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CLINICAL RESEARCH
Atrial fibrillation

Clinical and electrophysiological predictors of device-detected new-onset atrial fibrillation during 3 years after cardiac surgery

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Aims

Postoperative atrial fibrillation (POAF) after cardiac surgery is an independent predictor of stroke and mortality late after discharge. We aimed to determine the burden and predictors of early (up to 5th postoperative day) and late (after 5th postoperative day) new-onset atrial fibrillation (AF) using implantable loop recorders (ILRs) in patients undergoing open chest cardiac surgery.

Methods and results

Seventy-nine patients without a history of AF undergoing cardiac surgery underwent peri-operative high-resolution mapping of electrically induced AF and were followed 36 months after surgery using an ILR (Reveal XT™). Clinical and electrophysiological predictors of late POAF were assessed. POAF occurred in 46 patients (58%), with early POAF detected in 27 (34%) and late POAF in 37 patients (47%). Late POAF episodes were short-lasting (mostly between 2 min and 6 h) and showed a circadian rhythm pattern with a peak of episode initiation during daytime. In POAF patients, electrically induced AF showed more complex propagation patterns than in patients without POAF. Early POAF, right atrial (RA) volume, prolonged PR time, and advanced age were independent predictors of late POAF.

Conclusions

Late POAF occurred in 47% of patients without a history of AF. Patients who develop early POAF, with higher age, larger RA, or prolonged PR time have a higher risk of developing late POAF and may benefit from intensified rhythm follow-up after cardiac surgery.

Clinicaltrials.gov number

NCT01530750.

Keywords

Postoperative atrial fibrillation • Implantable loop recorder • Continuous rhythm monitoring • Atrial fibrillation substrate

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What's new?

- Almost 50% of patients without a history of atrial fibrillation (AF) develop short lasting AF episodes in the months to years after cardiac surgery potentially increasing their risk of stroke.
- Early postoperative atrial fibrillation (POAF), advanced age, enlarged right atria, and prolonged PR time are predictors of late POAF.
- In the first days after surgery, POAF onset shows a uniform distribution while late POAF onset peaks during daytime, suggesting adrenergic trigger mechanisms.

Introduction

Postoperative atrial fibrillation (POAF) is the most common complication after cardiac surgery.[1] It is associated with a five-fold increased likelihood of developing POAF recurrences after discharge and stroke in the months to years following the initial operation.[2] In fact, POAF is a stronger predictor of 3 years mortality after coronary artery bypass graft surgery (CABG) than diabetes or reduced left ventricular ejection fraction (LVEF), and patients without POAF after CABG show low stroke and mortality rates comparable to patients undergoing percutaneous coronary intervention.[3] Nevertheless, long-term prospective data of POAF and its burden is lacking so far and the recent guidelines consider it a transient arrhythmia in the first days after surgery but suggest prolonged oral anticoagulation (OAC) may be considered in POAF patients.[1] Here, we investigate temporal pattern of late POAF for up to 3 years following cardiac surgery and determine its clinical and electrophysiological predictors.

Methods

Study population

Consecutive patients >18 years, able to sign informed consent forms, without a history of atrial fibrillation (AF), undergoing open chest cardiac surgery were included in this study. Besides contraindications for the operation such as malignancy with low life expectancy, other exclusion criteria were prior cardiac surgery, off-pump surgery, minimal invasive surgery, high-risk operations, re-operations, haemodynamic instability, emergency surgery, sick sinus syndrome, AF/flutter, and other arrhythmias, AV-block and unavailability to participate in prolonged monitoring period using an implantable loop recorder (ILR). All patients underwent standard preoperative work-up including preoperative echocardiography and a thorough rhythm analysis of all known prior electrocardiograms (ECG's) and other available rhythm detection data. Clinical characteristics and perioperative data were collected. After surgery, at Days 2 and 4 additional ECG's and blood samples were obtained for standardized postoperative follow-up. The local Institutional Ethical Committee approved of this protocol.

ECG P-wave analysis

The day prior to the operation a 10-s ECG was digitally recorded in all patients with a sampling frequency of 250 Hz and analysed using custom-made software (MATLAB, The Mathworks, Inc., Natick, MA, USA). ECGs were filtered using a bandpass filter (1–100 Hz). After QRS complex detection and baseline correction the signal averaged P-wave was determined, following an approach described previously.[4] Parameters computed on the signal averaged P-wave included P-wave duration, dispersion, area, amplitude, axis, and PR time.

Epicardial mapping protocol

To assess the complexity of the potential substrate of AF, we performed direct contact epicardial mapping of electrically induced AF. Atrial fibrillation was acutely induced prior to cardiopulmonary bypass by right atrial (RA) burst pacing (Flexon™ unipolar pacemaker wires incremental or decremental, max 800 b.p.m.) in 53 patients. In other patients, induction attempts were stopped due to haemodynamic instability and when AF was not inducible after 10 min. A custom-made high-density square electrode array (FlexMEA, Maastricht Instruments BV, Maastricht, The Netherlands—26 × 26 mm, 256 electrodes, electrode diameter 0.5 mm, inter-electrode spacing 1.5 mm) was used for direct contact epicardial mapping of the right atrium (*Figure 3*). Unipolar AF electrograms were recorded from the RA wall at a filtering bandwidth of 0.1–400 Hz and a sampling rate of 1 kHz. We only used RA mapping for this analysis due to ease of access through sternotomy and for safety reasons as compared to left atrial (LA) mapping. All files were analysed using an automated analysis described previously.[5] Briefly, electrograms were filtered through a 0.5 Hz high-pass filter and, after substraction of far-field ventricular complexes, a template matching procedure with local activation time annotation based on the AF cycle length distribution was applied (intrinsic deflections). From the local activations, fibrillation waves were reconstructed based on wave conduction likelihood optimization, while considering conduction velocities of less than 20 cm/s between adjacent electrodes as conduction block.[5] Additional deflections were considered far-field activity from other fibrillation waves in the vicinity of the electrode if they were larger than 25% of the median of intrinsic deflections.[5] The Fractionation Index (FI) was calculated as the ratio between intrinsic and all deflections.

AF detection during follow-up

During surgery or the week prior to surgery, a Reveal XT™ (Medtronic Minneapolis, MN, USA) was inserted at the left parasternal area. This ILR classifies brady- and tachyarrhythmias based on an algorithm for detection of irregular RR intervals lasting at least 2 min. All patients received a remote monitoring system (CareLink®) before discharge, for a period of 3 years. Patients were instructed to interrogate the ILR once every two weeks or were invited to the hospital for device interrogation. All interrogated AF episodes between the previous and the current interrogation were stored in a protected central database (Carelink, Medtronic Minneapolis, MN, USA). Due to the limited storage capacity of the ILR, by design, only the most recent AF episodes were stored with an ECG recording while older episodes were stored as text file only. Episodes documented as text file only were excluded due to the known high false positive rate of up to 80%.[6] We included only AF episodes when an ECG lead recorded by the ILR was available and AF could be confirmed by the investigators and the treating cardiologist.

POAF episodes were defined as early POAF when occurring during the first 5 postoperative days, coinciding with the median hospitalization period of this population, and late POAF occurring after this period. Because the early postoperative triggers such as inflammation or fluid retention may last longer in some patients, we used different blanking periods ranging from 5 days till 3 months, to assess late POAF incidence rate outside the range of the acute postoperative phase (*Figure 1*).

Statistics

Statistical analysis was performed using SPSS (IBM SPSS statistics version 21.0). Data are expressed as medians, means ± standard deviation or

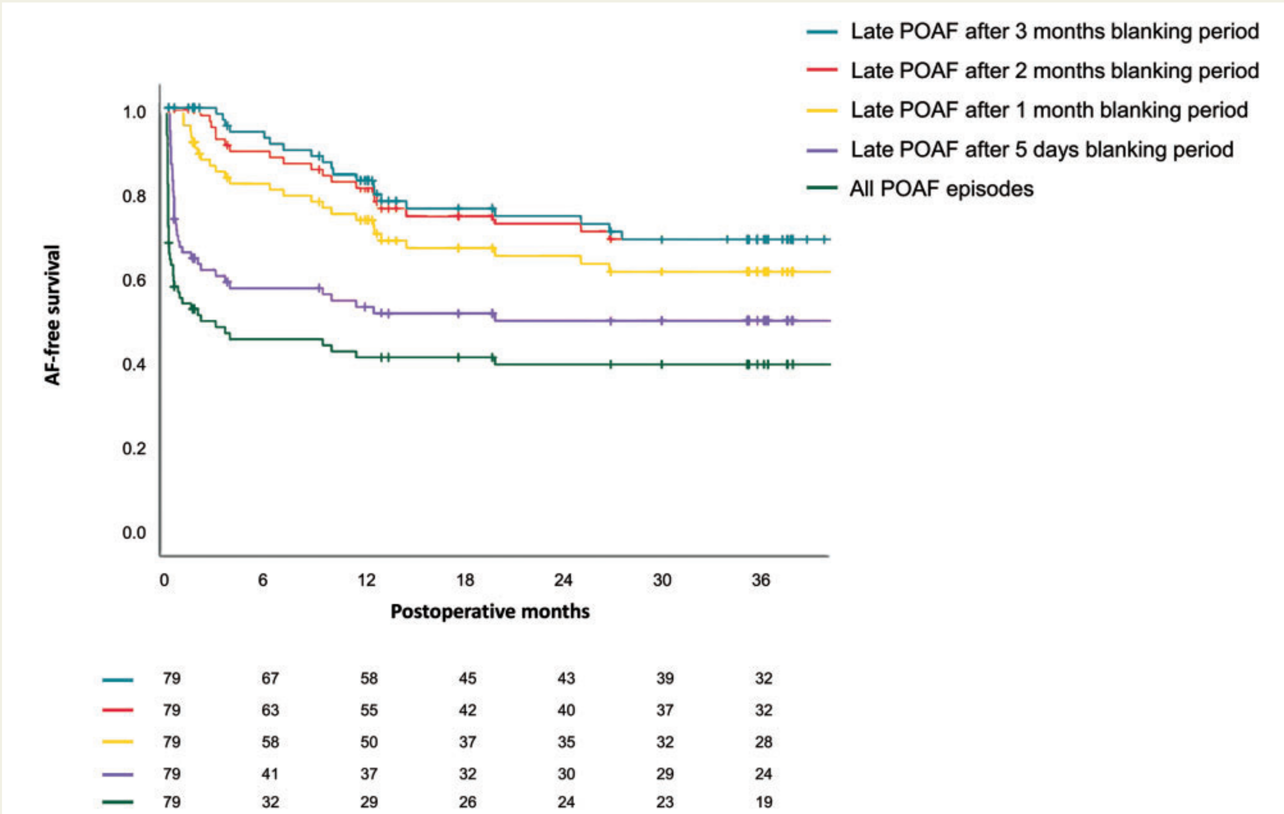

Figure 1 Kaplan–Meier AF-free survival curves of all POAF, and after different blanking periods. AF, atrial fibrillation; POAF, postoperative atrial fibrillation.

percentages. Patients developing POAF at different time points were compared to patients without POAF using an analysis of variance (ANOVA). Categorical data and percentages were analysed using Pearson's chi-square test. *P*-values <0.05 were considered statistically significant. Kaplan–Meier survival method was used to determine differences in POAF incidence during follow-up. For multivariate analysis, we first performed a univariate Cox regression analysis of 10 predetermined clinical and electrophysiological variables using POAF, early POAF, and late POAF as dependent variables. Afterwards, we used the variables with $P < 0.2$ in a multivariate Cox regression analysis (backward elimination). For the multivariate analysis, we excluded the electrophysiological data from the epicardial mapping (due to inadequate power) but conducted a subgroup multivariate analysis including these data.

Results

Clinical data

A total of 88 consecutive patients without a history of AF were included based on their medical history to represent a clinically relevant cohort. Of these, nine patients were excluded due to withdrawal ($n = 6$) or surgical complications (Supplementary material online, *Figure S2*). Seventy-nine patients received a Reveal XT™ IRL (Medtronic Minneapolis, MN, USA). Follow-up was complete for more than 12 months in 92% of patients. IRLs were explanted prematurely in 25 patients during the follow-up period because of pain ($n = 6$), infection ($n = 3$), or at patients request ($n = 16$) (Supplementary material online, *Figure S2*). Patients were on average 65 years of age and had a CHA_2DS_2VASc score of 2 ± 5 (*Table 1*). Postoperatively, all patients received standardized class II beta-blockers for POAF prevention and after discharge, unless contraindicated. Patients were followed by their treating cardiologist after discharge as standard care.

POAF incidence

During an average follow-up of 29 months (range 4 days–53 months), 3605 device interrogations (mean 48 per patient, range 3–150), including 9793 hours of potential AF were sent to the Carelink® central database for analysis. A total of 1578 AF episodes with a total duration of 4346 hours of AF were adjudicated on the device ECG lead and included in the analysis. Forty-six patients (46/79, 58.2%) developed POAF. Early POAF was detected in 27 patients (27/79, 34.2%). Two-thirds (18/27, 67%) of the early POAF group had subsequent late POAF while out of the 52 patients who did not have early POAF only 19 (19/52, 37%) developed late POAF (total 37/79, $P = 0.01$) (*Table 2*). Although patients were not monitored during the entire hospitalization period by telemetric monitoring, POAF was detected during hospitalization by the ILR in 63% of POAF patients (29/46). Kaplan–Meier survival curves of POAF incidence with different blanking periods are shown in *Figure 1*. When all AF episodes were taken into account, a high AF incidence rate was noticeable in the first

Table 1 Baseline characteristics

Clinical	
Age (years)	65 ± 9.0
BMI (kg/m^2)	27.5 ± 4.5
RA volume (mL)	51.9 ± 15.7
LA volume (mL)	79 ± 24.5
LVEF (%)	60 ± 5
Creatinin (U/L)	90.1 ± 21.2
COPD	11 (13.9%)
CHA_2DS_2 VASc	2 ± 5
CHF	10 (12.7%)
Hypertension	79 (100%)
Age >75/65–75	13 (16.5%)/23 (29.1%)
Diabetes	16 (20.3%)
Stroke/TIA	6 (7.6%)
Vascular disease	15 (19.0%)
Sex	20 female (25.3%)
Operative	
CABG	57 (72.2%)
AVR ± CABG	18 (22.8%)
MVR ± CABG	4 (5.0%)
AoCCT (min)	60 ± 25
ICU-stay (days)	1 (1–13)
Hospitalization (days)	5 (3–53)
Preoperative medication	
β-blockers	57 (72.2%)
ACE inhibitors	27 (34.2%)
Statins	67 (84.8%)

AoCCT, aortic cross clamp time; AVR, aortic valve replacement; BMI, body mass index; CABG, coronary artery bypass graft; CHA_2DS_2VASc score, CHF, congestive heart failure defined as EF < 40% and/or hospitalization for acute heart failure/hypertension/age/diabetes/sex/vascular disease; LVEF, left ventricular ejection fraction; MVP, mitral valve repair/replacement; RA, right atrium.

Table 2 Cross tabulation between early and late POAF

	No late POAF	Late POAF	Total
No early POAF	33 (42)	19 (24)	52 (66)
Early POAF	9 (11)	18 (23)	27 (34)
	42 (53)	37 (47)	79 (100)

X^2 6.5, N = 79, P = 0.01.
POAF, postoperative atrial fibrillation.

weeks after cardiac surgery. Thirty-six patients (36/46, 78%) developed their first POAF episode in the first postoperative month. However, after implementing blanking periods of 5 days until 3 months, the survival curve gradually flattened, showing lower AF incidence rate following the blanking period. *Figure 2* shows the associated effects of age, CHA_2DS_2VASc score, and early POAF on the incidence rate of total POAF and POAF after a 3-month blanking period.

Duration of POAF

The median duration of late POAF episodes was 20 min (±131 min, average 162 min) vs. 164 min (±1161 min, average 226 min) in early POAF (P = 0.002). Late POAF consisted mostly of short-lasting episodes of <6 min, compared to early POAF (63% vs. 30%, respectively, P < 0.05). Also, long-lasting episodes (>6 h) were more frequent during early POAF compared to late POAF (16% vs. 2% of episodes, respectively, P < 0.05) (*Figure 3*). In 14 patients (52%) with early POAF, episodes of >6 h were detected, while this was only the case in 5 patients in the late POAF group (14%, P = 0.003). Notably, 15 patients (41%) with late POAF received OAC form their treating cardiologist.

Circadian rhythm of POAF

Most late POAF episodes initiated during daytime (1004 episodes, 67%, between 06 a.m. and 06 p.m.) with a clear peak between 08.00 a.m. and 11.00 a.m. (431 episodes, 30% of all late POAF) (Supplementary material online, *Figure S1*). For early POAF, initiation was more spread out over the 24-h time frame (43% between 06 a.m. and 06 p.m., P < 0.05).

Characteristics of patients developing POAF

In this population, both the LVEF (60 ± 5%) as well as the LA volume (77.2 ± 25 mL) were comparable in POAF and non-POAF patients (P = 0.5 and P = 0.9, respectively). There were no differences in POAF incidence comparing CABG patients to patients with additional valve surgery (P = 0.5). Early POAF patients were older (63 ± 8 vs. 70 ± 9 years, P = 0.002) and had a higher CHA_2DS_2VASc score (3 ± 5 vs. 2 ± 5, P = 0.001) (*Table 3*). Late POAF was also characterized by advanced age (62 ± 9 vs. 69 ± 8 years, P = 0.002) and in addition by larger RA volume (48 ± 17 vs. 57 ± 14 ml, P = 0.03) and prolonged PR time in the preoperative ECG (161 ± 18 vs. 172 ± 19 ms, P = 0.01).

High-density mapping

Sustained AF was induced in 53 patients after sternotomy and high-density mapping of the right atrial wall was conducted in these patients (*Figure 4*). In nine patients AF was non-sustained and four patients were haemodynamically unstable during AF. Basic electrophysiological characteristics of the patients are presented in *Table 4*. Atrial fibrillatory cycle length was significantly longer in patients who subsequently developed POAF (181 ms ± 3 ms vs. 166 ms ± 2 ms, P = 0.03). Univariate Cox regression analysis of the electrophysiological data showed that higher number of RA waves/cycle was associated with both early (HR 1.4, 95% CI 1.01–1.83, P = 0.04) and late POAF (HR 1.3, 95% CI 1.003–1.63, P = 0.04). In addition, RA FI was higher in early POAF (HR 2.3, 95%CI 1.42–3.87, P = 0.001) and patients with late POAF had higher RA breakthrough waves/cycle (HR 1.95, 95% CI 1.04–3.66, P = 0.04). There were no correlations between P-wave parameters and mapping variables.

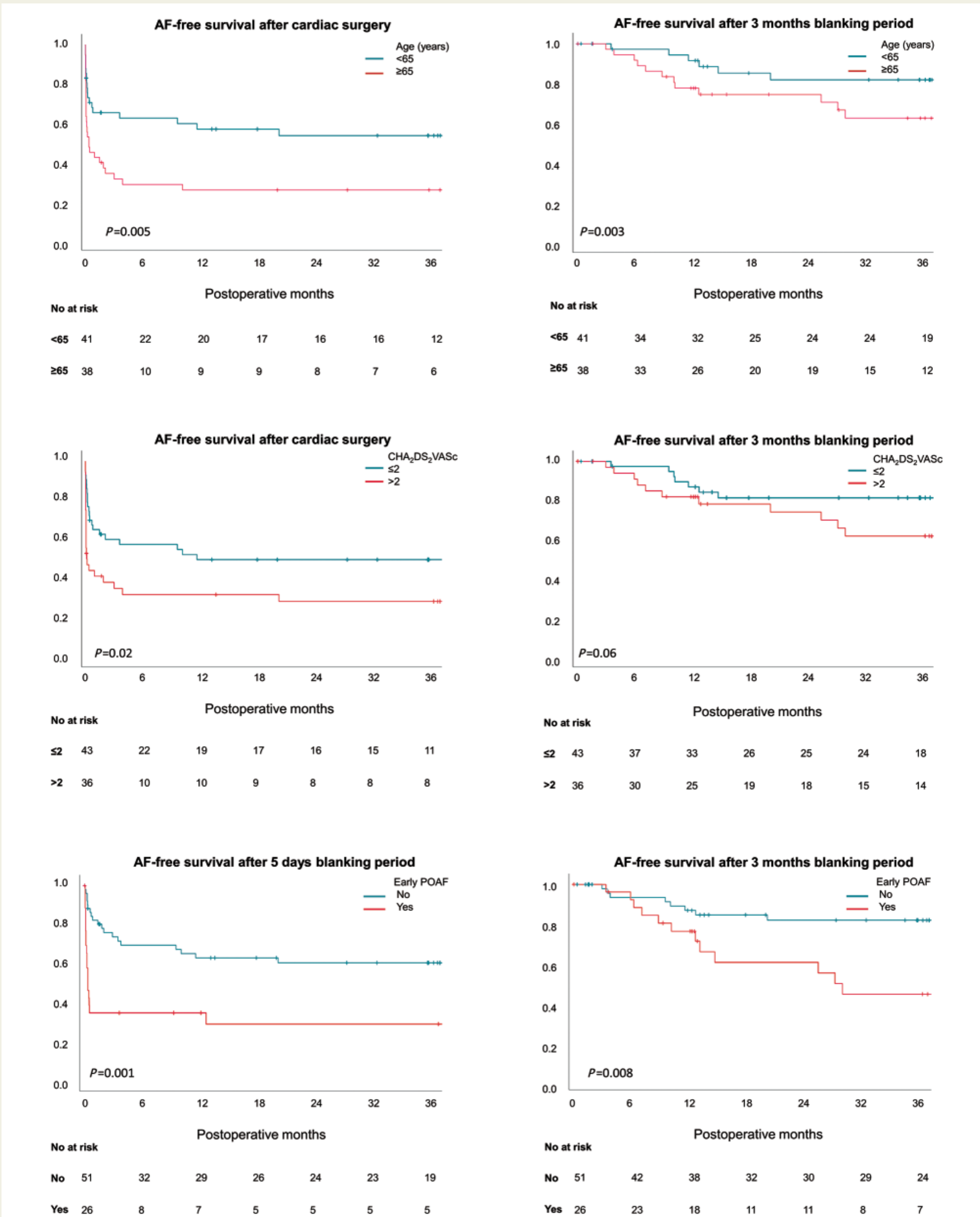

Figure 2 Kaplan–Meier AF-free survival curves with no-blanking period and 3 months blanking period, stratified by age at 65 years and CHA_2DS_2VASc score at 2, and of 5 days and 3 months blanking period stratified by early POAF. AF, atrial fibrillation; POAF, postoperative atrial fibrillation.

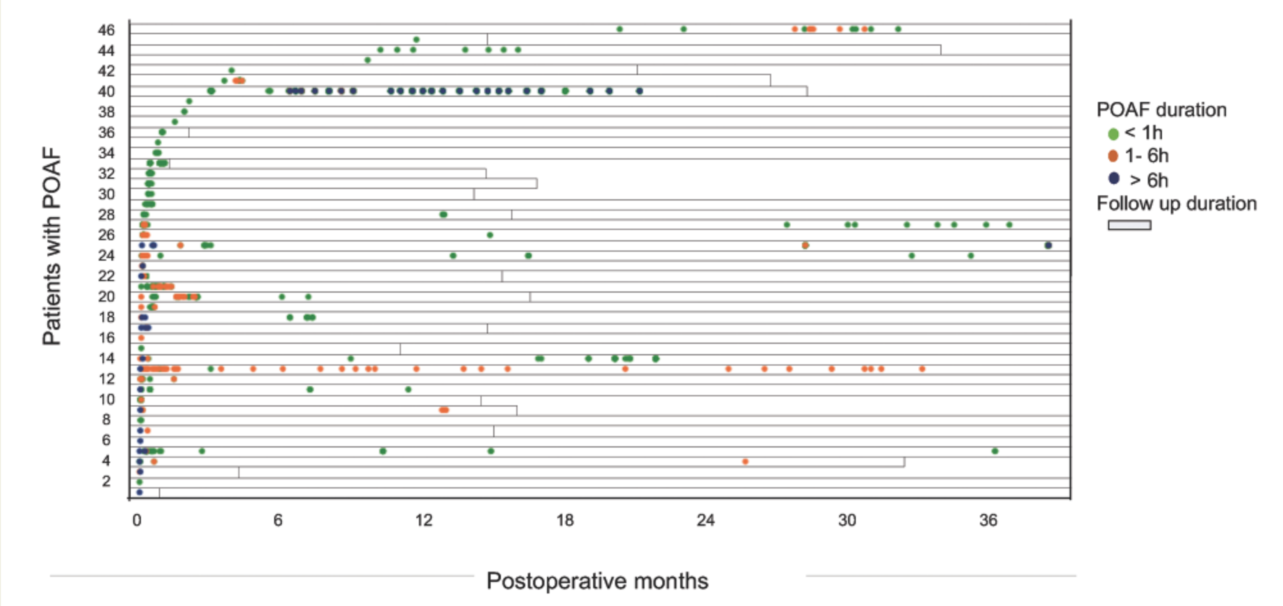

Figure 3 Scatterplot of all POAF episodes and their duration. Patients are ranked by earliest incidence of first POAF episode. POAF, postoperative atrial fibrillation.

Multivariate analysis

In the multivariate Cox regression analysis, age remained an independent predictor of POAF. Independent predictors of late POAF were early POAF, RAVI, and prolonged PR time (*Tables 5 and 6*). Early POAF, RA volume, and age were independent predictors of late POAF after implementing blanking periods of 1 month up to 3 months. These variables remained significant predictors also in the subgroup multivariate analysis including the electrophysiological data.

Discussion

Using long-term continuous rhythm monitoring, we found that 47% of patients without a history of AF developed late POAF. We defined POAF as an AF episode of at least 2 min identified on an ILR derived ECG recording. Previous studies using short lasting continuous rhythm monitoring have demonstrated up to 30% late POAF recurrences in the first month after discharge.[7] In patients with a comparable risk profile, device-detected short-lasting subclinical AF episodes or atrial high rate episodes (AHRE) have been demonstrated to occur with an annual incidence of around 10%.[8] After applying blanking periods of 1 month up till 3 months to exclude acute and subacute effects of cardiac surgery, we found a similar incidence rate of late POAF. Device-detected AF episodes have been suggested to increase the likelihood of future AF progression and risk of stroke.[8] In addition, AHRE is detected in more than 30% of patients with cryptogenic stroke,[9] and it is associated with significantly higher incidence of silent ischaemic brain lesions detected on computed tomography scan.[10] However, treatment of sub clinical AF is still debated[8] and only AHRE lasting longer than 24 h have been associated with an increased clinical risk of stroke.[11] Notably, upcoming trials such as the ARTESiA and the NOAH-AFNET 6 will study the effect of OAC on risk of stroke in patients with AHRE and may shed light on this debate.[12,13] In this study, however, late POAF episodes were adjudicated and lasted on average more than 2 h as opposed to AHRE which is usually not confirmed on an ECG lead and lasts between 5 and 6 min.[8] In addition, patients with late POAF had an average CHA_2DS_2VASc score of >2, which is associated with an increased risk of stroke in AF episodes of 5 min up to 24 h.[14] In fact in patients with paroxysmal AF only 15 min of AF or rapid pacing suffices to increase platelet activation and thrombin generation compared to sinus rhythm.[15] Therefore, it appears plausible that the potential prothrombotic effects of late POAF underlie the increased stroke and mortality rate in patients after cardiac surgery.

In our population, advanced age and large RA volume were independent predictors of late POAF. In addition, early POAF remained a significant predictor of late POAF and of POAF after blanking periods of 1 month up to 3 months. Previous studies have demonstrated additional risk factors for early POAF including valvular heart disease, hypertension, chronic obstructive pulmonary disease, obesity, heart failure,[7,16] and echocardiographic parameters such as LA volume index as independent predictors of POAF.[17] We aimed to determine the underlying substrate of POAF which in itself is the consequence of cardiovascular co-morbidities resulting in atrial remodelling through fibrosis and heterogeneous gap-junction protein distribution.[18] Direct contact epicardial mapping of the atrial wall is a well-established technique for assessing the electrophysiological properties during AF, which may vary from a low complexity of fibrillation patterns in acutely induced AF in normal atria to more complex patterns with higher number of simultaneous wavelets and breakthrough waves in persistent AF.[18] Here, we found more complex AF patterns in POAF patients, including higher RA FI and higher number of RA waves/cycle and breakthrough waves/cycle in late POAF. These findings suggest that in patients with cardiovascular

Table 3 Clinical and electrophysiological characteristics; results of analysis of variance (ANOVA) of patients developing early and late POAF

	No POAF ($n = 33$)	POAF ($n = 46$)	*P*	No early POAF ($n = 52$)	Early POAF ($n = 27$)	*P*	No late POAF ($n = 42$)	Late POAF ($n = 37$)	*P*
BMI	28.0	27.1	0.55	28	27	0.84	27	28	0.78
Age (years)	61	68	0.01	63	70	0.002	62	69	0.02
AoCCT (min)	60	60	0.98	59	63	0.55	59	62	0.58
CRP (mg/L)	3.9	3.7	0.87	3.8	3.7	0.94	3.5	4.1	0.67
CHA_2DS_2VASc	2	3	0.01	2	3	0.001	2	2	0.14
RA volume (mL)	49	55	0.09	53	49	0.40	48	57	0.03
RAVI (mL/m^2)	24	28	0.07	27	26	0.7	24	29	0.03
LA volume (mL)	76	74	0.8	78	69	0.2	73	77	0.5
LAVI (mL/m^2)	38	38	0.9	39	35	0.3	33	31	0.7
P duration (ms)	114	112	0.66	114	110	0.27	111	114	0.36
P dispersion	40.6	40.7	0.97	41.9	38.0	0.5	39.7	41.8	0.67
PR-time (ms)	160.5	169.3	0.05	165.6	165.3	0.95	161	172	0.01
P area (mm^2)	3.46	3.45	0.95	3.52	3.30	0.4	1.12	0.91	0.43
P amplitude (mV)	0.08	0.08	0.24	0.08	0.07	0.4	0.081	0.083	0.42
P axis°	43	41	0.7	41	44	0.5	43	41	0.7

AoCCT, aortic cross clamp time; BMI, body mass index; BT, breakthrough wave; CHA_2DS_2VASc score, CHF, congestive heart failure defined as EF < 40% and/or hospitalization for acute heart failure/hypertension/age/diabetes/sex/vascular disease; CRP, C-reactive protein; FI, fractionation index; LA, left atrium; LAVI, left atrial volume indexed for body surface area; P, P-wave; RA, right atrium; RAVI, right atrial volume indexed for body surface area.

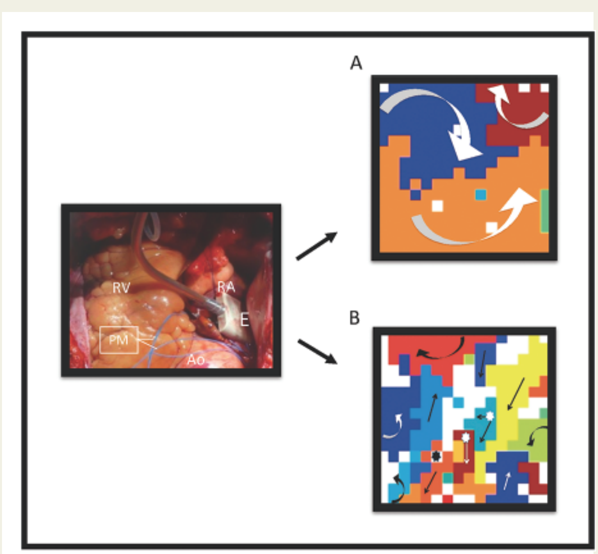

Figure 4 Epicardial mapping using a grid (E) of 256 unipolar electrodes on the entire right atrial wall (RA). On the right, two representative examples of activation patterns during electrically induced AF, acquired from patients without a history of AF: (*A*) a 59-year-old male patient with hypertension who underwent coronary artery bypass graft (CABG); (*B*) a more complex propagation pattern with wave narrowing and breakthroughs is seen in a 69-year-old patient with hypertension who underwent CABG. Different colours depict different waves, arrows depict wave propagation direction, asterisks depict breakthrough waves. Ao, aorta; RV, right ventricle; PM, atrial pacing wires.

comorbidity, enlarged RA and advanced age, atrial remodelling already exists prior to clinical manifestation of AF, which is subsequently triggered by the acute postoperative phase after cardiac surgery. Notably, while early POAF incidence was spread out over 24 h, late POAF consisted of short episodes of <6 h, with an almost 70% incidence during daytime. Contrary to the perceived nocturnal peak in the incidence of paroxysmal AF, implicating a role for vagal activity,[19] these findings suggest a more important role for sympathetic activity in the pathophysiology of late POAF and support a potential beneficial effect of beta-blockers for late POAF prevention.

Accordingly, P-wave characteristics have been used to estimate conduction heterogeneities or delays in the atria and parameters such as P-wave dispersion and duration have been reported to predict POAF.[20] The PR interval is thought of as a composite of these and other P-wave characteristics and prolonged PR interval has been associated with new-onset AF.[20] We found that prolonged PR time was an independent predictor of late POAF which is in agreement with the impaired conduction in the epicardial mapping data of patients with POAF. Therefore, P-wave characteristics in a 12-lead ECG may prove a useful addition to prediction models for late POAF and should be assessed in future studies.

Study limitations

The low storage capacity of the Reveal XT^{TM} combined with its relative low specificity and positive predictive value for AF detection (85.6% and 79.3%, respectively) along with the interrogation depending on patient compliance limit both sensitivity and specificity of AF detection in our study. For this reason, we likely underestimate the true burden of late POAF. We also could not assess the

Table 4 Electrophysiological characteristics of epicardial mapping, results of analysis of variance (ANOVA)

	POAF (n = 30)	No POAF (n = 23)	P	Early POAF (N = 16)	No early POAF (N = 37)	P	Late POAF (N = 25)	No late POAF (N = 28)	P
AFCL (ms)	183 (±34)	169 (±26)	0.1	181 (±31)	175 (±35)	0.5	182 (±34)	172 (±28)	0.2
CV (m/s)	0.58 (±0.09)	0.58 (±0.06)	0.9	0.58 (±0.09)	0.57 (±0.07)	0.7	0.57 (±0.08)	0.58 (±0.07)	0.9
BT/cycle	1.2 (±0.6)	1.0 (±0.5)	0.2	1.3 (±0.6)	1.1 (±0.6)	0.1	1.3 (±0.6)	1.0 (±0.5)	0.1
RA-FI	2.1 (±0.9)	1.7 (±0.7)	0.08	2.5 (±0.8)	1.7 (±0.7)	<0.001	2.0 (±0.8)	1.9 (±0.8)	0.8
waves/cycle	5.0 (±1.5)	4.1 (±1.6)	0.07	5.3 (±1.5)	4.3 (±1.5)	0.04	5.0 (±1.7)	4.2 (±1.4)	0.06

AFCL, atrial fibrillation cycle length; BT, breakthrough waves; CL, cycle length; CV, conduction velocity (m/s); FI, fractionation index; ms, milliseconds; POAF, postoperative atrial fibrillation; RA, right atrium.

Table 5 Results of multivariate Cox-regression analysis in the late POAF prediction model (N = 79)

	□	HR	95% CI	P
RAVI	0.5	1.05	1.01–1.09	0.01
Early POAF	1.3	3.50	1.7–7.1	0.001
PR time	0.3	1.03	1.01–1.05	0.003

CI, confidence interval; HR, hazard ratio; POAF, postoperative atrial fibrillation; RAVI, right atrial volume indexed for body surface area.

Table 6 Results of multivariate Cox-regression analysis in the late POAF after 3 months blanking period (N = 79)

	□	HR	95% CI	P
Age	0.06	1.1	1.00–1.13	0.05
RA volume	0.03	1.03	1.001–1.06	0.02
Early POAF	1.2	3.3	1.16–9.35	0.03

CI, confidence interval; HR, hazard ratio; POAF, postoperative atrial fibrillation; RA volume, right atrial volume.

symptomatology due to an irregular and short-lasting incidence pattern of AF during prolonged follow-up. In addition, using LA mapping files would add additional complexity parameters to the substrate of POAF, but this was unfortunately not feasible in all patients. Also, the patient dependent interrogation may have biased the incidence rate towards day time. Furthermore, although all patients underwent multiple thorough clinical examinations including ECGs prior to cardiac surgery, we cannot fully exclude that some of the patients may have had asymptomatic AF episodes also before surgery.

Conclusion

Our data indicate that almost half of the patients without a history of AF develop short-lasting AF episodes in the years following cardiac surgery. Patients with advanced age or large right atria, those developing early POAF, and patients with pre-existing electrophysiological alterations carry a higher risk for late POAF, potentially increasing their risk of stroke, and may benefit from intense rhythm follow-up.

Supplementary material

Supplementary material is available at *Europace* online.

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Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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