The relationship between the visceral adiposity index and carotid atherosclerosis in different genders and age groups

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Research Article

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Abstract

Objective: We aimed to investigate the possible relationship between visceral adiposity index (VAI) and carotid atherosclerosis(CAS) in different genders and age groups in China.

Methods: This study was an observational cross-sectional study and included 1996 participants who were health examination population .From January 2018 to June 2019, people over 18 years old who had physical examinations were included in the study. Each participant completed a standard questionnaire, anthropometric measurements, ultrasonic examination ,and provided blood samples for biochemical measurements. Regression models were utilized to evaluate the correlation between VAI and the CAS risk. An ROC curve was utilized to predict VAI diagnostic efficacy for carotid atherosclerosis.

Result: After adjusting for potential risks, high-VAI subjects had an increased OR of having CAS in women aged>44 years[OR= 3.09,95% Confdence interval (95%CI)=1.64~5.82, p <0.001]. In females, the AUC and sensitivity specificity were [(0.595, 76.68% and 39.85%, all females), (0.575, 78.51% and 30.37%, age ≤44), (0.609, 84.71% and 40.46%, age >44). When compared with traditional obesity indices(BMI, WC, and HC) , the predictive ability of VAI was stronger in females >44.The same relationships in males were not signifcant.

Conclusions: The VAI were associated with an increased risk of CAS,and it could be selected as new and simple predictors of CAS for middle-aged and elderly women(age >44)in China .

1 Introduction

Cardiovascular and cerebrovascular diseases(CCVD)are the top two causes of death in China. The number of years lost due to cardiovascular and cerebrovascular diseases is more than 2 years old every year, which seriously affects resident health and heavily burdens society and the economy[1]. Atherosclerosis is one of the most important cardiovascular and cerebrovascular disease causes[2]. The carotid artery is superficially located, carotid atherosclerosis(CAS) reliably correlates with cardiovascular and cerebrovascular disease [3]; it is a window for the formation and evolution of atherosclerosis in coronary artery, cerebral artery, and other artery. Early identification of high-risk groups of carotid atherosclerosis(CAS) can delay or prevent cardiovascular and cerebrovascular diseases from occurring.

Obesity, has been generally considered to be a key correlate in the pathogenesis of diabetes, hypertension (HTN),and cardiovascular disease(CVD)[4] .Current evidence has revealed that the clinical risk attributable to obesity depends not simply on the extent, but importantly, the distribution of the excess adiposity[5] .Moreover, visceral fat accumulation, may exert more detrimental effects on CVD risks than general fat accumulation. Traditional adiposity-based indices, such as waist circumference (WC), body mass index (BMI), and hip circumference(HC) are common indicators for the evaluation of obesity worldwide, but fat distribution and visceral fat function are not considered[6],and has not proven to be a predictor of cardiovascular events or mortality in some large cohorts[7, 8].

The visceral adiposity index (VAI) was proposed by Amato et al.[9] in 2010, which combines WC, BMI, and blood lipids and indirectly reflects visceral fat function and insulin resistance, especially for normal or lean bodied people. Subsequently, several studies reported that visceral adiposity index was a more accurate indicator than other simple anthropometric measures, such as BMI and so on, in predicting incident diabetes and CVD events [10, 11]. In addition, Johnson W and Lopez AA et al. [12, 13]proposed that VAI has been associated with prognostic value in the evaluation of cardiovascular risk. However, the relationship between the visceral adiposity index and carotid atherosclerosis, and the ability of VAI to predict CAS in different genders and age groups ,have not ever been reported .Hence, the aim of our study was to explore the correlation between VAI and carotid atherosclerosis in the Chinese population of different genders and ages groups, as well as whether it can be utilized to effectively predict CAS.

2 Materials And Methods

2.1 Study population

This study was an observational cross-sectional study. A total of 1996 participants were enrolled from the Changsha hospital physical examination center, from January 2018 to June 2019. Inclusion criteria: aged ≧ 18 years; those who had lived in the local area for more than 6 months over the past 12 months. Exclusion criteria: liver and kidney dysfunction, or complicated malignant tumors; hormone and lipid-lowering drug use within half a year; patients with mental disorders or cognitive and language communication disorders; and pregnant women.

All subjects agreed to participate in this study and gave informed consent. This study was approved by the institutional review board of Changsha Central Hospital of Medicine and complied with the Helsinki declaration.

2.2 Date collection

A standardized questionnaire was utilized to obtain baseline demographic information, such as age, gender, family history of diabetes, smoking status, physical activity, and so on. Anthropometric measurements included body weight, body height, WC, and blood pressure. Body weight and height were measured on an empty stomach via standard methods and each was recorded to the nearest 0.1 kg and 0.1 cm, whereas BMI was calculated as the weight in kilograms divided by the square. The WC was measured twice at one cm above the umbilicus level during minimal respiration. The hip circumference (HC) was measured at the highest point of the hip or the level of the trochanter of the femur. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were examined three times at 30 s intervals by trained doctors who utilized a standardized mercury sphygmomanometer on both arms after resting for 5 min in a sitting position at the height in meters. Laboratory examinations, including total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglyceride (TG), and fasting plasma glucose (FPG) were conducted. Blood samples were collected in the morning after overnight fasting for at least 8 h. All of the collected blood samples were measured via an automatic biochemical analyzer of the same model as that in the hospital laboratory.

2.3 Ultrasonic examination

An ACUSON 128XP/10 color Doppler ultrasonic detector and arterial health package(AHP) was utilized in the present study, and the probe frequency was set at 7–15 mhz. The subjects were placed in the supine position. According to the vascular ultrasound examination guidelines [14], the scanning sections included both the transverse and longitudinal sections. The Angle and position of the probe were fixed by vascular angle locator, and the dynamic images of the common carotid artery (CCA), the Bulb, and the internal carotid artery (ICA) with a range of 10mm were collected and stored by electrocardiogram simultaneously. Since the absolute value of IMT is small, subtle differences can affect patient risk stratificationTherefore, Arterial Health Package was used in this group[15],in the 2D gray scale mode, by collecting the original digital audio image, phase analysis and processing of the original data of the vessel wall radio frequency signal, extract the image of the carotid inner intima and automatically measure the IMTand the mean value was obtained after six measurements .According to the standard of American Heart Association(AHA)[16], the subjects were divided into two groups: the hardening group (IMT≥ 1.0 mm) and the normal group (IMT $cript >$ 1.0 mm).

2.4 VAI calculation method

VAI calculation method[9]: VAI(male)=WC(cm)/(39.68 + 1.88×BMI)×TG/1.03×1.31/HDL-C;VAIfemale=WC(cm)/(36.58 + 1.89×BMI)×TG/0.81×1.52/HDL-C

2.5 Related diagnosis/index definition

Age: According to the World Health Organization (WHO) age segmentation standards, divided into the young group(age≤44)middle-aged and elderly groupage $>$ 44[17].Criteria for hypertension diagnosis: refer to the 2017 American ACC/AHA guidelines: systolic/diastolic blood pressure greater than 130/80 mmHg, taking hypotensive drugs [18], or those diagnosed by previous medical institutions. The diagnostic criteria for diabetes: Chinese guidelines for type 2 diabetes prevention and treatment (2017 Edition), with fasting blood glucose ≥ 7.0 mmol/L or previously diagnosed with diabetes in medical institutions. Current smoking: smoking at the time of the survey or smoking within 1 y in the past. drinking alcohol: drinking alcohol was defined as drinking four times per month in the past six months. Exercise ≥ 3 times / week :exercise more than or equal to 3 times within a week, and each exercise time more than 30 minutes.Eating habits are salty: the index was calculated according to total salt consumption per month/number of family members/days of the month, and the daily salt intake > 6 g was defined as salty eating habits.

1.2.4 Statistical Analysis

The STATA version 13.0 statistical software were utilized to analyze the data. The continuous normal distribution data were expressed via the mean plus-or-minus the standard deviation, and the comparison between the groups was conducted via one-way ANOVA; the continuous non-normal distribution data were represented via median (25 quartiles, 75 quartiles), and the comparison between the groups was conducted via the Kruskal Wallis h test. The number of cases (rate) was utilized to express the count data, and the chi-square test was utilized to make comparisons between the groups. The VAI was divided into three groups according to the three quartiles. The carotid atherosclerosis risk in different VAI groups was analyzed via binary logistic regression. The CAS diagnostic ability was defined by the area under the curve in the ROC analyses, and the optimal cut-off value was determined via maximal the Youden index. Comparisons of the area under the receiver operating characteristics curve (AUROC) between visceral adiposity index and other adiposity-based measurements (BMI, WC, HC) were conducted by using the z-statistics. A two-tailed P value of < 0.05 was regarded as statistically significant.

3 Results

3.1 Gender Characteristics stratified by VAI

Men and women were divided into three groups according to the VAI tertile (Tertile 1, 2, 3). In women, BMI, WCHCTotal cholesterolTriglycerideHDL-CLDL-CFPGDiabetes Mellitusand current smoking were significantly different among the VAI tertile(P < 0.05); In men,significant differences were found among the VAI levels BMIWCHCTotal cholesterolTriglycerideHDL-CLDL-CFPGDiabetes Mellitusand exercise ≥ 3 times/week P < 0.05). The details are shown in Table 1.

Table 1
Characteristics of patients stratified by VAI tertiles

VAI Characteristics	Female			P-value	Male			P-value
	Tertile 1 (< 1.33)	Tertile 2(1.33 to 2.43)	Tertile 3(≥ 2.44)		Tertile 1 (< 0.91)	Tertile 2(1.33 to 2.43)	Tertile 3(≥ 2.44)	
No. of cases	378	382	376		285	287	291	
Age (years),`X±S	45.7 ± 16.97	48.45 ± 16.32	47.86 ± 16.59	0.057	44.42 ± 16.93	47.29 ± 18.78	45.57 ± 17.66	0.153
Body mass index (kg/m^2),`X±S	22.86 ± 3.64	23.42 ± 3.82	24.66 ± 4.34	< 0.001	22.66 ± 3.74	23.78 ± 4.02	24.42 ± 4.23	< 0.001
Waist circumference (cm),`X±S	73.13 ± 10.22	75.13 ± 10.29	75.87 ± 9.93	0.001	75.17 ± 10.86	76.68 ± 10.67	78.78 ± 10.59	< 0.001
hip circumference (cm),`X±S	89.14 ± 8.63	90.48 ± 8.18	90.69 ± 7.89	0.020	88.55 ± 7.34	88.67 ± 8.31	90.32 ± 8.51	0.013
Total cholesterol (mmol/L),`X±S	4.91 ± 0.87	5.14 ± 0.97	5.23 ± 0.96	< 0.001	4.98 ± 0.91	5.13 ± 0.95	5.2 ± 0.99	0.016
Triglyceride (mmol/L),M(P25,P75)	0.80(0.65,0.94)	1.29(1.08,1.51)	2.25(1.84,3.07)	< 0.001	0.81(0.64,0.95)	1.30(1.11,1.51)	2.19(1.77,2.76)	< 0.001
HDL-C (mmol/L),`X±S	1.59 ± 0.33	1.28 ± 0.24	1.06 ± 0.18	< 0.001	1.64 ± 0.36	1.26 ± 0.22	1.07 ± 0.17	< 0.001
LDL-C (mmol/L),`X±S	2.91 ± 0.76	3.29 ± 0.86	3.10 ± 0.88	< 0.001	2.9 ± 0.78	3.29 ± 0.87	3.14 ± 0.93	< 0.001
FPG (mmol/L),`X±S	4.98(4.71,5.36)	5.09(4.74,5.43)	5.26(4.94,5.80)	< 0.001	4.99(4.52,5.29)	5.15(4.57,5.48)	5.24(4.93,5.53)	< 0.001
Family history of hypertension, n (%)	99(26.19)	116(30.37)	96(25.53)	0.269	72(25.26)	60(20.91)	77(26.46)	0.262
Family history of Diabetes Mellitus, n (%)	17(4.50)	20(3.95)	12(9.92)	0.374	13(4.56)	9(3.14)	16(5.50)	0.379
Hypertension, n (%)	168(44.44)	186(48.69)	189(50.27)	0.254	131(45.96)	138(48.08)	153(52.58)	0.268
Diabetes Mellitus, n (%)	41(11.02)	49(12.83)	66(17.55)	0.028	29(10.18)	31(26.72)	56(19.24)	0.002
Current smoking, n (%)	5(1.32)	10(1.98)	19(15.7)	0.009	140(49.12)	128(44.6)	134(46.05)	0.542
Daily drinking, n (%)	9(2.38)	13(2.57)	18(14.88)	0.198	114(40)	104(36.24)	118(40.55)	0.513
Tea drinking ≥ 5 times / week,n (%)	118(31.22)	136(35.60)	136(36.17)	0.292	145(50.88)	152(52.96)	167(57.39)	0.188
Exercise ≥ 3 times / week,n (%)	105(27.78)	123(24.31)	102(27.12)	0.246	70(24.56)	101(35.19)	84(28.87)	0.020
Eating habits are salty,n (%)	99(26.19)	85(16.8)	101(26.86)	0.285	80(28.07)	91(31.71)	83(28.52)	0.581
Like pickled food,n (%)	39(10.32)	42(8.30)	34(28.10)	0.665	19(6.67)	26(9.06)	23(7.90)	0.569
Sweets ≥ 3 times / week,n (%)	64(16.93)	62(12.25)	54(14.36)	0.607	51(17.89)	64(22.30)	56(19.24)	0.399
Working hours over 10 hours /day,n (%)	10(2.65)	20(3.95)	19(15.70)	0.147	23(8.07)	22(7.67)	37(12.71)	0.071

3.2 Relationship between VAI and CAS in different genders

When compared with the low tertile (VAI tertile 1), the unadjusted model OR for CAS in VAI tertile 2 and VAI tertile 3 (female: OR = 1.99 and 2.26; males: OR = 1.40 and 1.44).Further adjustment for relevant confounding factors, including BMI ,WC, et al. VAI tertile 2 (OR = 2.16, 95% CI: 1.51–3.08) and VAI tertile 3 (OR = 2.44, 95% CI: 1.50–3.98) demonstrated increased CAS risk in females when compared to individuals within the VAI tertile 1. In contrast, we found no such association in males (VAI tertile 2: OR = 1.47, 95%CI = 0.97–2.23, *P* = 0.071; VAI tertile 3: OR = 1.74, 95%CI = 1.05–3.16, *P* = 0.056 vs. tertile 1). The details are shown in Table 2.

Table 2
Relationship between VAI and CAS in different genders

	Model one		**Model two**	
	OR(95%CI)	***P*-value**	**OR(95%CI)**	***P*-value**
Female				
Tertile 1	Reference		Reference	
Tertile 2	1.99(1.48–2.67)	< 0.001	2.16(1.51–3.08)	< 0.001
Tertile 3	2.26(1.68–3.03)	< 0.001	2.44(1.50–3.98)	< 0.001
male				
Tertile 1	Reference		Reference	
Tertile 2	1.40(1.01–1.95)	0.044	1.47(0.97–2.23)	0.071
Tertile 3	1.44(1.04–2.00)	0.029	1.74(1.05–3.16)	0.056
Model one was not adjusted;Model two was adjusted for Body mass index,Waist circumference，hip circumference，Total cholesterol，Triglyceride，HDL-C，LDL-C，Diabetes Mellitus，and Current smoking				

3.3 Relationship between VAI and CAS in female of different age groups

For aged ≤ 44 females in the unadjusted model, the highest VAI tertile was associated with carotid atherosclerosis risk (OR = 1.75, 95% CI: 1.10–2.80, P = 0.019 vs. tertile 1); after adjusting for confounding factors, the correlation disappeared. For aged > 44 females, when compared to individuals within the VAI tertile 1 in the unadjusted model, the OR of tertile 2 and tertile 3 were 2.17 (95% CI: 1.50–3.19) and 2.68 (95% CI: 1.81–3.97); for the further adjustment model, the OR in tertile2 and tertile 3 were 2.42 (95% CI: 1.53–3.82) and 3.09 (95% CI: 1.64–5.82). The details are shown in Table 3.

Table 3
Relationship between VAI and CAS in female of different ages

	Model one		**Model two**	
	OR(95%CI)	***P*-value**	**OR(95%CI)**	***P*-value**
age ≤ 44				
Tertile 1	Reference		Reference	
Tertile 2	1.59(0.99–2.56)	0.060	1.54(0.85–2.79)	0.156
Tertile 3	1.75(1.10–2.80)	0.019	1.52(0.67–3.44)	0.315
age＞44				
Tertile 1	Reference		Reference	
Tertile 2	2.17(1.50–3.19)	< 0.001	2.42(1.53–3.82)	< 0.001
Tertile 3	2.68(1.81–3.97)	< 0.001	3.09(1.64–5.82)	< 0.001

3.4 Relationship between VAI and CAS in male of different age groups

In men aged ≤ 44, VAI was not found to be associated with carotid atherosclerosis risk. For aged＞44 males in the unadjusted model,the highest tertile (VAI tertile 3) was signifcantly associated with CAS (OR = 1.86, 95%CI = 1.17–2.95, P = 0.009). However, VAI tertile did not impact on the risk of CAS in adjusted model. The details are shown in Table 4.

Table 4
Relationship between VAI and CAS in male of different ages

	Model one		**Model two**	
	OR(95%CI)	***P*-value**	**OR(95%CI)**	***P*-value**
age ≤ 44				
Tertile 1	Reference		Reference	
Tertile 2	1.41(0.86～2.29)	0.172	1.716(0.90～3.26)	0.099
Tertile 3	1.23(0.75～2.01)	0.407	2.44(0.832～4.64)	0.124
age＞44				
Tertile 1	Reference		Reference	
Tertile 2	1.40(0.88～2.20)	0.153	1.65(0.94～2.90)	0.084
Tertile 3	1.86(1.17～2.95)	0.009	2.00(0.95～4.42)	0.069

3.5 Prediction effect of VAI based on the ROC curve on CAS in different populations

The ability of VAI to predict CAS in different populations was determined by analyzing the receiver operating characteristic (ROC) curves. All of the subject groups were in the areas under the ROC curves (AUC) for the VAI (0.561, 95%CI = 0.535–0.586). To understand the VAI predictive effect on CAS in different populations, all of the populations were further analyzed according to gender and age. In females, ages ＞44 were the areas under the ROC curves (AUC = 0.609, 95%CI: 0.566–0.653,$P < 0.001$) for the VAI that were higher than females aged ≤ 44(AUC = 0.575, 95%CI: 0.520–0.629,$P < 0.001$). In contrast, the VAI was found to have no predictive value for CAS in males. The optimal cut-off values for the VAI levels of all of the subject groups were 0.90 (sensitivity = 57.00%, specificity = 89.01%). The optimal cut-off values for the VAI levels in all of the females were 1.60 (sensitivity = 76.68%, specificity = 39.84%), females aged ≤ 44 were 1.35 (sensitivity = 78.51%, specificity = 30. 37%), and females aged ＞44 were 1.61 (sensitivity = 84.71%, specificity = 40.46%). The details are shown in Table 5.

Table 5
Prediction of ROC curve of CAS by VAI in different population

Different populations	**AUC**	**std. errors**	***P*-value**	**95%CI for AUC**	
				Lower Bound	**Upper Bound**
All subject groups	0.561	0.013	< 0.001	0.535	0.586
All females	0.595	0.017	< 0.001	0.562	0.628
Female aged ≤ 44years	0.575	0.028	0.008	0.520	0.629
Female aged＞44 years	0.609	0.022	< 0.001	0.566	0.653
All males	0.537	0.020	0.060	0.499	0.575
Male aged ≤ 44 years	0.514	0.029	0.640	0.457	0.570
Male aged＞44 years	0.553	0.027	0.056	0.499	0.606

To further understand the VAI predictive effect for carotid atherosclerosis in women, the ROC curves were plotted to evaluate the predictive values of different obesity indices including VAI, BMI, WC, and HC. In females aged > 44 years, the areas under the ROC curves (AUC) for the VAI (0.609, 95%CI = 0.566–0.653,$P < 0.001$)were higher than those for the BMI, WC, and HC(all $P < 0.001$). There was no significant difference in the predictive effect of VAI on CAS compared with BIM, WC and HC in total women population and other women subgroups.The details are shown in Fig. 1.

4 Discussion

The present study assessed the VAI with the carotid atherosclerosis (CAS)occurrence in the Chinese population. Results showed a gradual increase in CAS with increasing VAI in females; after adjusting for the potential risk factors, an elevated CAS risk associated with the VAI was evident for females aged > 44, and but not consistently in males. The ROC analysis confirmed the VAI may be a useful biomarker for identifying CAS in women, especially for middle-aged and elderly women, and its predictive power was better than other obesity indicators. However, no such value was found in males.

In China with rapid economic growth, the lifestyles of people have also changed, with a sedentary lifestyle, lack of exercise, and high-calorie diets increasing[19]. According to the results of chronic diseases and risk factors in China in 2013, the overweight and obesity rates of Chinese adults reached 46.5% [20.21], and the overweight and obesity rates of children also reached 16.0% [20.22]. In the past 10 years, the overweight and obesity rates of Chinese residents have significantly increased, even surpassing those of many other developed countries[23]. Many studies have confirmed that[24.25]the obesity prevalence is increasing, especially visceral obesity that contributed to the development and increased incidence of cardiovascular and cerebrovascular diseases, type 2 diabetes, malignant tumors, and other diseases. In most population-based studies, BMI and WC were the most commonly utilized methods to measure obesity and abdominal adipose tissue, while TG can be utilized to reflect the visceral fat accumulation caused by metabolic disorders [26, 27]. While the above indicators have their advantages, they cannot account for the fat distribution and blood lipid levels[28].

As surrogate markers, the VAI were initially introduced by Amato et al.[29]. BMI, WC, TG, and HDL-C are central VAI parameters utilized to assess the adipose tissue distribution and visceral fat function. Amato et al. [30] utilized an MRI to measure the visceral fat and subcutaneous fat content in 315 physical examination population members with a BMI of 20–30 kg/m^2 and found that VAI closely related to visceral fat, which could predict the risk of cardiovascular metabolic diseases, especially for lean-bodied people. Mohammadreza et al. [31] proposed that VAI was an independent predictor of cardiovascular disease, which is better than traditional indicators when it comes to predicting cardiovascular disease in women. Also, Chinese scholars [32, 33] found that VAI was an independent influencing factor of atherosclerosis, and the atherosclerosis risk increased with the VAI increase.

Herein, we found a significant association between VAI and CAS in different genders and age groups, which, to our knowledge, is the first report of this association in the literature.Results of the present study showed that the carotid atherosclerosis risk in women with high VAI levels was higher than that of low-level people;Through stratified analysis by age, this trend was found to be very significant in women aged 44, but this trend was not observed in women aged ≤ 44. In contrast, we found no such association in males.The present study revealed a sex and ages specifc association between visceral adiposity and CAS.The specific reason for this difference remains unclear, and it may be related to the different distribution of sex hormones and visceral fat between men and women[34, 35, 36].The average age of post-menopause in China ranged between 48 and 51 years old [37, 38]. Therefore, women aged > 44 years old in the present study could be considered as part of the perimenopause population. Women going through menopausal transition were correlated with increased adiposity via the changes of inflammatory markers and adipokines, which could be the cause of increased cardiovascular disease risk among this population [39]. In contrast, the correlation between VAI and carotid atherosclerosis was found to have disappeared in men and women aged ≦ 44years, and visceral fat was positively correlated with age. Relevant studies [40] have shown that visceral fat increased with age, and adipose tissue was more likely to accumulate in viscera and the abdomen with age. Ran et al. [41, 42] showed that when no significant difference in BMI existed between young people and quinquagenarians, the contents of visceral fat and subcutaneous fat in the elderly were significantly increased.

Among women, the area under the curve of each age group was greater than 0.5. The VAI had the highest predictive value for CAS; it was higher than that of other obesity indicators in women aged > 44. However, there was a lower value in men and a sex difference for VAI. Li et al. [36] also showed this difference.

Obesity, especially visceral fat accumulation, secreted visfatin, interleukin-6, tumor necrosis factor Q, etc., cause insulin resistance [43], which is one of the main reasons for atherosclerosis. At present, CT and MRI scans are the best methods for accurately evaluating visceral fat [44]. Domestic and foreign research results show that [45,46] a significant correlation exists between abdominal visceral fat and arteriosclerosis via CT scanning. However, these imaging techniques are unsuitable in a general population or epidemiological research studies, due to availability, time-consuming, expense, and radiologic hazard. Therefore, an effective, convenient and relatively accurate process for the for the evaluation of visceral fat mass is needed [31].As a mathematical model that includes anthropometric and metabolic parameters, VAI is closely correlated with MRI-measured visceral adiposity, which is a useful indicator of adipose distribution[47]. Our study supplemented and confirmed the association between the VAI and carotid atherosclerosis in a general population, VAI could be selected as new and simple predictors of CAS for women aged > 44.

The data of the present study were collected from tertiary general hospitals in Changsha, China. For the first time, the relationship between VAI and carotid atherosclerosis in different age groups and genders was evaluated, and self-reported data were the advantage of this study; In addition, the large sample size. However, the present study has several limitations: First, the study was conducted in a limited area of China (Changsha City), and may not represent China as a multi-ethnicity country; second, although the data of diet, exercise, and work pressure of some subjects were collected, these data were all from self-reported data, which have certain subjectivity; third, the present study was a cross-sectional study, which has certain limitations and cannot verify the causal relationship between VAI and carotid atherosclerosis. Finally, some related risk factors exist, such as endothelial cell function, the economic status of subjects, homocysteine levels were not collected and analysed in this study.

In conclusion, the present study has shown that the VAI may be associated with the risk of CAS in females ,and it is more significant in women aged > 44. However, this trend was not observed in men, and women aged ≤ 44.

Declarations

Authors' contributions

JC contributed to the conception and design of this study. SL, QY,YZ andYZ were involved in the acquisition of data. JH and SL conducted the statistical analysis and interpretation of data. JC drafted the manuscript. JC, SL, QY and JH contributed to the revision of manuscript for important intellectual content. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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Figures

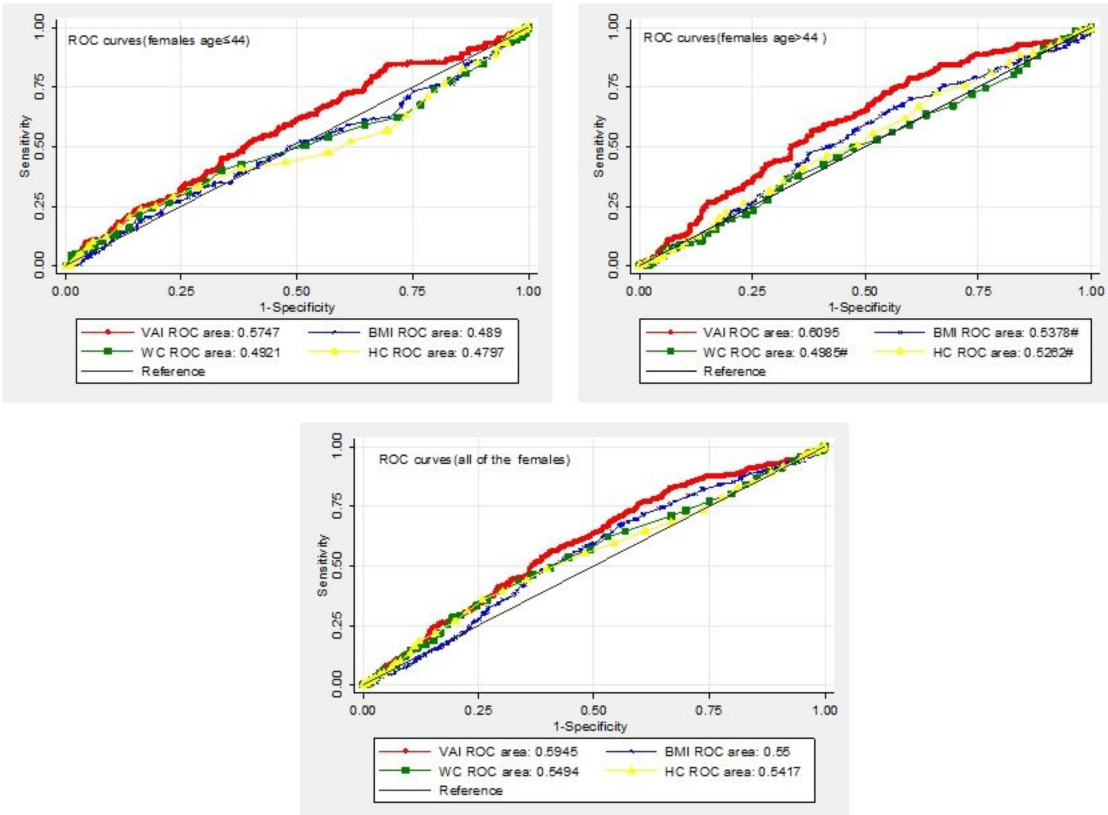

Figure 1

ROC of obesity indices (VAI, BMI, WC, HC) comparing the carotid atherosclerosis predictive values. A: ROC curves in the females aged ≦44 subgroup, B :ROC curves in the females aged >44 subgroup, C :ROC curves in the all females subgroup # The differences of AUC between VAI and the index were significant (P<0.001)