Reviews in Cardiovascular Medicine

Rev. Cardiovasc. Med. **2026**; 27(11): 52531
https://doi.org/10.31083/RCM52531

Original Research

Pericoronary Adipose Tissue Fat Attenuation Index Combined With Cardiometabolic Indices to Predict Five-Year Cardiovascular Events in Postmenopausal Women

Lin Yu[1], Song Yang[2], Xinfa Ding[3], Yangyang Sheng[3], Chengjia Liu[3,*]

[1]Laboratory Department, The Second Affiliated Hospital Zhejiang University School of Medicine, 310000 Hangzhou, Zhejiang, China
[2]Vascular Interventional Center, Taizhou Hospital Affiliated to Zhejiang University School of Medicine, 317000 Taizhou, Zhejiang, China
[3]Department of Radiology, The Second Affiliated Hospital Zhejiang University School of Medicine, 310000 Hangzhou, Zhejiang, China
*Correspondence: 2613133@zju.edu.cn (Chengjia Liu)
Academic Editor: Jerome L. Fleg
Submitted: 2 April 2026 Revised: 18 July 2026 Accepted: 22 July 2026 Published: 13 November 2026

Abstract

Background: Postmenopausal women face an accelerated risk of cardiovascular disease, and standard risk tools often underestimate this risk in this population. The pericoronary adipose tissue fat attenuation index (PCAT-FAI), measured by coronary computed tomography angiography (CCTA), reflects local coronary inflammation, while cardiometabolic indices derived from routine blood tests capture systemic metabolic burden. However, whether combining these two measures improves cardiovascular risk prediction in postmenopausal women remains unclear. Therefore, this study aimed to evaluate the prognostic value of three-vessel PCAT-FAI and multiple cardiometabolic indices in postmenopausal women, and to determine whether combining these local inflammatory and systemic metabolic markers improves cardiovascular risk stratification beyond traditional risk factors. **Methods:** This retrospective study included 538 postmenopausal women who underwent CCTA between January 2018 and December 2021. PCAT-FAI was measured around the left anterior descending (LAD), left circumflex, and right coronary arteries. We calculated 11 baseline cardiometabolic indices, including the triglyceride–glucose (TyG) index and its derivatives. The primary endpoint was a composite of MACE (cardiovascular death, non-fatal myocardial infarction, non-fatal stroke, heart failure hospitalization, and unstable angina requiring revascularization). Predictive performance was evaluated using Cox proportional hazards models, time-dependent receiver operating characteristic (ROC) curves, net reclassification improvement (NRI), and integrated discrimination improvement (IDI). **Results:** During a median follow-up of 4.80 years, the composite endpoint occurred in 87 women, corresponding to an event rate of 16.20%. Each 5-Hounsfield (HU) increase in LAD PCAT-FAI was associated with a 31% higher risk of adverse events (hazard ratio (HR) 1.31, 95% confidence interval (CI) 1.18–1.46). Among the cardiometabolic variables evaluated, triglyceride glucose body mass index (TyG-BMI) showed the strongest association, with an HR of 2.38 (95% CI 1.45–3.91) for extreme-quartile comparisons. Adding both markers to traditional risk factors improved the C-index from 0.71 (0.66–0.77) to 0.79 (0.74–0.84), with an NRI of 0.34 (0.20–0.49) and an IDI of 0.05 (0.03–0.07). Restricted cubic spline modeling demonstrated a curvilinear association between PCAT-FAI and adverse events, with an apparent threshold effect at approximately −77 HU. **Conclusions:** Combining an imaging-based marker of coronary inflammation (PCAT-FAI) with a simple systemic metabolic marker (TyG-BMI) significantly improves 5-year cardiovascular risk stratification in postmenopausal women beyond traditional risk factors.

Keywords: adipose tissue; insulin resistance; coronary vessels; postmenopause; computed tomography angiography; cardiovascular diseases; insulin resistance; triglycerides; blood glucose; risk assessment

1. Introduction

Cardiovascular disease remains the world's leading killer of women, with menopause serving as a pivotal turning point that heralds accelerated atherosclerotic progression [1]. Estrogen decline after menopause promotes visceral fat redistribution, insulin resistance, and chronic low-grade inflammation, each of which increases cardiovascular risk in this patient population [2,3]. Despite these recognized pathophysiological changes, current risk stratification tools often miss the specific metabolic and inflammatory profiles of postmenopausal females, leaving many at increased risk, which is often unrecognized [4,5].

Recent advances in coronary computed tomography angiography (CCTA) have enabled direct visualization of coronary inflammation using the pericoronary adipose tissue fat attenuation index (PCAT-FAI), a marker that quantifies the inflammatory state of adipose tissue surrounding coronary arteries [6,7]. Higher PCAT-FAI values reflect a shift of pericoronary adipocytes toward smaller, less differentiated cells with a higher water-to-lipid ratio, a pattern that becomes progressively more pronounced in adipose layers closer to the vascular wall and is considered an imaging surrogate of local coronary inflammation. This metric has been linked to plaque vulnerability and future cardiovascular events [8,9]. Independent studies have val-

Copyright: © 2026 The Author(s). Published by IMR Press.
This is an open access article under the CC BY 4.0 license.

Publisher's Note: IMR Press stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

idated PCAT-FAI as a predictor of major adverse cardiovascular events (MACE), yet its integration with systemic metabolic markers remains largely unexplored, particularly in sex-specific contexts [10,11]. Simultaneously, various cardiometabolic indices derived from routine clinical and laboratory parameters have emerged as practical tools for assessing insulin resistance and metabolic dysfunction [12]. Among them are the triglyceride-glucose (TyG) index and its related derivatives, the visceral adiposity index (VAI), and the lipid accumulation product (LAP) [13,14]. While these indices capture systemic metabolic burden, they do not directly reflect coronary vascular pathology. Combining coronary-specific imaging biomarkers with accessible metabolic indices could therefore improve cardiovascular risk assessment.

Given the distinct pathophysiology of cardiovascular disease in postmenopausal females and the complementary nature of PCAT-FAI and cardiometabolic indices, we hypothesized that their combination would provide superior prognostic value compared to using the approach alone. This retrospective cohort study aimed to evaluate the predictive performance of PCAT-FAI combined with cardiometabolic indices for 5-year cardiovascular events in postmenopausal females undergoing CCTA.

2. Materials and Methods

2.1 Study Design and Population

This single-center, retrospective cohort study was performed at the Second Affiliated Hospital Zhejiang University School of Medicine in China. The Institutional Review Board approved the protocol (I20221200) and waived informed consent due to the study's retrospective design. Between January 2018 and December 2021, we consecutively enrolled postmenopausal females (defined as ≥12 months of amenorrhea or bilateral oophorectomy) who underwent clinically indicated CCTA predominantly for stable angina or atypical chest pain with intermediate pre-test probability of CAD [76.9%], abnormal non-invasive ischemia testing [10.6%], pre-operative cardiac evaluation [7.8%], and unexplained dyspnea or risk-factor-based screening [4.7%]. Patients undergoing CCTA for acute coronary syndrome or known CAD were excluded. We also excluded patients with a history of cardiovascular disease, prior myocardial infarction, PCI, CABG, or stroke, severe hepatic or renal impairment (aspartate aminotransferase/alanine aminotransferase (AST/ALT) >3 times the upper limit of normal, or eGFR <30 mL/min/1.73 m^2), active malignancy, or incomplete follow-up data. The final cohort consisted of 538 females (Fig. 1). Baseline demographic and clinical data were extracted from the electronic health records.

2.2 CCTA Acquisition and PCAT-FAI Measurement

All CCTA examinations were conducted on a dual-source CT system (SOMATOM Force or New Force, Siemens Healthineers, Forchheim, Germany) with a prospective ECG-gated sequential acquisition protocol. Scan parameters included CARE kV (100 kV) and CARE Dose 4D (288 mAs reference). Reconstructed images had a slice thickness of 0.75 mm and an increment of 0.5 mm, using iterative reconstruction (ADMIRE, strength 3) and a Bv40 convolution kernel. A contrast agent (Ultravist 370 mg I/mL) was injected at a flow rate of 4.0–6.0 mL/s, adjusted according to individual patient characteristics. Two experienced radiologists, blinded to patient outcomes, quantified PCAT-FAI using dedicated software (Cardiac Risk Assessment Prototype, Syngo.via Frontier, Siemens Healthineers, Forchheim, Germany) as described in Fig. 2. FAI was measured surrounding the proximal 40 mm of the left anterior descending (LAD), left circumflex (LCx), and right coronary arteries (RCA). Adipose tissue was defined by an attenuation range of –190 to –30 Hounsfield units (HU) within a radial distance equal to the vessel diameter [15].

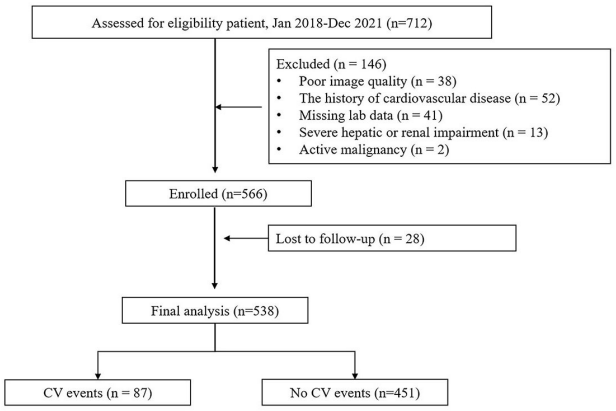


Fig. 1. Study flowchart showing participant screening, eligibility assessment, exclusion criteria, and final cohort inclusion for the retrospective analysis of postmenopausal women undergoing CCTA. CCTA, coronary computed tomography angiography.

We used the LAD PCAT-FAI for analysis due to its well-established prognostic reliability in the prediction of MACE, particularly in females, in line with recent Society of Cardiovascular Computed Tomography (SCCT) consensus statements; sensitivity analyses using LCxPCAT-FAI, RCAPCAT-FAI, and a vessel-averaged global PCAT-FAI as reported in **Supplementary Table 1**. Interobserver reproducibility, assessed in 50 random cases, yielded an intraclass correlation coefficient (ICC) of 0.92 (95% CI 0.87–0.95) for LAD-PCAT-FAI, 0.89 (0.83–0.93) for LCx-PCAT-FAI, and 0.91 (0.86–0.94) for RCA-FAI; intraobserver ICC for LAD-PCAT-FAI was 0.94 (95% CI 0.90–0.97), indicating excellent agreement.

2.3 Cardiometabolic Index Calculations

Fasting blood samples and anthropometric measurements were obtained within 24 hours of the CCTA. We com-

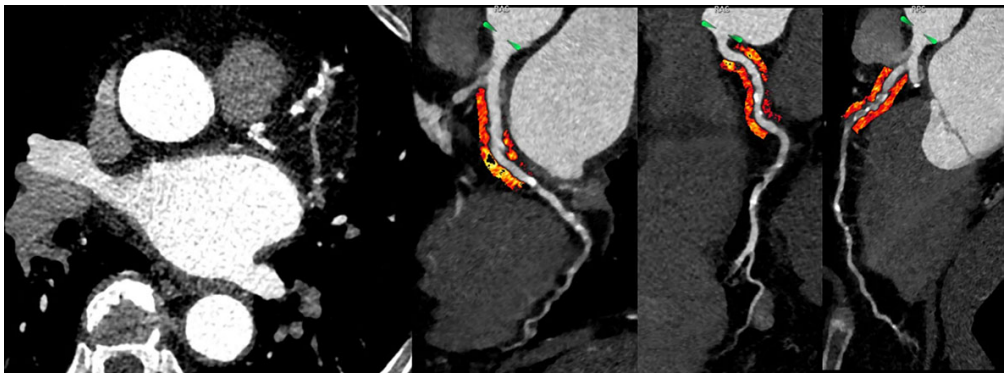


Fig. 2. A diagram showing the measurement of pericoronary adipose tissue (PCAT-FAI) around the proximal 40 mm of the left anterior descending artery fat in a 68-year-old female.

puted eleven cardiometabolic indices. The triglyceride-glucose (TyG) index was calculated as Ln[fasting triglycerides (mg/dL) × fasting glucose (mg/dL) / 2]. Related indices included TyG-BMI (TyG × BMI), TyG-WC (TyG × waist circumference), and TyG-WHtR (TyG × waist-to-height ratio). The additional indices assessed in this study included the cardiometabolic index (CMI), lipid accumulation product (LAP), visceral adiposity index (VAI), a body shape index (ABSI), body roundness index (BRI) and lipid comprehensive index (LCI) [16]. The derivation of these secondary indices is described in detail in the **Supplementary Material** (**Supplementary Table 2**).

2.4 Outcome Definition

The primary endpoint was a composite of MACE: cardiovascular death, non-fatal myocardial infarction (defined by the Fourth Universal Definition), non-fatal stroke, hospitalization for heart failure, and unstable angina requiring revascularization. Two independent cardiologists blindly adjudicated all events. Follow-up was conducted via clinic visits, telephone calls, and registry reviews. Follow-up was conducted through December 2025 via telephone interviews, outpatient clinic visits, and review of hospital records. For participants lost to direct follow-up, vital status was verified through the national death registry and regional health information systems.

2.5 Statistical Analysis

Continuous variables were reported as mean ± SD or median (interquartile range), depending on their distributional characteristics, with intergroup differences evaluated using Student's *t*-test or the Mann-Whitney U test as appropriate. Categorical data were expressed as frequencies (percentages) and compared using the chi-square or Fisher's exact test. To examine the relationship of PCAT-FAI and cardiometabolic indices with the primary endpoint, Cox proportional-hazards regression was applied. Three sequential adjustment strategies were implemented: Model 1 was adjusted for age; Model 2 additionally included hypertension, diabetes, and smoking; and Model 3 further accounted for LDL cholesterol, eGFR, and coronary artery calcium (CAC) score. In the final multivariable models the adjustment set was age, hypertension, diabetes mellitus, current smoking, LDL-C, eGFR, and CAC score. BMI was not included as a covariate in models containing TyG-BMI because TyG-BMI incorporates BMI; adjusting for BMI in these models would constitute overadjustment and could introduce collinearity. PCAT-FAI was analyzed both continuously (per 5-HU increment) and in tertiles, whereas the cardiometabolic indices were entered into the models as quartile-based variables. For predictive performance assessment, time-dependent ROC curves were constructed and Harrell's C-index was computed. The incremental contribution of adding PCAT-FAI and/or TyG-BMI to the clinical baseline model was estimated via net reclassification improvement (NRI) and integrated discrimination improvement (IDI). Restricted cubic splines (4 knots) were employed to explore potential non-linear relationships between LAD PCAT-FAI and cardiovascular risk. Net reclassification improvement was computed both as the category-free (continuous) NRI and as a category-based NRI using pre-specified 5-year risk thresholds (<5%, 5%–<7.5%, ≥7.5%); integrated discrimination improvement was computed with the survIDINRI package, and 95% confidence intervals were obtained from 1000 bootstrap resamples. Multicollinearity among TyG-derived indices (TyG, TyG-BMI, TyG-WC, TyG-WHtR) was assessed using Pearson correlation coefficients and variance inflation factors (VIF). Since these indices were highly correlated (r = 0.78–0.91), with a VIF of 5.8 for TyG, only one TyG-derived index was included in any single multivariable model to minimize potential multicollinearity. To address concerns about overfitting, internal validation was performed by 1000-resample bootstrapping (yielding optimism-corrected C-index and calibration slope/intercept) and by 10-fold cross-validation; the cohort was additionally split at random into a training set (70%) and an internal validation set (30%), with discrimination quantified by Harrell's C-index and time-dependent AUC and calibration assessed graphically and

with the Greenwood–Nam–D'Agostino test. Statistical analyses were performed using R version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1 Baseline Characteristics

A total of 538 postmenopausal females were included in the final analysis. The median age was 62 years (interquartile range 57–68), and the median time since menopause was 12.40 ± 7.80 years. Table 1 presents baseline characteristics according to cardiovascular status. During a median follow-up of 4.8 years, 87 participants (16.2%) experienced the composite cardiovascular endpoint, including 12 cardiovascular deaths (2.2%), 28 non-fatal myocardial infarctions (5.2%), 19 non-fatal strokes (3.5%), 18 heart failure hospitalizations (3.3%), and 10 cases of unstable angina requiring revascularization (1.9%).

Females who experienced cardiovascular events were older (median 65 versus 61 years, $p < 0.01$), had higher rates of hypertension (78.2% versus 54.1%, $p < 0.01$) and diabetes mellitus (48.3% versus 25.3%, $p < 0.01$), and were more likely to be current smokers (13.8% versus 7.3%, $p = 0.05$). Event-free survival analysis showed a cumulative incidence of 16.2% at 5 years.

3.2 PCAT-FAI and Cardiovascular Risk

Mean PCAT-FAI values surrounding the LAD were significantly higher in females who experienced cardiovascular events compared to those who remained event-free (–75.2 ± 8.1 HU versus –79.8 ± 7.3 HU, $p < 0.01$) (Fig. 3). Similar patterns were observed for the LCx (–77.3 ± 8.8 HU versus –80.6 ± 7.9 HU, $p = 0.01$) and RCA (–79.1 ± 9.5 HU versus –82.9 ± 8.8 HU, $p < 0.01$). In the multivariable Cox regression analysis adjusting for age, hypertension, diabetes, smoking, low-density lipoprotein cholesterol, estimated glomerular filtration rate, and coronary artery calcium score, each 5 HU increase in LAD PCAT-FAI was associated with a 31% higher risk of cardiovascular events (hazard ratio 1.31, 95%CI 1.18–1.46, $p < 0.01$). When analyzed by tertiles, females in the highest tertile of LAD PCAT-FAI had a hazard ratio of 2.42 (1.48–3.95) compared to the lowest tertile.

3.3 Cardiometabolic Indices and Cardiovascular Risk

Among the cardiometabolic indices evaluated, TyG-BMI demonstrated the strongest association with cardiovascular events (**Supplementary Fig. 1**). In fully adjusted models, females in the highest quartile of TyG-BMI had a 2.38-fold higher risk (95% confidence interval 1.45–3.91) compared to the lowest quartile (Table 2). Other indices showing significant associations included TyG (hazard ratio for Q4 versus Q1: 2.14, 1.32–3.47), TyG-WHtR (2.21, 1.36–3.59), TyG-WC (2.08, 1.26–3.38), CMI (1.89, 1.15–3.10), LAP (1.76, 1.08–2.87), and VAI (1.68, 1.03–2.74). The LCI showed a borderline association (1.52, 0.94–2.46, $p = 0.09$), while ABSI (1.41, 0.87–2.29, $p = 0.16$) and BRI (1.58, 0.97–2.57, $p = 0.07$) did not reach statistical significance.

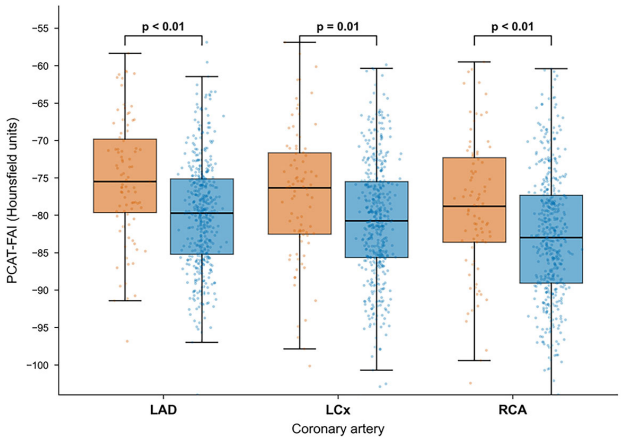


Fig. 3. Distribution of PCAT-FAI values in the LAD, LCx, and RCA according to cardiovascular event status, shown as boxplots with overlaid individual data points and *p* values. Orange: with primary endpoint; blue: without primary endpoint.

3.4 Predictive Performance and Incremental Value

The baseline model incorporating traditional cardiovascular risk factors (age, hypertension, diabetes, smoking, low-density lipoprotein cholesterol, estimated glomerular filtration rate, and coronary artery calcium score) achieved a C-index of 0.71 (95% CI 0.66–0.77). Adding PCAT-FAI alone improved the C-index to 0.76 (0.71–0.81), representing a statistically significant improvement ($p = 0.01$). Adding TyG-BMI alone to the base model yielded a C-index of 0.74 (0.69–0.79, $p = 0.02$). The combination of PCAT-FAI and TyG-BMI achieved the highest predictive performance with a C-index of 0.79 (0.74–0.84), significantly better than the base model ($p < 0.01$) and PCAT-FAI alone ($p = 0.04$). The addition of CMI to PCAT-FAI also improved prediction (C-index 0.78, 0.73–0.83, $p = 0.01$) (Table 3).

Net reclassification improvement analysis demonstrated that adding both PCAT-FAI and TyG-BMI to traditional risk factors resulted in a net reclassification improvement of 0.34 (95% confidence interval 0.20–0.49). As a complement to the continuous NRI, we computed a category-based NRI using pre-specified 5-year risk thresholds of <5%, 5% to <7.5%, and ≥7.5%. The category-based NRI for the combined model versus the traditional risk-factor model was 0.18 (95% CI 0.07 to 0.30), driven primarily by appropriate up-classification of females who experienced events from the intermediate-risk to the high-risk category, indicating substantial improvement in risk classification (Table 4). The integrated discrimination improvement was 0.05 (0.03–0.07). Addition of PCAT-FAI alone provided net reclassification improvement of 0.27 (0.13–

Table 1. Baseline characteristics of postmenopausal women stratified by cardiovascular events during 5-year follow-up.

Variable	Total (n = 538)	Event (n = 87)	Non-event (n = 451)	*p* value
Demographics				
Age, years, median (IQR)	62 (57–68)	65 (60–71)	61 (56–67)	<0.01
Time since menopause, years	12.40 ± 7.80	15.10 ± 8.20	11.90 ± 7.50	0.01
BMI, kg/m^2	25.30 ± 3.80	26.80 ± 4.10	25.00 ± 3.60	<0.01
Waist circumference, cm	84.20 ± 10.50	89.60 ± 11.20	83.20 ± 10.00	<0.01
Height, cm	158.30 ± 5.60	157.80 ± 5.90	158.40 ± 5.50	0.38
Weight, kg	63.50 ± 10.20	66.80 ± 11.00	62.90 ± 9.90	0.00
Comorbidities, n (%)				
Hypertension	312 (58.00)	68 (78.20)	244 (54.10)	<0.01
Diabetes mellitus	156 (29.00)	42 (48.30)	114 (25.30)	<0.01
Dyslipidemia	298 (55.40)	58 (66.70)	240 (53.20)	0.02
Current smoking	45 (8.40)	12 (13.80)	33 (7.30)	0.05
Family history of CAD	89 (16.50)	19 (21.80)	70 (15.50)	0.14
Laboratory values				
Fasting glucose, mg/dL	108.50 ± 32.40	121.30 ± 38.60	106.10 ± 30.20	<0.01
Fasting triglycerides, mg/dL	148.20 ± 78.50	178.60 ± 92.30	142.30 ± 74.10	<0.01
Total cholesterol, mg/dL	212.80 ± 42.10	221.50 ± 45.30	211.10 ± 41.20	0.04
HDL-C, mg/dL	52.30 ± 14.20	47.80 ± 12.60	53.20 ± 14.40	0.01
LDL-C, mg/dL	128.50 ± 36.80	135.20 ± 39.10	127.20 ± 36.20	0.07
eGFR, mL/min/1.73 m^2	82.40 ± 18.60	76.30 ± 20.10	83.60 ± 18.00	0.01
HbA1c, %	6.20 ± 1.10	6.80 ± 1.40	6.10 ± 1.00	<0.01
CCTA findings				
CAC score, median (IQR)	42 (0–186)	156 (38–412)	32 (0–142)	<0.01
Obstructive CAD (≥50%), n (%)	168 (31.20)	52 (59.80)	116 (25.70)	<0.01
PCAT-FAI values (HU)				
LAD-PCAT-FAI	−78.90 ± 7.60	−75.20 ± 8.10	−79.80 ± 7.30	<0.01
LCx-PCAT-FAI	−80.10 ± 8.20	−77.30 ± 8.80	−80.60 ± 7.90	0.01
RCA-PCAT-FAI	−82.30 ± 9.10	−79.10 ± 9.50	−82.90 ± 8.80	<0.01
Cardiometabolic indices				
TyG index	8.72 ± 0.62	9.05 ± 0.68	8.66 ± 0.58	<0.01
TyG-BMI	220.80 ± 38.50	243.60 ± 42.10	216.40 ± 36.20	<0.01
TyG-WC	734.20 ± 128.60	812.50 ± 141.30	719.10 ± 122.40	<0.01
TyG-WHtR	4.65 ± 0.82	5.14 ± 0.91	4.56 ± 0.78	<0.01
CMI	1.52 ± 0.89	1.98 ± 1.05	1.43 ± 0.82	<0.01
LAP	42.80 ± 28.60	56.30 ± 34.20	40.20 ± 26.80	<0.01
VAI	2.85 ± 1.92	3.62 ± 2.28	2.70 ± 1.82	<0.01
ABSI	0.08 ± 0.01	0.08 ± 0.01	0.08 ± 0.01	0.01
BRI	4.82 ± 1.45	5.38 ± 1.62	4.71 ± 1.39	<0.001
LCI	48.52 ± 32.18	59.84 ± 38.65	46.34 ± 30.42	0.01

Values are presented as mean ± SD, median (IQR), or n (%). *p* values from Student's *t*-test, Mann–Whitney U test, or chi-square test as appropriate. Abbreviations: BMI, body mass index; CAC, coronary artery calcium; CAD, coronary artery disease; CCTA, coronary computed tomography angiography; CMI, cardiometabolic index; eGFR, estimated glomerular filtration rate; FAI, fat attenuation index; HDL-C, high-density lipoprotein cholesterol; LAD, left anterior descending; LAP, lipid accumulation product; LCI, lipid Comprehensive Index; LCx, left circumflex; LDL-C, low-density lipoprotein cholesterol; PCAT, pericoronary adipose tissue; RCA, right coronary artery; TyG, triglyceride-glucose index; VAI, visceral adiposity index; ABSI, a body shape index; BRI, body roundness index.

0.40) and integrated discrimination improvement of 0.03 (0.01–0.05).

In a sensitivity analysis restricted to hard endpoints (cardiovascular death, non-fatal myocardial infarction, and non-fatal stroke; 59 events), associations between PCAT-FAI, TyG-BMI, and outcomes remained robust (**Supplementary Table 3**): each 5-HU increase in LAD PCAT-FAI was associated with a hazard ratio of 1.29 (95% CI 1.14–1.46), and the highest TyG-BMI quartile carried a hazard ratio of 2.21 (95% CI 1.31–3.74) versus

Table 2. Multivariable Cox proportional hazards regression for 5-year composite cardiovascular events: Individual predictors.

Variable	HR (95% CI)	*p* value
FAI-LAD (per 5 HU increase)	1.31 (1.18–1.46)	**<0.01**
TyG-BMI (Q4 vs Q1)	2.38 (1.45–3.91)	**<0.01**
TyG-WHtR (Q4 vs Q1)	2.21 (1.36–3.59)	0.01
TyG (Q4 vs Q1)	2.14 (1.32–3.47)	0.01
TyG-WC (Q4 vs Q1)	2.08 (1.28–3.38)	0.01
CMI (Q4 vs Q1)	1.89 (1.15–3.10)	0.01
LAP (Q4 vs Q1)	1.76 (1.08–2.87)	0.02
VAI (Q4 vs Q1)	1.68 (1.03–2.74)	0.04
BRI (Q4 vs Q1)	1.58 (0.97–2.57)	0.07
LCI (Q4 vs Q1)	1.52 (0.94–2.46)	0.09
ABSI (Q4 vs Q1)	1.41 (0.87–2.29)	0.16

HR, hazard ratio; CI, confidence interval; Q4, fourth quartile; Q1, first quartile.

Traditional risk factors include age, hypertension, diabetes mellitus, current smoking, LDL-C, eGFR, and CAC score. Bold *p* values indicate statistical significance ($p < 0.05$). (Adjusted for age, hypertension, diabetes, smoking, LDL-C, eGFR, and CAC score).

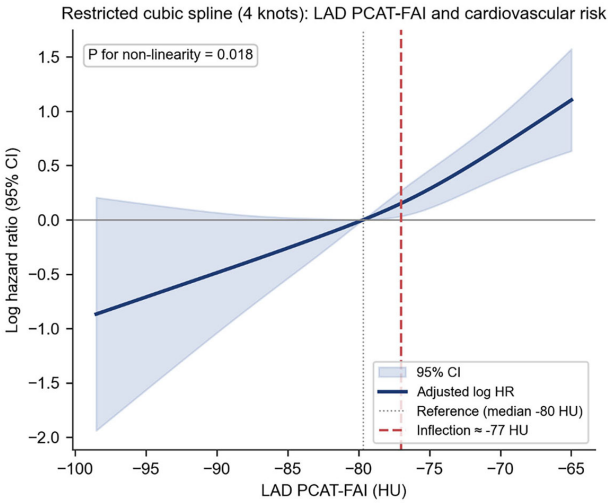


Fig. 4. Dose–response association between LAD PCAT-FAI and the log hazard ratio for the composite cardiovascular endpoint, as estimated by restricted cubic spline regression with 4 knots. The curve was adjusted for age, hypertension, diabetes, smoking, LDL-C, eGFR, and CAC score. The shaded region indicates the 95% confidence interval; the cohort median served as the reference; and the dashed vertical line denotes the inflection point at approximately −77 HU (*p* for nonlinearity = 0.018).

the lowest quartile. The combined PCAT-FAI plus TyG-BMI model retained good discrimination for the hard endpoint (C-index 0.78, 95% CI 0.72–0.84). Internal validation by 1000-resample bootstrapping yielded an optimism-corrected C-index of 0.776 with calibration slope 0.93 and intercept −0.04; 10-fold cross-validation produced a mean C-index of 0.77 (range 0.71–0.82). Performance in the random 70:30 train–validation split was concordant (training C-index 0.80; validation C-index 0.77). Calibration curves for the combined model in training and validation sets are shown in **Supplementary Fig. 2**.

3.5 Dose-Response Relationships

3.5.1 Dose–Response Relationship Between LAD PCAT-FAI and Cardiovascular Risk

Using restricted cubic spline analysis, we identified a nonlinear dose–response association between LAD PCAT-FAI and cardiovascular risk ($p < 0.05$). The hazard ratio exhibited a near-plateau below −77 HU but rose sharply thereafter, indicating a clear threshold phenomenon (Fig. 4).

3.5.2 Joint Stratification by PCAT-FAI and TyG-BMI Tertiles

For TyG-BMI, a relatively linear dose-response relationship was observed across quartiles, with each successive quartile showing incremental increases in hazard compared with the reference. Females in the highest tertiles of both PCAT-FAI and TyG-BMI had a 4.2-fold higher risk than those in the lowest tertiles of both markers. Cumulative event-free survival stratified by combined PCAT-FAI/TyG-BMI tertiles is shown in **Supplementary Fig. 3**. The −77 HU inflection identified in the spline analysis should be interpreted as exploratory and hypothesis-generating, since it was derived in the same cohort and has not been externally calibrated.

3.6 Subgroup Analyses

The predictive performance of the combined PCAT-FAI plus TyG-BMI model remained robust across clinical subgroups. In terms of model discrimination, the combined model achieved the highest C-index in patients with diabetes (0.82, 95% CI 0.75–0.89), followed by those with obesity (BMI ≥28 kg/m^2; C-index 0.81, 95% CI 0.74–0.88), women aged ≥65 years (C-index 0.80, 95% CI 0.74–0.87), and those with hypertension. A forest plot summarising hazard ratios with 95% CIs per 1-SD increase in the combined PCAT-FAI/TyG-BMI score (computed as the sum of the standardised values of LAD PCAT-FAI and TyG-BMI) across pre-specified subgroups is presented in Fig. 5. Overall, each 1-SD increase in the combined score was associated with a 62% higher risk of MACE (HR 1.62, 95% CI 1.41–1.86). Consistent positive associations were observed across all evaluable strata—including age (< 65 versus ≥65 years), BMI (< 28 versus ≥28 kg/m^2), diabetes, hypertension, smoking status, coronary artery calcium (CAC 1–99 and ≥ 100; not estimable in the CAC = 0 stratum due to insufficient events), and time since menopause (< 10 versus ≥10 years)—with the highest point estimates noted in patients with diabetes (HR 1.92, 95% CI 1.49–2.47) and

Table 3. Predictive performance of models for 5-year composite cardiovascular events.

Model	C-index (95% CI)	ΔC-index	*p* for ΔC
Model 1: Traditional risk factors	0.71 (0.66–0.77)	Reference	—
Model 2: Model 1 + LAD-PCAT-FAI	0.76 (0.71–0.81)	+0.05	0.01
Model 3: Model 1 + TyG-BMI	0.74 (0.69–0.79)	+0.03	0.02
Model 4: Model 1 + LAD-PCAT-FAI + TyG-BMI	0.79 (0.74–0.84)	+0.08	**<0.01**
Model 5: Model 1 + LAD-PCAT-FAI + CMI	0.78 (0.73–0.83)	+0.07	0.01
Model 6: Model 1 + LAD-PCAT-FAI + TyG-WHtR	0.78 (0.72–0.83)	+0.07	0.01

CI, confidence interval. Traditional risk factors include age, hypertension, diabetes mellitus, current smoking, LDL-C, eGFR, and CAC score. Bold *p* values indicate statistical significance ($p < 0.05$).

Table 4. Net reclassification improvement and integrated discrimination improvement for combined prediction models.

Model comparison	NRI (95% CI)	*p* value	IDI (95% CI)	*p* value
Model 2 vs 1 (+ LAD-PCAT-FAI)	0.27 (0.13–0.40)	**<0.01**	0.03 (0.01–0.05)	**<0.01**
Model 3 vs 1 (+ TyG-BMI)	0.20 (0.06–0.33)	0.01	0.02 (0.01–0.04)	0.01
Model 4 vs 1 (+ FAI + TyG-BMI)	0.34 (0.20–0.49)	**<0.01**	0.05 (0.03–0.07)	**<0.01**
Model 5 vs 1 (+ FAI + CMI)	0.32 (0.18–0.46)	**<0.01**	0.04 (0.02–0.06)	**<0.01**
Model 6 vs 1 (+ FAI + TyG-WHtR)	0.30 (0.16–0.45)	**<0.01**	0.04 (0.02–0.06)	**<0.01**
Model 4 vs 2 (+ TyG-BMI over FAI)	0.19 (0.05–0.32)	0.01	0.02 (0.01–0.03)	0.01

NRI, net reclassification improvement; IDI, integrated discrimination improvement; CI, confidence interval. Model 1: traditional risk factors (age, hypertension, diabetes, smoking, LDL-C, eGFR, CAC score). Bold *p* values indicate statistical significance ($p < 0.05$).

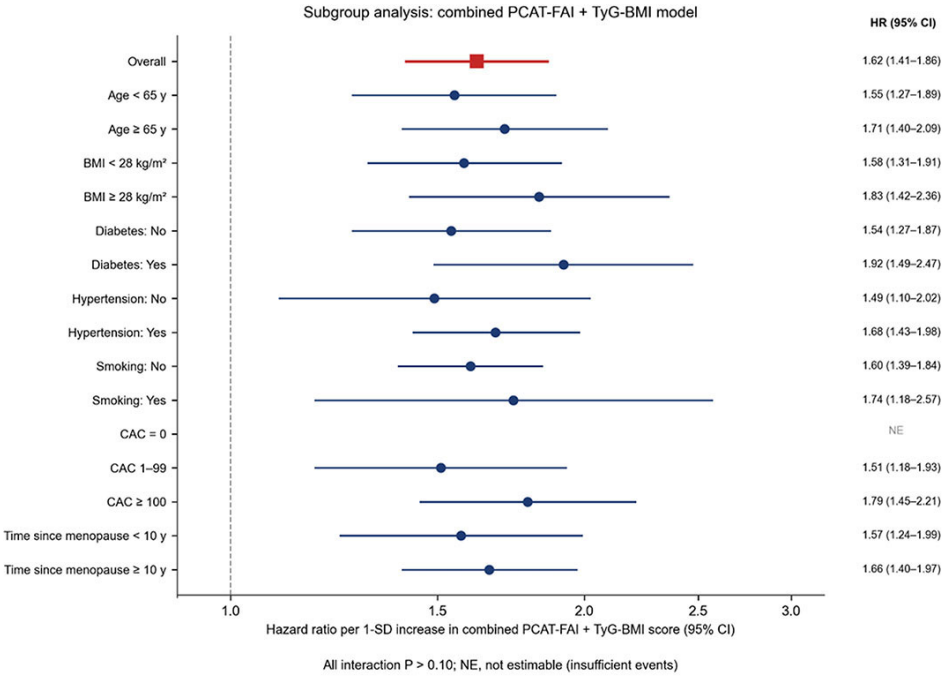


Fig. 5. Forest plot of subgroup analyses for summarizing hazard ratios with 95% confidence intervals for the combined PCAT-FAI plus TyG-BMI score across pre-specified subgroups (age <65 versus ≥65 years, BMI <28 versus ≥28 kg/m^2, diabetes, hypertension, smoking, CAC score strata, and time since menopause).

obesity (HR 1.83, 95% CI 1.42–2.36). Because HRs in Fig. 5 are scaled per 1-SD increase of the composite score, they are not directly comparable in magnitude to the per-5-HU HR for PCAT-FAI alone or the extreme-quartile HR for TyG-BMI reported in Tables 2 and 3. No significant interactions were observed across any subgroup (all $p > 0.05$), confirming the consistent prognostic value of the combined score across diverse risk profiles.

4. Discussion

This retrospective cohort study found that combining the pericoronary adipose tissue fat attenuation index with cardiometabolic indices, particularly TyG-BMI, improved the prediction of 5-year cardiovascular events in postmenopausal females. The combined model reclassified 34% of patients more accurately than traditional risk factors alone and achieved a C-index of 0.79. These results point to a complementary relationship between coronary-specific inflammation and systemic metabolic dysfunction in determining cardiovascular outcomes.

Several studies have established PCAT-FAI as an independent predictor of cardiovascular events. Higher PCAT-FAI surrounding the LAD has been shown to predict MACE independently of traditional risk factors and coronary artery disease severity, with increasing PCAT-FAI values associated with a graded increase in cardiovascular risk [17]. Two subsequent independent cohort studies have confirmed the prognostic value of PCAT-FAI in populations distinct from the original derivation cohort, including the multicentre ORFAN study and a cohort of young patients with suspected CAD [18,19]. In the present study, each 5 HU increase was associated with 31% higher risk. Whether this larger effect size reflects true biological differences in postmenopausal females or differences in study design cannot be determined from our data. The nonlinear relationship, with an inflection around −77 HU, is consistent with the hypothesis that PCAT-FAI captures a threshold phenomenon rather than a graded signal [8]. Clinically, this inflection point could help identify which females warrant closer surveillance, though prospective validation is needed before any cutoff is used in clinical practice.

TyG-based cardiometabolic indices have been studied as accessible surrogates for insulin resistance. Meta-analyses in defined cardiovascular populations report pooled hazard ratios indicating a higher cardiovascular risk for the highest versus lowest TyG categories, although the magnitude of this association varies across populations [20]. The finding that TyG-BMI outperformed TyG alone in our cohort is consistent with findings from Er et al. [21], who showed that adding BMI to TyG improved correlation with the hyperinsulinemic clamp. The cardiometabolic index, which weights the triglyceride-to-HDL ratio by waist-to-height ratio, showed intermediate performance; its lower ranking relative to TyG-BMI may reflect different sensitivity in a population where central adiposity and glycemic burden are correlated [22]. The visceral adiposity index and lipid accumulation product showed moderate associations in our study, though with smaller effect sizes than TyG-based indices [23]. This pattern aligns with prior research in postmenopausal females, suggesting that glucose-insulin axis dysfunction may be more predictive than pure adiposity measures in this population [24]. The stronger performance of TyG-BMI compared to TyG-WC or TyG-WHtR in our cohort may reflect the fact that BMI integrates both overall and central adiposity in postmenopausal females. However, this difference was modest and could also be influenced by the variability in measurements of waist circumference, ethnicity-specific body composition, and the limited sample size, and therefore should not be interpreted as evidence that visceral adiposity is not important. Visceral adiposity remains a well-established driver of cardiovascular risk in postmenopausal females, and the interplay between overall and central adiposity warrants further investigation. The biological rationale for combining PCAT-FAI with metabolic indices rests on the complementary nature of local coronary inflammation and systemic metabolic dysfunction [25]. Estrogen withdrawal after menopause promotes both processes through distinct but interconnected mechanisms. Decreasing estrogen levels lead to visceral fat redistribution, characterized by increased lipolysis and free fatty acid flux to the liver, driving hepatic insulin resistance and systemic inflammation [25]. Simultaneously, estrogen deficiency reduces nitric oxide production and antioxidant capacity in vascular endothelium, while promoting pro-inflammatory cytokine expression in peri-coronary adipose tissue [26]. The resulting coronary inflammation, captured by PCAT-FAI, creates a permissive environment for plaque vulnerability, while systemic metabolic dysfunction, reflected in cardiometabolic indices, provides the substrate for ongoing atherosclerotic progression [27]. Together, these processes compound cardiovascular risk in postmenopausal females in ways that biomarker class alone cannot fully capture.

These findings are particularly relevant to postmenopausal females. This population experiences a rapid acceleration in cardiovascular risk that conventional risk calculators often underestimate [28,29]. Menopause is not merely a change in lipid profiles but a shift in fat distribution, insulin sensitivity, and inflammatory tone that diverges from premenopausal physiology [30,31]. Our results suggest that imaging markers of coronary inflammation combined with accessible metabolic indices can improve risk detection during this period. Given the increasing availability of CCTA for evaluating chest pain in females, incorporating PCAT-FAI analysis into standard reporting could improve risk stratification without additional cost or radiation exposure.

From a clinical perspective, these findings support consideration of PCAT-FAI and TyG-BMI as complementary tools for cardiovascular risk assessment in postmenopausal females undergoing CCTA. TyG-BMI requires only fasting glucose and triglyceride measurements, both routinely available, making it highly practical for clinical implementation. PCAT-FAI analysis can be performed using standard CCTA datasets without additional imaging or contrast administration. This combination achieves risk reclassification that may inform decisions regarding the intensity of treatment, particularly for females at intermediate risk by traditional criteria. For instance, a postmenopausal

female with borderline risk factors but elevated PCAT-FAI and high TyG-BMI might warrant more aggressive preventive therapy than her risk profile would otherwise suggest.

A further clinical context for these findings is angina or ischemia with non-obstructive coronary arteries (ANOCA/INOCA), which accounts for up to 40–70% of patients undergoing coronary angiography for angina. Among women referred for invasive angiography, 50–70% are found to have non-obstructive coronary arteries, compared with 30–50% of men, and women constitute the majority of the ANOCA/INOCA population [32,33]. Coronary microvascular dysfunction, vasospasm, and chronic low-grade inflammation are central to its pathophysiology, and recent work has highlighted both the diagnostic challenges and the prognostic relevance of ANOCA/INOCA in postmenopausal females. Since PCAT-FAI captures pericoronary inflammation independent of luminal obstruction, it may also have value in stratifying ANOCA/INOCA patients, although current evidence on this specific application is not uniformly supportive. Our cohort was not specifically designed to test this hypothesis, but the present results justify prospective work linking PCAT-FAI with non-invasive or invasive measures of microvascular function.

Recent mechanistic work has further clarified the relationship between coronary adipose tissue and coronary microvascular dysfunction. Gašpárková and colleagues [34] recently provided a comprehensive review of the biological characteristics of epicardial adipose tissue and its mechanistic links to coronary microvascular dysfunction through inflammatory signaling, immune activation, extracellular matrix remodeling, endothelial dysfunction, and autonomic dysregulation. Their synthesis highlights that epicardial adipose tissue volume and attenuation, when combined with systemic cardiometabolic markers, may identify patients at heightened risk of microvascular dysfunction even in the absence of obstructive disease, and discusses emerging therapeutic strategies, including glucagon-like peptide-1 receptor agonists and sodium-glucose cotransporter-2 inhibitors, that may favorably remodel epicardial adipose tissue [34]. Pilot imaging data in women have shown that epicardial adipose tissue attenuation is altered in coronary microvascular dysfunction. However, dedicated studies of PCAT-FAI in INOCA have yielded inconsistent results: some report no association between FAI and CMD diagnosed by invasive coronary function testing, whereas vessel-specific analyses suggest that LAD-FAI may relate to impaired coronary flow reserve [35,36]. Coronary microvascular dysfunction is particularly prevalent in menopausal women, in whom declining estrogen levels promote both adipose-tissue remodeling and endothelial dysfunction [37]. Together, these findings provide additional pathophysiological context for our observation that PCAT-FAI captures prognostic information beyond traditional risk factors, suggesting that the peri-coronary attenuation signal reflects, at least in part, an adipocyte phenotype that is also permissive of microvascular dysfunction, particularly in postmenopausal females.

Limitations

Several limitations should be acknowledged in this study. Given the single-center retrospective design and the absence of an external validation cohort, our findings should be considered hypothesis-generating, and their generalizability will depend on prospective external validation in independent, multicenter, and multiethnic cohorts. Several specific limitations should also be noted. First, the single-center retrospective design limits generalizability and may introduce selection bias related to referral patterns for CCTA. Second, the lack of external validation indicates that these findings require confirmation in independent cohorts before broad clinical implementation. Third, CCTA itself represents a selected population with specific indications for noninvasive coronary evaluation, potentially limiting applicability to the general postmenopausal population. Fourth, the absence of serial measurements precludes assessment of whether changes in PCAT-FAI or metabolic indices over time predict outcomes beyond baseline values. Fifth, despite extensive adjustment, residual confounding from unmeasured variables cannot be excluded. Sixth, the study population was predominantly Chinese, and whether these findings apply to other ethnic groups requires investigation. Future research should prospectively validate the combined PCAT-FAI and cardiometabolic index approach in diverse populations and determine whether serial changes in these biomarkers predict treatment response. Randomized trials stratifying postmenopausal females by PCAT-FAI and metabolic indices for intensive risk factor modification would clarify the clinical utility of these observations. Mechanistic studies on the interplay between coronary and systemic metabolic inflammation may also identify new therapeutic targets.

In conclusion, this study shows that combining pericoronary adipose tissue fat attenuation index with cardiometabolic indices improves cardiovascular risk prediction in postmenopausal females. Pairing coronary inflammation assessment with metabolic markers offers a practical way to refine risk stratification in this patient population.

5. Conclusion

Among postmenopausal females undergoing coronary computed tomography angiography, peri-coronary adipose tissue fat attenuation index combined with cardiometabolic indices, particularly TyG-BMI, improved prediction of 5-year cardiovascular events beyond traditional risk factors. The combined model yielded better risk discrimination and reclassification, supporting its potential use for risk stratification in this patient population. These findings warrant prospective validation before adoption in clinical practice.

Abbreviations

ABSI, a body shape index; AUC, area under the curve; BMI, body mass index; CAC, coronary artery calcium; CCTA, coronary computed tomography angiography; CI, confidence interval; CMI, cardiometabolic index; eGFR, estimated glomerular filtration rate; FAI, fat attenuation index; HDL-C, high-density lipoprotein cholesterol; HR, hazard ratio; HU, Hounsfield units; IDI, integrated discrimination improvement; IQR, interquartile range; LAD, left anterior descending artery; LAP, lipid accumulation product; LCI, Lipid Comprehensive Index; LCx, left circumflex artery; LDL-C, low-density lipoprotein cholesterol; MACE, major adverse cardiovascular events; NRI, net reclassification improvement; PCAT, pericoronary adipose tissue; RCA, right coronary artery; ROC, receiver operating characteristic; TyG, triglyceride-glucose index; VAI, visceral adiposity index; WHtR, waist-to-height ratio.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

LY and CL: Conceptualization, Methodology. LY, SY, and XD: Data curation. LY and YS: Formal analysis, Software. CL: Funding acquisition, Resources, Supervision, Project administration. All five authors: Investigation, Writing—review & editing. CL is the corresponding author. All listed authors meet the four ICMJE authorship criteria: (1) substantial contributions to the conception and design of the work and the acquisition, analysis, and interpretation of data; (2) drafting the work and revising it critically for important intellectual content; (3) final approval of the version to be published; and (4) agreement to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study approved by the Human Research Ethics Committee of the Second Affiliated Hospital Zhejiang University School of Medicine (Approval No: I20221200) and waived informed consent due to the study's retrospective design. All procedures were performed in accordance with the Declaration of Helsinki.

Acknowledgment

The authors thank each of the study subjects for their participation.

Funding

This study has received funding by The Medical Science and Technology Project of Zhejiang Province, China (Grant Number 2021KY393).

Conflicts of Interest

The authors declare no conflicts of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/RCM52531.

References

[1] Vervoort D, Wang R, Li G, Filbey L, Maduka O, Brewer LC, et al. Addressing the Global Burden of Cardiovascular Disease in Women: JACC State-of-the-Art Review. Journal of the American College of Cardiology. 2024; 83: 2690–2707. https://doi.org/10.1016/j.jacc.2024.04.028

[2] El Khoudary SR, Aggarwal B, Beckie TM, Hodis HN, Johnson AE, Langer RD, et al. Menopause Transition and Cardiovascular Disease Risk: Implications for Timing of Early Prevention: A Scientific Statement From the American Heart Association. Circulation. 2020; 142: e506–e532. https://doi.org/10.1161/CIR.0000000000000912

[3] Nappi RE, Simoncini T. Menopause transition: a golden age to prevent cardiovascular disease. The Lancet. Diabetes & Endocrinology. 2021; 9: 135–137. https://doi.org/10.1016/S2213-8587(21)00018-8

[4] Park KE, Pepine CJ. Assessing cardiovascular risk in women: looking beyond traditional risk factors. Trends in Cardiovascular Medicine. 2015; 25: 152–153. https://doi.org/10.1016/j.tcm.2014.10.024

[5] Krishnan M, Babu S. Are we underestimating cardiovascular risks in midlife women? A call for gender-specific strategies. Experimental gerontology. 2025; 206: 112787. https://doi.org/10.1016/j.exger.2025.112787

[6] Antoniades C, Chan K. Pericoronary Adipose Tissue Imaging and the Need for Standardized Measurement of Coronary Inflammation: Translating PCAT Attenuation Gradients Into FAI Score for Clinical Use. JACC. Cardiovascular Imaging. 2025; 18: 895–898. https://doi.org/10.1016/j.jcmg.2025.06.012

[7] Lee SE, Sung JM, Andreini D, Al-Mallah MH, Budoff MJ, Cademartiri F, et al. Association Between Changes in Perivascular Adipose Tissue Density and Plaque Progression. JACC. Cardiovascular Imaging. 2022; 15: 1760–1767. https://doi.org/10.1016/j.jcmg.2022.04.016

[8] Antonopoulos AS, Sanna F, Sabharwal N, Thomas S, Oikonomou EK, Herdman L, et al. Detecting human coronary inflammation by imaging perivascular fat. Science Translational Medicine. 2017; 9: eaal2658. https://doi.org/10.1126/scitranslmed.aal2658

[9] Wen D, Li J, Ren J, Zhao H, Li J, Zheng M. Pericoronary adipose tissue CT attenuation and volume: Diagnostic performance for hemodynamically significant stenosis in patients with suspected coronary artery disease. European Journal of Radiology. 2021; 140: 109740. https://doi.org/10.1016/j.ejrad.2021.109740

[10] Antoniades C, Tousoulis D, Vavlukis M, Fleming I, Duncker DJ, Eringa E, et al. Perivascular adipose tissue as a source of therapeutic targets and clinical biomarkers. European Heart Journal. 2023; 44: 3827–3844. https://doi.org/10.1093/eurheartj/ehad484

[11] Tang Y, Zheng X, Yang X, Guo S, Luo Q, Su M, et al. Machine learning-based integration of pericoronary adipose tissue and clinical risk factors for cardiovascular risk prediction in type 2 diabetes: a retrospective cohort study. European Journal of Medical Research. 2025; 30: 961. https://doi.org/10.1186/s40001-025-03237-4

[12] Duan M, Zhao X, Li S, Miao G, Bai L, Zhang Q, et al. Metabolic

score for insulin resistance (METS-IR) predicts all-cause and cardiovascular mortality in the general population: evidence from NHANES 2001-2018. Cardiovascular Diabetology. 2024; 23: 243. https://doi.org/10.1186/s12933-024-02334-8

[13] Joshi H, Shah K, Patel P, Prajapati J, Parmar M, Doshi D, et al. Novel indexes for diagnosing metabolic syndrome in apparently healthy Gujarati Asian Indians: a cross-sectional study. QJM: Monthly Journal of the Association of Physicians. 2016; 109: 717–722. https://doi.org/10.1093/qjmed/hcw056

[14] Yang Z, Gong H, Kan F, Ji N. Association between the triglyceride glucose (TyG) index and the risk of acute kidney injury in critically ill patients with heart failure: analysis of the MIMIC-IV database. Cardiovascular Diabetology. 2023; 22: 232. https://doi.org/10.1186/s12933-023-01971-9

[15] Hu T, Lin S, Ding X, Wang X, Sun J. Prognostic Value of Pericoronary Adipose Tissue Attenuation After Transcatheter Aortic Valve Replacement in Patients With Aortic Stenosis and Obstructive Coronary Artery Disease. Reviews in Cardiovascular Medicine. 2025; 26: 40045. https://doi.org/10.31083/RCM40045

[16] Sun Q, Ren Q, Du L, Chen S, Wu S, Zhang B, et al. Cardiometabolic Index (CMI), Lipid Accumulation Products (LAP), Waist Triglyceride Index (WTI) and the risk of acute pancreatitis: a prospective study in adults of North China. Lipids in Health and Disease. 2023; 22: 190. https://doi.org/10.1186/s12944-023-01948-3

[17] Long Q, Yu M, Xiong YY, Yang F, Yuan YF, Xu JH, et al. Pericoronary fat attenuation index is a potential indicator for the prognosis of coronary heart disease: a systematic review and meta-analysis. Clinical Radiology. 2026; 97: 107310. https://doi.org/10.1016/j.crad.2026.107310

[18] Chan K, Wahome E, Tsiachristas A, Antonopoulos AS, Patel P, Lyasheva M, et al. Inflammatory risk and cardiovascular events in patients without obstructive coronary artery disease: the ORFAN multicentre, longitudinal cohort study. Lancet. 2024; 403: 2606–2618. https://doi.org/10.1016/S0140-6736(24)00596-8

[19] Yu Y, Shan D, Wang X, Liu Z, Dou G, Yang J, et al. Predictive value of the perivascular fat attenuation index for MACE in young people suspected of CAD. BMC Cardiovascular Disorders. 2025; 25: 80. https://doi.org/10.1186/s12872-024-04401-0

[20] Bampali E, Chiotis S, Zgouridou A, Koliastasis L, Vrachatis D, Pavlou DO, et al. Association of the Triglyceride-Glucose Index with Major Adverse Cardiovascular Events in Patients with Acute Coronary Syndromes: A Systematic Review and Meta-Analysis. Medicina (Kaunas, Lithuania). 2026; 62: 360. https://doi.org/10.3390/medicina62020360

[21] Er LK, Wu S, Chou HH, Hsu LA, Teng MS, Sun YC, et al. Triglyceride Glucose-Body Mass Index Is a Simple and Clinically Useful Surrogate Marker for Insulin Resistance in Nondiabetic Individuals. PloS One. 2016; 11: e0149731. https://doi.org/10.1371/journal.pone.0149731

[22] Zhong H, Luo L, Wang X, Xiao Y. Association between triglyceride to HDL cholesterol ratio and a risk of diabetes mellitus: a systematic review and meta-analysis. Laboratory Medicine. 2025; 56: 1–6. https://doi.org/10.1093/labmed/lmae052

[23] Qing L, Wei R, Chan L, Xiaoya Z, Xin X. Sensitivity of various body indices and visceral adiposity index in predicting metabolic syndrome among Chinese patients with adult growth hormone deficiency. Journal of Endocrinological Investigation. 2017; 40: 653–661. https://doi.org/10.1007/s40618-017-0621-2

[24] Moon S, Park JH, Jang EJ, Park YK, Yu JM, Park JS, et al. The Cut-off Values of Surrogate Measures for Insulin Sensitivity in a Healthy Population in Korea according to the Korean National Health and Nutrition Examination Survey (KNHANES) 2007-2010. Journal of Korean Medical Science. 2018; 33: e197. https://doi.org/10.3346/jkms.2018.33.e197

[25] Ko SH, Jung Y. Energy Metabolism Changes and Dysregulated Lipid Metabolism in Postmenopausal Women. Nutrients. 2021; 13: 4556. https://doi.org/10.3390/nu13124556

[26] Matthews KA, Crawford SL, Chae CU, Everson-Rose SA, Sowers MF, Sternfeld B, et al. Are changes in cardiovascular disease risk factors in midlife women due to chronological aging or to the menopausal transition? Journal of the American College of Cardiology. 2009; 54: 2366–2373. https://doi.org/10.1016/j.jacc.2009.10.009

[27] Ridker PM, Everett BM, Thuren T, MacFadyen JG, Chang WH, Ballantyne C, et al. Antiinflammatory Therapy with Canakinumab for Atherosclerotic Disease. The New England Journal of Medicine. 2017; 377: 1119–1131. https://doi.org/10.1056/NEJMoa1707914

[28] El Khoudary SR, Greendale G, Crawford SL, Avis NE, Brooks MM, Thurston RC, et al. The menopause transition and women's health at midlife: a progress report from the Study of Women's Health Across the Nation (SWAN). Menopause (New York, N.Y.). 2019; 26: 1213–1227. https://doi.org/10.1097/GME.0000000000001424

[29] Janssen I, Powell LH, Crawford S, Lasley B, Sutton-Tyrrell K. Menopause and the metabolic syndrome: the Study of Women's Health Across the Nation. Archives of Internal Medicine. 2008; 168: 1568–1575. https://doi.org/10.1001/archinte.168.14.1568

[30] Nappi RE, Chedraui P, Lambrinoudaki I, Simoncini T. Menopause: a cardiometabolic transition. Diabetes & Endocrinology. 2022; 10: 442–456. https://doi.org/10.1016/S2213-8587(22)00076-6

[31] Vecchiatto B, Castro TL, Ferreira NJR, Evangelista FS. Healthy adipose tissue after menopause: contribution of balanced diet and physical exercise. Exploration of Endocrine and Metabolic Diseases. 2025; 2: 101424. https://doi.org/10.37349/eemd.2025.101424

[32] Sucato V, Madaudo C, Galassi AR. The ANOCA/INOCA Dilemma Considering the 2024 ESC Guidelines on Chronic Coronary Syndromes. Journal of Cardiovascular Development and Disease. 2024; 11: 302. https://doi.org/10.3390/jcdd11100302

[33] Tudurachi A, Anghel L, Tudurachi BS, Zăvoi A, Ceasovschih A, Sascău RA, et al. Beyond the Obstructive Paradigm: Unveiling the Complex Landscape of Nonobstructive Coronary Artery Disease. Journal of Clinical Medicine. 2024; 13: 4613. https://doi.org/10.3390/jcm13164613

[34] Gašpárková V, Tran BT, Ošťádal P, Lambert L, Hájek P, Kala P. Epicardial adipose tissue in coronary microvascular disease. American Heart Journal Plus: Cardiology Research and Practice. 2026; 63: 100734. https://doi.org/10.1016/j.ahjo.2026.100734

[35] Smilowitz NR, Jerome B, Rhee DW, Donnino R, Jacobs JE, Hausvater A. Coronary perivascular adipose tissue fat attenuation index in patients with ischemia with no obstructive coronary arteries and coronary microvascular dysfunction. Coronary Artery Disease. 2026; 37: 187–194. https://doi.org/10.1097/MCA.0000000000001583

[36] Takizawa R, Kato S, Kodama S, Fukui K, Sekii R, Yasuda N, et al. Pericoronary Fat Attenuation Index and MRI-Derived Coronary Flow Reserve: A Comparative Study in Suspected Versus Known Coronary Artery Disease. Tomography (Ann Arbor, Mich.). 2026; 12: 55. https://doi.org/10.3390/tomography12040055

[37] Mathew D, Wang W, Kunadian V. Coronary microvascular dysfunction in menopausal women. Heart (British Cardiac Society). 2026. https://doi.org/10.1136/heartjnl-2026-328124 (online ahead of print)