P<0.001).

Conclusions: In patients without CHD, the PCAT attenuation values measured using CCTA were associated with various clinical characteristics. LAD_{PCAT} was associated with BMI, smoking duration, drinking, and hyperlipidemia. On the other hand, LCX_{PCAT} was associated with BMI, while RCA_{PCAT} was associated with hyperlipidemia and statin use.

Keywords: Pericoronary adipose tissue (PCAT); coronary heart disease (CHD); coronary computed tomographic angiography (CCTA)

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Introduction

Pericoronary inflammation is closely associated with the development and progression of coronary heart disease (CHD) and the occurrence of acute coronary syndromes (ACS) (1-3). The adipose tissue surrounds the cardiac, especially epicardial adipose tissue (EAT), which is anatomically and physiologically critical for CHD disease (4). The pericoronary adipose tissue (PCAT) is not only part of the EAT but also a metabolically active endocrine organ directly surrounding the coronary arteries, which has been found to have an essential role in regulating cardiovascular homeostasis and be associated with CHD (5-7). In addition, previous studies have also identified a significant association between EAT density, but not its volume, and mean PCAT attenuation values in patients with CAD and without CAD (8). The cardiovascular system has a reciprocal interaction between PCAT and vascular inflammation. Not only can PCAT release pro-inflammatory mediators, but inflamed vessels can also release inflammatory signals to induce PCAT breakdown and inhibit its formation, leading to pericoronary edema (9-11).

Recent landmark studies of PCAT attenuation have demonstrated that PCAT attenuation can not only detect biopsy-proven vascular inflammation (9) but can also be used as a noninvasive biomarker of vascular inflammation to assess CHD (12), adverse cardiac events (13), left ventricular function (14), and microvascular complications in patients with diabetes (15). In addition, high PCAT attenuation values detected using coronary computed tomographic angiography (CCTA) are related to endothelial dysfunction (16), oxidized HDL levels (17), cardiovascular events in patients with nonalcoholic fatty liver disease (18), and the recurrence of atrial fibrillation after ablation (19).

However, it is unclear which clinical characteristics are associated with increased PCAT attenuation values in patients without CHD, which is likely to contribute to the development of subsequent CHD. Moreover, few studies have used CCTA to determine the relationship between PCAT and clinical features in patients without CHD. Therefore, we intended to use CCTA to measure PCAT attenuation values to identify high-risk clinical features early and explore the relationship between increased PCAT attenuation values and different clinical features in patients without CHD. We present this article in accordance with the STROBE reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-1814/rc).

Methods

Population collection

The Ethics Committee of the Lanzhou University Second Hospital approved this study (ethical approval No. 2021A-165), and did not require the informed consent due to the nature of retrospective research. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Patients who met the following criteria were included:

(I) Patients without CHD who underwent CCTA examination from July 2020 to July 2022.
(II) Plaques that were not visible on CCTA images, evaluated by two radiologists with 10 years of cardiovascular diagnostic experience.
(III) No history of myocardial infarction, coronary artery malformation, prosthetic valves or pacemakers, myocarditis, or vasculitis.
(IV) Complete clinical and imaging records.
(V) Excellent-quality CCTA images for image evaluation and PCAT calculation.

The detailed screening process for the patients is shown in *Figure 1*. Subsequently, we collected the clinical data of the eligible patients, including age, sex, smoking, and drinking. Smoking history was defined as having smoked for more than 1 year and not quitting for more than 6 months. Drinking history was defined as greater than one alcoholic drink per week of >50 mL.

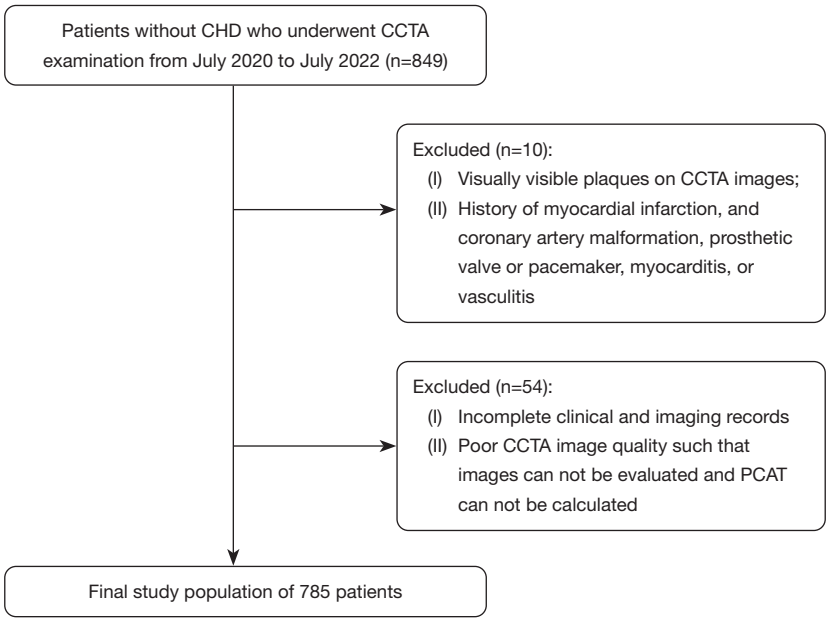

Figure 1 Flowchart of the included study population. CHD, coronary artery disease; CCTA, coronary computed tomography angiography; PCAT, pericoronary adipose tissue.

CCTA examination

The CCTA images were acquired with revolution computed tomography (CT) (General Electric Company, USA) in our institution, which includes all levels from 1 cm below tracheal bifurcation to the bottom of the heart. Before CCTA, blood pressure and heart rate were monitored, respiratory training was performed, and compliance was ensured. For imaging parameters, the following preset values were applied: prospective electrocardiographic gating, tube voltage, 100 KV; tube current, 400–700 mA; field of view, 36 cm; display field of view, 24 cm; matrix, 512×512; ASIR-V, 60%; rotation time, 0.28 s; and slice thickness, 0.625 mm. Each patient was administered 0.9 mL/kg of iopromide (370 mg/mL) at a flow rate of 5.0–5.5 mL/s via the median cubital vein using a high-pressure double-barrel injector (Bayer Health Care, CA, USA), followed by 40 mL normal saline at the same rate.

Fully automated measurement of PCAT attenuation values

Quantitative computation of PCAT attenuation values based on CCTA images was conducted on the Pericoronary Adipose Tissue Analysis software (Shukun Technology Co., Ltd., Shanghai, China) by a radiologist with vast training and 10 years of cardiovascular imaging experience. PCAT attenuation values were measured at 10–40 mm from the beginning of the left anterior descending branch (LAD), 10–40 mm from the beginning of the left circumflex branch (LCX), and 10–50 mm from the right coronary artery (RCA), with the cross-sectional area of the three locations set at three times the diameter of the respective vessel lumen (20). Within this region, a material with CT values of −190 to −30 Hounsfield units (HUs) is considered adipose tissue. Subsequently, the PCAT attenuation values for LAD (LAD_{PCAT}), LCX (LCX_{PCAT}), and RCA (RCA_{PCAT}) were recorded, respectively. *Figure 2* shows the measurement of PCAT attenuation values for the three coronary arteries.

Statistical analysis

Statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 9.0.0 (GraphPad Software Inc., San Diego, CA, USA). Categorical variables are presented as frequency (percentage) and were compared using Fisher's exact or chi-squared test. Continuous variables are presented as mean ± standard deviation or median (interquartile range) according to the results of the Kolmogorov-Smirnov test and were compared using the Wilcoxon Mann-Whitney U test or independent *t*-test. Correlations between the groups were assessed using Pearson's or Spearman's correlation

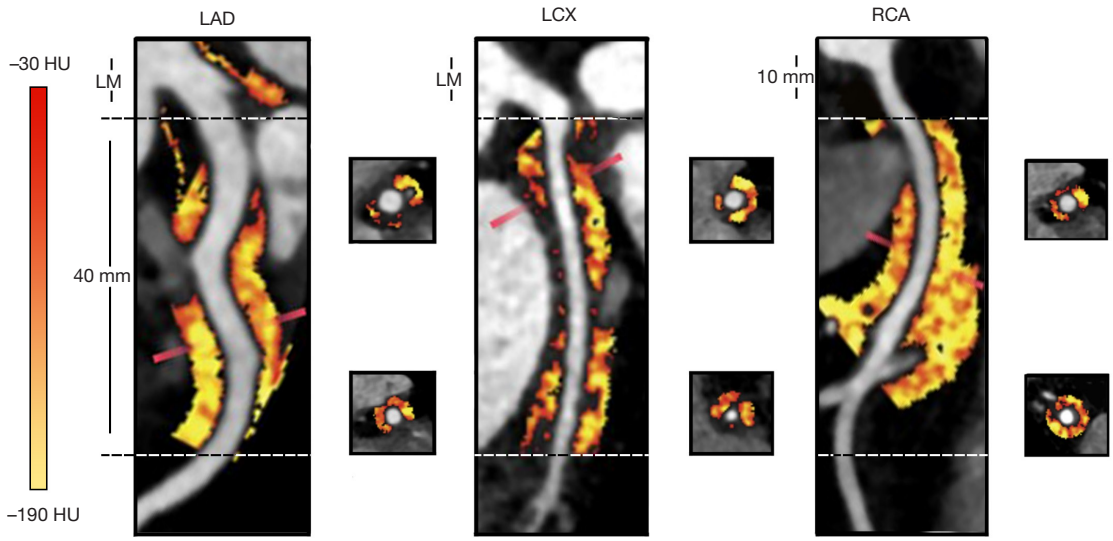

Figure 2 Measurement of PCAT attenuation values on three coronary arteries. HU, Hounsfield unit; LAD, left anterior descending branch; LCX, left circumflex branch; RCA, right coronary artery; LM, left main; PCAT, pericoronary adipose tissue.

Table 1 Patients' baseline characteristics

Characteristics	All (n=785)
Age (years)	55.00 (45.00, 66.00)
Men	361 (46.0)
BMI (kg/m^2)	24.89 (22.07, 27.72)
Current smoking	245 (31.2)
Duration of smoking (years)	0.00 (0.00, 11.50)
Drinking	179 (22.8)
Hypertension	311 (39.6)
Hyperglycaemia	248 (31.6)
Hyperlipidemia	250 (31.8)
Aspirin	76 (9.7)
Beta blockers	94 (12.0)
Alpha blockers	56 (7.1)
ACEI	119 (15.2)
ARB	99 (12.6)
CCB	122 (15.5)
Statins	105 (13.4)
LAD_{PCAT} (HU)	–87.00 (–96.00, –80.00)
LCX_{PCAT} (HU)	–83.00 (–91.00, –77.00)
RCA_{PCAT} (HU)	–87.00 (–94.00, –80.00)

Data are represented as median (interquartile range) or number (%). BMI, body mass index; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; CCB, calcium channel blockers; LAD, left anterior descending branch; PCAT, pericoronary adipose tissue; HU, Hounsfield unit; LCX, left circumflex branch; RCA, right coronary artery.

analysis. In addition, linear regression was used to assess the relationship between PCAT and different clinical characteristics. P values of <0.05 (bilateral) were deemed statistically significant.

Results

Clinical characteristics of all patients

A total of 785 consecutive patients [361 men, 424 women; mean age, 55.00 (45.00, 66.00) years] were retrospectively recruited for our study. LAD_{PCAT}, LCX_{PCAT}, and RCA_{PCAT} values were –87.00 (–96.00, –80.00) HU, –83.00 (–91.00, –77.00) HU, and –87.00 (–94.00, –80.00) HU, respectively. The clinical information of the patients is presented in *Table 1*.

Comparison of PCAT between different clinical characteristics

Among patients without CHD, LAD_{PCAT}, and LCX_{PCAT} values were significantly higher in patients with body mass index (BMI) of ≥24.89 kg/m^2 than in those with BMI of <24.89 kg/m^2 [–87.00 (–95.00, –78.50) *vs.* –89.00 (–97.00, –81.25) HU, P=0.001; –83.00 (–90.00, –76.00) *vs.* –84.00 (–92.00, –78.00) HU, P=0.014], whereas RCA_{PCAT} values showed no such difference between the two groups [–86.00 (–94.00, –79.00) *vs.* –88.00 (–94.00, –80.00) HU, P=0.181] (*Table 2*). Compared with patients without CHD who smoked (<15 years) or did not drink alcohol, higher

Table 2 Comparison of the differences in PCAT between different clinical characteristics

Characteristics	LAD_{PCAT} (HU)		LCX_{PCAT} (HU)		RCA_{PCAT} (HU)	
	Median (IQR)	P value	Median (IQR)	P value	Median (IQR)	P value
Age (years)		0.267		0.873		0.850
≥55	−87.00 (−96.00, −80.00)		−84.00 (−91.00, −78.00)		−87.00 (−95.00, −79.00)	
<55	−89.00 (−96.25, −80.00)		−83.00 (−92.00, −76.00)		−87.00 (−94.00, −80.00)	
Sex		0.776		0.488		0.605
Men	−88.00 (−97.00, −79.00)		−83.00 (−91.00, −77.00)		−87.00 (−94.00, −79.00)	
Women	−87.00 (−95.00, −80.00)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
BMI (kg/m^2)		0.001		0.014		0.181
≥24.89	−87.00 (−95.00, −78.50)		−83.00 (−90.00, −76.00)		−86.00 (−94.00, −79.00)	
<24.89	−89.00 (−97.00, −81.25)		−84.00 (−92.00, −78.00)		−88.00 (−94.00, −80.00)	
Current smoking		0.622		0.800		0.436
Yes	−88.00 (−97.00, −79.00)		−85.00 (−91.00, −77.00)		−86.00 (−94.50, −79.00)	
No	−87.00 (−96.00, −80.00)		−83.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
Duration of smoking (years)		0.006		0.363		0.311
≥15	−85.00 (−94.00, −77.00)		−85.00 (−91.00, −77.00)		−86.00 (−94.00, −79.00)	
<15	−88.00 (−96.00, −81.00)		−83.00 (−91.00, −77.00)		−87.00 (−94.25, −80.00)	
Drinking		<0.001		0.981		0.482
Yes	−84.00 (−91.00, −79.00)		−83.00 (−92.00, −76.00)		−88.00 (−96.00, −79.00)	
No	−89.00 (−97.00, −81.00)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
Hypertension		0.537		0.973		0.058
Yes	−87.00 (−95.00, −80.00)		−83.00 (−91.00, −77.00)		−86.00 (−93.00, −79.00)	
No	−87.50 (−97.00, −80.00)		−84.00 (−91.00, −77.00)		−87.00 (−95.00, −80.00)	
Hyperglycaemia		0.449		0.520		0.774
Yes	−87.00 (−98.00, −79.00)		−85.00 (−91.00, −78.00)		−86.50 (−96.00, −80.00)	
No	−87.00 (−95.00, −80.00)		−83.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
Hyperlipidemia		0.013		0.079		<0.001
Yes	−85.00 (−95.00, −78.00)		−83.00 (−90.00, −76.00)		−82.00 (−88.00, −77.00)	
No	−89.00 (−97.00, −81.00)		−84.00 (−92.00, −77.00)		−89.00 (−97.00, −82.00)	
Aspirin		0.064		0.355		0.105
Yes	−91.00 (−97.00, −81.00)		−82.00 (−90.50, −77.00)		−89.00 (−97.00, −80.00)	
No	−87.00 (−96.00, −79.50)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
Beta blockers		0.717		0.886		0.888
Yes	−87.00 (−93.25, −81.00)		−82.50 (−91.00, −78.00)		−86.00 (−95.25, −79.00)	
No	−88.00 (−97.00, −80.00)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	

Table 2 (*continued*)

Table 2 (*continued*)

Characteristics	LAD_{PCAT} (HU)		LCX_{PCAT} (HU)		RCA_{PCAT} (HU)	
	Median (IQR)	P value	Median (IQR)	P value	Median (IQR)	P value
Alpha blockers		0.972		0.883		0.254
Yes	−87.00 (−94.75, −79.00)		−83.00 (−91.00, −77.75)		−86.50 (−92.00, −78.25)	
No	−87.00 (−96.00, −80.00)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
ACEI		0.367		0.898		0.205
Yes	−87.00 (−95.00, −80.00)		−83.00 (−89.00, −78.00)		−86.00 (−92.00, −79.00)	
No	−88.00 (−96.00, −80.00)		−83.50 (−91.00, −77.00)		−87.00 (−95.00, −80.00)	
ARB		0.079		0.945		0.924
Yes	−86.00 (−95.00, −78.00)		−83.00 (−90.00, −79.00)		−86.00 (−96.00, −80.00)	
No	−88.00 (−96.00, −80.00)		−84.00 (−91.00, −77.00)		−87.00 (−94.00, −80.00)	
CCB		0.483		0.839		0.069
Yes	−86.50 (−95.00, −80.00)		−83.50 (−91.25, −77.00)		−85.00 (−92.00, −78.00)	
No	−88.00 (−96.00, −80.00)		−83.00 (−91.00, −77.00)		−87.00 (−95.00, −80.00)	
Statins		0.398		0.197		<0.001
Yes	−86.00 (−94.50, −79.00)		−84.00 (−92.00, −79.00)		−92.00 (−98.00, −83.00)	
No	−88.00 (−96.00, −80.00)		−83.00 (−91.00, −77.00)		−86.00 (−93.00, −79.00)	

PCAT, pericoronary adipose tissue; LAD, left anterior descending branch; HU, Hounsfield unit; LCX, left circumflex branch; RCA, right coronary artery; IQR, interquartile range; BMI, body mass index; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; CCB, calcium channel blockers.

LAD_{PCAT} values were observed in those who smoked (≥15 years) or drank alcohol [−85.00 (−94.00, −77.00) *vs.* −88.00 (−96.00, −81.00) HU, P=0.006; −84.00 (−91.00, −79.00) *vs.* −89.00 (−97.00, −81.00) HU, P<0.001], while no significant difference was observed in LCX_{PCAT} and RCA_{PCAT} values between the two groups (*Table 2*). In patients without CHD, LAD_{PCAT} and RCA_{PCAT} values were consistently higher in those with hyperlipidemia [−85.00 (−95.00, −78.00) and −82.00 (−88.00, −77.00) HU, respectively] than in those without hyperlipidemia [−89.00 (−97.00, −81.00) and −89.00 (−97.00, −82.00) HU; all P<0.05]. Regarding the different medications used, RCA_{PCAT} values were remarkably lower in patients without CHD taking statins [−92.00 (−98.00, −83.00) HU] than in those not taking this drug [−86.00 (−93.00, −79.00) HU, P<0.001; *Table 2*].

Correlation of different clinical characteristics with PCAT

The results showed that the LAD_{PCAT} values were positively correlated with BMI (rs=0.109, P=0.002), smoking duration (rs=0.099, P=0.006), drinking (rs=0.165, P<0.001), and hyperlipidemia (rs=0.089, P=0.012). LCX_{PCAT} was positively associated with BMI (r=0.076, P=0.032; *Table 3*, *Figure 3*). In addition, RCA_{PCAT} values were positively correlated with BMI (rs=0.083, P=0.019) and hyperlipidemia (rs=0.334, P<0.001) but negatively correlated with statin use (rs=−0.145, P<0.001; *Table 3*, *Figure 3*).

Linear regression model for different clinical characteristics with PCAT

The significant clinical parameters were included in the linear regression model, and the results revealed that the significant determinants of LAD_{PCAT} were BMI [β=0.359 (0.147–0.572), P=0.001], duration of smoking [β=2.612 (0.964–4.260), P=0.002], drinking [β=4.106 (2.472–5.740), P<0.001], and hyperlipidemia [β=1.664 (0.190–3.137), P=0.027; *Table 4*, *Figure 4*]. The linear regression model of LCX_{PCAT} showed that the most significant determinant of LCX_{PCAT} was BMI [β=0.218 (0.029–0.406), P=0.024].

Table 3 Correlation of different clinical characteristics with PCAT

Characteristics	LAD_{PCAT} (HU)	LCX_{PCAT} (HU)	RCA_{PCAT} (HU)
Age (years)			
rs	0.021	0.005	−0.014
P value	0.552	0.898	0.688
Sex			
rs	−0.010	0.025	0.018
P value	0.776	0.488	0.606
BMI (kg/m^2)			
rs	0.109**	0.076*	0.083*
P value	0.002	0.032	0.019
Current smoking			
rs	0.018	−0.009	0.028
P value	0.623	0.800	0.436
Duration of smoking (years)			
rs	0.099**	−0.033	0.036
P value	0.006	0.363	0.311
Drinking			
rs	0.165**	−0.001	−0.025
P value	<0.001	0.981	0.482
Hypertension			
rs	0.022	0.001	0.068
P value	0.537	0.973	0.058
Hyperglycaemia			
rs	−0.027	−0.023	−0.010
P value	0.449	0.520	0.774
Hyperlipidemia			
rs	0.089*	0.063	0.334**
P value	0.012	0.079	<0.001
Aspirin			
rs	−0.066	0.033	−0.058
P value	0.064	0.355	0.105
Beta blockers			
rs	0.013	0.005	0.005
P value	0.717	0.887	0.888
Alpha blockers			
rs	−0.001	−0.005	0.041
P value	0.972	0.884	0.254
ACEI			
rs	0.032	0.005	0.045
P value	0.367	0.898	0.205
ARB			
rs	0.063	−0.002	−0.003
P value	0.079	0.945	0.924
CCB			
rs	0.025	−0.007	0.065
P value	0.484	0.839	0.069
Statins			
rs	0.030	−0.046	−0.145**
P value	0.398	0.197	<0.001

*, the correlation is significant at the 0.05 level (two-tailed); **, the correlation is significant at the 0.01 level (two-tailed). PCAT, pericoronary adipose tissue; LAD, left anterior descending branch; HU, Hounsfield unit; LCX, left circumflex branch; RCA, right coronary artery; BMI, body mass index; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; CCB, calcium channel blockers.

In addition, the critical determinants of RCA_{PCAT} were hyperlipidemia [β=6.110 (4.901–7.319), P<0.001] and statins [β=−3.338 (−4.991 to −1.686), P<0.001]. On the other hand, BMI was not significant in the linear regression model of RCA_{PCAT} (P=0.100; *Table 4*, *Figure 4*).

Discussion

Based on this large-scale clinical study of 785 patients without CHD, we concluded that LAD_{PCAT} was related to BMI, duration of smoking, drinking, and hyperlipidemia. In contrast, LCX_{PCAT} is only related to BMI, while RCA_{PCAT} is associated with hyperlipidemia and statin use.

Among the studies conducted on the relationship between PCAT and the clinic, most studies focused on the correlation between PCAT and ACS or CHD (2,21,22). Clinical risk factors combined with CT-based imaging parameters and PCAT radiomic features in patients with type 2 diabetes showed that this model effectively diagnosed CHD in patients with type 2 diabetes (21). A cross-sectional

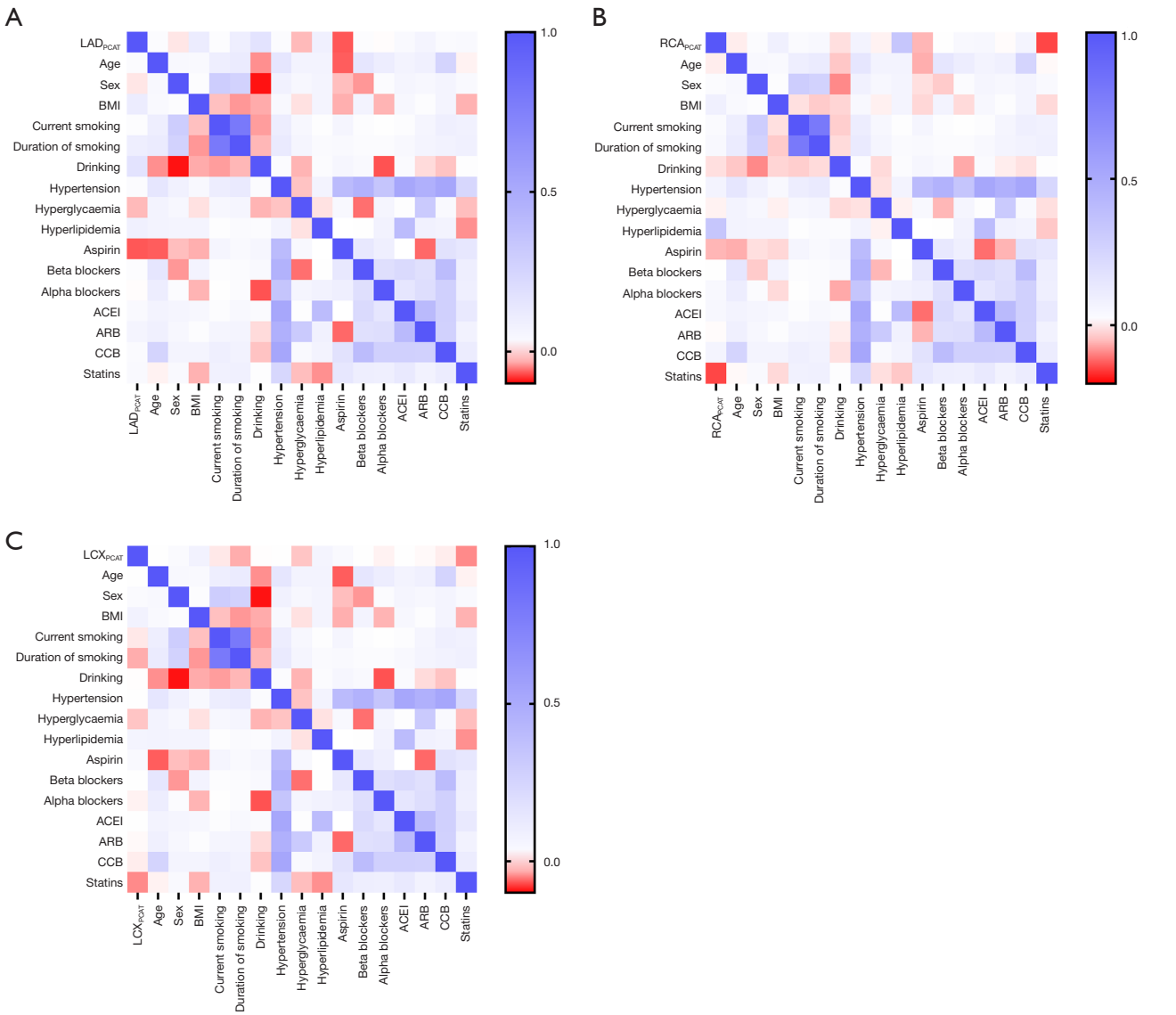

Figure 3 Correlation heat map of different clinical characteristics with (A) LAD_{PCAT}, (B) RCA_{PCAT}, and (C) LCX_{PCAT} values. LAD, left anterior descending branch; PCAT, pericoronary adipose tissue; BMI, body mass index; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; CCB, calcium channel blockers; RCA, right coronary artery; LCX, left circumflex branch.

study showed that the mean PCAT attenuation values were correlated with plaque parameters and the degree of stenosis in patients with ACS (22). In addition, Araki *et al.* (2) demonstrated that individuals diagnosed with ACS exhibited elevated PCAT attenuation values compared to those with stable CHD. Specifically, patients with ACS had higher PCAT values in the most stenotic lesions (culprit plaques) identified on coronary angiography or in the most stenotic plaques (culprit plaques) identified in patients undergoing percutaneous coronary intervention. Additionally, elevated values were noted in the vessels where these culprit plaques were located. However, the literature does not provide many studies that used CCTA to determine an association between PCAT and clinical characteristics in patients without CHD. A retrospective study showed that women had lower mean PCAT attenuation values than men, and LAD had significantly lower mean PCAT attenuation values than LCX and RCA (23). Contrary to the above research (23), we did not observe differences in PCAT attenuation values across sexes. It should be noted that some

Table 4 Linear regression models for PCAT and different clinical characteristics

Subgroup	β coefficient	95% CI		P value
		Lower	Upper	
LAD_{PCAT}				
BMI	0.359	0.147	0.572	0.001
Duration of smoking	2.612	0.964	4.260	0.002
Drinking	4.106	2.472	5.740	<0.001
Hyperlipidemia	1.664	0.190	3.137	0.027
LCX_{PCAT}				
BMI	0.218	0.029	0.406	0.024
RCA_{PCAT}				
BMI	0.146	−0.028	0.320	0.100
Hyperlipidemia	6.110	4.901	7.319	<0.001
Statins	−3.338	−4.991	−1.686	<0.001

PCAT, pericoronary adipose tissue; CI, confidence interval; LAD, left anterior descending branch; BMI, body mass index; LCX, left circumflex branch; RCA, right coronary artery.

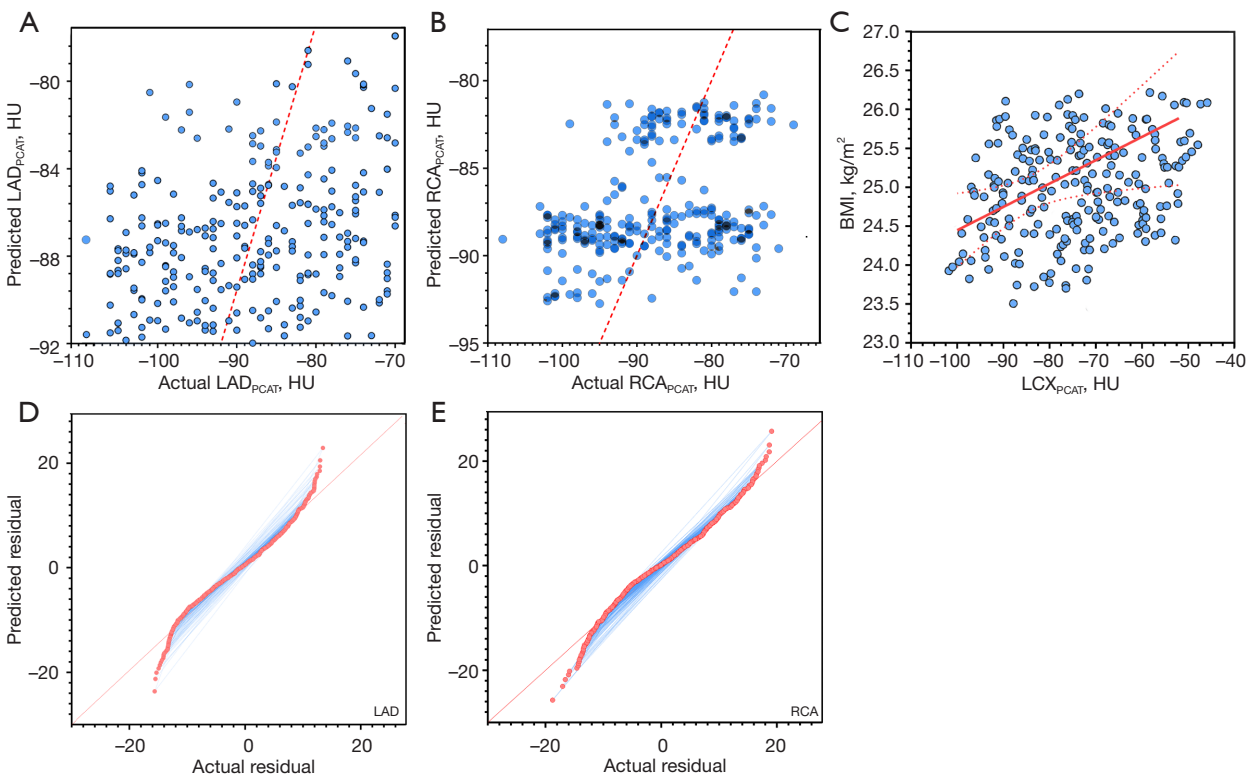

Figure 4 Linear regression model for different clinical characteristics with PCAT attenuation values. (A) LAD_{PCAT}; (B) RCA_{PCAT}; (C) LCX_{PCAT}; (D) QQ plot for LAD_{PCAT}; (E) QQ plot for RCA_{PCAT}. LAD, left anterior descending branch; PCAT, pericoronary adipose tissue; HU, Hounsfield unit; RCA, right coronary artery; LCX, left circumflex branch; BMI, body mass index; QQ, quantile-quantile.

clinical characteristics can be found to be more dangerous after quantification of pericoronary inflammation based on PCAT attenuation values.

Obesity is an independent risk factor for cardiovascular disease, and the relationship between obesity-related indicators and fatty tissue around the heart is constantly being explored (24,25). Yuvaraj *et al.* (26) demonstrated that the plasma atherogenic index (the base 10 logarithmic ratio of triglyceride to high-density lipoprotein) was related to increased EAT volume after correcting for coronary plaque load assessed by the CT-Leaman score and traditional cardiovascular risks factors such as obesity, smoking, hypertension, and hyperglycemia. As part of the EAT, PCAT was found to have a significantly negative relationship with density and BMI (27). In contrast, Maurovich-Horvat *et al.* (28) discovered that coronary atherosclerosis is related to the PCAT volume but not to the volume of epicardial, periaortic, and extracardiac adipose tissue. A retrospective study showed that the PCAT attenuation values were not associated with BMI in patients without plaques on CCTA images (29). However, we observed a significant positive correlation between PCAT attenuation values (LAD_{PCAT}, LCX_{PCAT}, and RCA_{PCAT}) and BMI in patients without CHD. The difference between the results of the present study and the abovementioned studies may be the different methods of PCAT measurement and the differences related to the population. In the present study, hyperlipidemia was associated with increased attenuation values (LAD_{PCAT} and RCA_{PCAT}). Hence, our findings suggest that overweight or obesity causes or even aggravates inflammation in the coronary arteries.

Because PCAT attenuation values are a risk indicator for vascular inflammation that can be quantified by CCTA, they can be used clinically to monitor disease onset and progression in patients. PCAT attenuation values are therefore considered an modifiable risk factor for measurement using CCTA. Moreover, these can be used to track responses to coronary artery disease interventions. Prospective research has revealed that the biological treatment of moderate-to-severe psoriasis is related to reduced coronary artery inflammation, as shown by PCAT attenuation values (30). Statins significantly reduce mortality associated with cardiovascular diseases (31). Our research also showed that statins inhibited inflammation (32,33), lowering PCAT attenuation values on CCTA images. Therefore, statin use in patients without CHD is associated with lower PCAT attenuation values. As such, PCAT attenuation may be a potential follow-up marker of drugs with cardiovascular benefits.

Most studies have demonstrated that smoking and drinking are recognized risk factors for cardiovascular disease (34,35). The present study found no significant difference in PCAT attenuation values between smokers and nonsmokers in patients without CHD. However, after more than 15 years of smoking, the PCAT attenuation values were higher than those of patients who had smoked for <15 years. This is related to the coronary inflammation caused by long-term smoking (36,37), suggesting that smoking cessation will reduce the incidence of cardiovascular risk events. Additionally, we showed that drinking was associated with high PCAT attenuation in patients without CHD, corroborating the harmful effects of drinking on the cardiovascular system. However, an overview summarized that moderate alcohol intake has anti-inflammatory effects, reducing the risk of CHD (38). In future studies, we need to further explore the relationship among the duration of drinking, alcohol intake, and PCAT attenuation values to specifically determine the inflammatory effects of alcohol on the coronary arteries.

This study has some limitations. First, the retrospective nature of the study did not allow the inclusion of additional and more detailed clinical features, such indicators as hematology, liver function, and kidney function tests. In addition, the primary limitation of this research is its single-center design. Despite the positive findings, there is a need to expand the sample size across different centers for further popularization. Finally, imaging parameters such as tube voltage and tube current may affect PCAT attenuation values, warranting further exploration in the future.

Conclusions

In conclusion, the PCAT attenuation values measured using CCTA were related to different clinical characteristics in patients without CHD. LAD_{PCAT} was found to be associated with BMI, smoking duration, drinking, and hyperlipidemia, whereas LCX_{PCAT} was associated with BMI. Furthermore, RCA_{PCAT} was associated with hyperlipidemia and statin use.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-1814/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Ethics Committee of the Lanzhou University Second Hospital approved this study (ethical approval No. 2021A-165), and did not require the informed consent due to the nature of retrospective research.

References

1. Guo L, Akahori H, Harari E, Smith SL, Polavarapu R, Karmali V, et al. CD163+ macrophages promote angiogenesis and vascular permeability accompanied by inflammation in atherosclerosis. J Clin Invest 2018;128:1106-24.
2. Araki M, Sugiyama T, Nakajima A, Yonetsu T, Seegers LM, Dey D, Lee H, McNulty I, Yasui Y, Teng Y, Nagamine T, Kakuta T, Jang IK. Level of Vascular Inflammation Is Higher in Acute Coronary Syndromes Compared with Chronic Coronary Disease. Circ Cardiovasc Imaging 2022;15:e014191.
3. Wang H, Liu Z, Shao J, Lin L, Jiang M, Wang L, Lu X, Zhang H, Chen Y, Zhang R. Immune and Inflammation in Acute Coronary Syndrome: Molecular Mechanisms and Therapeutic Implications. J Immunol Res 2020;2020:4904217.
4. Greco F, Salgado R, Van Hecke W, Del Buono R, Parizel PM, Mallio CA. Epicardial and pericardial fat analysis on CT images and artificial intelligence: a literature review. Quant Imaging Med Surg 2022;12:2075-89.
5. Mancio J, Oikonomou EK, Antoniades C. Perivascular adipose tissue and coronary atherosclerosis. Heart 2018;104:1654-62.
6. Farias-Itao DS, Pasqualucci CA, de Andrade RA, da Silva LFF, Yahagi-Estevam M, Lage SHG, Leite REP, Campo AB, Suemoto CK. Macrophage Polarization in the Perivascular Fat Was Associated With Coronary Atherosclerosis. J Am Heart Assoc 2022;11:e023274.
7. Goeller M, Achenbach S, Duncker H, Dey D, Marwan M. Imaging of the Pericoronary Adipose Tissue (PCAT) Using Cardiac Computed Tomography: Modern Clinical Implications. J Thorac Imaging 2021;36:149-61.
8. Ma R, van Assen M, Sidorenkov G, Ties D, Jan Pelgrim G, Stillman A, de Cecco C, van der Harst P, Vliegenthart R. Relationships of pericoronary and epicardial fat measurements in male and female patients with and without coronary artery disease. Eur J Radiol 2023;169:111154.
9. Antonopoulos AS, Sanna F, Sabharwal N, Thomas S, Oikonomou EK, Herdman L, et al. Detecting human coronary inflammation by imaging perivascular fat. Sci Transl Med 2017;9:eaal2658.
10. Antonopoulos AS, Margaritis M, Coutinho P, Shirodaria C, Psarros C, Herdman L, Sanna F, De Silva R, Petrou M, Sayeed R, Krasopoulos G, Lee R, Digby J, Reilly S, Bakogiannis C, Tousoulis D, Kessler B, Casadei B, Channon KM, Antoniades C. Adiponectin as a link between type 2 diabetes and vascular NADPH oxidase activity in the human arterial wall: the regulatory role of perivascular adipose tissue. Diabetes 2015;64:2207-19.
11. Lin A, Dey D, Wong DTL, Nerlekar N. Perivascular Adipose Tissue and Coronary Atherosclerosis: from Biology to Imaging Phenotyping. Curr Atheroscler Rep 2019;21:47.
12. Zou L, Xiao X, Jia Y, Yin F, Zhu J, Gao Q, Xue M, Dong S. Predicting coronary atherosclerosis heart disease with pericoronary adipose tissue attenuation parameters based on dual-layer spectral detector computed tomography:

a preliminary exploration. Quant Imaging Med Surg 2023;13:2975-88.
13. Li N, Dong X, Zhu C, Shi K, Si N, Shi Z, Pan H, Wang S, Zhao M, Zhang T. Model development and validation of noninvasive parameters based on coronary computed tomography angiography to predict culprit lesions in acute coronary syndromes within 3 years: value of plaque characteristics, hemodynamics and pericoronary adipose tissue. Quant Imaging Med Surg 2023;13:4325-38.
14. You D, Yu H, Wang Z, Wei X, Wu X, Pan C. The correlation of pericoronary adipose tissue with coronary artery disease and left ventricular function. BMC Cardiovasc Disord 2022;22:398.
15. Yu Y, Ding X, Yu L, Lan Z, Wang Y, Zhang J. Prediction of microvascular complications in diabetic patients without obstructive coronary stenosis based on pericoronary adipose tissue attenuation model. Eur Radiol 2023;33:2015-26.
16. Ichikawa K, Miyoshi T, Ohno Y, Osawa K, Nakashima M, Nishihara T, Miki T, Toda H, Yoshida M, Ito H. Association between High Pericoronary Adipose Tissue Computed Tomography Attenuation and Impaired Flow-Mediated Dilation of the Brachial Artery. J Atheroscler Thromb 2023;30:364-76.
17. Ichikawa K, Miyoshi T, Kotani K, Osawa K, Nakashima M, Nishihara T, Ito H. Association between high oxidized high-density lipoprotein levels and increased pericoronary inflammation determined by coronary computed tomography angiography. J Cardiol 2022;80:410-5.
18. Ichikawa K, Miyoshi T, Nakashima M, Nishihara T, Osawa K, Miki T, Toda H, Yoshida M, Ito H. Prognostic value of pericoronary adipose tissue attenuation in patients with non-alcoholic fatty liver disease with suspected coronary artery disease. Heart Vessels 2022;37:1977-84.
19. Nogami K, Sugiyama T, Kanaji Y, Hoshino M, Hara S, Yamaguchi M, Hada M, Sumino Y, Misawa T, Hirano H, Ueno H, Miwa N, Yamao K, Kusa S, Hachiya H, Kakuta T. Association between pericoronary adipose tissue attenuation and outcome after second-generation cryoballoon ablation for atrial fibrillation. Br J Radiol 2021;94:20210361.
20. Oikonomou EK, Marwan M, Desai MY, Mancio J, Alashi A, Hutt Centeno E, et al. Non-invasive detection of coronary inflammation using computed tomography and prediction of residual cardiovascular risk (the CRISP CT study): a post-hoc analysis of prospective outcome data. Lancet 2018;392:929-39.
21. Dong X, Li N, Zhu C, Wang Y, Shi K, Pan H, Wang S, Shi Z, Geng Y, Wang W, Zhang T. Diagnosis of coronary artery disease in patients with type 2 diabetes mellitus based on computed tomography and pericoronary adipose tissue radiomics: a retrospective cross-sectional study. Cardiovasc Diabetol 2023;22:14.
22. Zhang R, Ju Z, Li Y, Gao Y, Gu H, Wang X. Pericoronary fat attenuation index is associated with plaque parameters and stenosis severity in patients with acute coronary syndrome: a cross-sectional study. J Thorac Dis 2022;14:4865-76.
23. van Rosendael SE, Kuneman JH, van den Hoogen IJ, Kitslaar PH, van Rosendael AR, van der Bijl P, Reiber JHC, Ajmone Marsan N, Jukema JW, Knuuti J, Bax JJ. Vessel and sex differences in pericoronary adipose tissue attenuation obtained with coronary CT in individuals without coronary atherosclerosis. Int J Cardiovasc Imaging 2022;38:2781-9.
24. Katta N, Loethen T, Lavie CJ, Alpert MA. Obesity and Coronary Heart Disease: Epidemiology, Pathology, and Coronary Artery Imaging. Curr Probl Cardiol 2021;46:100655.
25. Ichikawa K, Miyoshi T, Osawa K, Miki T, Morimitsu Y, Akagi N, Nakashima M, Ito H. Association between higher pericoronary adipose tissue attenuation measured by coronary computed tomography angiography and nonalcoholic fatty liver disease: A matched case-control study. Medicine (Baltimore) 2021;100:e27043.
26. Yuvaraj J, Isa M, Che ZC, Lim E, Nerlekar N, Nicholls SJ, Seneviratne S, Lin A, Dey D, Wong DTL. Atherogenic index of plasma is associated with epicardial adipose tissue volume assessed on coronary computed tomography angiography. Sci Rep 2022;12:9626.
27. Hell MM, Achenbach S, Schuhbaeck A, Klinghammer L, May MS, Marwan M. CT-based analysis of pericoronary adipose tissue density: Relation to cardiovascular risk factors and epicardial adipose tissue volume. J Cardiovasc Comput Tomogr 2016;10:52-60.
28. Maurovich-Horvat P, Kallianos K, Engel LC, Szymonifka J, Schlett CL, Koenig W, Hoffmann U, Truong QA. Relationship of thoracic fat depots with coronary atherosclerosis and circulating inflammatory biomarkers. Obesity (Silver Spring) 2015;23:1178-84.
29. Ma R, Ties D, van Assen M, Pelgrim GJ, Sidorenkov G, van Ooijen PMA, van der Harst P, van Dijk R, Vliegenthart R. Towards reference values of pericoronary adipose tissue attenuation: impact of coronary artery and tube voltage in coronary computed tomography angiography. Eur Radiol 2020;30:6838-46.

30. Elnabawi YA, Oikonomou EK, Dey AK, Mancio J, Rodante JA, Aksentijevich M, Choi H, Keel A, Erb-Alvarez J, Teague HL, Joshi AA, Playford MP, Lockshin B, Choi AD, Gelfand JM, Chen MY, Bluemke DA, Shirodaria C, Antoniades C, Mehta NN. Association of Biologic Therapy With Coronary Inflammation in Patients With Psoriasis as Assessed by Perivascular Fat Attenuation Index. JAMA Cardiol 2019;4:885-91.
31. Almeida SO, Budoff M. Effect of statins on atherosclerotic plaque. Trends Cardiovasc Med 2019;29:451-5.
32. Parisi V. Statin might promote epicardial adipose tissue inflammatory remodeling via NLRP3 suppression: An intriguing hypothesis. Int J Cardiol 2020;300:219.
33. Parisi V, Petraglia L, D'Esposito V, Cabaro S, Rengo G, Caruso A, Grimaldi MG, Baldascino F, De Bellis A, Vitale D, Formisano R, Ferro A, Paolillo S, Davin L, Lancellotti P, Formisano P, Perrone Filardi P, Ferrara N, Leosco D. Statin therapy modulates thickness and inflammatory profile of human epicardial adipose tissue. Int J Cardiol 2019;274:326-30.
34. Jee Y, Jung KJ, Lee S, Back JH, Jee SH, Cho SI. Smoking and atherosclerotic cardiovascular disease risk in young men: the Korean Life Course Health Study. BMJ Open 2019;9:e024453.
35. Barbaresko J, Rienks J, Nöthlings U. Lifestyle Indices and Cardiovascular Disease Risk: A Meta-analysis. Am J Prev Med 2018;55:555-64.
36. Omar A, Chatterjee TK, Tang Y, Hui DY, Weintraub NL. Proinflammatory phenotype of perivascular adipocytes. Arterioscler Thromb Vasc Biol 2014;34:1631-6.
37. Ugur MG, Kutlu R, Kilinc I. The effects of smoking on vascular endothelial growth factor and inflammation markers: A case-control study. Clin Respir J 2018;12:1912-8.
38. Imhof A, Koenig W. Alcohol inflammation and coronary heart disease. Addict Biol 2003;8:271-7.

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