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Early and late post-operative arrhythmias after surgical myectomy: 45 years of follow-up

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ABSTRACT

Aims: The aims of this study are to investigate the incidence and determinants of post-operative atrial arrhythmias, conduction disorders and mortality in hypertrophic obstructive cardiomyopathy (HOCM) patients undergoing transaortic myectomy.

Methods and results: This retrospective single-center study was conducted in 249 patients (median age 54 years [40–64], 42% female) undergoing transaortic myectomy. Post-operative atrial fibrillation (AF) was reported in 84 patients (33.7%), including 56 patients (22.5%) with de novo AF. Older age (HR = 1.027 (1.003–1.052), p = 0.029) and hypercholesterolemia (HR = 2.296 (1.091–4.832) p = 0.029) were independent predictors for de novo post-operative AF. Late post-operative AF and atrial flutter (AFL) occurred in 18.9% and 6.8% of the patients, respectively. De novo early post-operative AF increased the risk of late post-operative AF (HR = 3.138 (1.450–6.789), p = 0.004). Patients with a right bundle branch block had a higher risk of early-postoperative pacemaker implantation (p = 0.003, HR = 9.771 (2.195–43.505)). Higher age at time of surgery (HR = 1.053 (1.026–1.081), $p < 0.001$) was a predictor for late mortality (n = 47, 18.9%).

Conclusion: Early and late post-operative AF, AFL and other SVTs are common sequelae after myectomy and are associated with older age at surgery, history of AF and early post-operative AF. Early post-operative arrhythmias are not transient and periodic rhythm monitoring is therefore essential to initiate therapy as soon as possible.

1. Introduction

Hypertrophic obstructive cardiomyopathy (HOCM) is a structural heart disease that affects 0.2% of the general population and is the leading cause of sudden cardiac death in young adults [1,2]. HOCM is predominantly an obstructive heart disease characterized by dynamic subaortic gradients which are mainly produced by interventricular septal hypertrophy and systolic anterior motion (SAM) of the anterior mitral valve leaflet. The SAM inevitably also results in mitral valve regurgitation and its severity varies with degree of left ventricular outflow tract (LVOT) obstruction [1]. Diastolic dysfunction, mitral valve regurgitation and LVOT obstruction result in increased left atrial pressure and eventually atrial dilatation. These factors predispose this population to atrial tachyarrhythmias of which atrial fibrillation (AF) is most common, with an incidence surpassing 20% [3].

According to the 2014 European Society of Cardiology (ESC) guidelines on HOCM management, surgical myectomy is the preferred treatment in patients with an indication for septal reduction, as opposed to other contemporary invasive strategies, such as alcohol ablation [1]. Because of the anatomical location of the atrioventricular node and bundle branches, atrioventricular and interventricular conduction disorders are common direct sequelae of surgical myectomy [4–6]. Septal myectomy, results in amelioration of symptoms, improvement in New York Heart Association (NYHA) class and reduction of mortality [5,7–9]. Nevertheless, patients who underwent septal myectomy remain at high risk for developing conduction disorders and arrhythmias, especially a left bundle branch block and atrial fibrillation (AF) which is poorly tolerated in HOCM patients. Loss of atrial kick in combination with high ventricular rates reduces cardiac output, especially in the presence of severe diastolic dysfunction.

AF in HOCM patients is associated with impaired quality of life [3], heart failure and all-cause mortality [10,11]. As stated in the guidelines, incidences and characteristics of early and late post-operative AF after myectomy are poorly investigated [1]. The reported incidence of early and late post-operative AF ranges from 8 to 29% and 21–30%,

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respectively [4,7,8,12–15]. However, variety in number of included patients, differences in surgical management of AF and incomplete documentation of early and late post-operative atrial tachyarrhythmias impair reliable comparison of study outcomes. Moreover, none of these studies report on progression of paroxysmal AF to more persistent types of AF.

Therefore, we aimed to investigate the incidence and determinants of post-operative atrial arrhythmias, conduction disorders and mortality in HOCM patients undergoing transaortic myectomy.

2. Methods

This retrospective study (MEC-2018-1385) was approved by the local ethics committee of the Erasmus University Medical Center Rotterdam. Informed consent was waived as this study is retrospective in nature.

2.1. Study population

Adult HOCM patients undergoing transaortic septal myectomy from February 1972 until July 2017 at our center were included. Patients were recruited from our surgical database. Patient data was collected from digital patient records by analyzing electronic records, Holter reports, electrocardiograms (ECGs) and echocardiography reports.

2.2. Arrhythmias

All available post-operative rhythm registrations and correspondence were evaluated for the occurrence of (1) sinus node dysfunction (SND), (2) first-, second- and third-degree atrioventricular block (AVB), (3) left- and right bundle branch block or intraventricular conduction delay, (4) AF, (5) AFL and (6) regular SVT, not specified. Arrhythmias were defined according to the guidelines [16,17]. Arrhythmias occurring within 30 days after myectomy were defined as early post-operative arrhythmias.

2.3. Pre-, intra- and post-operative data

Baseline characteristics, presence cardiovascular risk factors, echocardiographic variables, indications for pacemaker implantations were all obtained from digital patient records. PR- and QRS-duration were calculated from pre-operative ECGs. Intra-operative data regarding concomitant cardiac surgery was also collected. Post-operative data regarding early- and late post-operative arrhythmias, echocardiographic variables, ischemic neurological events, mortality rates and cause of death were also retrieved from electronic patient files. Early mortality after myectomy was defined as mortality within 30 days after surgery or longer when the patient was still in hospital.

2.4. Pacemaker implantation

Early post-operative pacemaker implantation was defined as procedures scheduled within 30 days after myectomy. Indications for pacemaker therapy were reported for every patient separately.

2.5. Statistical analyses

Normality was assessed using the Kolmogorov-Smirnov test. Baseline characteristics are denoted as mean ± standard deviation for normally distributed continuous variables and median with interquartile range (IQR) for skewed data. Differences in means and medians were calculated using the Student *t*-test or Mann-Whitney *U* test or Kruskal-Wallis test, respectively. Categorical data is presented as numbers and percentages and compared with the chi-squared test or, when appropriate, the Fisher exact test. Kaplan-Meier survival curves were compared using log-rank statistics. Possible predictors of post-operative arrhythmias, pacemaker implantation or mortality were determined using multivariable Cox regression analysis, entering variables with a p-value <0.2 derived from univariable Cox regression analyses. Hazard ratios (HRs) are reported with 95% confidence intervals (CIs). A p-value of <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., Armonk, New York).

3. Results

3.1. Study population

A total of 249 adult HOCM patients who underwent transaortic septal myectomy were included. Clinical characteristics of the study population are summarized in Table 1. Median age at surgery was 54 years (range [17–80]). Median follow-up duration of the entire cohort was 3 years [IQR: 0.6–8.9, maximal follow-up: 45.6 years]. As illustrated in Table 1, a genetic mutation was found in 50.8% of the patients who underwent genetic testing.

3.2. Patient characteristics

The majority of the patients ($n = 148$, 59.4%) were either in NYHA class III or IV prior surgery. At baseline, a pacemaker device was present in 5 (all DDD-pacemakers) patients and a total of 49 patients (19.7%) had a history of AF (paroxysmal AF:36, (longstanding) persistent AF:9, unspecified type of AF:4).

3.3. Concomitant procedures and re-operations

During primary repair, the majority of the patients also underwent concomitant mitral valve surgery (mitral valve repair:178 (71.5%) or mitral valve replacement:14 (5.6%)). A minority of the patients underwent concomitant aortic valve- or coronary artery bypass surgery (CABG) (aortic valve repair/replacement:13, CABG:10 and Bentall:2). Only one patient, with a history of paroxysmal AF, underwent concomitant surgical pulmonary vein isolation. Early post-operative interventions for bleeding or tamponade were required in 38 patients (15.2%). During follow-up, 23 patients (9.2%) underwent cardiac re-operation for different indications which are further specified in Supplemental Table 1.

3.4. Early post-operative echocardiographic findings

Echocardiographic examination in the early post-operative period showed a decrease in interventricular septum thickness from 20 mm [17–23] to 15 mm [13–17]. LVOT gradient decreased from 88 mmHg (70–100) to 12 mmHg (9–20). Early post-operative moderate ($n = 9$) and severe LVOT ($n = 1$) obstruction were rarely observed.

3.5. Early post-operative arrhythmias

Early post-operative arrhythmias were reported in 90 patients (36.1%). Post-operative AF was most common and occurred in 84 patients (33.7%), including 56 patients (22.5%) with de novo AF. Atrial flutter was observed in 4 patients and 4 patients experienced SVT episodes.

Uni- and multivariate analyses of determinants for early post-operative AF are shown in Table 2 (de novo post-operative AF) and Supplemental Table 2. Multivariate analysis showed that higher age at time of surgery (HR = 1.024 (1.002–1.047), $p = 0.035$) and a history of AF (HR = 3.273 (1.651–6.488), $p = 0.001$) were both independently associated with the occurrence of early post-operative AF. Subanalyses of patients who developed de novo post-operative AF revealed that age (HR = 1.027 (1.003–1.052), $p = 0.029$) and hypercholesterolemia (HR = 2.296 (1.091–4.832), p = 0.029) appeared to be independent predictors for the occurrence of de novo post-operative AF.

Table 1
Patient characteristics.

	n (%)
Number of patients	249 (100)
Age (years)	53.6 [39.9–64.2]
Male gender	145 (58.2)
Body mass index (kg/m^2)	26.5 [24.2–29.6]
NYHA functional class, n = 198 (79.5%)	
I	1 (0.4)
II	49 (19.7)
III	146 (58.6)
IV	2 (0.8)
Genetic testing	128 (51.4)
Positive genetic test	65 (50.8)
MYBPC3	43 (33.6)
MYBPC3-MYH7	1 (0.8)
MYH7	10 (7.8)
MYL2	3 (2.3)
TNNI3	4 (3.1)
TNNT2	4 (3.1)
CSRP3	2 (1.6)
Negative genetic test	63 (49.2)
AF in history	49 (19.7)
Paroxysmal AF	36 (14.5)
Longstanding (persistent) AF	9 (3.6)
Unspecified type AF	4 (1.6)
Pre-operative ICD	18 (7.2)
Pre-operative PM	5 (20)
Cardiovascular risk factors	
Diabetes Mellitus	21 (8.4)
Hypercholesterolemia	43 (17.3)
Hypertension	70 (28.1)
Electrocardiography	
Median PR interval (n = 135)	180 ms [160–200]
Median QRS duration (n = 144)	100 ms [90–110]
1st degree AVB	37 (14.9)
Left bundle branch block	12 (4.8)
Right bundle branch block	10 (4)
Interventricular conduction delay	22 (8.8)
Echocardiographic reports available	234 (94)
Left ventricular function	
Normal	146 (58.6)
Mild dysfunction	9 (3.6)
Moderate dysfunction	2 (0.8)
Severe dysfunction	2 (0.8)
Not reported	75 (30.1)
Right ventricular function	
Normal	14 (5.6)
Not reported	220 (88.4)
Mitral valve function reported in	214 (85.9)
None	11 (4.4)
I	16 (6.4)
II	25 (10)
III	36 (14.5)
IV	6 (2.4)
Grade unspecified	120 (48.2)
IVS thickness (mm)	20 (17–23)
LVOT gradient (mm Hg)	88 (70–100)
LVOT stenosis	
Mild	1 (0.4)
Moderate	35 (14.1)
Severe	149 (59.8)
Left atrial dilatation	51 (20.5)
Right atrial dilatation	4 (1.6)
Pre-operative use of AAD	212 (85.1)
Class I	9 (3.6)
Class II	151 (60.6)
Class III	33 (13.3)
Class IV	94 (37.8)

AAD = Antiarrhythmic drugs, AF = Atrial fibrillation, AVB = Atrioventricular block, ICD = Internal cardiac defibrillator, IVS=Interventricular septum, LVOT = Left ventricular outflow tract, MVR = Mitral valve repair or replacement, NYHA = New York Heart Association.

3.6. Late post-operative arrhythmias

Late post-operative AF occurred in 47 patients (18.9%) and regular SVTs were documented in 47 patients (18.9%, no sex differences, p = 0.244). Late post-operative Holter monitoring was performed in 110 patients (44.2%) of whom 46 were diagnosed with an episode of AF or regular SVT.

As demonstrated in Table 3, patients who had developed de novo early post-operative AF after myectomy, were more than 3 times at higher risk for developing AF during follow-up (HR = 3.138 (1.450–6.789), p = 0.004). At the end of the follow-up period, 4 patients (1.6%) had persistent AF and 19 patients (7.6%) had (longstanding) persistent AF. Late post-operative AFL occurred in a minority of the patients (n = 17, 6.8%, no sex differences; p = 0.11). Patients with AF prior to myectomy also had an increased risk for developing late AFL ($p < 0.001$); co-existence of AF and AFL was present in 14 patients (29.7% of all AF patients).

3.7. Progression of atrial fibrillation

Fig. 1 shows the duration of progression from paroxysmal AF to persistent or long-standing persistent AF. Progression from paroxysmal AF to persistent (blue bars) or longstanding persistent AF (red bars) was observed in 4 and 16 patients, respectively. Out of these 20 patients, 5 patients had a history of AF at time of surgery (4 paroxysmal- and 1 persistent AF) and progressed to (longstanding) persistent AF after a median follow-up duration of 4.9 years [2.2–9.3]. The remaining 15 patients were diagnosed with paroxysmal AF after a median follow-up of 9.4 years [0.3–18.9] after surgery. The majority of these patients (n = 13) progressed from paroxysmal AF to longstanding persistent AF (median duration 2.5 years [1.3–11.0]) and 3 patients from paroxysmal AF to persistent AF (median duration 4 years [1.1–9.1]).

3.8. Early and late post-operative pacemaker implantation

During follow-up, post-operative pacemaker implantation was indicated in 23 patients (9.2%). As demonstrated in Supplemental Table 3, main indication for pacemaker implantation was 2nd or 3rd degree atrioventricular conduction disorders (73.9%). The majority of the patients received a pacemaker in the early post-operative period (65.2%).

In contrast to patients with a pre-operative 1st degree AVB (p = 0.402, HR = 1.774 (0.464–6.776)) or LBBB (p = 0.626, HR = 1.697 (0.202–14.250)), patients with RBBB had a higher risk of early-postoperative pacemaker implantation due to development of 2nd or 3rd degree atrioventricular conduction disorders (p = 0.003, HR = 9.771 (2.195–43.505)). For patients receiving a pacemaker in the late post-operative period, median time to implantation was 13.4 years [0.5–18.1].

3.9. Mortality

A total of 47 patients (18.9%) died during follow-up with a median survival time of 9.2 years [3.5–19.4] after myectomy (Supplemental Fig. 1) and 3 underwent heart transplantation. Only 1 patient died in the early post-operative period after a re-operation (0.4%). This patient developed massive paravalvular aortic valve regurgitation and died due to acute heart failure. In the remaining patients, main causes of late mortality could be retrieved in 32 patients (68%) and consisted of heart failure (n = 11), sepsis (n = 6), sudden cardiac death (n = 5), malignancy (n = 4), neurovascular causes (n = 2), rejection after heart transplant (n = 1) and by accident (n = 2). Patients who were older at time of surgery appeared to have a higher mortality risk ($p < 0.001$). Development of post-operative AF did not affect survival (Supplemental Table 4).

Table 2
Factors associated with early de novo post-operative atrial fibrillation.

Determinant	Univariate analysis HR (95% CI)	p-value	Multivariate analysis HR (95% CI)	p-value
Age at repair	1.036 (1.013–1.059)	0.002	1.027 (1.003–1.052)	0.029
Baseline NYHA III/IV	1.333 (0.607–2.928)	0.473		
Female sex	1.278 (0.702–2.325)	0.422		
Diabetes	0.550 (0.156–1.941)	0.353		
Hypertension	1.763 (0.938–3.313)	0.078	1.187 (0.603–2.334)	0.620
Hypercholesterolemia	3.183 (1.580–6.415)	0.001	2.296 (1.091–4.832)	0.029
Use of AAD	1.061 (0.455–2.473)	0.891		
Concomitant MVR	0.675 (0.316–1.442)	0.311		
LA dilatation	0.929 (0.441–1.958)	0.846		
Early re-operation	1.348 (0.587–3.097)	0.481		

AAD = Antiarrhythmic drugs, AF = Atrial fibrillation, CI=Confidence interval, HR = Hazard ratio, LA = Left atrium, MVR = Mitral valve repair or replacement, NYHA = New York Heart Association.

Table 3
Factors associated with late post-operative atrial fibrillation.

Determinant	Univariate analysis HR (95% CI)	p-value	Multivariate analysis HR (95% CI)	p-value
Age at repair	1.016 (0.996–1.037)	0.123	1.006 (0.984–1.029)	0.578
Female sex	0.888 (0.495–1.592)	0.690		
Diabetes	0.915 (0.218–3.831)	0.903		
Hypertension	0.734 (0.326–1.648)	0.453		
Hypercholesterolemia	0.990 (0.382–2.565)	0.983		
Concomitant MVR	0.948 (0.509–1.767)	0.868		
Early POAF (with history of AF)	5.539 (2.665–11.554)	<0.001	4.299 (2.203–8.387)	<0.001
Early POAF de novo	2.182 (1.099–4.331)	0.026	3.138 (1.450–6.789)	0.004

AF = Atrial fibrillation, CI=Confidence interval, HR = Hazard ratio, MVR = Mitral valve repair or replacement, POAF = Post-operative atrial fibrillation.

3.10. Sex differences

Females ($n = 144$, 42%) had a significantly higher age at time of surgery compared to males ($p = 0.01$, ♀ 57.8y [41.9–66.3], ♂ 51.9y [37.9–61.5]), yet the prevalence of AF at baseline ($p = 0.62$) in male and female patients was comparable. Relatively more females ($n = 62$ (79.5%)) were in NYHA III-IV compared to males ($n = 89$ (71.7%)), but this difference did not reach statistical significance ($p = 0.22$). The presence of comorbidities ($p > 0.3$) in male and female patients is similar, except for hypercholesterolemia which occurred more frequently in female patients ($p = 0.02$). There were no sex differences in the usage of antiarrhythmic drugs (all $p > 0.06$). Early and late post-operative AF (respectively $p = 0.60$ and $p = 0.84$) and post-operative pacemaker ($p = 0.92$) occurred equally frequent in male and female patients.

4. Discussion

4.1. Key findings

This is the first report on the clinical course of post-operative AF, AFL and other SVTs in a substantial group of patients with HOCM undergoing surgical myectomy. Our data demonstrate that this population is at high risk of developing both early- and late post-operative AF. Patients who had de novo AF early after myectomy had a more than 3 times higher risk for developing AF during a median follow-up of 3 years. The prevalence and incidence of AF were comparable between male and female patients. Factors associated with late post-operative AF and AFL included older age at surgery, history of AF and occurrence of early post-operative AF. In our cohort, the high incidence of AF was

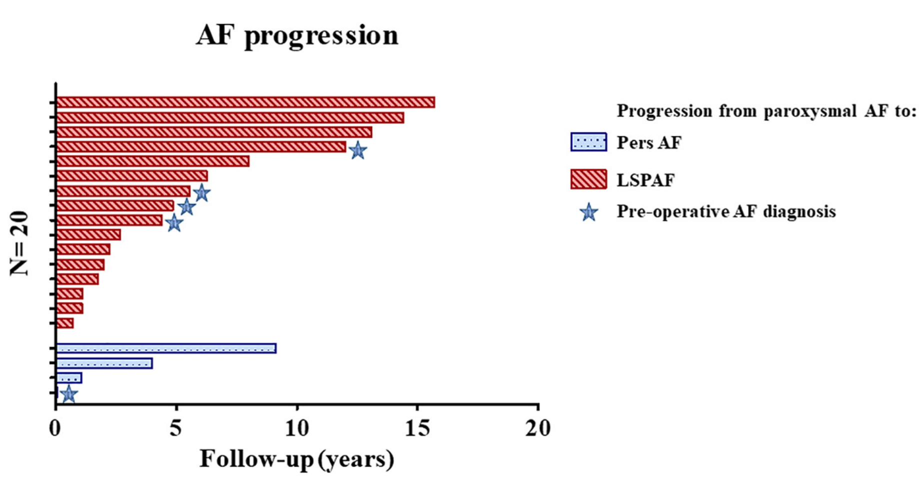

Fig. 1. Timespan of AF progression for each patient after paroxysmal AF diagnosis. AF = Atrial fibrillation, LSPAF = Longstanding persistent atrial fibrillation, Pers = Persistent.

not associated with increased mortality rates. However, older age at time of surgery was independently associated with mortality.

4.2. Pathophysiology of atrial fibrillation in HCM patients

Development of AF in HCM patients is likely a multifactorial process including genetic factors, atrial- and ventricular structural remodeling and electrophysiological abnormalities, such as atrial conduction disorders. Genetic mutations encoding sarcomere associated proteins are present in approximately 60% of HCM patients. Mutations in MYH7 gene (encoding β-myosin heavy chain), MYBPC3 gene (encoding myosin-binding protein C) and TNNT2 (encoding cardiac troponin T) are the most common genetic mutations encountered in this population. Several studies have demonstrated a higher incidence of AF in patients with a MYH7 mutation compared to patients with a MYBPC3 mutation [18,19]. More specifically, patients with a β-myosin heavy chain missense mutation Arg663His have a higher risk of AF and are characterized by predominantly subaortic interventricular septal hypertrophy [20]. The authors postulated an important role of LVOT hypertrophy as a potential trigger for AF in this population with normal survival.

A few other studies investigated the relation between multiple polymorphisms in the renin-angiotensin-aldosterone system (RAAS) and the presence of AF [21,22]. HOCM patients carrying the '1166/ polymorphism of AGTR1' and '–344T>C polymorphism of CYP11B2' were more frequently diagnosed with AF. These patients also had higher aldosterone serum levels and a thicker interventricular septum. Increased serum aldosterone serum levels may promote cardiac remodeling including atrial fibrosis, as a potential trigger of AF.

4.3. The incidence of pre-, early- and late post-operative atrial fibrillation

AF is a well-known complication after cardiac surgery and is associated with prolonged hospital stay, hemodynamic instability, increased risk of thromboembolic events, increased mortality and subsequently increased health care costs. It is also known that early post-operative AF occurs more frequently in patients undergoing valvular surgery compared to patients undergoing coronary artery bypass grafting [23]. HOCM patients undergoing myectomy, often accompanied by mitral valve repair, are therefore at high risk of developing post-operative AF. Nevertheless, studies reporting on the incidence and risk factors for early and late post-operative AF after myectomy are scarce. As a result, risk prediction-, management- and progression of AF after myectomy remains unexplored.

The reported prevalence of AF in HOCM patients undergoing surgical myectomy ranges between 3.4 and 37.5% [4,12,13,15,24–29]. The majority of these studies, reported a prevalence around 20–25%, which is in line with the present study (19.7%) [4,12,15,24,28,29]. In only one study, type of AF was classified prior to the surgical procedure. Of the 180 patients, (37.5% of the study population) known with AF, 166 were diagnosed with paroxysmal AF and the remaining 14 with (longstanding) persistent AF [25].

In the present study, new-onset- and early post-operative AF were reported in respectively 22.5% and 33.7% of the patients. These findings are also comparable with previous studies reporting incidences ranging between 21 and 30%. [4,12,15,25,26]; only 3 of these studies specified the incidence of *new-onset* early post-operative AF (range 2.9%–17.2%) [12,13,25].

Several factors may explain the lower incidences of new-onset post-operative AF found in literature compared to the present study. Firstly, mean age at time of surgery was substantially lower (6–7 years) in prior studies [12,13]. Secondly, concomitant valve or coronary artery bypass surgery was more frequently performed in our study (80%) compared to prior studies (range 10–44%).

Until now, there were no reports on incidences and progression of late post-operative AF following transaortic myectomy for HOCM. With an incidence around 20%, our study demonstrates that post-operative AF is a common sequela in this population. Moreover, AF progressed in a considerable number of patients in a relatively short period. Future studies investigating the incidence as well as progression of AF are therefore essential in order to guide therapy.

4.4. New-onset early post-operative AF after surgical myectomy, transient or lasting?

New-onset post-operative AF is often regarded as benign, transient and self-limiting. Whether to discharge HOCM patients with anti-arrhythmic drugs and oral anticoagulation remains a matter of debate. Advanced periodic rhythm monitoring (e.g. Holter monitoring) during follow-up is often at discretion of the treating physician. Our data, however, implies that new-onset POAF after myectomy is not transient and is rather independently associated with a higher risk of late post-operative AF development.

4.5. Concomitant AF surgery, enough evidence to perform?

Studies investigating the efficacy of concomitant AF surgery during myectomy are limited [30–33]. Therefore, according to the guidelines, concomitant AF ablation during septal myectomy is considered as a class 2A indication (evidence level C). The two largest studies reported an AF free survival rate of 78% [32] at 2 years and 64% [33] at 5 years after a Maze IV procedure. Left atrial dilatation (≥45 mm in diameter), increasing age and a higher LVOT gradient at time of surgery were identified as predictors for AF recurrence. Evidence supporting concomitant AF ablation during myectomy is scarce and recommendations are therefore mainly based on outcomes of a few experienced centers.

4.6. Limitations

Continuous rhythm monitoring during follow-up was performed at the discretion of the treating physician. As a result, silent episodes of SVTs may not have been detected. As data was acquired retrospectively without a predetermined follow-up protocol, frequency and follow-up may differ between patients. In addition, due to incomplete echocardiographic data we were unable to correlate the degree of mitral valve regurgitation with the occurrence of post-operative arrhythmias. Erasmus Medical Center is a specialized HOCM center, however HOCM patients are sometimes followed-up in the referral hospitals. Systematic long-term follow-up data part of the population was therefore not, or partially, available.

5. Conclusion

Early and late post-operative AF, AFL and SVTs are common sequelae in patients with HOCM undergoing transaortic myectomy. Factors associated with development of these tachyarrhythmias include older age at surgery, history of AF and occurrence of early post-operative AF. De novo early post-operative AF is associated with a more than 3 times higher risk of developing late post-operative AF. Moreover, AF progressed in a considerable number of patients in a relatively short period. Early post-operative arrhythmias in HOCM patients are not transient and periodic rhythm monitoring is therefore essential to initiate therapy as soon as possible.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcard.2020.11.055.

References

[1] Authors/Task Force m, P.M. Elliott, A. Anastasakis, M.A. Borger, M. Borggrefe, F. Cecchi, et al., 2014 ESC Guidelines on diagnosis and management of hypertrophic cardiomyopathy: the Task Force for the Diagnosis and Management of Hypertrophic Cardiomyopathy of the European Society of Cardiology (ESC), Eur. Heart J. 35 (2014) 2733–2779.

[2] B.J. Maron, J.M. Gardin, J.M. Flack, S.S. Gidding, T.T. Kurosaki, D.E. Bild, Prevalence of hypertrophic cardiomyopathy in a general population of young adults. Echocardiographic analysis of 4111 subjects in the CARDIA study. Coronary artery risk development in (young) adults, Circulation. 92 (1995) 785–789.

[3] E.J. Rowin, A. Hausvater, M.S. Link, P. Abt, W. Gionfriddo, W. Wang, et al., Clinical profile and consequences of atrial fibrillation in hypertrophic cardiomyopathy, Circulation. 136 (2017) 2420–2436.

[4] Z. Meghji, A. Nguyen, B. Fatima, J.B. Geske, R.A. Nishimura, S.R. Ommen, et al., Survival differences in women and men after septal Myectomy for obstructive hypertrophic cardiomyopathy, JAMA Cardiol. 4 (2019) 237–245.

[5] R.A. Nishimura, H. Seggewiss, H.V. Schaff, Hypertrophic obstructive cardiomyopathy: surgical Myectomy and septal ablation, Circ. Res. 121 (2017) 771–783.

[6] D.R. Talreja, R.A. Nishimura, W.D. Edwards, U.S. Valeti, S.R. Ommen, A.J. Tajik, et al., Alcohol septal ablation versus surgical septal myectomy: comparison of effects on atrioventricular conduction tissue, J. Am. Coll. Cardiol. 44 (2004) 2329–2332.

[7] P.A. Vriesendorp, A.F. Schinkel, O.I. Soliman, M.J. Kofflard, P.L. de Jong, L.A. van Herwerden, et al., Long-term benefit of myectomy and anterior mitral leaflet extension in obstructive hypertrophic cardiomyopathy, Am. J. Cardiol. 115 (2015) 670–675.

[8] L. Yao, L. Li, X.J. Lu, Y.L. Miao, X.N. Kang, F.J. Duan, Long-term clinical and echocardiographic outcomes of extensive septal myectomy for hypertrophic obstructive cardiomyopathy in Chinese patients, Cardiovasc. Ultrasound 14 (2016) 18.

[9] B.J. Maron, R.A. Nishimura, Surgical septal myectomy versus alcohol septal ablation: assessing the status of the controversy in 2014, Circulation. 130 (2014) 1617–1624.

[10] O.P. Guttmann, M. Pavlou, C. O'Mahony, L. Monserrat, A. Anastasakis, C. Rapezzi, et al., Predictors of atrial fibrillation in hypertrophic cardiomyopathy, Heart. 103 (2017) 672–678.

[11] K.C. Siontis, J.B. Geske, K. Ong, R.A. Nishimura, S.R. Ommen, B.J. Gersh, Atrial fibrillation in hypertrophic cardiomyopathy: prevalence, clinical correlations, and mortality in a large high-risk population, J. Am. Heart Assoc. 3 (2014), e001002, .

[12] S.R. Ommen, H.L. Thomson, R.A. Nishimura, A.J. Tajik, H.V. Schaff, G.K. Danielson, Clinical predictors and consequences of atrial fibrillation after surgical myectomy for obstructive hypertrophic cardiomyopathy, Am. J. Cardiol. 89 (2002) 242–244.

[13] B. Tang, Y. Song, S. Cheng, H. Cui, K. Ji, S. Zhao, et al., In-hospital postoperative atrial fibrillation indicates a poorer clinical outcome after Myectomy for obstructive hypertrophic cardiomyopathy, Ann. Thorac. Cardiovasc. Surg. 26 (2020) 22–29.

[14] H.G. van Velzen, D.A. Theuns, S.C. Yap, M. Michels, A.F. Schinkel, Incidence of device-detected atrial fibrillation and long-term outcomes in patients with hypertrophic cardiomyopathy, Am. J. Cardiol. 119 (2017) 100–105.

[15] M.Y. Desai, A. Bhonsale, N.G. Smedira, P. Naji, M. Thamilarasan, B.W. Lytle, et al., Predictors of long-term outcomes in symptomatic hypertrophic obstructive cardiomyopathy patients undergoing surgical relief of left ventricular outflow tract obstruction, Circulation. 128 (2013) 209–216.

[16] A.E. Epstein, J.P. DiMarco, K.A. Ellenbogen, N.A. Estes 3rd, R.A. Freedman, L.S. Gettes, et al., 2012 ACCF/AHA/HRS focused update incorporated into the ACCF/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities: a report of the American College of Cardiology Foundation/American Heart Association task force on practice guidelines and the Heart Rhythm Society, J. Am. Coll. Cardiol. 61 (2013) e6–75.

[17] R.L. Page, J.A. Joglar, M.A. Caldwell, H. Calkins, J.B. Conti, B.J. Deal, et al., 2015 ACC/AHA/HRS guideline for the Management of Adult Patients with Supraventricular Tachycardia: executive summary: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the Heart Rhythm Society, Circulation. 133 (2016) e471–e505.

[18] J.D. Marsiglia, F.L. Credidio, T.G. de Oliveira, R.F. Reis, O. Antunes Mde, A.Q. de Araujo, et al., Screening of MYH7, MYBPC3, and TNNT2 genes in Brazilian patients with hypertrophic cardiomyopathy, Am. Heart J. 166 (2013) 775–782.

[19] S. Wang, Y. Zou, C. Fu, X. Xu, J. Wang, L. Song, et al., Worse prognosis with gene mutations of beta-myosin heavy chain than myosin-binding protein C in Chinese patients with hypertrophic cardiomyopathy, Clin. Cardiol. 31 (2008) 114–118.

[20] E.J. Gruver, D. Fatkin, G.A. Dodds, J. Kisslo, B.J. Maron, J.G. Seidman, et al., Familial hypertrophic cardiomyopathy and atrial fibrillation caused by Arg663His beta-cardiac myosin heavy chain mutation, Am. J. Cardiol. 83 (1999) (13H-8H).

[21] Y.N. Belenkov, E.V. Privalova, V.Y. Kaplunova, D.V. Stambol'skii, A.A. Fomin, Analysis of morpho-functional parameters of the heart and polymorphisms of renin-angiotensin-aldosterone system genes in patients with different variants of the course of hypertrophic cardiomyopathy, Kardiologiia. 50 (2010) 27–34.

[22] E. Orenes-Pinero, D. Hernandez-Romero, A.I. Romero-Aniorte, M. Martinez, A. Garcia-Honrubia, L. Caballero, et al., Prognostic value of two polymorphisms in non-sarcomeric genes for the development of atrial fibrillation in patients with hypertrophic cardiomyopathy, Qjm. 107 (2014) 613–621.

[23] B. Maesen, J. Nijs, J. Maessen, M. Allessie, U. Schotten, Post-operative atrial fibrillation: a maze of mechanisms, Europace. 14 (2012) 159–174.

[24] S.R. Ommen, B.J. Maron, I. Olivotto, M.S. Maron, F. Cecchi, S. Betocchi, et al., Long-term effects of surgical septal myectomy on survival in patients with obstructive hypertrophic cardiomyopathy, J. Am. Coll. Cardiol. 46 (2005) 470–476.

[25] H. Rastegar, G. Boll, E.J. Rowin, N. Dolan, C. Carroll, J.E. Udelson, et al., Results of surgical septal myectomy for obstructive hypertrophic cardiomyopathy: the tufts experience, Ann. Cardiothorac. Surg. 6 (2017) 353–363.

[26] N.G. Smedira, B.W. Lytle, H.M. Lever, J. Rajeswaran, G. Krishnaswamy, R.K. Kaple, et al., Current effectiveness and risks of isolated septal myectomy for hypertrophic obstructive cardiomyopathy, Ann. Thorac. Surg. 85 (2008) 127–133.

[27] S. Firoozi, P.M. Elliott, S. Sharma, A. Murday, S.J. Brecker, M.S. Hamid, et al., Septal myotomy-myectomy and transcoronary septal alcohol ablation in hypertrophic obstructive cardiomyopathy. A comparison of clinical, haemodynamic and exercise outcomes, Eur. Heart J. 23 (2002) 1617–1624.

[28] P.A. Vriesendorp, M. Liebregts, R.C. Steggerda, A.F. Schinkel, R. Willems, F.J. Ten Cate, et al., Long-term outcomes after medical and invasive treatment in patients with hypertrophic cardiomyopathy, JACC Heart Fail. 2 (2014) 630–636.

[29] A. Iacovoni, P. Spirito, C. Simon, M. Iascone, G. Di Dedda, P. De Filippo, et al., A contemporary European experience with surgical septal myectomy in hypertrophic cardiomyopathy, Eur. Heart J. 33 (2012) 2080–2087.

[30] M.S. Chen, P.M. McCarthy, H.M. Lever, N.G. Smedira, B.L. Lytle, Effectiveness of atrial fibrillation surgery in patients with hypertrophic cardiomyopathy, Am. J. Cardiol. 93 (2004) 373–375.

[31] E. Lapenna, A. Pozzoli, M. De Bonis, G. La Canna, T. Nisi, S. Nascimbene, et al., Mid-term outcomes of concomitant surgical ablation of atrial fibrillation in patients undergoing cardiac surgery for hypertrophic cardiomyopathydagger, Eur. J. Cardiothorac. Surg. 51 (2017) 1112–1118.

[32] A.V. Bogachev-Prokophiev, A.V. Afanasyev, S.I. Zheleznev, A.N. Pivkin, M.S. Fomenko, R.M. Sharifulin, et al., Concomitant ablation for atrial fibrillation during septal myectomy in patients with hypertrophic obstructive cardiomyopathy, J. Thorac. Cardiovasc. Surg. 155 (2018) 1536–1542 (e2).

[33] G. Boll, E.J. Rowin, B.J. Maron, W. Wang, H. Rastegar, M.S. Maron, Efficacy of combined cox-maze IV and ventricular septal Myectomy for treatment of atrial fibrillation in patients with obstructive hypertrophic cardiomyopathy, Am. J. Cardiol. 125 (2020) 120–126.