ORIGINAL RESEARCH

Carotid Atherosclerosis Detected by Ultrasonography: A National Cross-Sectional Study

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***Background*—**Carotid atherosclerosis (CA) is a reflector of generalized atherosclerosis that is associated with systemic vascular disease. Data are limited on the epidemiology of carotid lesions in a large, nationally representative population sample. We aimed to evaluate the prevalence of CA detected by carotid ultrasonography and related risk factors based on a national survey in China.

***Methods and Results*—**A total of 107 095 residents aged ≥40 years from the China National Stroke Prevention Project underwent carotid ultrasound examination. Participants with carotid endarterectomy or carotid stenting and those with stroke or coronary heart disease were excluded. Data from 84 880 participants were included in the analysis. CA was defined as increased intima–media thickness (IMT) ≥1 mm or presence of plaques. Of the 84 880 participants, 46.4% were men, and the mean age was 60.7±10.3 years. The standardized prevalence of CA was 36.2% overall, increased with age, and was higher in men than in women. Prevalence of CA was higher among participants living in rural areas than in urban areas. Approximately 26.5% of participants had increased IMT, and 13.9% presented plaques. There was an age-related increase in participants with increased IMT, plaque presence, and stenosis. In multiple logistic regression analysis, older age, male sex, residence in rural areas, smoking, alcohol consumption, physical inactivity, obesity, hypertension, diabetes mellitus, and dyslipidemia were associated with CA.

***Conclusions*—**CA was highly prevalent in a middle-aged and older Chinese population. This result shows the potential clinical importance of focusing on primary prevention of atherosclerosis progression. **(*J Am Heart Assoc*. 2018;7:e008701. DOI: 10.1161/JAHA.118.008701.)**

Key Words: atherosclerosis • carotid ultrasound • China • epidemiology • risk factor

Atherosclerosis is a common systemic vascular condition that increases the risk of life-threatening cardiovascular diseases (CVDs), including coronary artery disease and ischemic stroke.[1,2] Studies demonstrated that carotid atherosclerosis (CA) had a strong relationship with the new occurrence of ischemic stroke, particularly for asymptomatic individuals with other risk factors, including smoking, low physical activity, hypertension, diabetes mellitus, or hyperlipidemia.[3,4] More than 90% of the global stroke burden is attributable to these modifiable risk factors, and controlling these factors could reduce the global stroke burden by a third.[5] CA is also thought to be associated with cognitive

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Accompanying Datas S1, S2 and Tables S1, S2 are available at http://jaha.ahajournals.org/content/7/8/e008701/DC1/embed/inline-supplementary-material-1.pdf

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Clinical Perspective

What Is New?

- This large, nationally representative study examined the epidemiology of carotid atherosclerosis in China.
- There was a high prevalence of carotid atherosclerosis in middle-aged and older Chinese participants, with 36.2% having increased carotid intima–media thickness, plaques, or stenosis.
- Participants living in rural areas had higher prevalence of CA than those in urban areas.

What Are the Clinical Implications?

- Early risk-reduction strategies to prevent the progression of carotid artery disease should be considered in middle-aged and older Chinese populations, especially in rural areas.

impairment, which affects daily activities.[6] The atherosclerotic process, however, may start at a young age and progresses silently over decades, so asymptomatic atherosclerosis is often neglected.[7] Early detection and management of atherosclerosis may prevent cognitive impairment and reduce morbidity and mortality of CVDs.[8]

Carotid intima–media thickness (IMT) and carotid plaques, measured by carotid ultrasound, have been proposed as surrogate markers for predicting cognitive impairment and CVD risk.[6,9] Carotid ultrasound examination of CA has been conducted in several population studies[10–12]; however, the epidemiology of carotid lesions in China may be different from other regions because of differences in ethnic and racial groups. Furthermore, data are limited in urban and rural areas, and there have been no nationally representative studies on the prevalence of CA in China. The present study aimed to report the prevalence of CA among Chinese adults aged ≥40 years, based on data from a nationally representative study in 2014–2015.

Methods

Study data were supported by China National Stroke Prevention Project (CSPP). The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure. The data are confidential and cannot be shared according to the terms of the contracts signed by the School of Public Health, Tongji Medical College, Huazhong University of Science and Technology, and CSPP. The study conformed with the Declaration of Helsinki and was approved by the ethics committee of the XuanWu Hospital institutional review board, Capital Medical University (Beijing, China). All participants received information on the study and provided written informed consent to participate.

Study Population and Data Collection

The present study was based on data from CSPP in 31 provinces (without Tibet) in mainland China from October 2014 to November 2015. The CSPP study was administrated by the National Project Office of Stroke Prevention and Control. Using a 2-stage stratified cluster sampling method, 200 project areas were selected in proportion to the local population size and the numbers of total counties. Then an urban community and a rural village were selected from each project area as primary sampling units, according to geographical locations and suggestions from local hospitals. The cluster sampling method was used in every primary sampling unit, and all residents aged ≥40 years were surveyed during the primary screening.

Demographic characteristics, behavioral risk factors, medical history, and physical examination were conducted by trained staff in primary healthcare institutions. Age, sex, smoking, alcohol consumption, physical activity, and medication use were self-reported. Smoking status was classified as current, past, and never smoking. Alcohol consumption was divided into regular heavy drinking (≥3 times/week), occasional drinking (<3 times/week), and never drinking. Physical activity was defined as regular physical exercise >3 times/week for at least 30 minutes per session.

Physical examinations included the measurement of body weight, height, and blood pressure. Body mass index was calculated as body weight (in kg) divided by the square of height (in m; kg/m^2). Obesity was defined as body mass index ≥28, according to the guidelines of the Working Group on Obesity in China.[13] Blood pressure was calculated using the average of 3 measurements at 1-minute intervals after 5 minutes of rest. Hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, self-reported hypertension diagnosed by a physician, or use of antihypertensive medications.

Blood samples were collected to test fasting plasma glucose, triglyceride, total cholesterol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol. Diabetes mellitus was defined as fasting plasma glucose ≥7.0 mmol/L, self-reported diagnosis of diabetes mellitus, or use of oral hypoglycemic agents or insulin injection. Dyslipidemia was defined as having one or more of the following results: triglyceride ≥2.26 mmol/L, total cholesterol ≥6.22 mmol/L, high-density lipoprotein cholesterol <1.04 mmol/L, low-density lipoprotein cholesterol ≥4.14 mmol/L, self-reported diagnosis of dyslipidemia, or taking cholesterol-lowering medications.

The risk of stroke was assessed according to the following variables: hypertension, atrial fibrillation, current smoking, dyslipidemia, diabetes mellitus, physical inactivity, obese or overweight (BMI ≥26), and family history of stroke.

Participants with ≥3 risk factors were considered at high risk of stroke, and those with <3 risk factors but having hypertension, diabetes mellitus, atrial fibrillation, or heart valve disorders were categorized as being at intermediate risk of stroke. Low risk of stroke was defined as having <3 risk factors and without the CVD conditions noted earlier.

According to the screening plan, participants who had ≥3 risk factors and those with a history of stroke or coronary heart disease received further laboratory-based tests and carotid ultrasound examination; however, a larger number of participants at low or intermediate risk also received additional examinations. A total of 726 451 participants were included in the CSPP, and 107 095 of them underwent carotid ultrasound examination. Because participants with carotid endarterectomy or carotid stenting and those with prior stroke or coronary heart disease might have received multiple interventions such as lifestyle changes or surgical treatment, we excluded them form subsequent analysis (Data S1 and Table S1). Finally, the present study included 84 880 participants (45 515 women and 39 365 men).

Carotid Ultrasonography

Carotid ultrasonography examination was performed by qualified ultrasound technologists who received unified training before embarking on the study, and all procedures were conducted according to Chinese stroke vascular ultrasound examination guidelines.[14] Participants were examined in the supine position using one of the ultrasound systems (Logiq 9 [GE Healthcare], iU22 [Philips Healthcare], S 2000 [Siemens Medical Solutions]). Linear array probes with transmission frequency of 6 to 10 MHz were used. Each common carotid artery, internal carotid artery, external carotid artery, and bulb was examined and recorded for the presence of atherosclerotic plaques in the longitudinal and transverse planes. IMT was measured manually 3 times in a plaque-free area of the common carotid artery that was 1.0 to 1.5 cm away from the carotid bifurcation, and the averaged thickness was recorded. Good reproducibility of carotid measures was tested by sonographers in each region.

Participants with increased IMT or plaques were defined as having CA. Increased IMT was defined as IMT ≥1 mm in either the left or right carotid artery. Plaque was defined as IMT ≥1.5 mm or focal narrowing of the vessel wall of >50% relative to adjacent segments. Stenosis severity was classified into the following categories: normal (no stenosis), <50%, 50% to 69%, 70% to 99%, and occlusion.[15] Moderate stenosis was defined as 50% to 69% stenosis and severe stenosis as ≥70% stenosis. When the bilateral carotid arteries were measured, we used the most severe stenosis to grade the severity.

Statistical Analyses

Continuous variables were presented as mean (SD), and categorical variables were presented as percentages. We used *t* tests for continuous variables, and χ^2 tests for categorical variables. The calculation of CA prevalence was standardized according to 2010 population census age and sex distribution in China. Because participants at high risk of stroke were more likely to be included in the analysis, the prevalence of CA was further adjusted according to the distribution of stroke risk among all asymptomatic participants (with or without the ultrasound examination), so the estimated CA prevalence could be more representative of the adult population in general.

Considering the sampling weight of stroke risk, the PROC SURVEYLOGISTIC procedure was used to estimate the association between CA severity and multiple independent variables including age, sex, location, obesity, smoking, alcohol drinking, physical activity, hypertension, diabetes mellitus, and hyperlipidemia. Statistical analyses were performed using SAS 9.3 for Windows (SAS Institute Inc), and a 2-tailed $P<0.05$ was considered statistically significant.

Results

General Characteristics of the Study Population

Of the 84 880 participants included in the analyses, 46.4% were men, and 52.1% were living in rural areas. The mean age was 60.7±10.3 years (range: 40–106 years). Cigarette smoking and drinking behaviors were significantly different for men and women (both $P<0.001$). Systolic blood pressure, diastolic blood pressure, and triglyceride levels were higher in men than women, whereas the levels of total cholesterol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol were significantly higher in women than men. Compared with men, women were less likely to do physical exercise and had a higher prevalence of obesity, hypertension, diabetes mellitus, and dyslipidemia. Nevertheless, the level of fasting plasma glucose was not statistically significantly different between men and women (Table 1). The comparison of urban and rural areas is also presented in Table 1. The distributions of age, cigarette smoking, alcohol consumption, physical activity, obesity, hypertension, diabetes mellitus, and dyslipidemia were significantly different between urban and rural areas.

Prevalence of CA

The standardized and risk-adjusted prevalence of CA among asymptomatic adults aged ≥40 years in China was 36.2% (Table 2). It increased with age from 22.3% among adults aged 40 to 49 years to 60.6% among adults aged ≥70 years

Table 1. Characteristics of the Study Population

Variables	Total (n=84 880)	Women (n=45 515)	Men (n=39 365)	*P* Value*	Urban (n=40 660)	Rural (n=44 220)	*P* Value†
Age (y), mean (SD)	60.7 (10.3)	60.9 (10.1)	60.3 (10.6)	<0.001	61.0 (10.2)	60.4 (10.3)	<0.001
Smoking				<0.001			<0.001
Never smoking	59 653 (70.3)	43 186 (94.9)	16 467 (41.8)		29 781 (73.2)	29 872 (67.6)	
Past smoking	3873 (4.6)	368 (0.8)	3505 (8.9)		2072 (5.1)	1801 (4.1)	
Current smoking	21 354 (25.2)	1961 (4.3)	19 393 (49.3)		8807 (21.7)	12 547 (28.4)	
Drinking				<0.001			<0.001
Never drinking	69 820 (82.2)	44 151 (97.0)	25 651 (65.2)		33 511 (82.4)	36 291 (82.1)	
Occasional drinking	9460 (11.2)	1150 (2.5)	8310 (21.1)		4701 (11.6)	4759 (10.8)	
Regular heavy drinking	5618 (6.6)	214 (0.5)	5404 (13.7)		2448 (6.0)	3170 (7.2)	
Physical activity				<0.001			<0.001
Regular physical activity	41 733 (49.2)	20 560 (45.2)	21 173 (53.8)		18 839 (46.3)	22 894 (51.8)	
Lack of physical activity	43 147 (50.8)	24 955 (54.8)	18 192 (46.2)		21 821 (53.7)	21 326 (48.2)	
SBP, mm Hg	138.6 (21.7)	138.4 (22.1)	138.7 (21.3)	0.02	136.0 (22.5)	140.9 (20.6)	<0.001
DBP, mm Hg	84.4 (13.1)	83.6 (12.9)	85.4 (13.2)	<0.001	82.6 (13.7)	86.1 (12.2)	<0.001
FPG, mmol/L	5.6 (2.0)	5.6 (2.0)	5.6 (2.0)	0.81	6.1 (2.0)	6.0 (2.0)	<0.001
TG, mmol/L	1.9 (1.5)	1.9 (1.3)	1.9 (1.6)	<0.001	1.9 (1.5)	1.9 (1.4)	<0.001
TC, mmol/L	5.0 (1.2)	5.2 (1.2)	4.8 (1.1)	<0.001	5.0 (1.1)	5.0 (1.2)	0.15
LDL-C, mmol/L	2.9 (1.0)	3.0 (1.0)	2.8 (0.9)	<0.001	2.9 (0.9)	2.9 (1.0)	<0.001
HDL-C, mmol/L	1.4 (0.6)	1.5 (0.6)	1.4 (0.6)	<0.001	1.4 (0.6)	1.4 (0.5)	<0.001
Obesity	19 690 (23.2)	11 005 (24.2)	8685 (22.1)	<0.001	8968 (22.1)	10 722 (24.2)	<0.001
Hypertension	55 663 (65.6)	30 223 (66.4)	25 440 (64.6)	<0.001	25 780 (63.4)	29 883 (67.6)	<0.001
Diabetes mellitus	20 235 (23.8)	11 556 (25.4)	8679 (22.0)	<0.001	11 159 (27.4)	9076 (20.5)	<0.001
Dyslipidemia	37 011 (43.6)	20 864 (45.8)	16 147 (41.0)	<0.001	20 574 (50.6)	16 437 (37.2)	<0.001

Data are presented as n (%) unless otherwise indicated. DBP indicates diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TC, total cholesterol; TG, triglyceride.
*Comparison of men and women.
†Comparison of urban and rural.

and was higher among men than women (39.2% versus 33.1%). Participants living in rural areas had a higher prevalence of CA than those in urban areas (41.6% versus 30.8%).

Characteristics of Carotid IMT, Plaques, and Stenosis

The prevalence of increased IMT (≥1.00 mm) was 26.5% overall, 5.7% unilaterally and 20.8% bilaterally (Table 2). Approximately 13.9% of the participants presented plaques, 4.1% with single and 9.8% with multiple plaques, and 0.4% of participants had carotid stenosis (severity >50%; Table 2). The prevalence of increased IMT, plaques, and stenosis severity increased with age, was higher in men than in women, and was higher in rural than in urban areas (Table 2). Although carotid plaques were associated with IMT, 8.7% of the participants with an IMT <1 mm had carotid plaques.

Multivariable Logistic Regression Analysis of Risk Factors for CA

The results of multivariate logistic regression analysis confirmed that the prevalence of CA increased with age, was higher in men than in women, and was higher in rural areas than in urban areas (Table 3). Smoking and drinking were significantly associated with carotid lesions. Finally, the prevalence of CA was significantly higher among participants with physical inactivity, obesity, hypertension, diabetes mellitus, and dyslipidemia. Using carotid plaque as the outcome, similar results were obtained by the multiple variable logistic regression analysis (Data S2 and Table S2).

Discussion

CA has rarely been examined in nationally representative studies, and the present study is the largest to assess the prevalence of CA at the national level in China. To compare

Table 2. Standardized and Risk-Adjusted Rates of Prevalence of CA, IMT, Carotid Plaque, and Stenosis Severity

	n	Rate, % (95% CI)*					
			IMT ≥1.00 mm		Carotid Plaque		Stenosis Severity >50%
		CA	Unilateral	Bilateral	Number ≥1	Number ≥1 & IMT <1.00 mm	
Overall	84 880	36.2 (35.9–36.5)	5.7 (5.5–5.9)	20.8 (20.6–21.1)	13.9 (13.7–14.2)	8.7 (8.5–8.9)	0.4 (0.3–0.4)
Age (y)							
40–49	13 441	22.3 (21.6–23.0)	4.7 (4.4–5.1)	11.1 (10.6–11.6)	8.5 (8.0–9.0)	5.4 (5.1–5.8)	0.1 (0.1–0.2)
50–59	24 837	34.4 (33.8–34.9)	5.8 (5.5–6.1)	19.9 (19.4–20.4)	13.8 (13.4–14.3)	7.9 (7.5–8.2)	0.2 (0.1–0.3)
60–69	29 487	53.4 (52.8–54.0)	7.4 (7.1–7.7)	32.1 (31.6–32.6)	20.1 (19.6–20.5)	13.0 (12.6–13.4)	0.6 (0.6–0.7)
≥70	17 115	60.6 (59.9–61.4)	7.0 (6.6–7.4)	37.3 (36.5–38.0)	22.6 (22.0–23.2)	15.3 (14.8–15.8)	1.2 (1.0–1.4)
Sex							
Female	45 515	33.1 (32.7–33.5)	5.4 (5.2–5.6)	19.3 (18.9–19.6)	13.0 (12.6–13.3)	7.4 (7.1–7.6)	0.3 (0.2–0.3)
Male	39 365	39.2 (38.7–39.7)	6.0 (5.8–6.2)	22.3 (21.9–22.8)	15.0 (14.6–15.3)	10.0 (9.7–10.3)	0.5 (0.4–0.5)
Location							
Urban	40 660	30.8 (30.4–31.3)	6.6 (6.4–6.8)	15.6 (15.3–16.0)	11.3 (11.0–11.6)	7.6 (7.3–7.8)	0.3 (0.3–0.4)
Rural	44 220	41.6 (41.1–42.0)	5.3 (5.1–5.5)	25.8 (25.4–26.2)	16.5 (16.1–16.8)	9.5 (9.2–9.8)	0.4 (0.4–0.5)

CA indicates carotid atherosclerosis; CI, confidence interval; IMT, intima–media thickening.
*The calculation of CA prevalence was standardized according to 2010 population census age and sex distribution in China and adjusted according to the distribution of stroke risk among all asymptomatic participants.

our results with previous studies, we searched PubMed to identify population-based studies that reported the prevalence of CA detected by ultrasound in China, and summarized findings are shown in Table 4. Of these previous studies,[16–26] only the CKB (China Kadoorie Biobank) study included a large sample of participants (N=24 822) from multiple geographic regions in China[16]; all other studies were geographically local. The CKB study reported that the overall prevalence of carotid plaque was 31%, which was much higher than the prevalence of 13.9% in the present study; however, the CKB study included participants with stroke (5.4%) or coronary heart disease (7.5%). Of the studies that excluded people with prior CVDs, the prevalence of carotid plaque was 9.7% in villages in Xinjiang,[17] 18.8% in Shanghai city,[18] 16.8% to 30.6% in Nanjing city,[19] and 41.5% in a low-income rural community in Tianjin.[20] The reported overall prevalence of CA or increased IMT was from 11.2% in a rural community in Shandong[21] to as high as 40.3% in Shenyang city.[22] Different approaches in participant sampling and selection, ultrasound techniques, and diagnosis criteria may cause such substantial differences in the reported prevalence of CA and carotid plaque, although it is generally impossible to be certain based on published literature. According to an individual-patient data meta-analysis of 4 population-based studies in Norway, Sweden, Germany, and the United States, the prevalence of moderate asymptomatic carotid stenosis (≥50%) ranged from 0.2% in men aged <50 years to 7.5% in men aged ≥80 years and ranged from 0% to 5.0%, respectively, in women.[27] In the present study, the prevalence of carotid stenosis (>50%) was 0.5% in men and 0.3% in women, which seems comparable with the meta-analysis results.

We found that bilaterally increased IMT was more frequent than unilaterally increased IMT (20.8% versus 5.7%). The ECST (European Carotid Surgery Trial) showed that patients with bilateral carotid lesions were associated with a higher rate of symptomatic disease in other arterial territories and had a higher risk of fatal events than unilateral carotid lesions.[28] Consequently, it is important to pay more attention to patients with bilateral carotid lesions for the prevention of arterial disease in other arterial territories and CVDs.

In the present study, 8.7% of participants with IMT <1 mm had single or multiple plaques. Although some studies found that IMT was an independent predictor of cardiovascular risk,[29,30] a meta-analysis showed that, compared with IMT, carotid plaques had higher diagnostic accuracy for the prediction of future CVDs.[31] Therefore, the measurement of IMT alone may not be sufficiently accurate to predict the risk of CVDs. The American College of Cardiology/American Heart Association cardiovascular risk assessment guidelines in 2014 did not recommend sole IMT measurements.[32] A combination of IMT and plaque assessment may provide more accurate information for clinical decision making, and further studies are required to evaluate the combined measurement of IMT and plaque for predicting long-term cardiovascular risk.

Similar to many previous studies,[22,33–36] we found that traditional risk factors, including older age, male sex, smoking,

Table 3. Multivariable Logistic Regression Analysis of Association Between CA and Other Risk Factors

Variables	OR (95% CI)	*P* Value
Age (y)		
40–49	1.00 (reference)	
50–59	2.01 (1.80–2.24)	<0.001
60–69	4.29 (3.85–4.78)	<0.001
≥70	5.75 (5.09–6.49)	<0.001
Sex		
Female	1.00 (reference)	
Male	1.10 (1.01–1.19)	0.018
Location		
Urban	1.00 (reference)	
Rural	1.77 (1.65–1.90)	<0.001
Smoking		
Never	1.00 (reference)	
Past	1.58 (1.27–1.96)	<0.001
Current	1.52 (1.36–1.69)	<0.001
Drinking		
Never	1.00 (reference)	
Occasional	1.21 (1.05–1.38)	0.007
Regular heavy	1.44 (1.21–1.71)	<0.001
Physical activity		
Regular physical activity	1.00 (reference)	
Lack of physical activity	1.30 (1.21–1.40)	<0.001
Obesity		
No	1.00 (reference)	
Yes	1.27 (1.16–1.40)	<0.001
Hypertension		
No	1.00 (reference)	
Yes	1.43 (1.35–1.51)	<0.001
Diabetes mellitus		
No	1.00 (reference)	
Yes	1.39 (1.30–1.49)	<0.001
Dyslipidemia		
No	1.00 (reference)	
Yes	1.65 (1.52–1.79)	<0.001

CA indicates carotid atherosclerosis; CI, confidence interval, OR, odds ratio.

physical inactivity, hypertension, diabetes mellitus, and dyslipidemia, were significantly associated with CA. Of all risk factors, aging was strongly associated with atherosclerotic lesions.[36–38] Men had a higher prevalence of carotid lesions than women, consistent with previous studies.[22,38] Sex-related differences might be caused by differential susceptibility to risk factors. In this study, men were more likely to have behavioral risk factors, such as smoking and alcohol consumption. In addition, there were physiological and anatomical differences between men and women.[39,40] All of these factors suggested that individually tailored recommendations should be developed to prevent CA in men and women.

In addition, living in rural areas was significantly associated with CA in our study. This might be due to rural residents having lower levels of education but larger financial burdens and more restricted access to health care than urban residents.[41] Further studies are required to understand the causes of the higher prevalence of CA in rural participants.

Cigarette smoking and alcohol consumption were also significantly associated with carotid lesions in our population. A dose-response relationship was found between baseline smoking pack-years and IMT and plaque formation in middle-aged and older Chinese adults.[42] Confirming results of previous reports, both current and past smoking were strongly associated with atherosclerosis.[34,35,42] However, the relationship between alcohol consumption and CA was inconsistent with previous studies.[43,44] A study in China showed that moderate drinking had an inverse association with CA.[44] Possible explanations were that self-reported alcohol consumption was inaccurate or that different classifications were used in the present and previous studies. Prospective studies are needed to confirm the effects of alcohol consumption on atherosclerosis lesions.

The study had several limitations. First, this was a cross-sectional study without follow-up information, and we could not empirically predict the development of future cardiovascular events. Second, the study enrolled only a Chinese population, limiting the generalizability of findings to other geographic regions. Third, according to the initial protocol, only high-risk participants with >3 risk factors or previous history of stroke or coronary heart disease should have received carotid ultrasound examination; however, without being predefined, a large number of participants with intermediate risk also underwent carotid ultrasound examination and were included in the analysis. To make our results representative of the adult population in general, the prevalence of CA was standardized according to the 2010 population census age and sex distribution in China and further adjusted according to the distribution of stroke risk. Fourth, we did not have access to information on medication use and dietary factors in our study. Last, because this study reflects a very large sample size, statistical significance may result for very small differences between groups. The results of this study provide clinicians with relevant information; however, whether the effects noted in this study are clinically relevant will depend on the specific clinical practice.

Table 4. Summary of Population-Based Studies of Carotid Ultrasound Screening of CA in China

First Author, Year	Study Population	Definition	Inclusion/Exclusion of Prior Stroke/CHD	Prevalence	Risk Factors
Clarke, 2017[16]	China Kadoorie Biobank study: adults from 10 geographical regions, China; study period: 2013–2014; N=24 822; mean age 59.0 (10.2) y	Carotid plaque defined as any focal thickening or protrusion from the wall into the lumen with IMT >1.5-mm thickness and preplaque as any focal thickening of IMT >1.0 and ≤1.5 mm	All included; prior stroke (5.4%) and CHD (7.5%)	Any plaque 31% (men, 39%, women, 26%; urban, 39%, rural, 24%)	IMT associated with age, male sex, region, smoking, high BP, urban residence
Wu, 2017[17]	A random sample of adults from 26 villages of 7 cities in Xinjiang, China; study period: 2007–2010; N=14 618; age ≥35 y	Carotid intimal thickening was defined as IMT ≥1.0 and <1.5 mm, and carotid plaques defined as a discrete focal wall thickening ≥1.5 mm or focal thickening ≥50% than the surrounding IMT	Excluded people with prior CVD	Carotid intimal thickening: 12.4% overall, 14.7% in men, and 10.5% in women; carotid plaque: 9.7% overall, 12.2% in men, and 7.4% in women	IMT varied for the different subtypes of hypertension with different ethnic backgrounds
Ma, 2017[18]	A community-based study (Changfeng) in Shanghai, China; study period: 2009–2012; N=1470; mean age 57.7 (8.1) y	Carotid plaque defined as thickness ≥50% of the surrounding vessel wall or a focal region with IMT >1.5 mm	Excluded prior CVD, hypertension, DM, use of lipid-lowering or antiplatelet agents	Carotid plaque: 18.8% overall, 27.0% in men, and 14.4% in women	Non-HDL-C was positively associated with IMT after adjusting for CVD risk factors
Wang, 2016[19]	A community study in Nanjing city, China; study period: 2013; N=1557; age >50 y	Carotid plaque defined as IMT >1.5 mm or focal wall thickening >50% of the surrounding vessel	Excluded prior CVD and thyroid diseases	Elevated IMT: 15.2–35.1%; carotid plaque: 16.8–30.6%	Elevated resting heart rate is associated with CA
Zhang, 2017[20]	Residents from a low-income rural area in Tianjin, China; study period: 2014–2015; N=3789; age ≥45 y	IMT was measured at near and far walls of the CCA; plaque was defined as a focal structure encroaching into the arterial lumen by at least 0.5 mm or 50% of the surrounding IMT value or a thickness of >1.5 mm from the intima–lumen interface to the media adventitia interface	Excluded people with a history of stroke and CVD	Increased IMT: 25.3%; carotid plaques: 41.5%	Associations with increased IMT and plaques: age, hypertension, DM, and HDL-C
Liang, 2014[21]	Residents in a rural community, Qufu, Shandong, China; study period: 2010–2011; N=1499; age ≥60 y	IMT and stenosis were assessed in the right and left ICA; increased IMT: ≥1.81 mm; moderate stenosis: ≥50%; severe stenosis: ≥70%	All included	Increased IMT: 11.2%; of the 1361 (90.8%) people with data on stenosis, prevalence was 8.9% for moderate stenosis, and 1.8% for severe stenosis	Associations with increased IMT: ever smoking, hypertension, and increased LDL-C/HDL-C ratio
Pan, 2016[22]	Relatively healthy community residents in (urban) Shenyang, China; study period: not reported; N=474; age 40–70 y	Diagnostic procedure for CA was conducted according to vascular ultrasonography examination guidelines in China	Excessive alcohol consumption, severe hepatitis or other liver disease, mental illness, severe cardiac or pulmonary insufficiency, and cancer	CA: 40.3% (men 53.7%, women 27.6%)	Associations with CA: age, male sex, and DM

Continued

Table 4. Continued

First Author, Year	Study Population	Definition	Inclusion/Exclusion of Prior Stroke/CHD	Prevalence	Risk Factors
Hong, 2013[23]	Community population in Guangzhou city, China; study period: 2008; N=942; age 46–75 y	Carotid plaque defined as localized thickening of IMT ≥1.3 mm that did not uniformly involve the whole wall of the carotid artery	Excluded malignant tumors, acute or subacute symptomatic CVD, or other critical illnesses; people with CVD >6 months but recovered totally were not excluded	Carotid plaque: 22.5% with normal BP (80–84/120–129 mm Hg), 28.8% with high normal BP (85–89/130–139 mm Hg)	Prehypertension was associated with carotid atherosclerotic plaque
Wang, 2010[24]	Participants from 2 studies: USA-PRC in Shijingshan, Beijing, and CMCS at University of Beijing; study period: 2007; N=2681; age 43 to 81 y	Carotid plaque defined as localized thickness of IMT ≥1.3 mm, a focal raised lesion of 2.5 mm, or focal thickening ≥50% of the surrounding IMT	All included	Carotid plaque: 60.3% overall, 66.7% in men, and 56.2% in women	Hypertension, DM, smoking and high LDL-C were independent predictors of risk of carotid plaque
Yin, 2012[25]	Participants of health screening programs (self-referred or sent by employers) in Hangzhou city, China; study period: 2009; N=6142; age 20–92 y	CA was defined as IMT >1.0 mm on the far wall of the distal 10 mm of the CCA and/or carotid plaque according to the modified criteria of several established epidemiological studies; a plaque was defined as any focal atherosclerotic change of the intima–media layer with a thickness ≥1.5 mm at the common or ICA or the carotid bulb with or without flow disturbance	All included	CA: 22.1% in men and 12.0% in women; carotid plaque: 12.6% in men, 7.2% in women	Associations with CA: male sex, age, DBP, FPG, LDL-C, and TG. HDL-C were protective factors
Ren, 2015[26]	Six community health centers in Futian District, Shenzhen city, China; study period: 2012–2013; N=4394; age >40 y	Carotid plaque and stenosis characterized according to the Mannheim Consensus 2006	Only included people with risk factors	CA prevalence was 20.1%, 22.9%, and 28.6%, respectively, in patients with 0, 1, and >1 chronic diseases	CA prevalence was associated with the existence of chronic diseases

BP indicates blood pressure; CA indicates carotid atherosclerosis; CCA, common carotid artery; CHD, coronary heart disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; DM, diabetes mellitus; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; ICA, internal carotid artery; IMT, intima–media thickening; LDL-C, low-density lipoprotein cholesterol; TG, triglyceride.

Conclusions

There was a high prevalence of CA in middle-aged and older Chinese participants, with 36.2% having increased carotid IMT, plaques, or stenosis. These data in a large sample will provide useful reference values for clinical practice and further research. The findings will help physicians initiate early risk reduction strategies to prevent the progression of cognitive impairment and atherosclerotic CVDs.

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Disclosures

None.

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SUPPLEMENTAL MATERIAL

Data S1.

Comparison Between Included and Excluded Participants

Of the 107,095 participants who underwent carotid ultrasound examination, 22215 potential participants were excluded (stroke, 15251; CHD, 8772; carotid endarterectomy or stenting treatment, 177). As shown in Table S1, the distribution of sex and the percentage of dyslipidemia were not statistically significantly different between included and excluded participants (both P>0.05). However, the mean age of excluded participants was significantly higher than the included participants (64.5±9.4 y vs 60.7±10.3 y, P<0.01). In addition, the percentage of hypertension and diabetes were significantly higher among excluded participants, while the percentage of smoking, drinking, physical inactivity and obesity were significantly higher among included participants (all P<0.01).

Data S2. Logistic Regression Analysis of Risk Factors for Carotid Plaque

Table S2 presents risk factors associated with carotid plaque, using the same model as defined for carotid atherosclerosis, including age, sex, location, obesity, smoking, alcohol drinking, physical activity, hypertension, diabetes, and hyperlipidemia. The results of multivariate logistic regression analysis showed that older age, male sex, living in rural areas, smoking, physical inactivity, obesity, hypertension, diabetes, and dyslipidemia were significantly associated with carotid plaque. However, alcohol consumption was only borderline significant.

Table S1. Comparison Between Included and Excluded Participants.

Variables	Included participants (n = 84880)	Exclude participants (n = 22215)	*P* value
Age (years), mean (SD)	60.7 (10.3)	64.5 (9.4)	< 0.001
Sex			0.5792
Women	45515 (53.6)	11866 (53.4)	
Men	39365 (46.4)	10349 (46.6)	
Smoking			< 0.001
Never smoking	59653 (70.3)	16025 (72.1)	
Past smoking	3873 (4.6)	1542 (6.9)	
Current smoking	21354 (25.2)	4648 (20.9)	
Drinking			< 0.001
Never drinking	69820 (82.2)	18673 (84.1)	
Occasional drinking	9460 (11.2)	2320 (10.4)	
Regular heavy drinking	5618 (6.6)	1222 (5.5)	
Physical activity			< 0.001
Regular physical activity	41733 (49.2)	13604 (61.2)	
Lack of physical activity	43147 (50.8)	8611 (38.8)	
SBP (mm Hg)	138.6 (21.7)	142.5 (20.4)	< 0.001
DBP (mm Hg)	84.4 (13.1)	85.3 (12.2)	< 0.001
FPG (mmol/L)	6.1 (2.0)	6.1 (2.0)	0.2455
TG (mmol/L)	1.9 (1.5)	1.8 (1.3)	< 0.001
TC (mmol/L)	5.0 (1.2)	4.9 (1.2)	< 0.001
LDL-C (mmol/L)	2.9 (1.0)	2.9 (1.0)	0.2581
HDL-C (mmol/L)	1.4 (0.6)	1.4 (0.6)	0.1129
Obesity	19690 (23.2)	4609 (20.8)	< 0.001
Hypertension	55663 (65.6)	16465 (74.1)	< 0.001
Diabetes	20235 (23.8)	5527 (24.9)	< 0.001
Dyslipidemia	37011 (43.6)	9539 (42.9)	0.0766

Data are presented as n (%) unless otherwise indicated.

DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride.

Table S2. Logistic Regression Analysis of Association Between Carotid Plaque and other Risk Factors.

Variables	OR (95% CI)	*P* value
Age group (year)		
40-49	1.00 (reference)	
50-59	1.99 (1.74-2.27)	< 0.001
60-69	4.30 (3.78-4.88)	< 0.001
≥ 70	7.33 (6.39-8.42)	< 0.001
Sex		
Women	1.00 (reference)	
Men	1.21 (1.11-1.31)	< 0.001
Location		
Urban	1.00 (reference)	
Rural	1.49 (1.38-1.60)	< 0.001
Smoking		
Never	1.00 (reference)	
Past	1.53 (1.24-1.90)	< 0.001
Current	1.70 (1.52-1.90)	< 0.001
Drinking		
Never	1.00 (reference)	
Occasional	1.08 (0.94-1.25)	0.252
Regular heavy	1.16 (0.97-1.38)	0.098
Physical activity		
Regular physical activity	1.00 (reference)	
Lack of physical activity	1.34 (1.24-1.44)	< 0.001
Obesity		
No	1.00 (reference)	
Yes	1.23 (1.11-1.36)	< 0.001
Hypertension		
No	1.00 (reference)	
Yes	1.62 (1.53-1.72)	< 0.001
Diabetes		
No	1.00 (reference)	
Yes	1.46 (1.37-1.56)	< 0.001
Dyslipidemia		
No	1.00 (reference)	
Yes	1.48 (1.36-1.62)	< 0.001

Data are expressed as odds ratio (OR) and 95% confidence interval (CI).