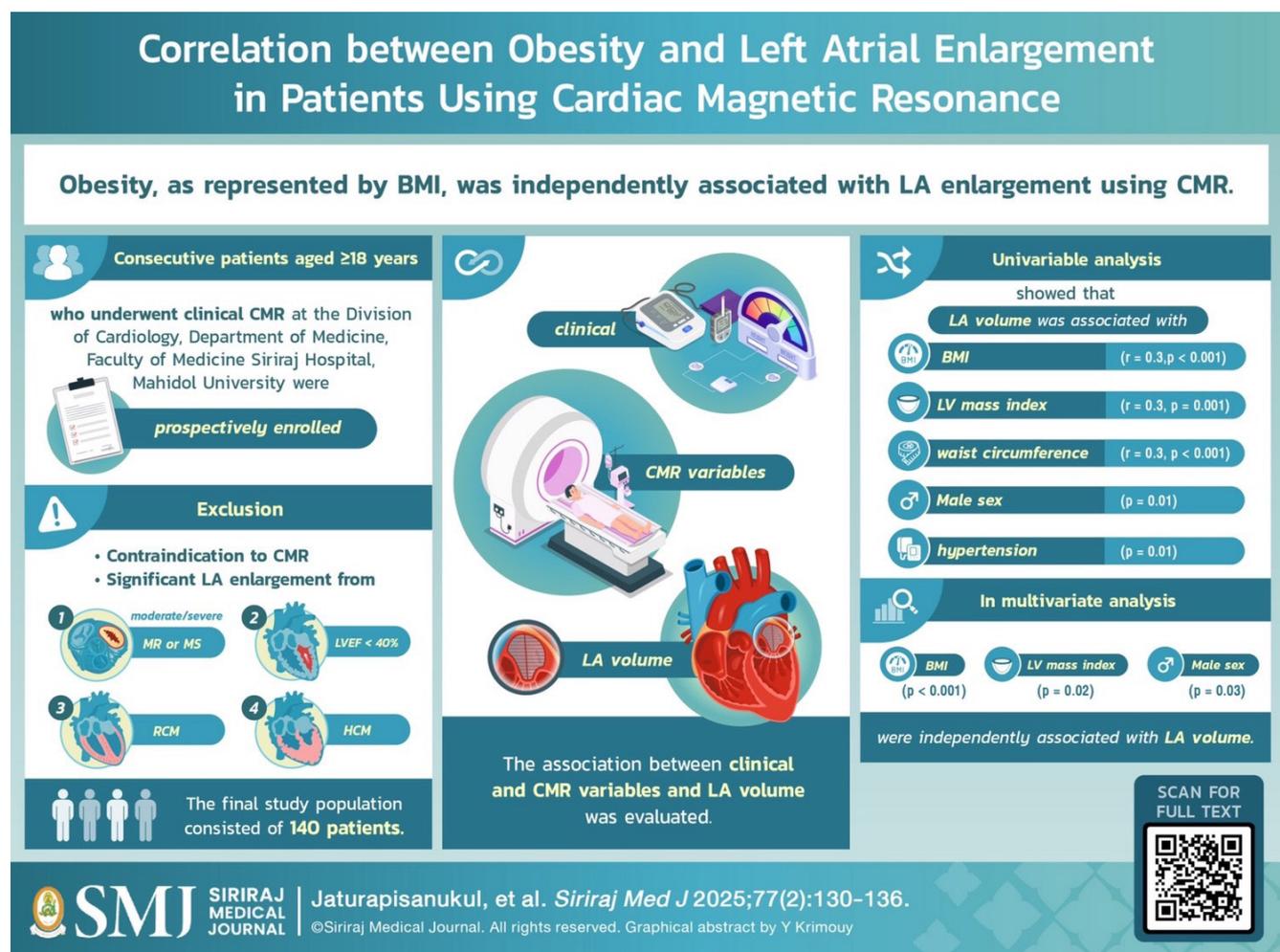


Correlation between Obesity and Left Atrial Enlargement in Patients Using Cardiac Magnetic Resonance

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ABSTRACT

Objective: The correlation between left atrial (LA) enlargement and obesity has been previously reported. However, most studies primarily evaluated LA diameter using echocardiography, which is less accurate and reliable than assessing LA volume with cardiac magnetic resonance (CMR). This study aimed to explore the correlation between obesity and LA volume by using CMR imaging.

Materials and Methods: We prospectively enrolled consecutive eligible patients aged 18 years or older who underwent CMR at a tertiary academic hospital. Clinical variables, including body mass index (BMI), were collected from the medical records. LA volume classification was based on the current guideline recommendations.

Results: A total of 140 patients (41% men), with a mean age of 66.5 ± 10.5 years, were studied. The mean BMI was 25.7 ± 4.2 kg/m². CMR parameters revealed an LA volume of 75.7 ± 22.5 mL, a left ventricular (LV) ejection fraction of $71.1 \pm 9.5\%$, and an LV mass index of 46.1 ± 27.4 g/m². Univariable analysis indicated that the factors affecting LA volume included BMI ($r = 0.3$, $p < 0.001$), LV mass index ($r = 0.3$, $p = 0.001$), waist circumference ($r = 0.3$, $p < 0.001$), male sex ($p = 0.01$), and hypertension ($p = 0.01$). In stepwise multivariable analysis, BMI ($p < 0.001$), LV mass index ($p = 0.02$), and male sex ($p = 0.03$) were independently associated with LA volume.

Conclusion: Obesity, as represented by BMI, was independently associated with LA enlargement. Other independent factors correlated with LA volume included the LV mass index and male sex.

Keywords: Cardiac magnetic resonance; correlation; left atrial enlargement; left atrium; left atrial volume; obesity; overweight. (Siriraj Med J 2025; 77: 130-136)

Abbreviations

BMI = body mass index

CMR = cardiac magnetic resonance

LA = left atrium

LV = left ventricle

LVEDV = left ventricular end-diastolic volume

LVEF = left ventricular ejection fraction

LVESV = left ventricular end-systolic volume

SD = standard deviation

SSFP = steady-state free precession

INTRODUCTION

According to the World Health Organization (WHO) expert consultation, individuals are generally considered obese if their body mass index (BMI) is 25 kg/m² or higher, with a range of 23 – 24.9 kg/m² defined as overweight in Asia-Pacific populations.¹ Patients with obesity are at an increased risk of various health problems.

Obesity is one of the primary preventable causes of death globally, with rising prevalence among both adults and children. The latest WHO report indicates that adult obesity rates worldwide have more than doubled since 1990, while the rates of adolescent obesity have increased fourfold. In 2022, one in eight people worldwide lived with obesity, with 2.5 billion adults (43%) aged 18 and older classified as overweight and 890 million (16%) affected by obesity.^{2,3} In Thailand, the incidence of obesity has increased significantly since 1991, when 12.1% of males and 21.9% of females were classified as

obese.⁴ Data from the Thai National Health Examination Survey indicated that the prevalence of obesity among individuals aged 15 years or older increased from 28.6% in 1991 to 42.2% in 2020. Obesity also increases the risk of several health conditions, including heart disease, type 2 diabetes, obstructive sleep apnea, specific cancers, and osteoarthritis.⁵⁻⁷

There is evidence that the presence of left atrial (LA) enlargement is associated with cardiovascular risks, such as heart failure, atrial fibrillation, cerebrovascular disease, and increased mortality.⁸⁻¹⁰ It is interesting to note that obesity may be an independent factor associated with LA enlargement. Previous studies have demonstrated a correlation between obesity and LA enlargement. For example, Gerds et al. found that BMI has a continuous correlation with LA size and is an independent factor, unrelated to left ventricular (LV) hypertrophy or baseline blood pressure.¹¹ Huang et al. recently showed that

higher BMI and male sex were independently associated with increased LA diameter, LA area, and LA volume. Furthermore, older age and larger LA diameter were independently associated with a higher incidence of atrial fibrillation.¹²

However, previous studies have limitations in identifying LA enlargement by measuring LA diameter in one or two dimensions using transthoracic echocardiography, which has lower accuracy and reliability due to investigator dependence. Cardiac magnetic resonance imaging (CMR) is superior to echocardiography for measuring LA volume, as it provides more reliable, reproducible measurements and serves as a better predictor of cardiovascular risk and mortality.^{13,14} Our aim is to investigate the relationship between obesity and LA volume using CMR.

MATERIALS AND METHODS

Study population

We prospectively enrolled consecutive eligible patients aged 18 years or older who underwent clinical CMR at the Division of Cardiology, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand. Exclusion criteria included patients with contraindications to CMR or those with underlying heart diseases that cause significant LA enlargement, such as moderate or severe mitral regurgitation, mitral stenosis, LV systolic dysfunction (left ventricular ejection fraction [LVEF] less than 40%), restrictive cardiomyopathy, and hypertrophic cardiomyopathy. Blood pressure, BMI, and waist circumference were measured for each patient. Clinical variables and medical history were collected from medical records. The study protocol was approved by the Siriraj Institutional Review Board. Written informed consent was obtained from all patients.

CMR

All patients were examined using a 1.5-T Achieva XR MRI scanner (Phillips, Netherlands). After acquiring a scout image to locate the cardiac axis, steady-state free precession (SSFP) cine imaging was performed in standard axis views, including short axis, and 2-, 3-, and 4-chamber views. CMR parameters included a repetition time/echo time/number of excitations of 3.7/1.8/1, an 8 mm slice thickness with no gap, a field of view measuring 270 x 320 mm for the short axis and 350 x 320 mm for the long axis, a reconstruction pixel size of 1.25 x 1.25 x 8 mm², a 60° flip angle, and 25 cardiac phases per minute. Other CMR parameters, including LV end-systolic and end-diastolic dimensions, LVEF, and LV mass index, were measured in accordance with current recommendations.¹⁵

The LA volume was measured during the end-atrial diastolic phase using the biplane area-length technique, including the LA appendage while excluding the pulmonary veins.^{13,16} To identify potential measurement errors, randomization was performed for repeat measurements after 4 weeks by another investigator.

Statistical analysis

Statistical analyses were conducted using SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were reported as mean ± standard deviation, while categorical variables were presented as absolute numbers and percentages. Comparisons of normally distributed continuous variables between the two groups were performed using Student's unpaired t-test. Categorical data were compared using the chi-square test or Fisher's exact test, as appropriate. Correlations were applied to evaluate univariable relationships between clinical variables and LA volume. Stepwise multiple regression analysis was used to determine the independent variable of clinical descriptors. For multiple regression analyses, models were developed using individual predictor variables and by examining all possible two-way interactions. Group comparisons of the distribution of continuous variables were conducted using the chi-square test for homogeneity in contingency tables. All statistical tests were two-tailed, with $p < 0.05$ considered statistically significant.

RESULTS

Patients' characteristics

The study included 140 patients, comprising 58 (41%) men, with an average age of 66.5 ± 10.5 years. The average BMI was 25.7 ± 4.2 kg/m², and the mean waist circumference was 92.8 ± 10.8 cm. Patients were categorized into two groups: the obese group (BMI ≥ 25 kg/m²) and the non-obese group (BMI < 25 kg/m²). The non-obese group comprised 48.6% ($n = 68$) of patients, while the obese group comprised 51.4% ($n = 72$). In the obese group, significant differences were found in waist circumference (99.3 ± 9.4 cm vs. 86.0 ± 7.3 cm, $p < 0.001$), mean body weight (72.8 ± 11.9 kg vs. 56.0 ± 8.1 kg, $p < 0.001$), the prevalence of hypertension (88.9% vs. 67.8%, $p < 0.001$), and hypercholesterolemia (63.2% vs. 84.7%, $p = 0.01$). The other parameters showed no significant differences between the two groups. A comparison of patients' characteristics is presented in [Table 1](#).

CMR parameters

All patients in both groups underwent CMR imaging. Patients in the obese group had significantly greater values

TABLE 1. Baseline demographic, clinical, and anthropometric characteristics of study patients compared between those with a BMI < 25 and those with a BMI ≥ 25 kg/m².

Characteristics	BMI < 25 kg/m ² (n = 68)	BMI ≥ 25 kg/m ² (n = 72)	P-value
Age (years), mean ± SD	67.9 ± 10.6	65.2 ± 10.3	0.13
Male sex, n (%)	26 (38.0)	32 (44.0)	0.46
Mean waist circumference (cm), mean ± SD	86.0 ± 7.3	99.3 ± 9.4	<0.001
Mean body weight (kg), mean ± SD	56.0 ± 8.1	72.8 ± 11.9	<0.001
Mean height (cm), mean ± SD	158.7 ± 7.4	158.6 ± 9.3	0.92
Mean SBP (mmHg), mean ± SD	131.3 ± 19.5	135.3 ± 16.8	0.22
Mean DBP (mmHg), mean ± SD	67.8 ± 11.3	68.5 ± 12.2	0.72
Prior coronary heart disease, n (%)	14 (20.6)	23 (31.9)	0.09
Hypertension, n (%)	42 (67.8)	64 (88.9)	<0.001
Diabetes mellitus, n (%)	33 (45.8)	22 (32.4)	0.10
Hypercholesterolemia, n (%)	61 (84.7)	43 (63.2)	0.01

A p-value < 0.05 indicates statistical significance.

Abbreviations: BMI, body mass index; DBP, diastolic blood pressure; kg/m², kilograms divided by meters squared; mmHg, millimeters of mercury; SBP, systolic blood pressure; SD, standard deviation

than those in the non-obese group for left ventricular end-diastolic volume (124.5 ± 29.1 ml vs. 108.3 ± 30.2 ml, p = 0.002), LVEF (73.2 ± 8.4% vs. 68.9 ± 10.1%, p = 0.007), and LA volume (80.8 ± 21.1 ml vs. 68.4 ± 22.4 ml, p = 0.001) (Table 2). None of the patients had a significant valvular heart disease.

Correlation factors affecting LA volume

Univariable analysis revealed that LA volume, as a continuous variable, was positively correlated with BMI (r = 0.3, p < 0.001), LV mass index (r = 0.3, p = 0.001), waist circumference (r = 0.3, p < 0.001), male sex (p = 0.01), and hypertension (p = 0.01). The correlation between BMI and LA volume is illustrated in Fig 1.

TABLE 2. CMR parameters of study patients compared between those with a BMI < 25 and those with a BMI ≥ 25 kg/m².

CMR parameter (mean ± SD)	BMI < 25 kg/m ² (n = 68)	BMI ≥ 25 kg/m ² (n = 72)	P-value
LV end-diastolic volume (ml)	108.3 ± 29.1	124.5 ± 30.2	0.002
LV end-systolic volume (ml)	35.8 ± 18.7	34.8 ± 17.1	0.75
LVEF (%)	68.9 ± 10.1	73.2 ± 8.4	0.007
LV mass index (g/m ²)	45.1 ± 15.1	47.0 ± 12.9	0.43
LA volume (ml)	68.4 ± 22.4	80.8 ± 21.1	0.001

A p-value < 0.05 indicates statistical significance.

Abbreviations: BMI, body mass index; CMR, cardiac magnetic resonance; g/m², grams divided by meters squared; kg/m², kilograms divided by meters squared; LA, left atrial; LV, left ventricular; LVEF, left ventricular ejection fraction; ml, milliliters; SD, standard deviation.

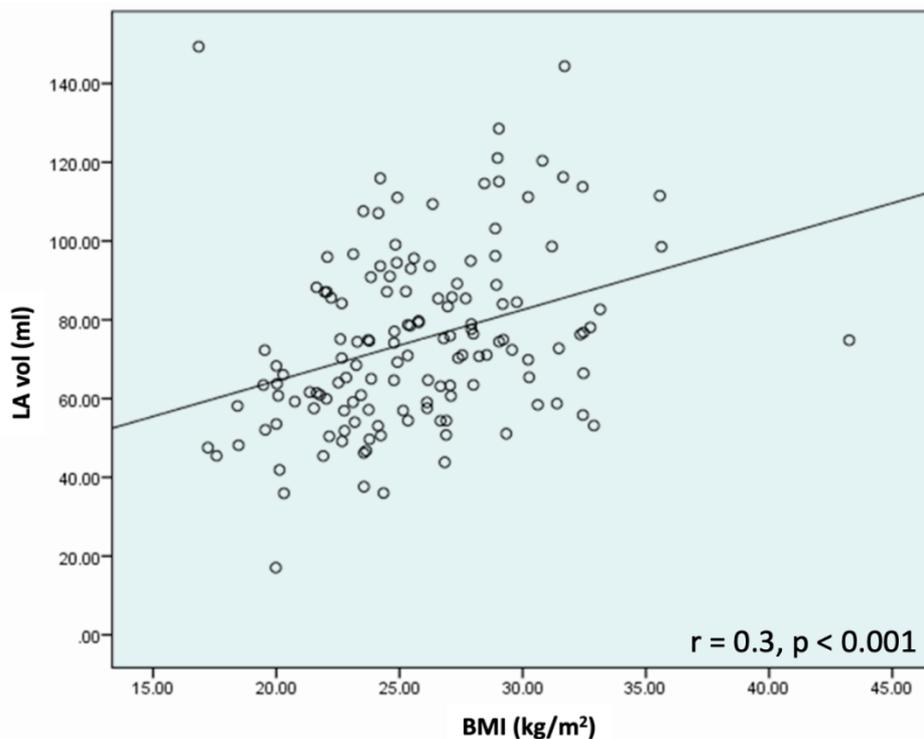


Fig 1. Correlation between body mass index (BMI) and left atrial volume (LA vol)

Stepwise multivariable analysis, using an indicator variable for LA enlargement as the dependent variable, revealed that BMI ($p < 0.001$), LV mass index ($p = 0.02$), and male sex ($p = 0.03$) were independently associated with LA volume.

DISCUSSION

This study revealed that obesity, as measured by BMI, was an independent predictor of LA enlargement. Other independent factors identified included the LV mass index and male sex.

The importance of the LA in cardiac pathophysiology is often underappreciated. However, LA size and/or function has been implicated in various cardiovascular and cerebrovascular disorders, either as a causal factor or as an indirect marker of disease.

Previous studies have demonstrated the significance of LA enlargement in various populations. A study by Bombelli et al. involving 1,785 participants from the general population showed that an LA diameter >2.3 cm/m² was associated with a significantly higher risk of fatal and nonfatal cardiovascular events.¹⁷ LA enlargement and remodeling are also important risk markers for heart failure with preserved ejection fraction.¹⁸ Furthermore, research has shown that a larger LA size is associated with a higher risk of ischemic stroke and all-cause mortality.^{19,20} Notably, some studies suggest that this association between LA size and stroke exists independently of atrial fibrillation.²¹

Several studies have indicated that obesity is linked to increased LA size regardless of factors such as hypertension, LV geometry, and age. A study by Garza et al., which included nearly sixty patients who underwent bariatric surgery (gastric bypass) and transthoracic echocardiography before and after the procedure, found a positive correlation between changes in body weight and LA volume ($r = 0.22$, $p = 0.006$).²² The study concluded that effective weight reduction achieved through bariatric surgery can prevent an increase in LA volume.²²

Varying methods and values affected the proportion of patients with LA enlargement. Currently, the recommended and most commonly used parameter for normalizing LA volume measurements is body surface area (BSA). However, because BSA is determined using both weight and height, indexing LA volume using BSA may underestimate LA remodeling, particularly in obese individuals. In this study, we used LA volume measured by CMR to determine the correlation between obesity and LA enlargement, providing more accurate, non-operator dependent, and reproducible results.^{13,14} In our study, we found a significant association between obesity and LA volume. Patients in the obese group exhibited significantly greater LV end-diastolic volume, LA volume, and LVEF. These findings suggested that obesity is associated with diastolic dysfunction. Next, we identified that BMI, LV mass index, and male sex were significantly correlated with the LA volume. Consistent with previous studies, our findings support the hypothesis that obese individuals

are more prone to diastolic dysfunction leading to LA enlargement.²³

Diastolic dysfunction is more common among obese patients, especially those with obesity-related conditions such as hypertension. Studies have shown a direct association between obesity and structural cardiac abnormalities. For instance, elevated blood volume in obese individuals promotes eccentric hypertrophy, which reduces LV compliance. When the LV is non-compliant, LA pressure increases to ensure sufficient LV filling, resulting in increased atrial wall tension and subsequent LA enlargement.²³ Other explanations include obesity-induced obstructive sleep apnea, lipotoxicity-induced oxidative stress, and effects of adipokines.²⁴

Our study has some limitations. First, we included patients referred for CMR imaging, primarily due to suspected myocardial ischemia, rather than healthy individuals. These factors may have increased the risk of selection bias. Second, patients in the obese group had a significantly higher prevalence of hypertension and hypercholesterolemia than those in the non-obese group did. These conditions may act as confounders; however, we performed adjusted analyses using multivariable methods, which showed that BMI was significantly correlated with LA volume, independent of hypertension or hypercholesterolemia. Finally, we did not use indexed LA volume in this study because it may underestimate LA remodeling, particularly in obese individuals.

CONCLUSION

Obesity, as represented by BMI, was an independent factor associated with LA enlargement. Other independent factors correlated with LA volume included the LV mass index and male sex. Future larger studies, along with prognostic studies, would be beneficial to further support our findings and to enhance the value of LA volume measurement using CMR in this population.

Data Availability Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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None

DECLARATION

Grants and Funding Information

None

Conflict of Interests

No potential conflict of interest relevant to this study was reported.

Author Contributions

S.J. conceived and designed the study, conducted research operations, collected and analyzed data, interpreted results, drafted and revised the manuscript, and approved the final version. Y.K., M.M., and T.B. also contributed to conception and design, data analysis and interpretation, discussion of results, manuscript revision, and final approval

Ethical Statement

Study protocol was reviewed and approved by the Siriraj Institutional Review Board. Written informed consent was obtained from all patients.

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