Circ J 2009; **73:** 438–443

Metabolic Syndrome and Risk of Recurrence of Atrial Fibrillation After Catheter Ablation

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Background: Metabolic syndrome (MetS), as well as several risk factors of cardiovascular diseases, is known to be associated with atrial fibrillation (AF), but its impact on the recurrence of AF after catheter ablation has not been explored.

Methods and Results: The data for 654 consecutive AF patients who underwent an index circumferential pulmonary vein ablation were retrospectively analyzed. Of them, 323 (49.4%) had MetS according to the modified National Cholesterol Education Program-Adult Treatment Panel III criteria and Chinese ethnic criteria. After a mean follow-up of 470±323 (91–1,245) days, patients with MetS had a significantly higher incidence of AF recurrence (43.7%) compared with non-MetS patients (30.5%, P<0.001). Univariate analysis revealed that nonparoxysmal AF, left atrial size, MetS and body mass index were predictors of AF recurrence. Multivariate analysis revealed that MetS (hazard ratio=1.64, 95% confidence interval (CI) 1.07–2.49, P=0.022) and nonparoxysmal AF (hazard ratio=1.57, 95% CI 1.15–2.14, P=0.004) were independent predictors of AF recurrence. The major complications rate did not differ between the MetS and the non-MetS groups (1.86% vs 2.42%, P=0.621).

Conclusions: MetS diagnosed prior to AF ablation is an independent predictor of AF recurrence. (*Circ J* 2009; **73:** 438–443)

Key Words: Atrial fibrillation; Catheter ablation; Metabolic syndrome

Atrial fibrillation (AF) is the most common sustained arrhythmia, affecting more than 2 million patients in the United States alone, with prevalence expected to rise throughout the world.[1] Metabolic syndrome (MetS) is progressing as an epidemic and its association with AF has been reported by several groups.[2–4]

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In the past decade, catheter ablation has emerged as an effective rhythm control solution, mainly for patients with drug-refractory AF.[5] Although previous studies have examined some predictors of AF recurrence after catheter ablation, little is known about the success rate of this procedure in MetS patients.[6,7] Because most of the disorders included in MetS persist after ablation and are well-known to associate with AF,[2,8–10] it would be expected that MetS is an independent risk factor of AF recurrence after ablation. We specifically hypothesized that a diagnosis of MetS prior to AF catheter ablation is associated with a higher AF recurrence rate.

(Received August 27, 2008; revised manuscript received September 26, 2008; accepted October 16, 2008; released online January 28, 2009)
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Methods

Study Subjects

This retrospective study investigated 662 consecutive patients with refractory AF who underwent index circumferential pulmonary vein radiofrequency ablation in our prospectively established database. All patients were referred to Beijing An Zhen Hospital (affiliated with Capital Medical University) from January 2005 to September 2007. Of the 662 patients, 8, whose baseline characteristics did not differ, were lost in the first 90 days after the procedure. This study was approved by the institutional review board and all patients gave written informed consent before the completion of mapping and ablation procedures.

Hypertension was defined as any of the following criteria: supine systolic blood pressure (BP) ≥140 mmHg, diastolic BP ≥90 mmHg, or current use of antihypertensive medication. Diabetes mellitus (DM) was diagnosed according to the American Diabetes Association diagnostic criteria (fasting blood glucose (FBG) ≥7.0 mmol/L or insulin or oral hypoglycemic agents at the time of the procedure).[11]

Definition of MetS

MetS was defined according to the updated National Cholesterol Education Program-Adult Treatment Panel III criteria.[12,13] The diagnosis was made when at least 3 of the following 5 characteristics were present: (1) body mass index (BMI) ≥25 kg/m^2 in accordance with Chinese Ethnic Criteria as previously validated by the Chinese Medical Association Diabetes Branch;[14] (2) fasting triglycerides (TG) ≥1.69 mmol/L; (3) fasting level of high-density lipoprotein (HDL) <1.03 mmol/L in males and <1.29 mmol/L in females; (4) BP ≥130/85 mmHg or treatment for hypertension; and (5) FBG ≥5.6 mmol/L or a clinical history of DM.

Table 1. Characteristics of MetS and Non-MetS Patients

	All patients (n=654)	Non-MetS (n=331)	MetS (n=323)	P value
Age (years)	57±12	56±13	57±11	0.182
Male, n (%)	465 (71.1%)	232 (70.1%)	233 (72.1%)	0.564
AF duration (years)	6.5±6.2	6.5±5.8	6.4±6.4	0.878
Paroxysmal AF, n (%)	522 (79.8%)	269 (81.3%)	253 (78.3%)	0.349
DM, n (%)	78 (11.9%)	13 (3.9%)	65 (20.1%)	<0.001*
Structural heart disease, n (%)	78 (11.9%)	36 (10.9%)	42 (13.0%)	0.401
Left atrial size (mm)	38.4±6.3	37.2±6.3	39.7±6.2	<0.001*
LVEDD (mm)	48.3±6.6	47.9±6.2	48.8±7.0	0.086
LVESD (mm)	31.9±5.4	31.3±5.3	32.3±5.6	0.017*
Ejection fraction (%)	63.0±8.0	63.1±8.1	62.9±7.8	0.726
BMI (kg/m^2)	25.4±3.6	23.8±3.2	27.0±3.0	<0.001*
FBG (mmol/L)	5.16±1.14	4.86±0.94	5.46±1.25	<0.001*
Triglycerides (mmol/L)	1.76±1.26	1.35±0.76	2.18±1.50	<0.001*
HDL (mmol/L)	1.01±0.26	1.09±0.26	0.92±0.22	<0.001*
Hypertension or BP ≥130/85 mmHg, n (%)	360 (55.0%)	125 (37.8%)	235 (72.8%)	<0.001*
BMI ≥25 kg/m^2, n (%)	359 (54.9%)	99 (29.9%)	260 (80.5%)	<0.001*
FBG ≥5.6 mmol/L or DM, n (%)	161 (24.6%)	27 (8.2%)	134 (41.5%)	<0.001*
Triglycerides ≥1.69 mmol/L, n (%)	263 (40.5%)	58 (17.5%)	205 (63.5%)	<0.001*
HDL <1.03 mmol/L (M) <1.29 mmol/L (F), n (%)	456 (69.7%)	172 (52.0%)	284 (87.9%)	<0.001*
Anti-arrhythmic medication				0.279
None, n (%)	105 (16.1%)	57 (17.2%)	48 (14.9%)	
Class I, n (%)	103 (15.7%)	56 (16.9%)	47 (14.6%)	
Amiodarone, n (%)	417 (63.8%)	200 (60.4%)	217 (67.2%)	
Sotalol, n (%)	29 (4.4%)	18 (5.4%)	11 (3.4%)	
β-blockers, n (%)	142 (21.7%)	73 (22.1%)	69 (21.4%)	0.830
ACEI/ARB, n (%)	211 (32.2%)	63 (19.0%)	148 (45.9%)	<0.001*
Statins, n (%)	78 (11.9%)	35 (10.6%)	43 (13.3%)	0.280
Fenofibrate, n (%)	11 (1.7%)	1 (0.3%)	10 (3.1%)	0.005*

*Statistically significant value (P<0.05).
MetS, metabolic syndrome; AF, atrial fibrillation; DM, diabetes mellitus; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; BMI, body mass index; FBG, fasting blood glucose; HDL, high-density lipoprotein; BP, blood pressure; M, male; F, female; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin-receptor blocker.

Electrophysiological Study, Mapping and Ablation

The ablation procedure was performed in the fasting state under sedation. All antiarrhythmic drugs, with the exception of amiodarone, were discontinued for at least 5 half-lives prior. We used the technique of circumferential pulmonary vein ablation guided by 3-D left atrial mapping, which has been described previously in detail![5] Briefly, the left atrium was explored using a trans-septal approach and the geometry was reconstructed with a 3.5 mm tip ablation catheter (Navi-Star Thermo-Cool™, Biosense-Webster Inc, Diamond Bar, CA, USA) in the CARTO system. A continuous irrigated radiofrequency ablation was performed along each pulmonary vein's antrum in order to encircle the ipsilateral pulmonary veins (target temperature: 45°, maximum power: 35 W, infusion rate: 17 ml/min). Procedural endpoints were completeness of the continuous circular lesions and electrical isolation of all pulmonary veins identified by a decapolar circumferential mapping catheter (Biosense-Webster Inc). Linear lesions (eg, roof line and mitral isthmus line), the coronary sinus and complex fractional atrial electrograms were targeted, most commonly in patients with nonparoxysmal AF as described previously in detail![7] If typical atrial flutter had been documented before the procedure, the cavotricuspid isthmus was ablated to achieve a bidirectional conduction block. According to the ablative strategy, the patients were grouped into the pulmonary vein isolation (PVI) alone arm or the PVI+substrate modification (SM) arm, which included additional linear lesion and complex fractional atrial electrograms.

Postablation Management and Follow-up

After the procedure, all patients received antiarrhythmic drugs if there were no contraindications or intolerance (either a maintenance dose of 200 mg amiodarone orally per day or 150 mg propafenone orally 3 times daily, or 80 mg sotalol orally twice daily). If recurrent atrial tachyarrhythmia did not occur after 2 or 3 months the drug treatment was discontinued.

All patients were followed up with 12-lead electrocardiogram (ECG) and 24-h Holter recordings before discharge, at 1, 3, 6 and 12 months after the ablative procedure and every 6 months subsequently beyond 12 months. If the patient was symptomatic, a new ECG or 24-h Holter recordings was obtained. Additionally, telephone interviews were conducted monthly with all patients by a physician and a trans-telephonic event recorder (Life care networks, Beijing, China) was used in some patients as needed. To avoid considering the very common early atrial tachyarrhythmia recurrences, recurrence was defined as confirmed atrial tachyarrhythmia (documented by ECG or Holter recording) more than 3 months after the index catheter ablation in the absence of any antiarrhythmic treatment![6]

Statistical Analysis

All analyses were performed with SPSS software version 13.0 (Chicago, IL, USA). Continuous data are presented as mean±standard deviation. Univariate analysis to assess the predictive value of clinical variables for AF recurrence was computed using the unpaired independent samples t-test for continuous variables and the chi-square test or Fisher's exact test, if necessary, for categorical variables. A Kaplan-Meier

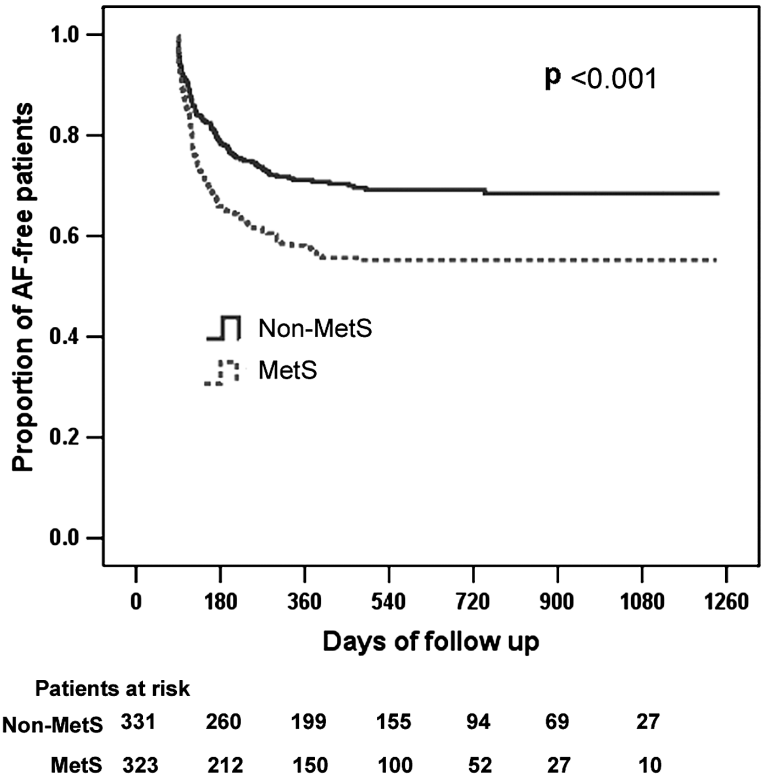

Figure 1. Kaplan-Meier curves depict recurrence of atrial fibrillation (AF) in patients with and without metabolic syndrome (MetS). Patients with MetS have a significantly increased incidence of AF recurrence compared with patients without MetS (43.7% vs 30.5%, P<0.001 by log-rank test).

estimation with a log-rank test served for the unadjusted analysis of the impact of MetS and its 5 components on the recurrence of AF. Multivariate Cox proportional-hazards regression analysis was used to examine the risk of recurrence in the MetS group compared with the non-MetS group. We entered into the multivariate model the AF type, AF duration, left atrial diameter, and all the variables with a probability value <0.10 on the univariate analysis. All probability values were 2-sided and P<0.05 was considered significant.

Results

Clinical Characteristics of MetS and Non-MetS Patients

Among the 654 patients, 323 (49.4%) had MetS. The age, gender, AF type, AF duration, left ventricular ejection fraction, left ventricular end-diastolic diameter, structural heart disease (such as valvular heart disease, dilated or hypertrophic cardiomyopathy, coronary artery disease, and heart failure), antiarrhythmic medications or statins did not differ significantly between the 2 groups (**Table 1**). The patients with MetS had a moderately larger left atrial diameter, as well as a larger left ventricular end-systolic diameter. Following the definition of MetS, patients with MetS showed a significantly higher BMI, FBG, and TG, and lower level of HDL. Also, the prevalence of hypertension or BP ≥130/85 mmHg and of DM was significantly higher in patients with MetS than in those without MetS. The proportion of patients under angiotensin-converting enzyme inhibitor/angiotensin-receptor blocker therapy or fenofibrate medication was significantly higher in the patients with MetS. Statins and β-blockers did not differ between the MetS and non-MetS groups. The proportion of patients undergoing the PVI+SM ablative strategy did not differ between the MetS group and the non-MetS group (61.0% vs 59.5%).

Relationship of MetS and Its Individual Components to AF Recurrence Rate

Figure 1 shows that MetS patients had a higher AF recurrence rate in comparison with non-MetS patients (43.7% vs 30.5%, P<0.001). There was a significantly higher incidence of AF recurrence in patients with BMI ≥25.0 kg/m^2 compared with those with BMI <25.0 kg/m^2 (41.5% vs 31.5%, P=0.009). As a continuous variable, BMI was significantly higher in the recurrence group than in the no recurrence group, with respective mean values of 25.8±3.4 kg/m^2 vs 25.2±3.5 kg/m^2 (P=0.028). Receiver-operating characteristic curve analysis was used to evaluate the efficiency of BMI as a continuous variable for predicting late recurrence and the area under the receiver-operating characteristic curve was 0.562. There were no significant differences in the recurrence rate between the high level of glucose (FBG ≥5.6 mmol/L or DM) arm and the normal level of glucose arm (43.5% vs 34.9%, P=0.060), the BP ≥130/85 mmHg or hypertension arm and the BP <130/85 mmHg arm (38.1% vs 35.7%, P=0.537), the TG ≥1.69 mmol/L arm and the TG <1.69 mmol/L arm (38.0% vs 36.3%, P=0.658), or the low level of HDL arm and the normal level of HDL arm (38.8% vs 32.8%, P=0.145). The AF recurrence rates were 24.5%, 29.3%, 33.8%, 45.1%, 39.4%, and 45.2%, respectively, in the patients with 0, 1, 2, 3, 4, and 5 components of MetS (P=0.002 for trend).

Univariate Predictors of AF Recurrence

After a mean follow-up of 470±323 (91–1,245) days, 242 patients (37.0%) experienced AF recurrence and of them, 141 had MetS. The overall proportion of MetS in the recurrence arm was significantly higher than in the no-recurrence arm (58.3% vs 44.2%, P=0.001). Univariate predictors of AF recurrence are detailed in **Table 2**: nonparoxysmal AF, left atrial size, MetS and BMI (both as a continuous variable

Table 2. Clinical Characteristics of Patients With and Without Recurrence of AF

	No recurrence (n=412)	Recurrence (n=242)	P value
Age (years)	57±12	57±11	0.814
Male, n (%)	288 (69.9%)	177 (73.1%)	0.378
AF duration (years)	6.1±6.1	7.0±6.2	0.083
Paroxysmal AF, n (%)	347 (84.2%)	175 (72.3%)	<0.001*
DM, n (%)	49 (11.9%)	29 (12.0%)	0.973
Structural heart disease, n (%)	53 (12.9%)	25 (10.3%)	0.334
Left atrial size (mm)	37.8±6.2	39.6±6.4	<0.001*
LVEDD (mm)	47.9±7.2	49.0±5.5	0.053
LVESD (mm)	31.6±5.6	32.2±5.3	0.195
Ejection fraction (%)	63.2±7.9	62.7±8.0	0.442
BMI (kg/m^2)	25.2±3.5	25.8±3.4	0.028*
FBG (mmol/L)	5.09±1.15	5.27±1.12	0.052
Triglyceride (mmol/L)	1.71±1.09	1.85±1.50	0.166
HDL (mmol/L)	1.01±0.27	1.00±0.23	0.458
Hypertension or BP ≥130/85 mmHg, n (%)	223 (54.1%)	137 (56.6%)	0.537
BMI ≥25 kg/m^2, n (%)	210 (51.0%)	149 (61.6%)	0.009*
FBG ≥5.6 mmol/L or DM, n (%)	91 (22.1%)	70 (28.9%)	0.060
Triglycerides ≥1.69 mmol/L, n (%)	163 (39.6%)	100 (41.3%)	0.658
HDL <1.03 mmol/L (M) <1.29 mmol/L (F), n (%)	279 (67.7%)	177 (73.1%)	0.145
MetS, n (%)	182 (44.2%)	141 (58.3%)	0.001*
β-blockers, n (%)	86 (20.9%)	56 (23.1%)	0.497
ACEI/ARB, n (%)	130 (31.6%)	81 (33.5%)	0.663
Statins, n (%)	53 (12.9%)	25 (10.3%)	0.334
Fenofibrate, n (%)	6 (1.5%)	5 (2.1%)	0.558

*Statistically significant value (P<0.05).
Abbreviations as in Table 1.

Table 3. MetS and Its Components Predicting Recurrence in Multivariate Analysis

	HR	95% CI	P value
AF duration	1.01	0.995–1.03	0.138
Nonparoxysmal AF	1.57	1.15–2.14	0.004*
Left atrial size	1.02	0.995–1.04	0.128
LVEDD	1.01	0.99–1.03	0.300
MetS	1.64	1.07–2.49	0.022*
BMI ≥25 kg/m^2	0.97	0.70–1.34	0.850
FBG ≥5.6 mmol/L or DM	1.04	0.76–1.42	0.802
Hypertension or BP ≥130/85 mmHg	0.87	0.65–1.17	0.366
Triglycerides ≥1.69 mmol/L	0.85	0.63–1.15	0.294
HDL <1.03 mmol/L (M) <1.29 mmol/L (F)	0.98	0.71–1.36	0.918
Ablative strategy			
PVI alone	Reference		
PVI+SM	0.93	0.71–1.22	0.604

*Statistically significant value (P<0.05).
HR, hazard ratio; CI, confidence interval; PVI, pulmonary vein isolation; SM, substrate modification. Other abbreviations as in Table 1.

and as a category variable). The other MetS components did not differ significantly between the recurrence and no-recurrence arms. All other factors, including age, gender, AF duration, structural heart disease, DM, left ventricular end-diastolic diameter, left ventricular end-systolic diameter, left ventricular ejection fraction, angiotensin-converting enzyme inhibitor/angiotensin-receptor blocker, statins, and fenofibrate, were not differently associated with patients that experienced an AF recurrence and those that did not. Among the 522 patients with paroxysmal AF, 98 of 253 (38.7%) patients with MetS and 77 of 269 (28.6%) patients without MetS experienced recurrence (P=0.014). Among the 132 patients with nonparoxysmal AF, 43 of 70 (61.4%) patients with MetS and 24 of 62 (38.7%) patients without MetS experienced recurrence (P=0.009).

Multivariate Predictors of AF Recurrence

After adjustment for AF duration, AF type, left atrial diameter, left ventricular end-diastolic diameter and ablative strategy, MetS was an independent predictor of AF recurrence (hazard ratio=1.64, 95% confidence interval (CI) 1.07–2.49, P=0.022). However, none of the 5 MetS components stood as independent predictors of AF recurrence in the same model (**Table 3**). When BMI was considered as a continuous variable, it was not found to be an independent predictor of AF recurrence (hazard ratio=0.99, 95%CI 0.95–1.04, P=0.686). Besides MetS, nonparoxysmal AF was an independent predictor of recurrence in the same model, with a hazard ratio of 1.57 (95%CI 1.15–2.14, P=0.004). The other variables, including AF duration, left atrial size, left ventricular end-diastolic diameter and ablative strategy, were not independent predictors of recurrence. Sub-analysis in nonparoxysmal AF showed that MetS (hazard ratio=3.05,

95%CI 1.25–7.44, P=0.014), but none of its components, was an independent predictor of AF recurrence. However, neither MetS nor its components stood as independent predictor of recurrence in paroxysmal AF sub-analysis.

Procedure Outcome and Complications

There were no differences in procedural time or fluoroscopy time between the MetS group and non-MetS group (mean value: 175±41 min vs 172±39 min, P=0.390; 37±8 min vs 36±8 min, P=0.122, respectively). Also, no difference in the percentage of pulmonary veins isolated was noted between the MetS group and non-MetS group (94.1% vs 96.1%, P=0.247). Of the 99 patients who underwent a re-do procedure, 91 had pulmonary vein reconnections. Major procedural complications occurred in the MetS group with pneumothorax (1 case), cardiac tamponade (1 case), stroke (3 cases) and pulmonary vein stenosis (1 case), while cardiac tamponade (3 cases), cardiac arrest (1 case), stroke (1 case) and pulmonary vein stenosis (3 cases) occurred in the non-MetS group. The major complications rate did not differ between the MetS and non-MetS groups (1.86% vs 2.42%, P=0.621).

Discussion

Main Findings

The main results of this study are as follows.

(1) MetS and AF commonly coexist. In our study population, 49.4% of patients who underwent AF catheter ablation had MetS.
(2) We provide evidence that MetS diagnosed before a first AF ablation procedure stands as an independent risk factor of AF recurrence.
(3) Among the 5 components of MetS, AF recurrence occurred mostly in patients with BMI ≥25 kg/m^2 on univariate analysis. However, none of the 5 components of MetS stood as an independent predictor of AF recurrence on multivariate analysis.

Here, the impact of MetS diagnosed before an index catheter ablation procedure was found to significantly decrease the post-ablation success rate. Thus, we propose that, together with nonparoxysmal forms of AF, MetS should be considered as an independent factor of AF recurrence and of potential re-do procedures. This is especially important considering that most of the AF patients in the present study were symptomatic and that, on this basis, a rhythm control strategy was chosen.

Role of MetS in AF Recurrence After Catheter Ablation

There are several MetS definitions, but it was recently shown that both the International Diabetes Federation (IDF) and updated ATPIII criteria are applicable to the Chinese population.[17] Additionally, it should be mentioned that in our study, obesity was solely defined as a BMI ≥25 kg/m^2 without including waist circumference because this definition of obesity has been validated to well correlate with waist circumference measurement.[18,19] The Chinese Medical Association Diabetes Branch suggest the BMI cut-off point for obesity is 25.0 kg/m^2.[14]

Noticeably, the proportion of patients with MetS in our study was 49.4%, which stands in contrast with the 20.7% of males and 20.0% of females that are known to have MetS in the general Chinese population.[17] This further emphasizes the importance of understanding better the impact of MetS in patients undergoing an index AF catheter ablation. We found that AF recurrence after catheter ablation increased in MetS patients; however, the costly AF ablation was mostly undergone by wealthy patients who tend to have a higher prevalence of MetS. It might be that the prevalence of MetS was overestimated in this study because of the selection bias.

The exact mechanisms by which MetS affects the outcome of AF catheter ablation remain to be explored. One possibility is that MetS impinges, directly or indirectly, on atrial electrophysiology. For instance, in a work by Kipshidze et al, the dispersion of refractoriness between the right and left atria in MetS patients was suggested to set the stage for AF and type II (atypical) atrial flutter.[20] The extent to which increased AF recurrence could be explained by persistence after ablation, and of individual AF risk factors, such as BMI ≥25 kg/m^2, has yet to be investigated.

Role of BMI ≥25 kg/m^2

Wang et al reported an association between a larger incidence of newly diagnosed AF in a population with an increased body mass (Framingham Heart Study).[9] The effect of BMI on the outcome of catheter ablation of AF has been reported recently.[21,22] Cha et al found AF catheter ablation was effective in obese patients, although a weak trend toward a reduced efficacy was observed in the most obese patients.[21] Our finding that BMI ≥25 kg/m^2 stands as a univariate, but not an independent, predictor of AF recurrence is in good accordance with Jongnarangsin et al.[22] Their group reported a 2.48-fold increase in the probability of recurrent AF in obese patients, albeit BMI was not predictive of recurrent AF after adjustment for other clinical variables. BMI was not related independently to the risk of recurrent AF after catheter ablation in the present study. It may be that comorbid conditions, such as left atrial enlargement, are the key variables that promote AF in overweight and obese patients. Also, Wang et al suggested that left atrial dilatation constitutes an intermediate phenotype that could favor AF in this population.[9]

Study Limitations

The principle limitation of this study is that the exact mechanism linking MetS to a higher AF recurrence rate after catheter ablation remains to be investigated. The relationship between inflammation, MetS and AF has been previously explored.[10,23] Because data on C-reactive protein levels were not available because of the retrospective nature of the study, whether the exact mechanism linking MetS to a higher AF recurrence rate after catheter ablation is mediated by inflammation remains to be investigated. However, Verma et al showed that inflammation indexed by high-sensitivity C-reactive protein was not a predictor of recurrence after AF catheter ablation.[9] There is accumulating evidence of an independent association between obstructive sleep apnea and MetS or its components.[24] Patients with untreated obstructive sleep apnea have a higher recurrence of AF after cardioversion and a higher risk of recurrence of AF after catheter ablation.[22,25] The role of obstructive sleep apnea was not determined in this study and will require further investigation. In the present study, AF recurrence diagnosis was based upon symptoms occurrence, ECG tracings and Holter-ECG findings. Potentially, AF recurrence rate may have been underestimated because asymptomatic AF episodes may have remained undetected after catheter ablation.[26] In this regard, we followed the recent HRS expert consensus.[16] The additional fact that more patients had DM in the

MetS group may have further masked AF symptoms because of potential DM-associated neuropathy[27] Therefore, this limitation is unlikely to have qualitatively influenced the results presented in this work.

Conclusions

This study provides the evidence that MetS is an independent predictor of AF recurrence after catheter ablation. In daily practice, the presence of MetS should be considered in the evaluation of patients amenable to AF catheter ablation.

Acknowledgments

We thank Xin Du and Jing Liu for their advice regarding the manuscript, and Chang Liu and Xiao-Kui He for collecting the data. This work was funded by the National Science Foundation Council of China (No. 30500202, No. 30570724, No. 30670843 and No. 30770876), Beijing Science Foundation Council (No. 07G0179), China "863" Research Project (No. 2006AA02Z4E4), RO1-HL087055 and ACCF/GE Healthcare Career Development Award (J.K).

Disclosure

None.

References

1. Go AS, Hylek EM, Phillips KA, Chang Y, Henault LE, Selby JV, et al. Prevalence of diagnosed atrial fibrillation in adults: National implications for rhythm management and stroke prevention: The AnTicoagulation and Risk Factors in Atrial Fibrillation (ATRIA) Study. *JAMA* 2001; **285:** 2370–2375.
2. Umetani K, Kodama Y, Nakamura T, Mende A, Kitta Y, Kawabata K, et al. High prevalence of paroxysmal atrial fibrillation and/or atrial flutter in metabolic syndrome. *Circ J* 2007; **71:** 252–255.
3. Korantzopoulos P, Kokkoris S, Papaioannides D. The association of metabolic syndrome with atrial fibrillation: An emerging epidemiological and pathophysiological hypothesis. *Cardiology* 2005; **104:** 148–149.
4. Watanabe H, Tanabe N, Watanabe T, Darbar D, Roden DM, Sasaki S, et al. Metabolic syndrome and risk of development of atrial fibrillation: The Niigata preventive medicine study. *Circulation* 2008; **117:** 1255–1260.
5. Cappato R, Calkins H, Chen SA, Davies W, Iesaka Y, Kalman J, et al. Worldwide survey on the methods, efficacy, and safety of catheter ablation for human atrial fibrillation. *Circulation* 2005; **111:** 1100–1105.
6. Verma A, Wazni OM, Marrouche NF, Martin DO, Kilicaslan F, Minor S, et al. Pre-existent left atrial scarring in patients undergoing pulmonary vein antrum isolation: An independent predictor of procedural failure. *J Am Coll Cardiol* 2005; **45:** 285–292.
7. Li XP, Dong JZ, Liu XP, Long DY, Yu RH, Tian Y, et al. Predictive value of early recurrence and delayed cure after catheter ablation for patients with chronic atrial fibrillation. *Circ J* 2008; **72:** 1125–1129.
8. Benjamin EJ, Levy D, Vaziri SM, D'Agostino RB, Belanger AJ, Wolf PA. Independent risk factors for atrial fibrillation in a population-based cohort: The Framingham Heart Study. *JAMA* 1994; **271:** 840–844.
9. Wang TJ, Parise H, Levy D, D'Agostino RB Sr, Wolf PA, Vasan RS, et al. Obesity and the risk of new-onset atrial fibrillation. *JAMA* 2004; **292:** 2471–2477.
10. Aviles RJ, Martin DO, Apperson-Hansen C, Houghtaling PL, Rautaharju P, Kronmal RA, et al. Inflammation as a risk factor for atrial fibrillation. *Circulation* 2003; **108:** 3006–3010.
11. Genuth S, Alberti KG, Bennett P, Buse J, Defronzo R, Kahn R, et al. Follow-up report on the diagnosis of diabetes mellitus. *Diabetes Care* 2003; **26:** 3160–3167.
12. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. *Circulation* 2002; **106:** 3143–3421.
13. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: An American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* 2005; **112:** 2735–2752.
14. Lu YH, Lu JM, Wang SY, Li CL, Liu LS, Zheng RP, et al. Comparison of the diagnostic criteria of metabolic syndrome by International Diabetes Federation and that by Chinese Medical Association Diabetes Branch. *Zhonghua Yi Xue Za Zhi* 2006; **86:** 386–389.
15. Tang RB, Dong JZ, Liu XP, Fang DP, Long de Y, Liu XH, et al. Safety and efficacy of catheter ablation of atrial fibrillation in patients with diabetes mellitus: Single center experience. *J Interv Card Electrophysiol* 2006; **17:** 41–46.
16. Calkins H, Brugada J, Packer DL, Cappato R, Chen SA, Crijns HJ, et al. HRS/EHRA/ECAS expert Consensus Statement on catheter and surgical ablation of atrial fibrillation: Recommendations for personnel, policy, procedures and follow-up. A report of the Heart Rhythm Society (HRS) Task Force on catheter and surgical ablation of atrial fibrillation. *Heart Rhythm* 2007; **4:** 816–861.
17. Liu J, Grundy SM, Wang W, Smith SC Jr, Vega GL, Wu Z, et al. Ethnic-specific criteria for the metabolic syndrome: Evidence from China. *Diabetes Care* 2006; **29:** 1414–1416.
18. Janssen I, Katzmarzyk PT, Ross R. Body mass index, waist circumference, and health risk: Evidence in support of current National Institutes of Health guidelines. *Arch Intern Med* 2002; **162:** 2074–2079.
19. Sundstrom J, Riserus U, Byberg L, Zethelius B, Lithell H, Lind L. Clinical value of the metabolic syndrome for long term prediction of total and cardiovascular mortality: Prospective, population based cohort study. *BMJ* 2006; **332:** 878–882.
20. Kipshidze NN, Katsitadze GA, Khosroshvili LB. Effect of the metabolic syndrome on the electrophysiological parameters of the heart. *Georgian Med News* 2005; **119:** 9–13.
21. Cha YM, Friedman PA, Asirvatham SJ, Shen WK, Munger TM, Rea RF, et al. Catheter ablation for atrial fibrillation in patients with obesity. *Circulation* 2008; **117:** 2583–2590.
22. Jongnarangsin K, Chugh A, Good E, Mukerji S, Dey S, Crawford T, et al. Body mass index, obstructive sleep apnea, and outcomes of catheter ablation of atrial fibrillation. *J Cardiovasc Electrophysiol* 2008; **19:** 668–672.
23. Dandona P, Aljada A, Chaudhuri A, Mohanty P, Garg R. Metabolic syndrome: A comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* 2005; **111:** 1448–1454.
24. Lam JC, Ip MS. An update on obstructive sleep apnea and the metabolic syndrome. *Curr Opin Pulm Med* 2007; **13:** 484–489.
25. Kanagala R, Murali NS, Friedman PA, Ammash NM, Gersh BJ, Ballman KV, et al. Obstructive sleep apnea and the recurrence of atrial fibrillation. *Circulation* 2003; **107:** 2589–2594.
26. Hindricks G, Piorkowski C, Tanner H, Kobza R, Gerds-Li JH, Carbucicchio C, et al. Perception of atrial fibrillation before and after radiofrequency catheter ablation: Relevance of asymptomatic arrhythmia recurrence. *Circulation* 2005; **112:** 307–313.
27. Sugishita K, Shiono E, Sugiyama T, Ashida T. Diabetes influences the cardiac symptoms related to atrial fibrillation. *Circ J* 2003; **67:** 835–838.