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Incremental Value of Noncontrast Chest Computed Tomography-derived Parameters in Predicting Subclinical Carotid Atherosclerosis

From the PERSUADE Study

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Purpose: To investigate the incremental value of noncontrast chest computed tomography (CT)-derived parameters, such as coronary artery calcium score (CACS) and epicardial adipose tissue volume (EATv), in predicting subclinical carotid atherosclerosis above traditional risk factors in community-based asymptomatic populations of northern China.

Materials and Methods: A total of 2195 community-based asymptomatic individuals were enrolled from Jidong Oilfield in accordance with the PERSUADE study. CACS and EATv were measured on noncontrast chest CT. Demographics and ideal cardiovascular health score (ICHS) were collected through questionnaires. We recalculated the ideal cardiovascular health risk score (ICHRS) (ICHRS = 14−ICHS) and standardized the parameters as log-CACS and body mass index adjusted EATv (i-EATv). Subclinical carotid atherosclerosis was assessed by Doppler sonography and defined as any prevalence of average carotid intima-media thickness ≥ 1.00 mm, appearance of carotid plaque, and carotid arterial stenosis in the areas of extracranial carotid arteries on both sides.

Results: A total of 451 (20.55%) individuals presented subclinical carotid atherosclerosis. CACS and EATv were significantly greater in the subclinical group, while ICHS was lower. In multivariate logistic regression, ICHRS (odds ratio [OR] = 1.143, 95% confidence interval [CI]: 1.080-1.210, $P < 0.001$), log-CACS (OR = 1.701, 95% CI: 1.480-1.955, $P < 0.001$), and i-EATv (OR = 1.254, 95% CI: 1.173-1.341, $P < 0.001$) were found to be independent risk predictors for subclinical carotid atherosclerosis. In receiver-operating characteristic curve analysis, when combined with male sex and age level, the area under the curve of the ICHRS basic model increased from 0.627 (95% CI: 0.599-0.654) to 0.757 (95% CI: 0.732-0.781) ($P < 0.0001$). Further adding log-CACS and i-EATv, the area under the curve demonstrated a statistically significant improvement (0.788 [95% CI: 0.765-0.812] vs. 0.757 [95% CI: 0.732-0.781], $P < 0.0001$).

Conclusion: Noncontrast chest CT-derived parameters, including CACS and EATv, could provide significant incremental improvement for predicting subclinical carotid atherosclerosis beyond the conventional risk assessment model based on ICHRS.

Key Words: subclinical carotid atherosclerosis, ideal cardiovascular health score, coronary artery calcium score, epicardial adipose tissue volume

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The atherosclerotic pathologic changes of peripheral arteries could reflect subclinical atherosclerosis to some extent in community-based asymptomatic populations. Subclinical atherosclerosis refers to subclinical carotid atherosclerosis or atherosclerosis in general. Published results of the Multi-Ethnic Study of Atherosclerosis (MESA) suggested that both carotid intima-media thickness (CIMT) and carotid atherosclerotic plaque were strongly associated with cardiovascular events.[1] Other studies illustrated that early detection or prediction of subclinical carotid atherosclerosis is a pivotal step in primary prevention protocols.[2,3]

For cardiovascular health (CVH) promotion, the American Heart Association (AHA) proposed ideal CVH metrics in detail, which were defined by the presence of ideal health behaviors and health factors.[4] In the past decade, ideal CVH metrics have been greatly promoted and applied in the form of ideal cardiovascular health score (ICHS). More favorable ICHS was associated with a lower risk of peripheral artery disease and lower levels of cardiovascular disease (CVD) risk factors.[5] However, little is known about the association between ICHS and subclinical carotid atherosclerosis due to insufficient clinical metrics.

Noncontrast chest computed tomography (CT) could be routinely acquired through an appropriate scan protocol regardless of whether it is electrocardiography (ECG) gated or not. The coronary artery calcium score (CACS)

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and epicardial adipose tissue volume (EATv) are the most widely used parameters gained from noncontrast chest CT. Both CACS and EATv were related to subclinical atherosclerosis in several studies in recent years.[6–8] However, the association of ICHS, noncontrast chest CT-derived parameters, and subclinical carotid atherosclerosis remains unclear in community-based asymptomatic populations.

In this study, we hypothesized that noncontrast chest CT parameters, such as CACS and EATv, could provide certain incremental value for predicting subclinical carotid atherosclerosis above the traditional risk assessment model based on ICHS.

MATERIALS AND METHODS

Study Design and Participants

The PERSUADE study is an observational, longitudinal, and prospective cohort study in a target population of asymptomatic subjects based on Jidong Oilfield (Tangshan city, Hebei province, China).[9] From July 2013 to August 2014, more than 9000 participants were enrolled in this cohort consecutively, including employees from Jidong Co. Ltd and their family members. The exclusion criteria were as follows: (1) prior history of peripheral artery disease and CVD (including myocardial infarction, stroke, heart failure, atrial fibrillation, and severe carotid artery stenosis); (2) inadequate clinical and laboratory data; and (3) severe motion artifacts deemed unable to evaluate CT parameters. Finally, 2195 participants aged from 40 to 75 years, who had complete information on ideal CVH metrics, noncontrast chest CT parameters, and carotid Doppler sonography assessments were enrolled in the analysis (Fig. 1). Questionnaires and physical examinations were performed by trained medical professionals from Jidong Oilfield Hospital. The research was performed according to the Helsinki Declaration guidelines and approved by the Ethics Committee of Jidong Oilfield Hospital. All participants signed written informed consents.

Assessment of ICHS

In accordance with the AHA guidelines, we defined ideal CVH metrics into 7 items under 3 levels.[4] Poor level scored 0 points, intermediate level scored 1 point, and ideal level scored 2 points. Detailed CVH metrics are provided in Supplementary Table 1 (Supplemental Digital Content 1, http://links.lww.com/JTI/A221). A total ICHS was calculated, and moreover, the ideal cardiovascular health risk score (ICHRS) was recalculated as a total of 14 points minus ICHS (ICHRS = 14−ICHS).

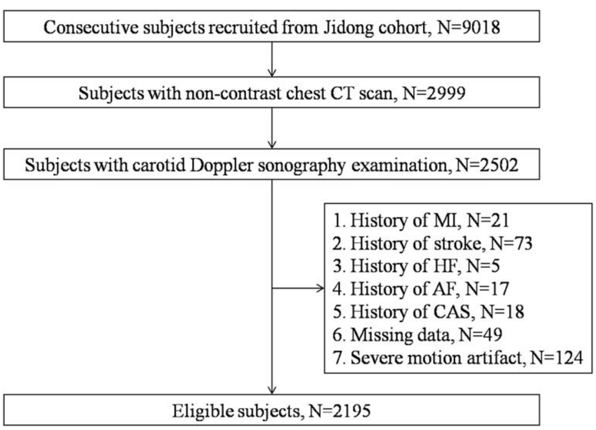

FIGURE 1. Flowchart illustrating the study populations. AF indicates atrial fibrillation; CAS, carotid arterial stenosis; HF, heart failure; MI, myocardial infarction.

Data on current smoking, physical activity, and healthy diet were assessed through questionnaires. Body mass index was calculated as the body weight (kg) divided by the square of height (m^2). Blood pressure was measured using a mercury sphygmomanometer. The researchers recorded the average of 2 readings of systolic blood pressure and diastolic blood pressure after an interval at which all the participants rested in the seated position for at least 5 minutes. Blood samples were obtained and separated according to previous methods. Biochemical variables were measured using an autoanalyzer (Olympus, AU400, Japan) at the central laboratory of the Jidong Oilfield Hospital.

Assessment of Carotid Doppler Sonography

Carotid Doppler sonography was performed by two experienced sonographers, who were blinded to the information of participants with a portable machine (EME Companion, Nicolet, Madison, WI). All participants received bilateral common carotid artery, carotid bifurcation, internal carotid artery, and external carotid artery examinations in a supine position with their heads turned to the contralateral side.[10] CIMT was measured at the far wall of the common carotid artery proximal to the bifurcation along a plaque free segment ≥ 10 mm long on each side. CIMT was measured twice by the same operator, and the average values were recorded for each subject. Carotid plaque was defined as a focal structure either encroaching into the arterial lumen of at least 0.5 mm or 50% of the surrounding IMT value or demonstrating a thickness of 1.5 mm from the intima-lumen interface to the media adventitia interface. Carotid arterial stenosis was defined as a peak systolic blood flow velocity of ≥ 125 cm/s and vertical artery peak systolic blood flow velocity of ≥ 170 cm/s in the common carotid artery or internal carotid artery. Furthermore, carotid artery stenosis was graded on previous recommendations.[11,12] In this study, we raised a composite endpoint of CIMT of ≥ 1.00 mm[13] and the appearance of carotid plaque and carotid arterial stenosis as previously described.[14,15] Participants were diagnosed with subclinical carotid atherosclerosis in any exhibition of at least one of the above signs.

Assessment of Noncontrast Chest CT

Noncontrast chest CT examination was scanned using a 64-slice CT scanner (Siemens Sensation 64-Slice CT, Forchheim, Germany) for extra CACS and EATv quantification. All CT DICOM files were transferred to semiautomatic software (Syngo MultiModality Workplace, Siemens, Germany) after a standard non–ECG-gated prospective scan protocol. Two experienced cardiologists who were blinded to the patients' clinical information were responsible for quantification assessment of CACS and EATv. An example for imaging quantification is provided in Figure 2.

CACS is calculated by the Agatston scoring method,[16] which is based on the area of calcification and weighted by the highest density of calcification. Calcified plaque is defined as a threshold attenuation value of > 130 HU on at least 4 contiguous pixels. The total CACS is the sum of the calcified plaque scores of all coronary arteries at the individual level.

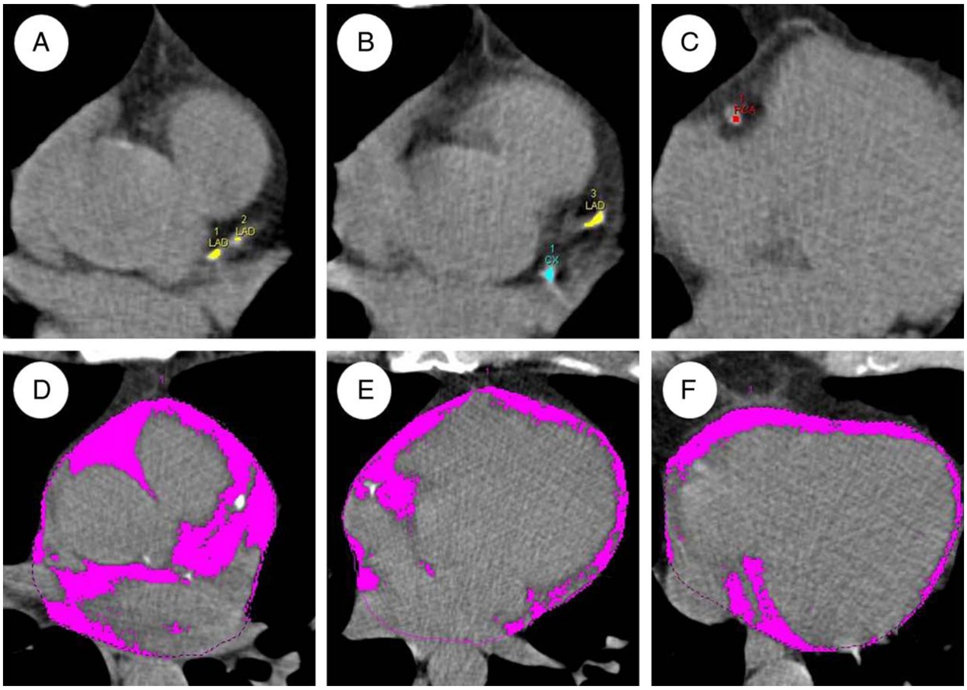

FIGURE 2. Example for CACS and EATv quantification in a 58-year-old male participant from Jidong Oilfield community. Transverse CT sections obtained from non–ECG-gated noncontrast chest CT imaging are shown. A–C, The figures illustrate CACS quantification manually, and calcification in each coronary artery is represented in different colors. D–F, Demonstrate total EATv quantification tracing the contour of the pericardium semiautomatically based on Hounsfield unit (HU) attenuation.

The measurement range of EATv is from bifurcation of the pulmonary artery to the diaphragm. A threshold attenuation value of −195 to −45 HU is defined as the adipose tissue. According to the size of the heart, cardiologists manually extract 7 to 10 parallel and equidistant axial contours of the pericardium. Finally, the EATv is calculated automatically in accordance with the above ranges and threshold attenuation value.[17]

Intraclass correlation coefficient tests of both CACS and EATv assessment are provided in Supplementary Table 2 (Supplemental Digital Content 1, http://links.lww.com/JTI/A221), which showed excellent agreement on both intraobserver and interobserver data.

Statistical Analysis

Continuous variables are presented as the mean and SD or median and interquartile range. In the case of a normal distribution, the Student *t* test was used for intergroup comparisons; otherwise, the rank sum test was used. Categorical variables are represented by percentages, and the χ^2 or Fisher exact test was used for comparisons between groups. Multivariate logistic regression analysis was used to reveal the association between ICHRS combined with noncontrast chest CT parameters and subclinical carotid atherosclerosis by calculating the odds ratios (ORs) and 95% confidence interval (CI). ICHRS was generated based on ICHS during the analysis of multivariate logistic regression. We recalculated log-transformed CACS as well. I-EATv was defined as EATv divided by body mass index to correct for the effect of obesity as previously described.[18] The area under the curve (AUC) and 95% CI were determined by receiver-operating characteristic (ROC) curve analysis. In addition, differences among several models were analyzed by the DeLong method. All statistical analyses were performed by SPSS (version 23.0, IBM Corporation, Armonk, NY) and MedCalc (version 15.2.2, MedCalc Software, Mariakerke, Belgium). All statistical tests were 2-tailed, and a *P* value <0.05 was considered to be statistically significant.

RESULTS

Demographic Characteristics of Participants

There were 2195 individuals (55.47 ± 7.68 y of age, 47.6% male) enrolled in this cross-sectional study for further analysis. The prevalence of hypertension, diabetes mellitus, and dyslipidemia was 24.6%, 8.7%, and 15.1%, respectively. Detailed demographic characteristics, as well as information regarding noncontrast chest CT parameters and ICHS, are summarized in Table 1.

Specifically, increased CIMT $\geq$1.0 mm was observed in 104 (4.7%) cases; carotid arterial stenosis was detected in 92 (4.2%) cases; and carotid plaque was present in 409 (18.6%) cases. Participants were divided into 2 groups in accordance with subclinical carotid atherosclerosis. As a result, 451 individuals were diagnosed with subclinical carotid atherosclerosis. Male residents were more likely to suffer subclinical carotid atherosclerosis, similar to subgroups of above 55 years of age (Table 1).

The subclinical carotid atherosclerosis group had a higher prevalence of traditional risk factors, such as hypertension, diabetes mellitus, and dyslipidemia. Glucose, total cholesterol, low-density lipoprotein cholesterol, CIMT, EATv, i-EATv, CACS, log-CACS, and ICHS were significantly greater in the subclinical carotid atherosclerosis group (Table 1).

TABLE 1. Demographic Characteristic of Enrolled Individuals

Parameters	Overall (N = 2195)	Subclinical Carotid Atherosclerosis (N = 451)	Normal (N = 1744)	*P*
Sex (male)	1045 (47.6)	283 (62.7)	762 (43.7)	< 0.001
Age (y)	55.47 ± 7.68	60.60 ± 7.10	54.14 ± 7.26	< 0.001
Age level				< 0.001
45-	150 (6.9)	6 (1.3)	144 (8.3)	—
45-55	880 (40.1)	83 (18.4)	797 (45.7)	—
55-65	927 (42.2)	257 (57.0)	670 (38.4)	—
65+	238 (10.8)	105 (23.3)	133 (7.6)	—
BMI (kg/m^2)	25.12 ± 3.25	25.64 ± 3.08	24.99 ± 3.29	< 0.001
SBP (mm Hg)	132.98 ± 20.00	139.69 ± 21.10	131.25 ± 19.34	< 0.001
DBP (mm Hg)	84.10 ± 13.21	85.72 ± 13.20	83.68 ± 13.19	0.004
Tobacco use	503 (22.9)	147 (32.6)	356 (20.4)	< 0.001
Alcohol	638 (29.1)	149 (33.0)	489 (28.0)	0.037
Hypertension	541 (24.6)	174 (38.6)	367 (21.0)	< 0.001
Diabetes mellitus	191 (8.7)	72 (16.0)	119 (6.8)	< 0.001
Dyslipidemia	331 (15.1)	86 (19.1)	245 (14.0)	0.008
Glucose (mmol/L)	5.60 ± 1.47	5.96 ± 1.86	5.51 ± 1.34	< 0.001
TC (mmol/L)	4.75 ± 0.90	4.87 ± 0.87	4.72 ± 0.91	0.002
TG (mmol/L)	1.71 ± 1.38	1.81 ± 1.15	1.69 ± 1.43	0.103
LDLC (mmol/L)	2.68 ± 0.60	2.81 ± 0.60	2.65 ± 0.60	< 0.001
HDLC (mmol/L)	1.22 ± 0.28	1.17 ± 0.26	1.23 ± 0.28	< 0.001
CIMT (mm)	0.85 ± 0.18	0.95 ± 0.21	0.82 ± 0.16	< 0.001
EATv (ml)	123.97 (94.63, 160.63)	150.91 (119.30, 187.11)	117.63 (90.04, 151.98)	< 0.001
i-EATv	4.97 (3.88, 6.24)	5.89 (4.89, 7.14)	4.72 (3.74, 5.93)	< 0.001
CACS	0.00 (0.00, 0.00)	0.00 (0.00, 38.10)	0.00 (0.00, 0.00)	< 0.001
log-CACS	0.00 (0.00, 0.00)	0.00 (0.00, 1.59)	0.00 (0.00, 0.00)	< 0.001
ICHS	10.00 (8.00, 11.00)	9.00 (7.00, 10.00)	10.00 (8.00, 11.00)	< 0.001

BMI indicates body mass index; DBP, diastolic blood pressure; HDLC, high-density lipoprotein cholesterol; LDLC, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride.

Distribution of Subclinical Carotid Atherosclerosis Under Different ICHS

The included individuals were divided and regrouped by different ICHS levels. The numbers of normal subjects, as well as the cases of subclinical carotid atherosclerosis, are shown in Figure 3. Individuals with subclinical carotid atherosclerosis accounted for more than 25% when ICHS was <8, while the proportions were <20% when the ICHS was > 10. There was a decreasing trend of the prevalence of subclinical carotid atherosclerosis as ICHS increased, which demonstrated a negative correlation between ideal CVH metrics and peripheral arterial atherosclerosis (Fig. 3).

Univariate and Multivariate Logistic Regression Analysis of Subclinical Carotid Atherosclerosis

Male sex, age level, i-EATv, log-CACS, and ICHRS demonstrated statistical significance in univariate logistic regression analysis. When the aforementioned variables were included in multivariate logistic regression analysis, the ORs for subclinical carotid atherosclerosis were male (OR = 1.506,

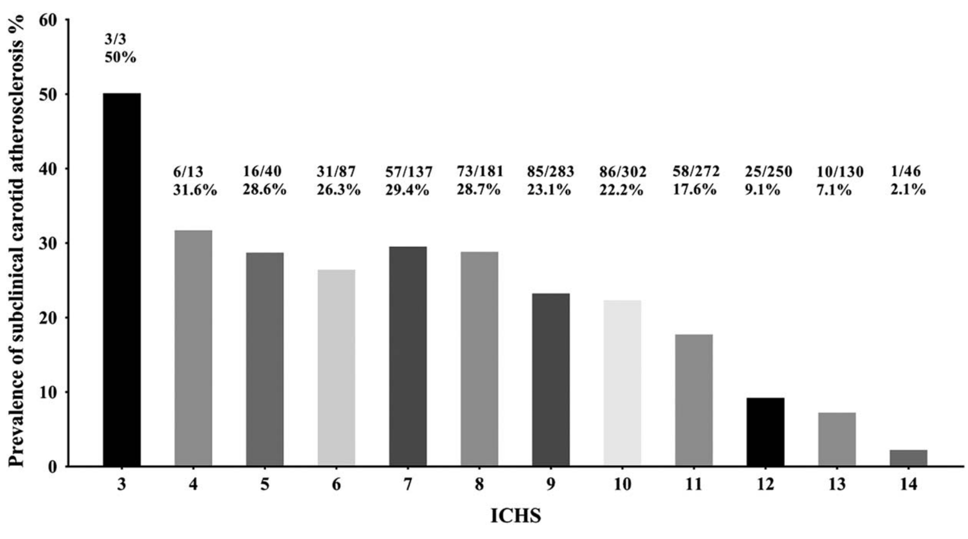

FIGURE 3. Distribution of subclinical carotid atherosclerosis under different ICHS.

TABLE 2. Risk Factors for Subclinical Carotid Atherosclerosis

	Univariate logistic regression			Multivariate logistic regression		
Parameters	**OR**	**95% CI**	***P***	**OR**	**95% CI**	***P***
Sex (male)	2.171	1.754-2.686	< 0.001	1.506	1.177-1.926	0.001
Age level						
45-	1.000	—	—	1.000	—	—
45-55	2.499	1.071-5.832	0.034	1.965	0.829-4.655	0.125
55-65	9.206	4.017-21.096	< 0.001	5.743	2.460-13.405	< 0.001
65+	18.947	8.052-44.588	< 0.001	9.849	4.084-23.755	< 0.001
i-EATv	1.447	1.364-1.536	< 0.001	1.254	1.173-1.341	< 0.001
log-CACS	2.302	2.025-2.617	< 0.001	1.701	1.480-1.955	< 0.001
ICHRS	1.220	1.162-1.280	< 0.001	1.143	1.080-1.210	< 0.001

ICHRS = 14−ICHS.

95% CI: 1.177-1.926, $P = 0.001$), age 55 to 65 years (OR = 5.743, 95% CI: 2.460-13.405, $P < 0.001$), age 65+ (OR = 9.849, 95% CI: 4.084-23.755, $P < 0.001$), i-EATv (OR = 1.254, 95% CI: 1.173-1.341, $P < 0.001$), and log-CACS (OR = 1.701, 95% CI: 1.480-1.955, $P < 0.001$) and ICHRS (OR = 1.143, 95% CI: 1.080-1.210, $P < 0.001$) (Table 2).

ROC Analysis of Different Models for Subclinical Carotid Atherosclerosis

Adding male sex and age level on the basis of ICHRS significantly increased the AUC for predicting subclinical carotid atherosclerosis (0.757 [95% CI: 0.732-0.781] vs. 0.627 [95% CI: 0.599-0.654], $P < 0.0001$). The incremental improvement values of log-CACS and i-EATv were significant when added to model 2, with elevations in the AUC from 0.757 to 0.776 (model 4 vs. model 2, $P = 0.0002$) and from 0.757 to 0.773, respectively (model 3 vs. model 2, $P = 0.0017$). The AUC for model 5, which combined i-EATv and log-CACS on the basis of model 2 at the same time, peaked at 0.788 (95% CI: 0.765-0.812) among the total models. The differences between model 5 and model 3 ($P = 0.0007$) showed that log-CACS outperformed i-EATv with a further increment in predicting subclinical carotid atherosclerosis (Table 3, Fig. 4).

DISCUSSION

In this cross-sectional study, we demonstrated the general characteristics of community-based asymptomatic subjects, including the prevalence of subclinical carotid atherosclerosis, traditional risk factors, CACS, and EATv. It was found that noncontrast chest CT-derived parameters, such as CACS and EATv, could provide significant incremental value for predicting subclinical carotid atherosclerosis on the basis of traditional risk factors.

Multiple biological and lifestyle risk factors could constantly induce cardiovascular and peripheral atherosclerosis over a period of years. Under this circumstance, early detection of arterial atherosclerotic changes demonstrated prominent merit in risk assessment.[15] Carotid atherosclerosis is regarded as a marker of systemic atherosclerosis, which means that patients with extracranial carotid atherosclerosis frequently have atherosclerosis elsewhere and face an increased risk of myocardial infarction and death attributable to CVD.[19] The MESA study showed that CIMT and carotid atherosclerotic plaque were available noninvasive measurements and well-performing predictors of cardiovascular events.[20,21] In this study, the overall 20.55% incidence of subclinical carotid atherosclerosis was lower than that in previously published studies due to younger age levels and fewer risk factor distributions, reflecting the actual situation of subclinical carotid atherosclerosis in regional individuals of northern China.[2,22]

Although carotid arteries could be examined by noninvasive means, such as sonography, it seemed to be unrealistic and costly for every asymptomatic individual to undergo this type of examination because sonography assessments were laborious and time-consuming tasks that required considerable manpower with adequate operation experience. On the other hand, noncontrast CT for lung cancer screening is being widely used in adults across China, but the data derived from noncontrast CT seems to be insufficiently analyzed. Moreover, initiating systematic atherosclerosis risk assessment with appropriate scales deserves to be taken into consideration within apparently healthy individuals.[20] Several CVD risk estimation systems for use in asymptomatic populations, including Framingham, SCORE, ASSIGN-SCORE, PROCAM, CUORE, and CHINA-PAR, enable clinical practitioners to evaluate the potential risk of subclinical atherosclerosis. In this study, we selected the ICHS as the fundamental risk assessment

TABLE 3. ROC Analysis of Different Models

Models	**AUC**	**95% CI**	***P***	**vs. M1**	**vs. M2**	**vs. M3**	**vs. M4**
Model 1:ICHRS	0.627	0.599-0.654	< 0.0001	—	—	—	—
Model 2:M1+male+age	0.757	0.732-0.781	< 0.0001	< 0.0001	—	—	—
Model 3:M2+i-EATv	0.773	0.749-0.797	< 0.0001	< 0.0001	0.0017	—	—
Model 4:M2+log-CACS	0.776	0.752-0.800	< 0.0001	< 0.0001	0.0002	0.6162	—
Model 5:M2+i-EATv+log-CACS	0.788	0.765-0.812	< 0.0001	< 0.0001	< 0.0001	0.0007	0.0053

$P < 0.005$ was considered to be statistically significant abided by Bonferroni rule.
ICHRS = 14−ICHS.

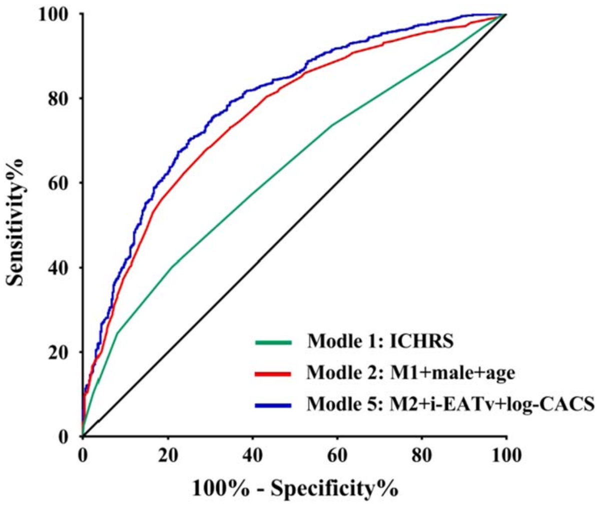

FIGURE 4. ROCs of model 1, model 2, and model 5. Model 1 demonstrated a basic model of ICHRS with AUC = 0.627 (95% CI: 0.599-0.654). Model 2 gained an ROC curve with an AUC = 0.757 (95% CI: 0.732-0.781) when adding male sex and age to model 1. Further combining i-EATv and log-CACS to model 2, model 5 reached a peak AUC = 0.788 (95% CI: 0.765-0.812). full color online

scale for subclinical atherosclerosis because it contained both ideal health behaviors and ideal health factors, which were unique compared with other scales and suitable for community-based populations. In actual practice, ICHS provides convenience due to its integration of a variety of clinical characteristics and its application as a whole instead of concrete but redundant parameters.

Olatokunbo Osibogun et al[23] reported that a more favorable ICHS was associated with lower concentrations of CVD biomarkers in a cross-sectional study of 5379 participants. In another study, researchers analyzed the association between ideal CVH metrics and subclinical atherosclerosis, reaching a similar result on the importance of ideal ICHS for the primordial prevention of subclinical atherosclerosis.[24] In this study, we demonstrated the distribution of ideal CVH metrics among a community-based population and found lower ICHS in the subclinical carotid atherosclerosis group than in the normal group. However, ICHRS could not be satisfactory to predict subclinical peripheral atherosclerosis with a low AUC value. Even after gender and age were added, the performance of the corresponding model increased to only 0.757 (95% CI: 0.732-0.781).

Because cardiovascular atherosclerosis and peripheral atherosclerosis are closely interlinked, Madaj and Budoff[25] suggested adding noncontrast chest CT parameters to routine models to achieve full prognostic and diagnostic potential. The AWHS study proved the association of subclinical carotid and femoral plaque with risk factors and CACS in middle-aged men.[26] Another middle-aged cohort study demonstrated that adding CACS to SCORE could have a considerable effect on cardiovascular risk classification.[27] Because calcification indicated late-stage subclinical coronary atherosclerosis and its outstanding negative predictive value in risk assessment, CACS might present added predictive value with radiation exposure of no more than 1 mSv. EATv could also be obtained from noncontrast chest CT, which is considered another parameter related to subclinical atherosclerosis. From the population-based Rotterdam study, the results showed that a larger EATv was associated with larger amounts of coronary and extracranial carotid atherosclerosis.[28]

In this study, we found that CACS and EATv could provide incremental performance of the conventional prediction model (M3 vs. M2, M4 vs. M2, both $P < 0.005$). Moreover, combining these 2 noncontrast chest CT-derived parameters could provide further incremental value for AUC improvement over the traditional risk assessment model (0.788 [95% CI: 0.765-0.812] vs. 0.757 [95% CI: 0.732-0.781], $P < 0.0001$). Our study was partly in line with the above results, and the results could be interpreted in the following ways. First, calcification is a direct sign of subclinical cardiovascular atherosclerosis and is positively associated with CIMT and the prevalence of carotid plaque.[22] Second, the EATv, referring to the volume of epicardial adipose tissue, might reflect an inflammatory state locally limited to pericoronary arteries. Therefore, evidence suggests that EATv has established associations with CVD, CACS, and future events.[29] In addition, several recent studies have pointed out that EAT inflammation rather than volume could trigger the atherosclerosis process, which deserves in-depth discussion.[30]

It should be noted that the noncontrast chest CT parameters referred to in this study came from low-dose non–ECG-gated examinations for lung disease CT screening. Additional benefits could be expected from these CT-derived indices without extra radiation burden.[31] Published data from the United States showed that nearly 7 to 10 million low-dose chest CT examinations were performed per year for lung disease screening.[32] From this perspective, it was not the first attempt but also an innovative practice, which ensured that additional information was not abandoned from imaging data for lung disease screening and provided valuable incremental elevation for subclinical atherosclerosis prediction. Although CACS of non–ECG-gated examinations has been shown to correlate well with scores obtained from ECG-gated scans, different degrees of motion artifacts should impact the image quality and decrease the credibility of the current data. To avoid this objective matter, we executed exclusion criteria strictly according to the image quality based on a Likert scale.

There were several limitations in the present study. First, this study was cross-sectional on the basis of a local community, reflecting limited regional lifestyles, demographic characteristics, and risk factors. Further cost-effective analysis should be performed to justify this approach in consideration of radiation exposure. Second, other nontraditional risk factors besides ideal CVH metrics were not included in the present study, which would bring up some bias during statistical analysis. Third, although several works support the uniformity of epicardial adipose volumetric analysis and standardization, the correlation between CT-derived EATv and other well-established methods, such as T1 Dixon MR, remains to be investigated. Finally, EAT volume but not EAT attenuation was used in the present study. Therefore, inclusion of EAT attenuation may enhance the discrimination capacity and should be further warranted.

In summary, ICHS was inadequate for predicting subclinical carotid atherosclerosis alone in Chinese community-based asymptomatic populations. Sex and age should still be included in risk assessment. Noncontrast chest CT-derived parameters, including CACS and EATv, could provide significant incremental improvement for predicting subclinical carotid atherosclerosis beyond the traditional risk assessment model.

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REFERENCES

1. Hodis HN, Mack WJ, LaBree L, et al. The role of carotid arterial intima-media thickness in predicting clinical coronary events. *Ann Intern Med*. 1998;128:262–269.
2. Mitu O, Roca M, Floria M, et al. Subclinical cardiovascular disease assessment and its relationship with cardiovascular risk SCORE in a healthy adult population: a cross-sectional community-based study. *Clin Investig Arterioscler*. 2017;29:111–119.
3. Mamudu HM, Paul TK, Wang L, et al. The effects of multiple coronary artery disease risk factors on subclinical atherosclerosis in a rural population in the United States. *Prev Med*. 2016;88:140–146.
4. Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121:586–613.
5. Garg PK, O'Neal WT, Mok Y, et al. Life's simple 7 and peripheral artery disease risk: the Atherosclerosis Risk in Communities Study. *Am J Prev Med*. 2018;55:642–649.
6. Hruskova J, Maugeri A, Podroužková H, et al. Association of cardiovascular health with epicardial adipose tissue and intima media thickness: the Kardiovize Study. *J Clin Med*. 2018;7:113.
7. Luo TY, Liu XH, Dai TY, et al. Ideal cardiovascular health metrics and coronary artery calcification in Northern Chinese population: a cross-sectional study. *Biomed Environ Sci*. 2016;29:475–483.
8. Hwang SJ, Onuma O, Massaro JM, et al. Maintenance of ideal cardiovascular health and coronary artery calcium progression in low-risk men and women in the Framingham Heart Study. *Circ Cardiovasc Imaging*. 2018;11:e006209.
9. Shan DK, Zhou Y, Wang YX, et al. Population-based Cohort Study in Outcome of Phased Progression of Atherosclerosis in China (PERSUADE): objective, rationale and design. *J Geriatr Cardiol*. 2017;14:491–495.
10. Hao Z, Zhang Y, Li Y, et al. The association between ideal cardiovascular health metrics and extracranial carotid artery stenosis in a Northern Chinese population: a cross-sectional study. *Sci Rep*. 2016;6:31720.
11. Li Q, Zhou Y, Dong K, et al. The association between serum uric acid levels and the prevalence of vulnerable atherosclerotic carotid plaque: a cross-sectional study. *Sci Rep*. 2015;5:10003.
12. Zhou Y, Wang D, Yang X, et al. Effect of menopausal status on carotid intima-media thickness and presence of carotid plaque in Chinese women generation population. *Sci Rep*. 2015;5:8076.
13. Zhao Y, Evans MA, Allison MA, et al. Multisite atherosclerosis in subjects with metabolic syndrome and diabetes and relation to cardiovascular events: the Multi-Ethnic Study of Atherosclerosis. *Atherosclerosis*. 2019;282:202–209.
14. Aboyans V, Ricco JB, Bartelink MEL, et al. 2017 ESC Guidelines on the Diagnosis and Treatment of Peripheral Arterial Diseases, in collaboration with the European Society for Vascular Surgery (ESVS): document covering atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal, upper and lower extremity arteriesEndorsed by: the European Stroke Organization (ESO) The Task Force for the Diagnosis and Treatment of Peripheral Arterial Diseases of the European Society of Cardiology (ESC) and of the European Society for Vascular Surgery (ESVS). *Eur Heart J*. 2018;39:763–816.
15. Brott TG, Halperin JL, Abbara S, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, and the American Stroke Association, American Association of Neuroscience Nurses, American Association of Neurological Surgeons, American College of Radiology, American Society of Neuroradiology, Congress of Neurological Surgeons, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, Society for Vascular Medicine, and Society for Vascular Surgery [published correction appears in *J Am Coll Cardiol*. 2011 Jun 7;57(23):2379] [published correction appears in *J Am Coll Cardiol*. 2012 Aug 7;60(6):566]. *J Am Coll Cardiol*. 2011;57:e16–e94.
16. Agatston AS, Janowitz WR, Hildner FJ, et al. Quantification of coronary artery calcium using ultrafast computed tomography. *J Am Coll Cardiol*. 1990;15:827–832.
17. Tan Y, Zhou J, Zhou Y, et al. Epicardial adipose tissue is associated with high-risk plaque feature progression in non-culprit lesions. *Int J Cardiovasc Imaging*. 2017;33:2029–2037.
18. Hartiala O, Magnussen CG, Bucci M, et al. Coronary heart disease risk factors, coronary artery calcification and epicardial fat volume in the Young Finns Study. *Eur Heart J Cardiovasc Imaging*. 2015;16:1256–1263.
19. Chimowitz MI, Poole RM, Starling MR, et al. Frequency and severity of asymptomatic coronary disease in patients with different causes of stroke. *Stroke*. 1997;28:941–945.
20. Polak JF, O'Leary DH. carotid intima-media thickness as surrogate for and predictor of CVD. *Glob Heart*. 2016;11:295–312e3.
21. Ambale-Venkatesh B, Yang X, Wu CO, et al. Cardiovascular event prediction by machine learning: the multi-ethnic study of atherosclerosis. *Circ Res*. 2017;121:1092–1101.
22. Bjerrum IS, Sand NP, Poulsen MK, et al. Non-invasive assessments reveal that more than half of randomly selected middle-aged individuals have evidence of subclinical atherosclerosis: a DanRisk substudy. *Int J Cardiovasc Imaging*. 2013; 29:301–308.
23. Osibogun O, Ogunmoroti O, Tibuakuu M, et al. Sex differences in the association between ideal cardiovascular health and biomarkers of cardiovascular disease among adults in the United States: a cross-sectional analysis from the multiethnic study of atherosclerosis. *BMJ Open*. 2019;9:e031414.
24. Wang YQ, Wang CF, Zhu L, et al. Ideal cardiovascular health and the subclinical impairments of cardiovascular diseases: a cross-sectional study in central south China. *BMC Cardiovasc Disord*. 2017;17:269.
25. Madaj P, Budoff MJ. Risk stratification of non-contrast CT beyond the coronary calcium scan. *J Cardiovasc Comput Tomogr*. 2012;6:301–307.
26. Laclaustra M, Casasnovas JA, Fernández-Ortiz A, et al. Femoral and carotid subclinical atherosclerosis association with risk factors and coronary calcium: the AWHS Study. *J Am Coll Cardiol*. 2016;67:1263–1274.
27. Xia C, Vonder M, Sidorenkov G, et al. Cardiovascular risk factors and coronary calcification in a middle-aged Dutch population: the ImaLife study. *J Thorac Imaging*. 2021;36:174–180.
28. Bos D, Shahzad R, van Walsum T, et al. Epicardial fat volume is related to atherosclerotic calcification in multiple vessel beds. *Eur Heart J Cardiovasc Imaging*. 2015;16:1264–1269.
29. Cabrera-Rego JO, Iacobellis G, Castillo-Herrera JA, et al. Epicardial fat thickness correlates with carotid intima-media thickness, arterial stiffness, and cardiac geometry in children and adolescents. *Pediatr Cardiol*. 2014;35:450–456.
30. Goeller M, Achenbach S, Marwan M, et al. Epicardial adipose tissue density and volume are related to subclinical atherosclerosis, inflammation and major adverse cardiac events in asymptomatic subjects. *J Cardiovasc Comput Tomogr*. 2018;12:67–73.
31. Troschel AS, Troschel FM, Best TD, et al. Computed tomography-based body composition analysis and its role in lung cancer care. *J Thorac Imaging*. 2020;35:91–100.
32. Moyer VA. U.S. Preventive Services Task Force. Screening for lung cancer: US Preventive Services Task Force recommendation statement. *Ann Intern Med*. 2014;160:330–338.

