

Vital Surveillances

Carotid Atherosclerosis and Metabolic Characteristics Among High-Risk Cardiovascular Populations of Four Ethnic Groups — Yunnan Province, China, 2024

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ABSTRACT

Introduction: This study explored the distribution of carotid atherosclerosis (CAS) in high-risk individuals with cardiovascular disease (CVD) across four ethnic groups: the Han, Yi, Dai, and Lisu.

Methods: The China-PAR model was used to estimate 10-year CVD risk. Participants with a 10-year risk score of 10% or higher underwent carotid ultrasonography, biochemical tests for blood glucose, lipids, homocysteine, and a standardized physical examination.

Results: The Han had the lowest remnant cholesterol (Remnant-C) levels but the highest atherogenic index of plasma (AIP), triglyceride-glucose (TyG), and lipid accumulation product (LAP) levels. The Dai had the highest prevalence of hypertension, diabetes, hyperhomocysteinemia (HHcy), and Remnant-C. The Lisu had the lowest prevalence of diabetes and HHcy but the highest rates of obesity, central obesity, and dyslipidemia. Yi had the lowest burden of overweight, obesity, dyslipidemia, and the continuous metabolic syndrome score (cMetS), AIP, TyG, and LAP. Carotid intima-media thickness (cIMT) differed minimally among ethnic groups (range: 0.81–0.85 mm). The Dai had the lowest prevalence of carotid plaque (CP) 15.27% (341/2,233), yet the highest prevalence of carotid stenosis (CS) 46.22% (1,032/2,233). In contrast, Lisu had the highest prevalence of CP 57.29% (495/864) and the lowest prevalence of CS 3.13% (27/864). The Han population had the highest prevalence of multiple CP 31.82% (6,081/19,109) and CAS 74.79% (14,291/19,019), while the Yi population had the lowest prevalence 70.53% (3,453/4,896).

Conclusion: The marked ethnic differences in CAS and metabolic status should be taken into account in future CVD prevention and control strategies.

Cardiovascular disease (CVD) is the leading cause of death worldwide (1), and atherosclerosis (AS) is a major contributor to its growing burden. Therefore, identifying populations at a high risk of AS is central to effective CVD prevention (2). However, differences in genetic background, lifestyle, dietary patterns, and environmental exposure result in distinct distributions of atherosclerotic lesions and CVD risk across ethnic groups (3). Consequently, it has been proposed that ethnic-specific reference values for markers such as carotid intima-media thickness (cIMT) should be established to enable more precise CVD prevention (4).

Carotid atherosclerosis (CAS) is a widely used indicator of systemic AS risk. Although international studies have reported extensive data on ethnic differences (3), research on the prevalence and metabolic characteristics of CAS across ethnic groups in China remains limited. Yunnan Province has the most diverse ethnic minority population in China, with 25 ethnic groups native to the region. This study aimed to characterize the CAS and metabolic profiles among populations at high risk for CVD from the Han, Yi, Dai, and Lisu ethnic groups using a unified sample collection and analysis protocol. The findings provide evidence for research on AS mechanisms, inform the development of reference standards and intervention strategies, and support efforts to reduce the regional burden of CVD.

METHODS

Study Population

The 2024 Yunnan Province Screening and Intervention Project for High-Risk Populations of Cardiovascular Disease was conducted in five counties: Jinggu, Fumin, Yuanmou, Wuding, and Yongping. Among these, Jinggu, Yuanmou, and Wuding counties

have large ethnic minority populations. The project provided free CVD screening to all permanent residents aged 45–75 years in these five counties, which were selected using cluster random sampling. A total of 201,851 residents were initially screened, of whom 28,480 (14.11%) were identified as high-risk, with within-group high-risk proportions of 14.12% (19,109/135,349) for Han, 13.18% (4,896/37,141) for Yi, 18.98% (2,233/11,765) for Dai, and 14.71% (864/5,874) for Lisu. All individuals from the project who did not meet any exclusion criteria and were from the Han, Yi, Dai, and Lisu ethnic groups were included in this study. The exclusion criteria were as follows:

- 1) a history of myocardial infarction or stroke;
- 2) the presence of significant mental illness, language impairment, or intellectual disability;
- 3) any condition that would interfere with study participation or cooperation.

Screening Methods

The Prediction for Atherosclerotic Cardiovascular Disease Risk in China (China-PAR) model was applied to assess the 10-year CVD risk among the initially screened participants. Individuals with a 10-year CVD risk $\geq 10\%$ (5) underwent further examination, including carotid ultrasonography. Demographic information and medical histories were collected using interview-based questionnaires. Physical examinations, blood pressure measurements, and blood sample collection were performed onsite. All participants provided blood samples following an overnight fast of at least 8 hours. Carotid ultrasound examinations were performed by licensed ultrasound physicians at county-level or higher medical institutions. A standardized ultrasound protocol was developed for the project, with uniform specifications for equipment, scanning procedures, and record-keeping. Bilateral carotid arteries were scanned. Plaques in the common carotid artery, carotid bifurcation, and internal and external carotid arteries were also evaluated. Intima-media thickness (IMT) was measured 1–1.5 cm distal to the bifurcation on longitudinal views; for irregular thickening, the maximal thickness was captured away from plaques.

Definitions and Calculations

CAS was defined by the presence of cIMT thickening or carotid plaque (CP); cIMT thickening was defined as cIMT ≥ 1.0 mm but < 1.5 mm in the absence of plaque. CP was defined as any focal

thickening with cIMT ≥ 1.5 mm, or a cIMT that was > 0.5 mm greater than the adjacent cIMT (6). Based on the number of plaques, CP was classified as single or multiple (≥ 2). Carotid stenosis (CS) was assessed using Doppler ultrasonography. Peak systolic velocity (PSV) was the primary reference index; end-diastolic velocity (EDV) and PSV ratio (stenotic segment/distal segment) were used adjunctively when PSV findings were equivocal. Stenosis was categorized as mild ($< 50\%$) or moderate to severe ($\geq 50\%$) (7). If a patient had more than one of these conditions, the most severe condition was used for classification (order of severity: cIMT thickening $<$ CP $<$ CS). For example, a patient with both cIMT thickening and CP was classified as having plaque.

The following indicators were analyzed (1–7):

continuous metabolic syndrome score (cMetS) (8):

$$\text{cMetS} = Z(\text{WC}) + Z(\text{MAP}) + Z(\text{FBG}) + Z(\text{TG}) - Z(\text{HDL-C}) \quad (1)$$

$$\text{MAP} = [(\text{SBP} - \text{DBP})/3] + \text{DBP} \quad (2)$$

atherogenic index of plasma (AIP) (9):

$$\text{AIP} = \log_{10}(\text{TG}/\text{HDL-C}) \quad (3)$$

triglyceride-glucose (TyG) index (10):

$$\text{TyG} = \ln(\text{TG}) + \ln(\text{FBG}/2) \quad (4)$$

lipid accumulation product (LAP) (11):

$$\text{Male: LAP} = (\text{WC} - 65) \times \text{TG} \quad (5)$$

$$\text{Female: LAP} = (\text{WC} - 58) \times \text{TG} \quad (6)$$

Remnant Cholesterol (Remnant-C) (12):

$$\text{Remnant-C} = \text{TC} - \text{HDL-C} - \text{LDL-C} \quad (7)$$

WC means waist circumference; MAP means mean arterial pressure; FBG means fasting blood glucose; TG means triglycerides; HDL-C means high-density lipoprotein cholesterol; SBP means systolic blood pressure; DBP means diastolic blood pressure; TC means total cholesterol; LDL-C means low-density lipoprotein cholesterol.

Statistical Analysis

Continuous data are presented as median (25th and 75th percentiles [P25, P75]). Group comparisons were performed using the Kruskal-Wallis H test. Categorical variables are presented as numbers (percentages), and group differences were assessed using the chi-square test. The prevalence was directly standardized to the age distribution of the overall study population. All statistical analyses were performed using R (version 4.3.3, R Foundation for Statistical Computing,

Vienna, Austria), with a two-tailed significance level of $P<0.05$.

RESULTS

Basic Characteristics of the Study

Participants

A total of 27,102 participants were included, comprising 19,109 Han (70.51%), 4,896 Yi (18.07%), 2,233 Dai (8.24%), and 864 Lisu (3.19%). Participants across all ethnic groups were predominantly male, aged ≥ 50 years, and engaged in agricultural work. Marked metabolic differences were

observed among ethnic groups: the Han Chinese had the lowest Remnant-C but the highest levels of insulin resistance and atherosclerosis-related markers (AIP, TyG, LAP); the Dai ethnic group had the highest prevalence of hypertension, diabetes, hyperhomocysteinemia (HHcy), and the highest Remnant-C; the Lisu had the lowest prevalence of diabetes and HHcy, but they had the highest prevalence of obesity, central obesity, and dyslipidemia; the Yi had the lowest prevalence of overweight, obesity, dyslipidemia, and the lowest levels of cMetS, AIP, TyG and LAP, suggesting a relatively favorable metabolic profile (Table 1).

TABLE 1. General characteristics of high-risk cardiovascular populations from four ethnic groups — Yunnan Province, China, 2024.

Variables	Han (n=19,109)	Yi (n=4,896)	Dai (n=2,233)	Lisu (n=864)	P
Age groups, n (%)					<0.01
45–49	374 (1.96)	1,60 (3.27)	57 (2.55)	24 (2.78)	
50–54	1,000 (5.23)	338 (6.90)	162 (7.25)	56 (6.48)	
55–59	2,202 (11.52)	719 (14.69)	352 (15.76)	116 (13.43)	
60–64	3,460 (18.11)	934 (19.08)	462 (20.69)	191 (22.11)	
65–69	5,555 (29.07)	1,379 (28.17)	668 (29.91)	227 (26.27)	
70–75	6,518 (34.11)	1,366 (27.90)	532 (23.82)	250 (28.94)	
Sex, n (%)					<0.05
Male	1,4243 (74.54)	3,687 (75.31)	1,631 (73.04)	613 (70.95)	
Female	4,866 (25.46)	1,209 (24.69)	602 (26.96)	251 (29.05)	
Occupation, n (%)					<0.01
Farmers	1,4957 (78.27)	4,065 (83.03)	1,800 (80.61)	794 (91.90)	
Non-farmers	4,152 (21.73)	831 (16.97)	433 (19.39)	70 (8.10)	
Overweight, n (%)	6,881 (36.01)	1,649 (33.68)	795 (35.60)	305 (35.30)	<0.05
Obesity, n (%)	3,360 (17.58)	842 (17.20)	409 (18.32)	161 (18.63)	<0.05
Central obesity, n (%)	7,189 (37.62)	1,748 (35.70)	795 (35.60)	331 (38.31)	<0.05
Hypertension, n (%)	14,978 (78.38)	4,033 (82.37)	1,927 (86.30)	742 (85.88)	<0.01
Diabetes, n (%)	5,920 (30.98)	1,452 (29.66)	709 (31.75)	215 (24.88)	<0.01
Dyslipidemia, n (%)	12,858 (67.29)	3,255 (66.48)	1,561 (69.91)	612 (70.83)	<0.05
HHcy, n (%)	7,750 (40.56)	2,048 (41.83)	983 (44.02)	271 (31.37)	<0.01
cMetS, median (P25, P75)	−0.11 (−1.85, 1.69)	−0.29 (−2.07, 1.61)	−0.16 (−1.92, 1.58)	−0.11 (−1.91, 1.72)	<0.05
AIP, median (P25, P75)	0.58 (0.35, 0.84)	0.53 (0.30, 0.81)	0.55 (0.30, 0.83)	0.54 (0.29, 0.82)	<0.01
TyG, median (P25, P75)	9.22 (8.67, 9.83)	9.14 (8.60, 9.76)	9.19 (8.69, 9.80)	9.15 (8.58, 9.76)	<0.01
LAP, median (P25, P75)	44.22 (19.80, 87.12)	39.96 (16.37, 81.16)	42.84 (19.36, 82.96)	43.59 (19.10, 85.63)	<0.05
Remnant-C, median (P25, P75)	0.80 (0.39, 1.45)	0.88 (0.39, 1.54)	0.92 (0.50, 1.51)	0.85 (0.27, 1.66)	<0.01

Note: Overweight was defined as $24.0 \text{ kg/m}^2 < \text{BMI} \leq 28.0 \text{ kg/m}^2$; obesity as $\text{BMI} > 28.0 \text{ kg/m}^2$; central Obesity as $\text{WC} \geq 90 \text{ cm}$ in males and $\geq 85 \text{ cm}$ in females; hypertension as $\text{SBP} \geq 140 \text{ mmHg}$ and/or $\text{DBP} \geq 90 \text{ mmHg}$ and/or taking antihypertensive medication; diabetes as $\text{FBG} \geq 7.0 \text{ mmol/L}$ or use of glucose-lowering drug; dyslipidemia as $\text{TC} \geq 6.22 \text{ mmol/L}$, or $\text{LDL-C} \geq 4.14 \text{ mmol/L}$, or $\text{TG} \geq 2.26 \text{ mmol/L}$, or $\text{HDL-C} < 1.04 \text{ mmol/L}$; and HHcy as $\text{homocysteine} \geq 15 \text{ } \mu\text{mol/L}$.

Abbreviation: BMI=body mass index; HHcy=hyperhomocysteinemia; cMetS=continuous metabolic syndrome score; AIP=atherogenic index of plasma; TyG=triglyceride-glucose; LAP=lipid accumulation product; Remnant-C=remnant cholesterol.

Distribution Characteristics of CAS Among Four Ethnic Groups

Although there were minimal differences in cIMT among ethnic groups (0.81–0.85 mm), the distribution of CP and CS varied significantly. The Dai had the lowest prevalence of single CP 9.14% (204/2,233) and multiple CP 6.14% (137/2,233), but the highest prevalence of mild CS 44.78% (1,000/2,233) and moderate-to-severe CS 1.43% (32/2,233); in contrast, the Lisu ethnic group showed the highest prevalence of single CP 25.58% (221/864) and multiple CP 31.71% (274/864), but the lowest CS prevalence: 2.31% (20/864) for <50% stenosis and 0.81% (7/864) for $\geq$ 50% stenosis. The Han population had the highest prevalence of multiple CP 31.82% (6,081/19,109) and CAS 74.79% (14,291/19,019), whereas the Yi population had the lowest overall CAS burden, with the lowest prevalence of CAS 70.53% (3,453/4,896) (Table 2).

DISCUSSION

Data from a nationwide health examination survey of adults aged ≥ 20 years showed that the prevalences of cIMT thickening, CP, and moderate-to-severe CS in the general population were 26.2%, 21%, and 0.2%, respectively. Among individuals with hypertension, diabetes, overweight, obesity, dyslipidemia, and metabolic syndrome, the estimated prevalences ranged from 31% to 59%, 24% to 50%, and 0.1% to 0.6%, respectively. Among those aged ≥ 60 years, the corresponding estimates ranged from 66.8% to 92.7%, 54.6% to 87.3%, and 0.4% to 1.8%, respectively (13). A prospective study using the China-PAR risk

assessment showed that the prevalence of CP among high-risk individuals was 63.4%, and the overall prevalence of CAS was 79.4% (2). In this study, the overall prevalence of CP and CS across all ethnic groups ranged from 59.9% to 63.0%, and the prevalence of CAS ranged from 70.5% to 74.8%, consistent with results from other studies.

Compared with the Han population, the Dai and Lisu ethnic groups showed distinct metabolic and carotid characteristics. The Dai had the lowest prevalence of CP formation but the highest prevalence of CS; at the same time, their homocysteine (Hcy) levels were significantly higher than those of other ethnic groups. This observation suggests a potential link between elevated Hcy levels and the carotid disease pattern among the Dai, possibly reflecting Hcy-mediated vascular wall remodeling (14). In contrast, the Lisu population exhibited the highest prevalence of CP and the lowest prevalence of CS. They had the highest prevalence of obesity, central obesity, and dyslipidemia, yet the lowest prevalence of Hcy and diabetes. Previous studies have shown that the risk of CVD may not increase in obese individuals with normal metabolic markers (15). One possible explanation is that among the Lisu, although obesity and dyslipidemia promote lipid deposition in the vascular wall, contributing to CP formation, lower blood glucose and Hcy levels may mitigate endothelial oxidative stress and glycototoxicity, potentially stabilizing CP and slowing the progression of CS.

The Han Chinese population exhibited marked insulin resistance and visceral fat accumulation with the highest TyG (9.22), AIP (0.58), and LAP (44.22) indices. In addition, they had the highest rates of

TABLE 2. Distribution characteristics of carotid artery atherosclerosis among four ethnic groups — Yunnan Province, China, 2024.

Variables	Han (n=19, 109)	Yi (n=4, 896)	Dai (n=2, 233)	Lisu (n=864)	P
Mean cIMT [mean $\pm$ SD, mm]	0.85 $\pm$ 0.36	0.85 $\pm$ 0.46	0.84 $\pm$ 0.50	0.81 $\pm$ 0.50	<0.01
cIMT thickening [crude rate (ASR), %]	11.76 (11.86)	10.62 (10.41)	11.02 (10.87)	12.50 (12.44)	0.10
CP [crude rate (ASR), %]					<0.01
Single CP	20.28 (20.22)	20.57 (20.69)	9.14 (9.24)	25.58 (25.46)	
Multiple CP	31.82 (31.33)	23.49 (24.28)	6.14 (6.67)	31.71 (32.47)	
CS [crude rate (ASR), %]					<0.01
<50%	10.21 (10.16)	15.07 (15.41)	44.78 (46.00)	2.31 (2.35)	
$\geq$ 50%	0.72 (0.71)	0.78 (0.81)	1.43 (1.51)	0.81 (0.84)	
CAS [crude rate (ASR), %]	74.79 (74.28)	70.53 (71.61)	72.50 (74.29)	72.92 (73.60)	<0.01

Note: The standard population is the age structure of the total sample (n=27,102).

Abbreviation: ASR=age-standardized rate; cIMT=Carotid intima-media thickness; CP=carotid plaque; CS=carotid stenosis; CAS=carotid artery atherosclerosis.

multiple CP 31.82% (6,081/19,109) and CAS 74.79% (14,291/19,019). TyG is a reliable indicator of insulin resistance (16), whereas AIP is strongly correlated with the diameter of small, dense low-density lipoprotein (sdLDL) particles and atherosclerosis (17). The elevated AIP and TyG levels in Han Chinese individuals suggest that their pathological changes may be related to insulin resistance-mediated lipid metabolic disorders, which could hypothetically promote multifocal, scattered deposition of sdLDL particles within the vascular wall, thereby contributing to the formation of extensive lipid-rich CP. However, these speculations were based on cross-sectional data and required validation through future basic research or longitudinal cohort studies. The Yi ethnic group had the lowest overall prevalence of abnormalities. The high proportion of farmers in this group 83.03% (4,065/4,896) might indicate higher levels of occupational physical activity, which could partially explain the favorable metabolic profile observed. However, the prevalence of CS among the Yi population was not low, suggesting that non-metabolic factors may warrant further attention.

The ethnic heterogeneity observed in this study was consistent with findings from the Multi-Ethnic Study of Atherosclerosis (MESA), which reported significant differences in CAS scores among White, Black, Hispanic, and Chinese participants (18). However, MESA and similar international studies have not encompassed specific ethnic minorities native to China, and this study was restricted to examining the prevalence of CAS and associated metabolic characteristics among four ethnic groups in Yunnan Province, China. The cross-sectional design and lack of data on dietary habits, smoking, and alcohol consumption limited adjustment for potential confounders. In addition, despite standardized protocols, differences in ultrasound equipment and operator experience across county-level institutions may have compromised measurement consistency.

There were marked differences in carotid atherosclerosis and metabolic status among the Han, Yi, Dai, and Lisu ethnic groups. Future research should extend these findings by conducting targeted investigations into lifestyle and risk factors, as well as underlying mechanisms, thereby developing ethnicity-specific prevention and control strategies for CVD.

Conflicts of interest: No conflicts of interest.

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