

BMJ Open Independent associations of blood pressure and body mass index with interatrial block: a cross-sectional study in general Chinese population

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ABSTRACT

Objectives This current study was performed to characterise the independent associations of obesity and hypertension with interatrial block (IAB) after adjusting for cardiovascular risk factors, echocardiographic left atrial diameter (LAD) and left ventricular mass index (LVMI) in a large general Chinese population.

Design A cross-sectional study.

Setting and participants A total of 11 956 permanent residents (≥ 35 years of age) from Liaoning Province in China were included in this study. Following the completion of a questionnaire, the enrolled participants were subjected to physical examinations, laboratory analyses, ECG and echocardiogram. Linear and logistic regression analyses were performed to evaluate the associations of hypertension and obesity with IAB.

Outcome measures IAB was defined as a prolongation of the P wave duration ≥ 120 ms on a digital 12-lead ECG.

Results The prevalence of IAB in hypertensive individuals was higher than the normotensive in both men (9.5 vs 5.9%; $p < 0.001$) and women (6.6 vs 3.6%; $p < 0.001$). In addition, the prevalence of IAB exhibited a sharp increase with advancing body mass index (BMI) in both men (from 4.9% to 13.0%) and women (from 3.5% to 6.9%) (p -for trend < 0.001). Multiple relevant clinical covariates, echocardiographic LAD and LVMI were adjusted in the multivariate linear and logistic regression analyses. The results revealed that systolic blood pressure, diastolic blood pressure and BMI were all independently associated with P wave duration ($\beta = 0.02, 0.09$ and 0.25 , respectively; all p s < 0.005). Furthermore, hypertension was found to be independently associated with IAB (OR=1.27; $p = 0.018$), while both overweight and obesity exhibited higher odds of IAB (OR=1.42 and 1.67, respectively; p s < 0.005), compared with BMI < 24.0 kg/m².

Conclusions The key findings of this study highlighted that hypertension and overweight/obesity were independently and significantly associated with IAB in general Chinese population.

INTRODUCTION

Interatrial block (IAB) is characterised by the presence of a prolonged P wave exceeding 120 ms on a 12-lead ECG.¹ Accumulating reports have indicated that the prevalence of IAB is frequently underappreciated in clinical

Strengths and limitations of this study

- The current study evaluated the independent associations of hypertension and overweight/obesity with interatrial block.
- This was a large population-based study, providing adequate data and sample size to delineate the study objective.
- Digital ECG was an important strength since automatic measures had superior validity and reliability compared with manual readings.
- Besides multiple clinical covariates, echocardiographic left atrial diameter and left ventricular mass index were also adjusted in multivariate logistic regression analyses.
- This was a cross-sectional study and further prospective ones should be conducted.

practice, particularly in the male and ageing populations.^{2–4} Further worsening the magnitude, IAB has been linked with numerous medical conditions including atrial arrhythmias,^{5–7} abnormal left atrial function⁸ and thromboembolic ischaemic stroke.^{9–12} A follow-up study demonstrated that advancing P wave durations are significantly associated with increasing cardiovascular and all-cause mortality.¹³ Therefore, as a potentially crucial predictor of long-term patient outcome, additional efforts are necessitated in order to further elucidate the prevalence of IAB and its associated risk factors.

Obesity and hypertension are two highly prevalent conditions which remain to be burden on clinical resources, and remarkably, have been reported to possibly lead to left atrial enlargement. Previous studies have highlighted that both obesity and hypertension serve as risk factors for IAB, but the majority of these studies were performed in general hospitals with patients admitted for non-acute issues with limited sample sizes.^{14 15} More notably, the study conducted by Atherosclerosis Risk in Communities (ARIC)

demonstrated that both obesity and metabolic syndrome (especially with hypertension) are correlated with IAB, independent of age and other cardiovascular risk factors.¹⁶ However, these studies failed to take left atrial size into account. Hence, the current study sought to examine whether these associations with IAB were dependent on echocardiographic left atrial diameter (LAD) changes, a novel investigation that is yet to be conducted. In addition, no previous studies have incorporated large sample size studies emphasising the risk factors contributing to IAB in Chinese population. Thereby, the current study aimed to assess the independent associations of obesity and hypertension with IAB after adjusting for cardiovascular risk factors and echocardiographic changes in general Chinese population using a large-scale cross-sectional study.

MATERIALS AND METHODS

Study population

Between January 2013 and August 2013, a representative sample of men and women from Liaoning province of China were evaluated for cardiovascular risk factors (primarily hypertension) using a multi-stage, random, stratified, cluster-sampling scheme, referred to as the Northeast China Rural Cardiovascular Health Study. The current study intentionally enrolled a representative sample aged ≥ 35 years, due to its purpose of evaluating hypertension and related cardiovascular risk factors. Within the Liaoning province, three counties (Dawa, Zhangwu and Liaoyang) were selected from the eastern, southern and northern regions, where the greater majority of residents are agricultural labourers. One township near a city in each county was randomly selected, totaling 3 townships and 5–8 villages from each township were randomly selected, with a total of 18 rural villages finally selected. Those who were pregnant, suffering from cancers or mental disorders were excluded from the current study.

All eligible permanent residents ≥ 35 years of age from each village ($n=14016$) were initially recruited, and a total of 11 956 (85.3%) participants completed the study. Subjects with incomplete data, poor ECG quality, atrial fibrillation (AF)/flutter, paced rhythm, Wolff-Parkinson-White syndrome or congenital heart diseases were excluded from the study, leaving a total of 11 264 participants for the final analyses. All participants signed written consent after they had been informed of the study's objectives, benefits, medical procedures and confidentiality safeguards for personal information. Also, informed consent was obtained from the proxies of participants who were illiterate.

Data collection and measurements

Data were collected during a single clinic visit by cardiologists and trained nurses using a standard questionnaire with face-to-face interviews. All the potential investigators had received training in relation to the objectives of the

study, how to perform the questionnaire, the standard methods of measurement, the importance of standardisation, as well as the finer details of the study procedures. Only those who earned a perfect score on a post-training test were permitted to participate as study investigators. During the process of data collection, the investigators were provided with additional instructions and support. Data on demographic characteristics, medical history and lifestyle risk factors were obtained using the above-mentioned interviews with a standardised questionnaire. A central steering committee with a subcommittee for quality control ensured that all data were collected in accordance with the aforementioned standards.

According to the guidelines of the American Heart Association, blood pressure (BP) was measured three times at 2 min intervals, with a resting period of at least 5 min using a standardised automatic electronic sphygmomanometer (HEM-907; Omron, Kyoto, Japan). Independently, two doctors checked the calibration of the Omron device every month using a standard mercury sphygmomanometer in accordance with the British Hypertension Society protocol.¹⁷ All participants were directed to avoid caffeinated beverages and exercise at least 30 min prior to evaluation. During BP measurement, the participants were seated with their arms supported at the level of their hearts. The mean value of three BP measurements were calculated and used in all the subsequent analyses. Hypertension was defined by the criteria widely employed and considered to be the worldwide standard in epidemiological research studies: a systolic blood pressure (SBP) ≥ 140 mm Hg and/or diastolic blood pressure (DBP) ≥ 90 mm Hg and/or the use of antihypertensive medications. All participants were classified into the following groups based on mean SBP/DBP values and the most recent 2017 American College of Cardiology/American Heart Association guidelines¹⁸: (a) normal: SBP < 120 mm Hg and DBP < 80 mm Hg, (b) elevated BP: SBP 120–129 mm Hg and DBP < 80 mm Hg, (c) stage 1 hypertension: SBP 130–139 mm Hg or DBP 80–89 mm Hg and (d) stage 2 hypertension: SBP ≥ 140 mm Hg or DBP ≥ 90 mm Hg. During the course of the study, subjects who were taking anti-hypertensive medication and had a history of hypertension were considered to be at stage 2 hypertension as their BP levels would have exceeded 140/90 mm Hg during their initial hypertension diagnosis in accordance with the previous criteria. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with all participants given lightweight clothing and evaluated barefoot. The body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres (kg/m^2). As recommended by the Working Group on Obesity in China, overweight was defined as a BMI of 24.0–27.9 kg/m^2 and obesity as a BMI of 28.0 kg/m^2 or higher.¹⁹

Fasting blood samples were collected in the morning after ≥ 8 hour of fasting. Blood samples were collected from the antecubital vein using BD Vacutainer tubes containing EDTA (Becton, Dickinson and Co., Franklin

Table 1 Demographic characteristics of the study population

Variable	IAB – (n=10553)	IAB + (n=711)	P value
Age, years	53.6±10.6	55.5±10.2	<0.001
Male	4724 (44.8)	402 (56.5)	<0.001
Race of Han	10 009 (94.8)	668 (94.0)	0.300
Height, cm	160.4±8.2	163.1±8.1	<0.001
Weight, kg	63.7±11.3	69.2±11.6	<0.001
BMI, kg/m ²	24.7±3.7	25.9±3.6	<0.001
BMI category, kg/m ²			<0.001
<24	4752 (45.0)	206 (29.0)	
24–28	3989 (37.8)	315 (44.3)	
≥28	1812 (17.2)	190 (26.7)	
SBP, mm Hg	141.3±23.3	149.4±24.9	<0.001
DBP, mm Hg	81.7±11.6	85.7±12.7	<0.001
Hypertension	5288 (50.1)	459 (64.6)	<0.001
BP category			<0.001
Normal	1657 (15.7)	67 (9.4)	
Elevated	1333 (12.6)	54 (7.6)	
Stage 1 Hypertension	2275 (21.6)	131 (18.4)	
Stage 2 Hypertension	5288 (50.1)	459 (64.6)	
FBG, mmol/L	5.88±1.61	6.08±1.75	0.003
Diabetes	1067 (10.1)	89 (12.5)	0.041
TC, mmol/L	5.22±1.07	5.37±1.31	0.003
TG, mmol/L	1.62±1.49	1.86±1.65	<0.001
LDL-C, mmol/L	2.92±0.81	3.03±0.93	0.001
HDL-C, mmol/L	1.41±0.38	1.37±0.38	0.002
SUA, mg/dL	4.87±1.42	5.22±1.45	<0.001
Current smoker	3712 (35.2)	245 (34.5)	0.699
Current drinker	2313 (21.9)	196 (27.6)	<0.001
Education level			0.004
≤Primary school	5274 (50.0)	348 (48.9)	
Middle school	4328 (41.0)	273 (38.4)	
≥High school	951 (9.0)	90 (12.7)	
Family income, CNY/y			0.281
≤5000	1317 (12.5)	85 (12.0)	
5000–20 000	5787 (54.8)	373 (52.5)	
>20 000	3449 (32.7)	253 (35.6)	
LAD, mm	33.6±3.9	35.3±4.6	<0.001
LAE	968 (9.4)	141 (20.4)	<0.001
LVMI, g/m ²	81.7±19.0	87.7±21.5	<0.001
LVH	1047 (10.3)	111 (16.3)	<0.001
P wave duration, ms	99.4±12.2	125.6±7.7	<0.001
Heart rate, bpm	71.5±12.0	73.2±15.5	0.004
Anti-arrhythmic medication	58 (0.5)	9 (1.3)	0.037

Continued

Table 1 Continued

Variable	IAB – (n=10553)	IAB + (n=711)	P value
Anti-hypertensive medication	1641 (15.6)	174 (24.5)	<0.001
History of MI	117 (1.1)	13 (1.8)	0.082
History of HF	84 (0.8)	10 (1.4)	0.083
Mitral stenosis/regurgitation	158 (1.5)	17 (2.4)	0.062

Data are expressed as mean ±SD or n (%). BMI, body mass index; BP, blood pressure; CNY, China Yuan; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipid cholesterol; HF, heart failure; IAB, interatrial block; LAD, left atrial diameter; LAE, left atrial enlargement; LDL-C, low-density lipid cholesterol; LVH, left ventricular hypertrophy; LVMI, left ventricular mass index; MI, myocardial infarction; SBP, systolic blood pressure; SUA, serum uric acid; TC, total cholesterol; TG, triglycerides.

Lakes, NJ, USA). Subsequently, serum was isolated from whole blood, with all serum samples subsequently frozen at –20°C for testing at a central, certified laboratory. Fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), high-density lipid cholesterol (HDL-C), low-density lipid cholesterol (LDL-C), serum uric acid (SUA) and other routine blood biochemical indices were analysed enzymatically using an auto-analyzer (Olympus AU640 Auto-Analyzer; Olympus Corp., Kobe, Japan). According to the criteria issued by WHO, diabetes mellitus was defined as a FBG ≥7.0 mmol/L and/or patients currently being treated for diabetes.²⁰

In addition, 12-lead resting, 10-s ECGs were performed on all participants by well-trained cardiologists using an electrocardiography machine (MAC 5500; GE Healthcare, Little Chalfont, Buckinghamshire, UK). The results were automatically analysed by the MUSE Cardiology Information System (V.7.0.0; GE Healthcare). The P wave in each lead was defined as the initial upward point or downward deflection from the isoelectric line to the point of the initial baseline. For the calculation of the P wave duration, onsets were defined as the earliest deflection in any lead and offsets were defined as the latest deflection in any lead. Employing the most recent consensus guidelines,¹ IAB was defined as a prolonged P wave duration ≥120 ms on a 12-lead ECG in the current study.

Echocardiograms were obtained using a commercially available Doppler echocardiograph (Vivid; GE Healthcare) with a 3.0-MHz transducer. Echocardiogram analyses and readings were performed by three separate doctors, all of whom were specialised in echocardiography, while two other specialists were called in case of any questions or uncertainties. LAD in the current study was defined as the left atrial anteroposterior measurement in the parasternal long-axis view according to the recommendations of the American Society of Echocardiography.²¹ The reported LAD values in our study were not indexed by body surface area. Left ventricular mass

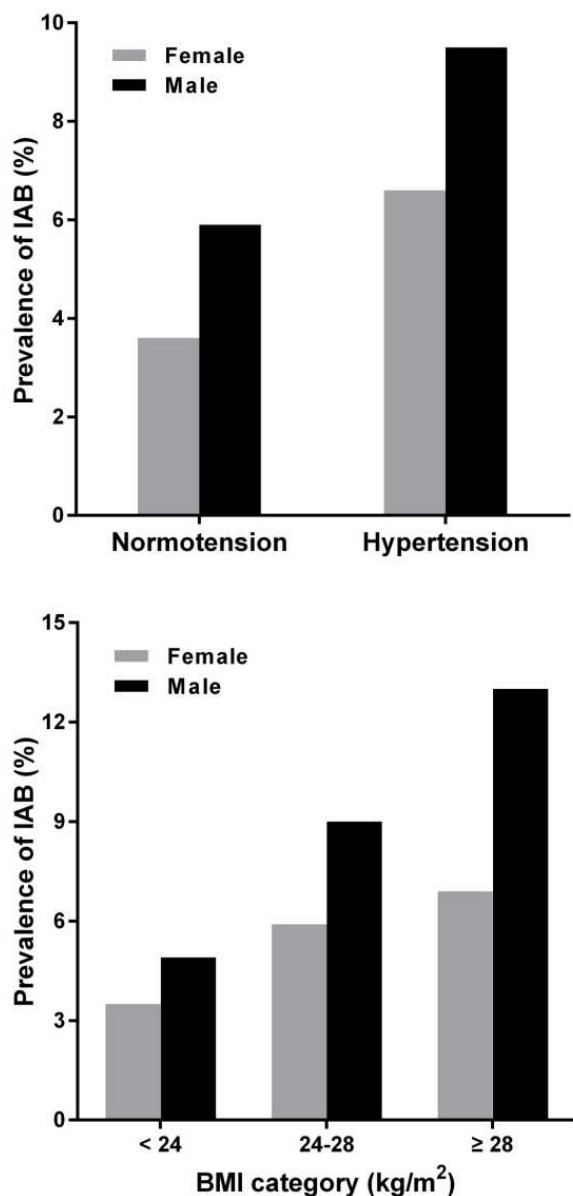


Figure 1 Gender-specific prevalence of interatrial block (IAB) by hypertension and body mass index (BMI) category.

index (LVMI) was calculated based on body surface area, while left ventricular hypertrophy (LVH) was defined as a LVMI >115 g/m² in men and >95 g/m² in women.

Statistical analysis

All statistical analyses were performed using SPSS V.17.0 statistical software (SPSS, Inc, Chicago, IL, USA). Differences between groups were compared using a two-tailed Student's t-test for continuous variables and a χ^2 test for categorical variables. IAB prevalence by BMI category and hypertension were calculated and presented accordingly. Multivariate linear regression analyses were performed to identify the linear correlation among BP, BMI and P wave duration. Multivariate logistic regression analyses were conducted to evaluate the link between hypertension and obesity with IAB. Data were expressed as OR and 95% CI,

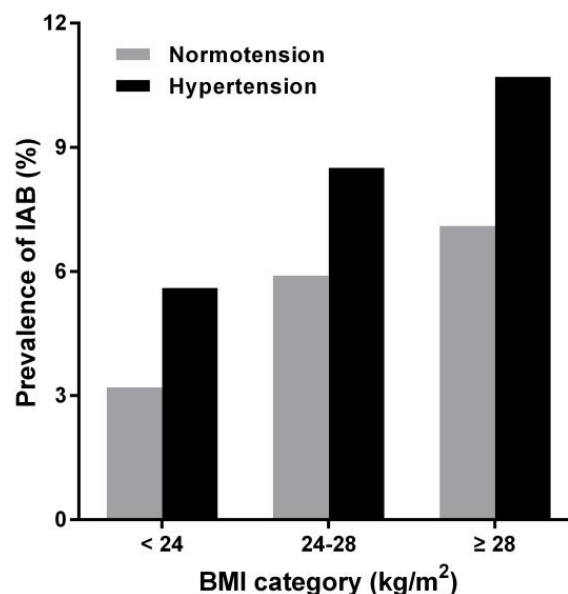


Figure 2 Prevalence of interatrial block (IAB) for body mass index (BMI) category by hypertension.

β , mean \pm SD or frequency and percentages; A p value <0.05 was considered to be statistically significant.

Patient and public involvement

No patients were involved in setting the research questions or the outcome measures, nor were they involved in the design or performance of the study. No participants or patients were asked to advise on the interpretation or writing up of results. No plans were set in place to disseminate the results of the research to study participants.

RESULTS

Characteristics of the study population

A total of 11 264 participants were included for final analyses, comprising of 5126 men and 6138 women with a mean age of 53.8 years. The general prevalence of IAB was calculated to be 6.3% (711/11 264) within the total population, which was significantly higher in subjects with left atrial enlargement (LAE) than those without (12.7 vs 5.6%; $p < 0.001$). The subjects with IAB ($n = 711$) were significantly older and exhibited higher BMI, SBP, DBP, FBG, TC, TG, LDL-C, SUA, LAD, LVMI and heart rate values compared with those with normal P wave durations (all $ps < 0.005$) (table 1). Furthermore, the participants with IAB had significantly higher percentages of men, current drinker, anti-arrhythmic medication and anti-hypertensive medication, and higher prevalences of obesity, hypertension, diabetes mellitus, LAE and LVH (all $ps < 0.05$). Notably, HDL-C levels were found to be lower in subjects with IAB than those without IAB ($p = 0.002$). No significant differences were detected regarding smoking status between the two groups ($p = 0.699$). Furthermore, IAB participants were identified with a relatively higher prevalence of myocardial infarction (MI), heart failure

Table 2 Multivariate linear regression analyses for associations between BP, BMI and P wave duration

	Model 1		Model 2		Model 3		Model 4	
	β	P value	β	P value	β	P value	β	P value
SBP, mm Hg	0.03	<0.001	0.03	<0.001	0.02	<0.001	0.02	0.002
DBP, mm Hg	0.11	<0.001	0.09	<0.001	0.09	<0.001	0.09	<0.001
BMI, kg/m ²	0.44	<0.001	0.36	<0.001	0.25	<0.001	0.25	<0.001
Age, year	0.05	0.001	0.05	0.001	0.05	0.001	0.05	0.003
Male (1) vs. Female (0)	3.11	<0.001	2.55	<0.001	2.02	<0.001	1.98	<0.001
FBG, mmol/L	–		0.04	0.614	0.04	0.603	0.04	0.608
TC, mmol/L	–		0.83	0.007	0.73	0.018	0.71	0.023
TG, mmol/L	–		–0.05	0.682	–0.02	0.843	–0.02	0.899
LDL-C, mmol/L	–		–0.36	0.312	–0.21	0.573	–0.17	0.647
HDL-C, mmol/L	–		–1.96	<0.001	–1.81	<0.001	–1.81	<0.001
SUA, mg/dL	–		0.05	0.646	0.01	0.914	0.00	0.994
Current smoker (yes/no)	–		0.02	0.949	0.13	0.663	0.10	0.751
Current drinker (yes/no)	–		1.21	0.001	1.19	0.002	1.18	0.002
Anti-arrhythmic medication (yes/no)	–		–1.83	0.263	–2.54	0.125	–2.60	0.116
Anti-hypertensive medication (yes/no)	–		1.25	0.001	1.17	0.003	1.15	0.003
Mitral stenosis/regurgitation (yes/no)	–		–0.04	0.968	–0.94	0.356	–1.12	0.273
History of MI (yes/no)	–		–0.16	0.891	–0.30	0.805	–0.33	0.785
History of HF (yes/no)	–		–1.40	0.314	–1.84	0.189	–1.89	0.179
LAD, cm	–		–		2.83	<0.001	2.66	<0.001
LVMI, g/m ²	–		–		–		0.01	0.208

Model 2: additional variables including FBG, plasma lipids, SUA, smoking, drinking, education, income, anti-arrhythmic medication, anti-hypertensive medication, mitral stenosis/regurgitation, and history of MI and HF; model 3: additional variable LAD; model 4: additional variable LVMI.; Note, model 1: SBP, DBP, BMI, age, gender and race in the multivariate regression.

BMI, body mass index; BP, blood pressure; CNY, China Yuan; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipid cholesterol; HF, heart failure; IAB, interatrial block; LAD, left atrial diameter; LAE, left atrial enlargement; LDL-C, low-density lipid cholesterol; LVH, left ventricular hypertrophy; LVMI, left ventricular mass index; MI, myocardial infarction; SBP, systolic blood pressure; SUA, serum uric acid; TC, total cholesterol; TG, triglycerides.

(HF) and mitral stenosis/regurgitation, even though no statistical significance was detected (all $p > 0.05$).

IAB prevalence by hypertension and BMI category

The gender-specific prevalence of IAB categorised according to hypertension and BMI category were shown in [figure 1](#). The prevalence of IAB in hypertensive subjects was found to be higher than the normotensive in both men (9.5 vs 5.9%; $p < 0.001$) and women (6.6 vs 3.6%; $p < 0.001$). In addition, the prevalence of IAB demonstrated a sharp rise with advancing BMI in both men (4.9% , 9.0% and 13.0% in those with BMI < 24.0, 24.0–27.9 and ≥ 28.0 kg/m², respectively; p for trend < 0.001) and women (3.5% , 5.9% and 6.9% in those with BMI < 24.0, 24.0–27.9 and ≥ 28.0 kg/m², respectively; p for trend < 0.001). The prevalence of IAB for BMI category by hypertension was calculated and presented in [figure 2](#). Our results demonstrated that the prevalence of IAB rose significantly with advancing BMI in both normotensive and hypertensive subjects (p s for trend < 0.001). Furthermore, higher prevalence of IAB

was detected in the hypertensive subgroup at each BMI category (all p s < 0.05).

Linear relationship of BP, BMI with P wave duration

Multivariate linear regression analyses were performed to elucidate the association of BP, BMI and P wave duration, which are presented in [table 2](#). To better understand the complex effects of the numerous clinical factors associated with P wave duration, 4 sets of multivariate models were employed accordingly. In model 1, factors such as BP, BMI, age, gender and race were included, with results demonstrating that SBP, DBP and BMI were all independently associated with P wave duration ($\beta = 0.03, 0.11$ and 0.44 , respectively; all p s < 0.001). In model 2, additional variables such as FBG, plasma lipids, SUA, smoking, drinking, education, income, use of anti-arrhythmic medication, use of anti-hypertensive medication, mitral stenosis/regurgitation and history of MI and HF were adjusted accordingly, the results of which revealed that the independent associations were presented with a relatively lower β (all p s < 0.001). In

model 3, after LAD had been further adjusted, the linear regression coefficients were found to decline to 0.02, 0.09 and 0.25 for SBP, DBP and BMI, respectively (all $ps < 0.001$). Finally, in model 4, while LVMI was added to the multivariate linear regression, SBP, DBP and BMI were still all found to be independently associated with P wave duration (all $ps < 0.005$).

Associations between hypertension, overweight/obesity and IAB

In an attempt to further evaluate the associations of hypertension and overweight/obesity with IAB, we performed a series of multivariate logistic regression analyses, the results of which were shown in [table 3](#). In model 1, factors such as hypertension, BMI categories, age, gender and race were included, with results demonstrating that hypertensive subjects exhibited higher odds of IAB than the normotensive subjects (OR=1.42; 95% CI 1.19 to 1.68). Compared with individuals with a BMI $< 24.0 \text{ kg/m}^2$, higher odds of IAB were found in both overweight (OR=1.76; 95% CI 1.46 to 2.11) and obese individuals (OR=2.32; 95% CI 1.88 to 2.87). In model 2, additional variables of diabetes, plasma lipids, SUA, smoking, drinking, education, income, use of anti-arrhythmic medication, use of anti-hypertensive medication, mitral stenosis/regurgitation, history of MI and history of HF were adjusted accordingly, with the subsequent results obtained indicating that the independent associations preserved with relatively lower ORs (all $ps < 0.05$). In model 3, after LAD had been further adjusted, the ORs decreased to 1.29, 1.40 and 1.64 for hypertension, overweight and obesity, respectively (all $ps < 0.05$). Finally, LVMI was added in model 4, and the ORs changed to 1.27, 1.42 and 1.67 (all $ps < 0.05$).

DISCUSSION

The current study aimed to conduct the largest evaluation ($n=11\,264$) of the potential factors associated with IAB in a general Chinese population. Our key findings indicated that IAB is significantly less prevalent in China compared with the American population. Our current study focused on obesity and hypertension, which are pandemic clinical issues that often coexist in people across the world. Our results identified a higher prevalence of IAB in subjects presenting with hypertension and advancing BMIs. Hypertension was further demonstrated to increase the prevalence of IAB among overweight and obesity individuals. Furthermore, we uncovered that both obesity and hypertension were significantly and independently associated with IAB, even after adjusting for multiple clinical covariates, echocardiographic LAD and LVMI.

An extremely low prevalence of IAB was detected during the current study in comparison to previous data,^{2,4} which may be attributed to the fact that our study population comprised of rural residents with a relatively young mean age. In addition, it is also noteworthy that the prevalence of AF in Asian population is considerably

lower compared with Western populations.²² Based on the aforementioned analysis, we asserted that IAB might contribute to the relatively low prevalence of AF in China.

Some previous studies have reported the correlations of IAB with obesity^{23,24} and hypertension.^{25–28} Additionally, our results on the potential risk factors contributing to IAB are consistent with existing literatures reported in the ARIC¹⁶ and Multiethnic Study of Atherosclerosis (MESA) studies.²⁹ The ARIC research demonstrated that IAB is significantly associated with obesity and hypertension in a cross-sectional population-based analysis, which are independent of age and cardiovascular risk factors.¹⁶ This was consistent with our findings of the current study. The subgroup analysis of the MESA study further confirmed our discoveries, illustrating the association of increased BMI with IAB after adjusting for age, sex, ethnicity and pericardial fat.²⁹ However, the examination in both of these aforementioned two studies failed to adjust for factors such as LAD and LVMI. In contrast, a considerable strength of our current study was our comprehensive adjustment for echocardiographic LAD and LVMI, in addition to cardiovascular risk factors in the multivariable analyses.

Our key findings revealed that the associations of hypertension and obesity with IAB were independent of echocardiographic LAD and LVMI, indicating that a prolonged P wave may occur prior to left atrial enlargement or at least was not consistent. The aforementioned finding was supported by Antoni Bayés de Luna's study, who proposed the concept of 'Bayes' syndrome'. He stated that the potential pathophysiology of IAB was directly related to a block in the area of the Bachmann's bundle. Although atrial enlargement and IAB share a similar electrocardiographic pattern, they are two separate entities.^{1,30,31} Another study highlighted that the mechanism underlying the associations of hypertension and obesity with IAB is likely to be multifactorial in nature.³² Obesity and hypertension have been demonstrated to increase cardiac preload, resulting in compensatory remodelling,³³ with various reports indicating that obesity induces the expression of paracrine hormone with endovascular effects that may also alter atrial pressures and preload conditions.^{34,35} The abovementioned findings elucidated the role of LAD in relation to the impact of obesity and hypertension on IAB. On the other hand, insulin resistance, a basic feature of metabolic syndrome, exhibits cellular and electrophysiologic effects by modifying metabolic function, including impairment of mitochondrial function and oxidative stress.³⁶ Furthermore, obesity has been reported to directly drive electrophysiologic remodelling by altering the myocardial matrix secondary to adipose-derived hormones.^{37,38} Therefore, it can be summarised that the association of hypertension and obesity with IAB is not entirely dependent on LAD and LVMI, which serves as an explanation for our findings regarding the independent influence of hypertension and obesity on IAB.

Table 3 Multivariate logistic regression analyses for associations between hypertension, BMI categories and IAB.

	Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Hypertension (Yes/No)	1.42 (1.19 to 1.68)	<0.001	1.32 (1.09 to 1.59)	0.004	1.29 (1.07 to 1.57)	0.009	1.27 (1.04 to 1.54)	0.018
BMI<24 kg/m ²	1		1		1		1	
24-28	1.76 (1.46 to 2.11)	<0.001	1.63 (1.35 to 1.98)	<0.001	1.40 (1.15 to 1.72)	0.001	1.42 (1.16 to 1.74)	0.001
≥28	2.32 (1.88 to 2.87)	<0.001	2.04 (1.62 to 2.57)	<0.001	1.64 (1.28 to 2.10)	<0.001	1.67 (1.30 to 2.14)	<0.001
Age, per 10years	1.14 (1.06 to 1.23)	0.001	1.16 (1.07 to 1.27)	<0.001	1.14 (1.04 to 1.24)	0.005	1.12 (1.03 to 1.23)	0.010
Male vs Female	1.60 (1.37 to 1.87)	<0.001	1.56 (1.27 to 1.91)	<0.001	1.40 (1.13 to 1.73)	0.002	1.37 (1.11 to 1.69)	0.004
Diabetes (Yes/No)	-		0.93 (0.73 to 1.19)	0.581	0.85 (0.66 to 1.10)	0.221	0.85 (0.66 to 1.10)	0.211
TC, per mmol/L	-		1.14 (0.95 to 1.37)	0.151	1.13 (0.94 to 1.36)	0.181	1.12 (0.93 to 1.35)	0.224
TG, per mmol/L	-		0.99 (0.93 to 1.06)	0.735	1.00 (0.93 to 1.07)	0.886	1.00 (0.93 to 1.07)	0.971
LDL-C, per mmol/L	-		0.92 (0.75 to 1.14)	0.448	0.94 (0.76 to 1.16)	0.561	0.96 (0.77 to 1.19)	0.693
HDL-C, per mmol/L	-		0.78 (0.59 to 1.03)	0.077	0.80 (0.60 to 1.07)	0.126	0.81 (0.61 to 1.07)	0.140
SUA, per mg/dL	-		1.02 (0.96 to 1.08)	0.570	1.01 (0.95 to 1.08)	0.717	1.01 (0.95 to 1.07)	0.817
Current smoker (yes/no)	-		0.84 (0.70 to 1.00)	0.055	0.82 (0.68 to 0.99)	0.039	0.81 (0.67 to 0.98)	0.028
Current drinker (yes/no)	-		1.17 (0.94 to 1.44)	0.153	1.16 (0.93 to 1.44)	0.191	1.15 (0.93 to 1.44)	0.201
Anti-arrhythmic medication (yes/no)	-		1.52 (0.73 to 3.16)	0.266	1.23 (0.57 to 2.68)	0.600	1.17 (0.53 to 2.56)	0.696
Anti-hypertensive medication (yes/no)	-		1.24 (1.00 to 1.52)	0.047	1.20 (0.97 to 1.48)	0.100	1.17 (0.94 to 1.45)	0.158
Mitral stenosis/regurgitation (yes/no)	-		1.48 (0.88 to 2.49)	0.141	1.10 (0.64 to 1.89)	0.723	1.04 (0.60 to 1.80)	0.898
History of MI (yes/no)	-		1.09 (0.60 to 2.00)	0.777	1.12 (0.61 to 2.06)	0.708	1.10 (0.60 to 2.02)	0.752
History of HF (yes/no)	-		1.36 (0.68 to 2.72)	0.386	1.29 (0.65 to 2.59)	0.467	1.26 (0.63 to 2.52)	0.521
LAD, per cm	-		-		2.01 (1.62 to 2.49)	<0.001	1.86 (1.48 to 2.33)	<0.001
LVMi, per 10g/m ²	-		-		-		1.05 (1.00 to 1.09)	0.044

Model 2: additional variables including diabetes, plasma lipids, SUA, smoking, drinking, education, income, anti-arrhythmic medication, anti-hypertensive medication, mitral stenosis/regurgitation, and history of MI and HF; model 3: additional variable LAD; model 4: additional variable LVMi.; Note, model 1: hypertension, BMI category, age, gender and race in the multivariate regression.

BMI, body mass index; BP, blood pressure; CNY, China Yuan; DBP, diastolic blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; HF, heart failure; IAB, interatrial block; LAD, left atrial enlargement; LDL-C, low-density lipoprotein cholesterol; LVH, left ventricular hypertrophy; LVMi, left ventricular mass index; MI, myocardial infarction; SBP, systolic blood pressure; SUA, serum uric acid; TC, total cholesterol; TG, triglycerides.

However, this study has several limitations. First, the cross-sectional design of our study was unable to examine the longitudinal associations and distinguish causality between hypertension, obesity and IAB. Second, the detailed information of ECG waveform recorded using automatic measures were unable to be read by the MUSE system, so we did not differentiate between partial and advanced IAB. Third, left atrial volume is a better index than LAD to estimate left atrial size according to the recommendations of the American Society of Echocardiography.²¹ However, as a large-scale epidemiological investigation, we only measured LAD in our current study. Therefore, it may not represent an accurate picture of left atrial size although this measurement has been used extensively in clinical practice and research. Fourth, the sample size in some subgroups by stage of hypertension in our study was relatively small. For example, the number of subjects with elevated BP stage and IAB was only 54, thus we did not perform subgroup analyses according to BP stages. Finally, all the enrolled participants were from the same province in China, resulting in limited representation.

CONCLUSION

The current study evidenced a relatively higher prevalence of IAB in subjects with hypertension and advancing BMIs. Hypertension additionally augmented the prevalence of IAB among individuals from each BMI category. Furthermore, it was uncovered that both hypertension and overweight/obesity significantly and independently increased the prevalence of IAB even after adjusting for multiple relevant covariates, echocardiographic LAD and LVMI.

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Competing interests None declared.

Patient consent for publication Not required.

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Data sharing statement Data are available upon reasonable request.

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