Original Article

In-Hospital Postoperative Atrial Fibrillation Indicates a Poorer Clinical Outcome after Myectomy for Obstructive Hypertrophic Cardiomyopathy

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Objectives: This study aims to investigate the risk factors of in-hospital postoperative atrial fibrillation (POAF) and the impact of POAF on the clinical outcome in hypertrophic cardiomyopathy (HCM) patients who underwent myectomy.
Methods: Data from a total of 494 obstructive HCM patients, who had undergone preoperative cardiac magnetic resonance (CMR) testing and who underwent myectomy at Fuwai Hospital from June 2011 to June 2016, were collected.
Results: Multivariate logistic regression analysis showed that old age (odds ratio [OR], 4.326; 95% confidence interval [CI], 2.248–8.325; p <0.001), maximal left atrium volume (LAV) (OR, 1.137; 95% CI, 1.075–1.202; p <0.001), and hypertension (OR, 2.754; 95% CI, 1.262–6.007; p = 0.011) were associated with the incidence of POAF. In the patients without preoperative AF, Cox regression analysis demonstrated that POAF (p = 0.002), decreased left atrium (LA) ejection fraction (LAEF) (p = 0.036), concomitant procedure (p = 0.039), and postoperative residual moderate or severe mitral valve regurgitation (p = 0.030) were independent predictors of composite cardiovascular events.
Conclusions: POAF indicated a poorer clinical outcome after myectomy for obstructive HCM patients, which was similar to those with preoperative AF. Elevated LAV was independently related to POAF onset in HCM patients who underwent myectomy.

Keywords: atrial fibrillation, hypertrophic cardiomyopathy, myectomy

Introduction

Atrial fibrillation (AF) is the most common arrhythmia in hypertrophic cardiomyopathy (HCM) patients and affects approximately 25% of this population. AF is related to a poorer clinical outcome, which includes an increased risk of stroke, death, and symptomatic heart failure in HCM patients.[1,2] Surgical myectomy is regarded as the gold standard for the treatment of obstructive HCM refractory to medication treatment. For

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the HCM patients who underwent surgical myectomy, preoperative AF was an independent predictor of postoperative cardiac mortality.[3] In another study, late postoperative AF (POAF) (occurring more than 30 days after myectomy) was also independently associated with cardiac mortality.[4]

Early POAF occurs in 15%–45% of patients who have undergone cardiac surgery.[5] It is also common after other kinds of major surgery, especially in elderly patients.[6] Patients with POAF own higher risk of early stroke, increased morbidity, and 30-day mortality.[7,8] Over the long term, these patients also have a twofold increase in cardiovascular mortality and an increased risk of future AF and ischemic stroke than who maintain sinus rhythm postoperatively.[8–12] However, it is still unclear whether short episodes of POAF carry a similar risk as longer episodes.[13] Previous research has predominantly involved the patients without structural heart disease: the conclusions may not be completely applicable to patients with other heart diseases. In one study regarding prediction of long-term outcomes after surgical myectomy, early POAF (occurring in postoperative hospitalization stay) was excluded from the definition of residual postoperative AF.[4] The clinical significance of early POAF (including short episodes) in HCM patients who underwent myectomy is still unclear.

Although several risk factors including advanced age, male sex, and a history of congestive heart failure (CHF) have been reported to be associated with POAF following cardiac surgery,[14,15] the underlying mechanism of POAF is still to be elucidated in HCM patients who undergo myectomy. The present study aims to investigate the relationship between left atrium (LA) remodeling and POAF, and to evaluate the impact of both remodeling of the LA and POAF on mid-term outcomes in HCM patients who undergo myectomy.

Methods

Study population

Between June 2011 and June 2016, a total of 728 consecutive adult HCM patients underwent myectomy at Fuwai Hospital. Of these, 494 patients in whom have finished preoperative cardiac magnetic resonance (CMR) testing were included in this study so that we could focus on patients with more detailed data on LA dimension and function. Electrocardiograph (ECG) and (or) Holter were applied to assess the preoperative electrocardiogram status. Furthermore, continuous ECG monitoring was performed

on all patients during the postoperative hospital stay. These patients were divided into three groups: (1) *Sinus group*: no preoperative AF and maintained sinus rhythm during the postoperative hospital stay; (2) *preoperative AF group*: electrocardiogram record detected AF preoperatively (including paroxysmal, persistent, and permanent AF); (3) *POAF group*: no preoperative AF but continuous ECG recoded new-onset AF (even short episodes and self-termination) during the postoperative hospital stay. ECG was performed in all patients with the use of commercially available instrument following the standard procedure.[16] The degree of the mitral regurgitation was assessed on a scale of 0–3 (0, none; 1, mild; 2, moderate; 3, severe) using multiple Doppler criteria.

The ethics committee of the Fuwai Hospital approved this research.

CMR imaging

A 1.5 Tesla MR scanner (Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany) was used in the preoperative CMR scanning. Cine scans in multiple short-axis and three long-axis views (two-chamber, four-chamber, and left ventricle outflow tract [LVOT]) were acquired by applying true imaging with steady-stage precession sequence (TrueFISP). Fifteen minutes after intravenous administration of 0.2 mmol/kg gadolinium-DTPA (Magnevist, Schering, Berlin, Germany), a phase-sensitive inversion recovery spoiled gradient echo sequence was applied to acquire late gadolinium enhancement (LGE) images. CMR image analysis was performed using a commercial imaging workstation (Siemens Medical Systems). The maximal left atrium volume (LAV) was calculated using a biplane area length method (LAV = [8 × (two-chamber area) × (four-chamber area)]/3πL) previously described.[17,18] L is the shortest of the LA length in two-chamber and four-chamber views and was measured from the midpoint of the mitral annulus plane to the posterior aspect of the atrium. LAV was measured at the end of atrial diastole, and minimum LAV was measured at the end of atrial systole. LA stroke volume was calculated as LAV – minimum LAV and LA ejection fraction (LAEF) as LA stroke volume/LAV.

Cardiac surgery

As previously described,[19] a modified Morrow procedure was applied in this study. Relief of the LOVT obstruction was assessed by palpation of the septum by experienced cardiac surgeons and confirmed by intraoperative transesophageal echocardiography testing after

weaning from extracorporeal circulation. If the postoperative LVOT gradient was greater than 30 mmHg, or moderate and severe mitral valve regurgitation occurred, then reoperation was required.

Drug treatment

A non-vasodilating beta-blocker was the first-line choice of symptomatic obstructive HCM patients. If a beta-blocker was contraindicated, diltiazem was the secondary option. All patients with preoperative AF received beta-blocker treatment. Anticoagulation treatment was only recommended to those patients with persistent AF. After myectomy, the preoperative drug was usually continued. The discontinuity of postoperative medicine therapy was tailored to individual patients after consideration of symptoms, lifestyle and sudden cardiac death (SCD) risk stratification. During the postoperative hospital stay, the beta-blocker and anticoagulants were used after POAF occurred. Most POAF terminated spontaneously. These patients received beta-blocker continuously, and the anticoagulant therapy was stopped after discharge. There were a few patients who presented recurrent episodes of POAF after initial intervention. For these patients, amiodarone was prescribed. The anticoagulant therapy (i.e., warfarin) was continued for 3 months after discharge. All patients were strictly followed, and the treatments were adjusted timely according to latest evaluation.

Follow-up and endpoints

All patients received continuous ECG monitoring after surgical myectomy until discharge. Clinical status was obtained from patients or family members after myectomy every 1 year. Composite cardiovascular events were recorded, including SCD, resuscitation from SCD, death due to cardiac failure, stroke, arterial system embolism, and onset of congestive failure requiring in-hospitalization intervention.

Statistical analysis

Continuous variables were presented as the mean ± standard deviation (SD) or median (interquartile range [IQR]). Student's t-test or one-way analysis of variance with a Student–Newman–Keuls post hoc test was used to compare normally distributed parametric variables. Comparison of nonnormally distributed variables among different groups was performed using Mann–Whitney U test or Kruskal–Wallis test. Categorical data are presented as the percentage frequency, while the comparison among different groups was performed using χ^2 test. To

determine the predictive value of preoperative variables in terms of in-hospital POAF after myectomy, univariate logistic regression analyses were applied. To determine independent predictive risk factors, individual predictors with a significance level of p <0.10 were entered into a multivariate logistic regression model (backward stepwise). The results are reported as odds ratios (ORs) with 95% confidence intervals (95% CIs). A stepwise multivariable Cox proportional hazards model was developed to determine the independent predictors of the composite events in the patients without preoperative AF after myectomy. Kaplan–Meier survival curve with log-rank test was further used to assess the significant difference of event-free survival between subgroups. A p value <0.05 was considered statistically significant. The statistical analyses were performed using SPSS (Version 23.0, IBM Corp., Armonk, NY, USA).

Results

Baseline characteristic

Among the total of 494 patients with preoperative CMR, 67 (13.6%) patients had a history of preoperative AF, whereas in the remaining 427 patients, 55 (12.9%) patients experienced early POAF during the postoperative hospital stay (median [IQR], 7.0 [2.0] days). **Table 1** shows the comparison of baseline characteristics among the three groups. As expected, compared to patients who maintained sinus rhythm, patients with POAF had greater left atrium diameter (LAD), lower LAEF values, and elevated LAV values and LAV indices. Interestingly, the LAD, LAV, and LAV index of patients with POAF were lower than those with preoperative AF, whereas LAEF was higher. The postoperative hospital stays of the patients with POAF and those with preoperative AF were both longer than those who maintained sinus rhythm, but there was no difference between POAF and preoperative AF group.

Risk factors of POAF in patients without preoperative AF

Logistic regression was used to develop a risk adjustment model for the prediction of early POAF in 427 patients without preoperative AF (**Table 2**). Multivariate logistic regression was used to assess the independent risk factors associated with POAF. Only old age (OR, 4.326; 95% CI, 2.248–8.325, p <0.001), elevated LAV (OR, 1.137; 95% CI, 1.075–1.202, p <0.001), and hypertension (OR, 2.754; 95% CI, 1.262–6.007, p = 0.011)

Table 1 Baseline characteristics of patients with different electrocardiograph status

Variables	Sinus (372)	Preoperative AF (67)	POAF (55)	p value
Age, year	47.0 (38.6–54.0)	51.3 (45.3–60.4)*	57.0 (43.9–60.5)†	<0.001
Female gender	149 (40.1)	22 (32.8)	20 (36.4)	0.500
BMI (kg/m²), mean ± SD	25.0 ± 3.4	25.1 ± 3.6	25.4 ± 3.0	0.638
Hypertension	104 (38.1)	16 (23.9)	10 (18.2)	0.273
Diabetes	14 (3.8)	3 (4.5)	3 (5.5)	0.823
Dyspnea	345 (92.7)	64 (95.5)	51 (92.7)	0.705
Chest pain	134 (36.0)	24 (35.8)	23 (41.8)	0.699
Syncope	131 (35.2)	16 (23.9)	19 (35.4)	0.193
NYHA function III/IV	286 (76.9)	56 (83.6)	39 (70.9)	0.247
Concomitant procedure	100 (26.9)	32 (47.8)*	19 (34.5)	0.002
Preoperative resting gradients (mmHg), mean ± SD	77.9 ± 31.6	70.0 ± 28.4	83.1 ± 31.8†,‡	0.066
LAD, mm	41.0 (38.0–47.0)	49.0 (43.0–55.0)*	44.0 (38.5–53.0)†,‡	<0.001
LGE positive	315 (84.7)	55 (82.1)	42 (76.4)	0.288
LAV, ml	113.5 (88.0–144.5)	180.0 (138.7–224.1)*	132.8 (106.4–187.5)†,‡	<0.001
LAV index, ml/m²	66.5 (50.8–82.0)	102.6 (79.6–134.0)*	77.2 (61.6–105.3)†,‡	<0.001
LAEF (%), mean ± SD	41.6 ± 11.8	30.5 ± 12.9*	36.3 ± 13.1†,‡	<0.001
Clamping time, min	57.0 (45.0–72.0)	58.0 (47.0–90.0)	58.0 (44.0–72.0)	0.425
Postoperative hospitalization stay, d	7.0 (6.0–7.0)	7.0 (7.0–10.0)*	8.0 (7.0–10.0)†	<0.001
Postoperative gradients >30 mmHg	29 (7.8)	4 (6.0)	3 (5.5)	0.745

Variables are presented as n (%), median (interquartile range [IQR]) or mean ± standard deviation (SD). *p <0.05, preoperative AF vs. Sinus group; †p <0.05, POAF vs. Sinus group; ‡p <0.05, POAF vs. preoperative AF group. AF: atrial fibrillation; BMI: body mass index; IQR: interquartile range; LAD: left atrium diameter; LAEF: left atrium ejection fraction; LAV: left atrium volume; LGE: late gadolinium enhancement; NYHA: New York Heart Association; POAF: postoperative atrial fibrillation; SD: standard deviation

Table 2 Univariate and multivariate logistic analyses for POAF in HCM patients who underwent myectomy without preoperative AF

	Variables	OR	95% CI for OR	p value
Univariate	LAV (10 ml increment)	1.121	1.057–1.190	<0.001
	LAEF (10% increment)	0.802	0.614–1.046	0.104
	Age (>50y)	4.234	2.136–8.393	<0.001
	NYHA function III/IV	0.957	0.444–2.062	0.910
	Female gender	0.844	0.435–1.638	0.616
	Hypertension	2.932	1.311–6.558	0.009
	Diabetes	1.281	0.328–4.997	0.722
	Concomitant procedure	1.237	0.645–2.371	0.521
	BMI (kg/m²)	1.044	0.949–1.148	0.376
	Residual moderate or severe MR	0.503	0.105–2.409	0.390
Multivariate	Hypertension	2.754	1.262–6.007	0.011
	Age (>50y)	4.326	2.248–8.325	<0.001
	LAV (10 ml increment)	1.137	1.075–1.202	<0.001

Because of the significant interaction between LAV and LAD, we did not include LAD in the analysis in order to address collinearity. AF: atrial fibrillation; BMI: body mass index; CI: confidence interval; HCM: hypertrophic cardiomyopathy; LAD: left atrium diameter; LAEF: left atrium ejection fraction; LAV: left atrium volume; MR: mitral regurgitation; NYHA: New York Heart Association; OR: odds ratio; POAF: postoperative atrial fibrillation

remained independently associated with a higher risk of POAF after myectomy (**Table 2**).

POAF and poorer outcome

This study aims to determine the risk factors in patients without preoperative AF. In the patients without preoperative AF, multivariate Cox regression analysis demonstrated that POAF (hazard ratio [HR], 1.785; 95% CI, 1.248–2.552; p = 0.002), LAEF (HR, 0.758; 95% CI, 0.586–0.982; p = 0.036), concomitant procedure (HR, 2.003; 95% CI, 1.035–3.877; p = 0.039), and residual moderate or severe mitral regurgitation (HR, 3.202; 95% CI,

Table 3   Cox proportional hazards regression analysis for composite events in HCM patients without preoperative AF after myectomy

	Variables	HR	95% CI for HR	p value
Univariate	LAV (10 ml increment)	1.036	0.972–1.104	0.273
	LAEF (10% increment)	0.784	0.586–1.049	0.102
	Age (>50y)	1.277	0.597–2.728	0.528
	NYHA function III/IV	1.489	0.572–3.877	0.415
	Female gender	1.283	0.637–2.584	0.485
	POAF	1.714	1.156–2.541	0.007
	Hypertension	1.238	0.571–2.685	0.589
	Diabetes	1.500	0.444–5.070	0.514
	Concomitant procedure	1.864	0.959–3.624	0.066
	BMI (kg/m^2)	1.065	0.961–1.181	0.228
	Residual LVOT gradient ≥30 mmHg	1.682	0.571–4.952	0.346
	Residual moderate or severe MR	2.120	0.619–7.268	0.232
Multivariate	LAEF (10% increment)	0.758	0.586–0.982	0.036
	POAF	1.785	1.248–2.552	0.002
	Concomitant procedure	2.003	1.035–3.877	0.039
	Residual moderate or severe MR	3.202	1.118–9.169	0.030

AF: atrial fibrillation; BMI: body mass index; CI: confidence interval; HCM: hypertrophic cardiomyopathy; HR: hazard ratio; LAEF: left atrium ejection fraction; LAV: left atrium volume; LVOT: left ventricle outflow tract; MR: mitral regurgitation; NYHA: New York Heart Association; OR: odds ratio; POAF: postoperative atrial fibrillation

Table 4   Early complications and late operative outcome

| Variables	N = 494
Early complications	
Perioperative death	1 (0.20)
Permanent pacemaker	14 (2.83)
Reoperation for bleeding	2 (0.40)
Wound infection	3 (0.61)
Iatrogenic VSD	4 (0.81)
Postoperative heart function	
NYHA class III or IV*	23 (4.66)
Residual LVOT gradient >30 mmHg	36 (7.29)
Maximal residual LVOT gradient >50 mmHg	8 (1.62)
Residual moderate or severe MR (2–3)†	26 (5.26)
Non-cardiac death (lung cancer)	1 (0.20)
Cardiovascular death	
Sudden cardiac death	5 (1.01)
Resuscitation from SCD	5 (1.01)
Death due to congestive heart failure	1 (0.20)
Nonfatal cardiovascular events	
Onset of CHF requiring hospitalization intervention	29 (5.87)
Stroke	10 (2.02)
Arterial thromboembolic events	2 (0.40)
Repeated myectomy	1 (0.20)
Pericardiectomy for pericardial effusion	3 (0.61)

The values shown are n (%). *None patient belonged to NYHA heart function classification IV. †No patients presented with severe MR (grade 3) postoperatively. CHF: congestive heart failure; LVOT: left ventricle outflow tract; MR: mitral regurgitation; NYHA: New York Heart Association; SCD: sudden cardiac death; VSD: ventricular septal defect

1.118–9.169; p = 0.030) were independent predictors of composite events (**Table 3**).

Early postoperative complication and survival analysis

There was only one death due to severe septic shock, which occurred in the early postoperative period (0.20%). All of the patients with nonfatal complications were discharged uneventfully. Details of postoperative outcome are summarized in **Table 4**. Four patients were lost to the last follow-up and were censored. There was only one perioperative death and one death attributable to lung cancer, and these deaths were also censored. After a follow-up of 2.4 ± 1.4 years, 56 patients suffered from composite cardiovascular events. The breakdown of events is summarized in **Table 4**.

In the POAF, preoperative AF and sinus groups, 12 (21.8%), 18 (26.9%), and 26 (7.0%) patients experienced composite cardiovascular events, respectively. Kaplan–Meier survival curves showed that the event-free survival among the three groups was different (**Fig. 1**). Further analysis demonstrated a reduced event-free survival for patients with either POAF or preoperative AF compared to those who maintained in sinus rhythm, but there was no difference between preoperative AF and POAF groups.
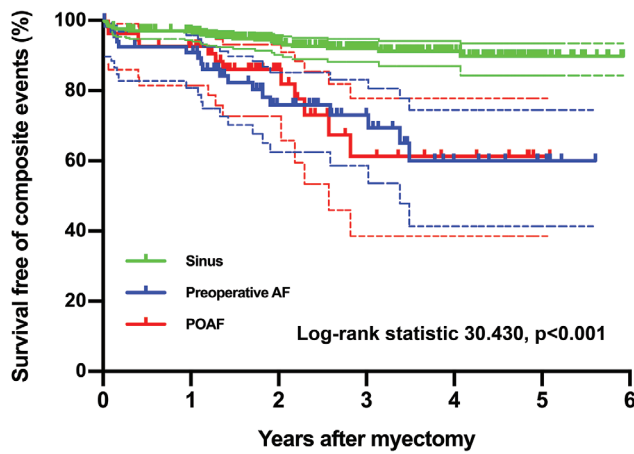
Fig. 1 Event-free survival in HCM patients after myectomy according to different electrocardiographic status. Event-free survival in HCM patients after myectomy with pre-operative AF, POAF and keeping in sinus rhythm was different (Log-rank statistic 30.430, p <0.001). Subgroup analysis demonstrated that survival without composite cardiovascular events of patients in POAF was lower than those who maintained sinus rhythm (Log-rank statistic 15.378, p <0.001). Patients with preoperative AF had lower event-free survival than patients in sinus rhythm (Log-rank statistic 25.054, p <0.001). There was no difference between the preoperative AF and POAF groups (Log-rank statistic 0.045, p = 0.832). Error bars indicates 95% confidence interval. AF: atrial fibrillation; HCM: hypertrophic cardiomyopathy; POAF: postoperative atrial fibrillation; Sinus: sinus rhythm group; Pre-AF: preoperative AF group

Discussion

In accordance with previous findings,[20] our results showed that early (in-hospital) POAF was common in HCM patients who underwent surgical myectomy. Elevated LAV and hypertension, as well as old age, were associated with a higher incidence of POAF. Furthermore, POAF (even short and self-terminating episodes) indicated worse clinical outcome after myectomy. The clinical significance of POAF was similar to that of preoperative AF, although the structural remodeling of these patients was less serious.

POAF occurs in 15%–45% of patients after cardiac surgery.[15,21] POAF is also common after other major surgeries, especially in elderly patients.[6] Similar to previous reports,[14,15] old age was proven to be associated with

POAF. The incidence of POAF was lower in this study, which may have been because these patients were younger and that we only calculated this incidence in the 427 patients without preoperative AF. Although POAF is independently related to advanced age, male sex, and a history of CHF,[14] the exact mechanisms of POAF remain to be elucidated.[15]

LVOT obstruction, mitral valve regurgitation, and LV diastolic dysfunction present in most of obstructive HCM patients, which may lead to LA enlargement. LA enlargement confers electric remodeling, which causes the occurrence of AF, CHF, and stroke-related outcomes in obstructive HCM. LAD >45 mm represents the threshold that is associated with an increased risk of AF development.[1] Accurate assessement of LA remodeling by CMR helps to better stratify risk for individuals at risk of new-onset AF development.[22] In patients with a normal LA size, LAV can refine risk stratification for new-onset AF.[23] In accordance with a previous report,[22,24] elevated LAV was independent indicators of POAF. LAV may own more pathophysiological significance and prognostic value than LAD because LAV can reflect the enlargement of LA more accurately in consideration of the stereochemical structure.

LA remodeling results in electrical dissociation between muscle bundles and local conduction heterogeneities, which favor re-initiation and perpetuation of the arrhythmia.[25] In many patients, the structural remodeling process occurs before the onset of AF.[26] Patients with a structural change are more vulnerable to physiological perturbations (i.e., increased sympathetic outflow, metabolic derangements, and local inflammation) that are encountered in the postoperative period.[27,28] This may explain why patients who experienced POAF had higher LAV and lower LAEF values than those maintained sinus rhythm, whereas this remodeling was less serious than in patients with preoperative AF. The previous study lacked a comprehensive evaluation of LA by CMR, which may have led to an underestimation of the relationship between LA remodeling and AF. In our viewpoint, POAF may be not the root cause of the increased adverse clinical events, but is rather an indicator of LA remodeling.

The clinical significance of preoperative AF has been widely reported for heart diseases. AF was established as an independent predictor of long-term outcomes, including in patients with HCM.[1–4] In this study, patients with preoperative AF demonstrated severe LA remodeling and poorer clinical outcomes. However, sufficient attention

has not been paid to early POAF (usually transient). Similar to a previous report,[5] POAF was associated with an increase in the length of the hospital stay. Survival analysis demonstrated that the outcome of patients with POAF was poorer than those who maintained sinus rhythm,[8–12] and was similar to those with preoperative AF. This finding indicated that HCM patients with in-hospital POAF also require strict follow-up and close monitoring after myectomy.

Although several interventions may reduce the incidence of POAF and improve the perioperative outcomes, it is still controversial whether these interventions can translate into a long-term benefit. These prevention strategies might temporarily suppress the incidence of POAF and realize slight perioperative benefits, but might not change the adverse LA remodeling that made the patients prone to incidence of AF and poorer clinical outcomes. Surgical myectomy was only indicated in patients with a LVOT gradient ≥50 mmHg, moderate-to-severe symptoms, and/or recurrent exertional syncope in spite of maximally tolerated drug therapy.[29,30] However, patients with preoperative AF still demonstrated poorer long-term outcomes after myectomy.[3,4] It was imperative to reevaluate the timing of surgical myectomy for obstructive HCM patients.[30] Anticipating the timing of myectomy in those patients with severe LA remodeling (elevated LAV and decreased LAEF) may reduce the occurrence of POAF and further improve postoperative outcome in obstructive HCM patients.

Limitations

This study has several limitations. First, there was some selection bias in our cohort. CMR was not performed in all patients due to the long waiting time (average 4 weeks), and those patients (234) who did not undergo preoperative CMR testing were excluded. Only a few parameters differed between patients with or without preoperative CMR testing (**Supplementary Table 1**). Second, preoperative Holter testing was not available in all patients preoperatively (available in 280/494 [56.7%] patients). The result may underestimate the occurrence of preoperative AF in HCM patients who underwent myectomy.

Conclusion

Early POAF indicated a poorer clinical outcome after myectomy for obstructive HCM patients, which was similar to those with preoperative AF. In patients without preoperative AF, increased LAV was related to the onset of POAF after myectomy, which was an independent predictor of poorer outcome. The timing of surgical myectomy might have to be reconsidered in those patients with severe LA remodeling.

Supplementary Material

Supplementary Table 1 was submitted as Supplementary material.

Acknowledgments

Source of Funding

Disclosure Statement

None.

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