Prediction of postoperative atrial fibrillation with postoperative epicardial electrograms

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atrial electrograms (aEGs) from epicardial pacing wires to aid in the differentiation between ventricular and supraventricular arrhythmias in early postoperative care.

The present study aimed to investigate whether it is possible to predict early POAF after cardiac surgery from a combination of patient characteristics and early postoperative electrocardiograms derived from right atrial epicardial pace wires. We hypothesized that specific atrial electrocardiogram measurements in combination with patient characteristics are associated with an increased risk of developing POAF after cardiac surgery and can therefore be used to identify patients at high risk of developing POAF. A decisive risk score for early prediction of POAF will allow clinicians to make informed decisions on whether to initiate prophylactic antiarrhythmic interventions.

Methods

Study design

The present study was conducted as a single-center prospective, observational study and was performed in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. All measurements and recordings were collected in the Department of Cardiothoracic Surgery and the Cardiothoracic Intensive Care Unit at Aalborg University Hospital, Denmark, which performs approximately 400 open heart surgeries a year. This study was approved by the Institutional Review Board at Aalborg University Hospital (ID No. 2019-92). Ethical approval for this study was waived by The North Denmark Region Committee on Health Research Ethics because of the observational nature of the study, where only routine measurements were used.

Study data were collected and managed using the REDCap (Research Electronic Data Capture) database hosted at Region Nordjylland [9]. To reduce errors, double entry of all of the data were performed.

Subjects

All adult patients undergoing cardiac surgery at our hospital were screened from June 2019 to March 2020. The surgical procedures were either coronary artery bypass grafting (CABG), valve surgery, combined procedures as well as closures of atrial or ventricular septal defects. Patients were excluded if they had preoperative atrial fibrillation (AF) at the time of surgery, at the time of ECG recording, or had a history of AF, a pacemaker or total dependence on external pacing postoperatively, or the patient was placed in an ICU bed without the required software installed in monitors. Only the initial aEG and ECG recordings were used if patients underwent reoperation due to bleeding or ischemia during the same admission.

Most patients were discharged within six to seven days postoperatively and were then booked for an outpatient visit, including a 12-lead ECG, one month later.

All patients were on continuous telemonitoring three days postoperatively and for longer if the patient presented with arrhythmic episodes. POAF was documented by AF on the ECG. AF was defined as the absence of a P-wave and an irregular rhythm on a 12-lead ECG regardless of the duration and whether the patient received treatment for POAF.

Clinical variables

Baseline characteristics and information regarding the surgical procedure, as well as possible events of POAF up to 30 days postoperatively, were retrieved from the patient records. Details on the surgical procedure and postoperative events incl. POAF were registered by the surgeon responsible for the treatment of the patient. The pre- and postoperative variables sex, age, hypertension (requiring medical treatment), chronic pulmonary obstructive disease (defined as the need for long-term use of bronchodilators and/or steroids for lung disease), diabetes mellitus, dialysis, peripheral vascular disease (either carotid occlusion > 50%, claudication, or amputation due to arterial disease), ejection fraction, preoperative medication, body mass index (BMI), alcohol and smoking habits, euroSCORE II [10], type of surgery, use of cardiopulmonary bypass, and aortic cross-clamp were collected because each has been described as a predictor of POAF in previous studies [11–14]. Routine quality data checks for incorrect entries and missing values were made.

Electrograms, ECG, and hemodynamic recordings

Four temporary epicardial pacemaker wires (TME T quadri-polar, Osypka TME, Dr. Osypka GmbH, Rheinelden, Germany) are routinely sutured to the heart at the end of all cardiac procedures in Aalborg University Hospital. Two wires are placed on the right atrium, and two wires are placed on the right ventricle or one on the right ventricle and one on the left ventricle, depending on the surgeon’s preferences. The percutaneous pace wires can be connected to a temporary external pacemaker if the patient’s hemodynamic condition requires pacing assistance. Furthermore, atrial wires can be used to record an aEG with augmented P-waves when they are not used for pacing.

ECG recordings from these pace wires can be performed by connecting two precordial leads (e.g. V1 and V2) to the atrial wires or by adding two separate unipolar atrial wires to the conventional 12-lead ECG. The latter method was used in the present study. A 12-lead standard ECG and the two atrial unipolar electrograms were recorded for at least one minute, and the most noise-free 10-s segment was selected for analysis. All ECG recordings were performed using Cardiosoft version 6.73 (GE Health care, Milwaukee, USA) on the first postoperative morning (time of ECG recording, t = 0), while the patients were in the intensive care unit (ICU). If the patient had an external pacemaker connected, then it was paused during the recording. Simultaneously, the hemodynamic parameters detected by the right heart catheter (Swan-Ganz catheter, CCOMbo catheter, Edwards...
Lifesciences, Irvine, CA, USA) were recorded, when possible, with Vital Recorder [15]. Some intensive care beds did not have this option; therefore, vital parameters were recorded from the patient records.

The experimental setup is shown in Figure 1.

**ECG parameters**

Clinically obtained sinus rhythm ECGs were imported to the GE MUSE Cardiology Information System (version 9.0) and reanalyzed with 12SL analysis software (version 243; GE Healthcare, Wauwatosa, WI, USA). The 12SL algorithm uses all 12 leads to construct a median beat in each lead from nonectopic P-QRS-T complexes and measures global intervals from the earliest onset in any lead to the latest offset in any lead as well as the lead specific intervals and amplitudes in all 12 leads. A single investigator blinded to the outcome (CG) manually overrode the fiducial points and corrected it if necessary. The following ECG measurements were derived from the 12SL algorithm and used in the present study: PR interval, P-wave duration (Pdur), QRS duration, and left atrial enlargement (LAE), which was defined as a P-wave duration in lead II greater than 120 milliseconds (ms) or a P-terminal force in V1 exceeding 40 mm × ms (Figure 2).

**Electrogram parameters**

Two unipolar electrograms recorded from the right atrium were used to measure the two variables: local atrial activation time (uLAT) and the degree of fractionation (uFRAC) of the electrograms (Figure 3). The stability over time of the electrograms allowed for median electrograms to be obtained and used for subsequent analyses. This is advantageous because it eliminates small negative deflections caused by noise while retaining the true deflections caused by physiological properties. The local activation time was manually measured in each unipolar lead as the duration from P-wave onset to the steepest negative slope of the electrogram that fell within the P-wave duration. The latest of the two activation times was used to define uLAT.

Upon visual inspection, the degree of electrogram fractionation was quantified by counting the number of negative slopes, regardless of the magnitude, within the P-wave boundaries. An electrogram with a single negative slope was categorized as a single nonfractionated electrogram, whereas electrograms with more than one negative slope were categorized as fractionated (two negative slopes) or complex fractionated (more than two negative slopes). The degree of fractionation was assessed in both electrograms, and uFRAC was defined as a dichotomous parameter that quantifies the presence (more than one negative slope in either electrode) or absence (a single negative slope in both electrodes) of fractionation.
Statistical analysis and prediction models for POAF

Continuous data are summarized as the mean values with standard deviations. Categorical data are reported as counts and percentages. Differences between groups were tested using two sample t-tests and Fisher’s exact tests. Because we were unsuccessful in identifying other studies using atrial ECG data for predicting POAF, no formal sample size calculation was performed.

All prediction models were univariable or multivariable logistic regression models with POAF as the outcome. All predictors were screened for linear or nonlinear associations using fractional polynomials [16] and they were included in the multivariate analysis when a p value < .2 was observed. With more advanced atrial structural changes, the electrogram will become fractionated, and the activation time indicated on the steepest negative slope of the electrogram will occur later. Structural changes in the atrium may therefore be reflected in the later atrial activation time on the electrogram (uLAT) and likely on more fractionated electrograms (uFRAC).

Assessment of the prediction model performance

Multivariable prediction models were evaluated using the area under the receiver operating characteristic curve (AUC) and cross-validated using the leave-one-out method. The standard errors for the AUC were calculated with bootstrapping with 5000 replications. The optimal threshold value (cutoff point) for the best model was identified using the Youden index [17], and the sensitivity, specificity, and predictive ability of the model were calculated. Analyses were conducted using Stata/MP (version 16; StataCorp LP, College Station, Texas).

Results

A total of 260 patients were screened, and among these, 161 were excluded from the study (43 had AF at admission, 53 were unstable/dependent on pacemakers, and 65 had logistic obstacles). Among the 99 patients analyzed, 37 developed postoperative AF (37.4%).

Patient characteristics and information about the surgical procedures are shown in Table 1. The patients with POAF were older and had a higher body mass index than those without POAF. Although not all patients had a right heart catheter at the time of the ECG recording, the available results showed that only mixed venous oxygen saturation (SvO₂) reached significance and it was significantly lower in the POAF group. The majority of patients who developed POAF did so within three days of surgery (30 out of 37, 81%), and 89% of the patients who developed POAF were identified within five days of the surgery. Patients who developed POAF were treated according to surgeons’ decision. If POAF persisted after 48 h OAC were initiated until successful Direct Current-conversion.

Compared with those who did not develop POAF, patients with POAF had, on average, a longer duration of the P-wave and signs of left atrial enlargement (LAE) but not a significantly longer QRS duration (Table 2). The atrial electrogram parameters uLAT and uFRAC showed that the patients who developed POAF had later atrial activation times and were more likely to have fractionated electrograms (Figure 4).

In univariate regression analyses, age (OR: 1.08 (95%CI: 1.03–1.13), BMI (OR: 1.10 (95%CI: 1.01–1.21), P-wave duration (OR: 1.04 (95% CI: 1.01–1.07), LAE (OR: 2.57 (95%CI: 1.05–6.30), uLAT (OR: 1.04 (95%CI: 1.01–1.07), using the PR interval, QRS duration, LAE, and age (M2: ECG-clinical), as previously described by our group [7]; and (3) a combined electrogram and clinical model using the unipolar electrogram parameters uLAT and uFRAC, together with age and BMI (M3: atrial-clinical). The three models’ scores were calculated from a linear combination of the three or four variables with no specific cutoff level for the individual components of the model. Thus, the chosen prediction models were an internal validation of two existing prediction models and a validation of a new potentially improved model.
and uFRAC (OR: 2.68 (1.12–6.39) were found to be independent predictors of POAF (Table 3). As can be seen from Table 3, multivariate analyses for the three prediction models showed that age, sex, LAE, uLAT, and uFRAC were independent predictors of POAF.

**Prediction models**

The apparent best model for the prediction of POAF was M3 using the atrial-derived electrogram parameters uLAT and uFRAC, together with age and BMI (Figure 5 and Supplementary Figure 1). This model had the highest ROC area both with and without cross-validation as follows: AUC 0.796 (95% CI 0.698–0.894) and AUC 0.837 (95% CI 0.750–0.923), respectively (Table 4). Furthermore, calibration plots revealed a reasonable risk assessment of the M3 model (Supplementary Figure 1). Table 5 shows the ability of the M3 model to predict the outcome POAF when calculated from the optimal cutoff point of the model (cutpoint = −0.13585592). The M3 model had a sensitivity

| Table 1. Descriptive characteristics of the patients. |
|------------------------------------------------------|
| No POAF | POAF | p Value |
|---------|------|---------|
| n = 62 | n = 37 | |
| Male, n (%) | 42 (67.74) | 31 (83.78) | .100 |
| Female, n (%) | 20 (32.26) | 6 (16.22) | |
| Age, mean, year (SD) | 60.8 (13.2) | 70.3 (9.3) | <.001 |
| Comorbidities, n (%) | | | |
| Hypertension | 37 (59.68) | 24 (64.86) | .673 |
| COPD | 8 (12.90) | 5 (13.51) | -.001 |
| Diabetes (NIDDM) | 5 (8.06) | 3 (8.11) | 1 |
| Diabetes (IDDM) | 10 (16.13) | 2 (5.41) | .201 |
| Dialysis | 2 (3.23) | 0 | .527 |
| Peripheral vascular disease | 6 (9.68) | 2 (5.41) | .706 |
| LVEF, mean (SD) | 52.94 (1.27) | 54.19 (1.71) | .5524 |
| Medication, n (%) | | | |
| Beta blocker | 22 (35.48) | 12 (32.43) | .829 |
| Thrombocyte inhibitor | 31 (50) | 22 (59.46) | .409 |
| ACE inhibitor | 16 (25.81) | 11 (29.73) | .416 |
| Calcium antagonist | 17 (27.42) | 10 (27.03) | 1 |
| Oral anticoagulation | 1(1.61) | 1 (2.70) | 1 |
| Steroid | 2 (3.23) | 2 (5.41) | .628 |
| Statin | 37 (59.68) | 24 (64.86) | .673 |
| BMI (kg/m²), mean (SD) | 26.24 (4.21) | 28 (4.77) | .0344 |
| Alcohol consumption | | | |
| 0 units/week | 4 (6.45) | 0 | .180 |
| <7/14 units/week for women/men | 52 (83.87) | 34 (91.89) | .897 |
| >7/14 units/week for women/men | 6 (9.68) | 2 (5.41) | |
| Not given | 0 | 1 (2.7) | |
| Smoking | | | |
| No | 25 (40.32) | 17 (45.95) | |
| Former | 20 (32.26) | 11 (29.73) | |
| Active | 17 (27.42) | 9 (24.32) | |
| EuroSCORE II, mean (SD) | 1.92 (2.54) | 2.15 (1.92) | .6377 |
| Type of operation | | | |
| CABG | 30 (48.39) | 14 (37.84) | .231 |
| Valve | 23 (37.10) | 12 (32.43) | |
| CABG + valve | 3 (4.84) | 6 (16.22) | |
| Other | 6 (9.68) | 5 (13.51) | |
| CPB(On-pump) | 52 (83.87) | 35 (94.59) | .201 |
| Aortic cross-clamp time (minutes), mean | 63.61 (31.10) | 75.06 (30.85) | .0897 |
| Postoperative ICU data, mean | | | |
| SvO2 (%) | 68.63 (7.67) | 65.49 (6.64) | .0437 |
| CO (L/min) | 5.59 (1.63) | 5.50 (1.14) | .8211 |
| CI (L/min/m²) | 3.23 (0.93) | 2.81 (0.69) | .0223 |
| MAP (mmHg) | 77.21 (11.22) | 73.86 (9.93) | .1377 |
| SBP (mmHg) | 119.13 (16.35) | 119.57 (18.71) | .9029 |
| DBP (mmHg) | 55.94 (10.72) | 55.46 (8.60) | .0971 |
| MPAP (mmHg) | 21.58 (7.16) | 20.17 (5.24) | .3104 |
| PASP (mmHg) | 27.47 (5.87) | 27.93 (6.34) | .7703 |
| PADP (mmHg) | 15.39 (5.10) | 15.33 (5.25) | .9664 |
| CVP (mmHg) | 11.95 (8.03) | 10.53 (5.45) | .3550 |

Notes: Continuous data are presented as the mean ± standard deviation, and categorical data are presented as numbers (percentages). COPD: chronic obstructive pulmonary disease; NIDDM: noninsulin-dependent diabetes mellitus; IDDM: insulin-dependent diabetes mellitus; LVEF: left ventricular ejection fraction; ACE: angiotensin-converting enzyme; BMI: body mass index; Former smoker: stopped >1 month prior to the day of operation; EuroSCORE: European System for Cardiac Operative Risk Evaluation; CABG: coronary artery bypass grafting; CPB: cardiopulmonary bypass; SvO2: mixed venous oxygen saturation; CO: cardiac output; CI: cardiac index; SBP: systolic arterial blood pressure; DBP: diastolic arterial blood pressure; MPAP: mean pulmonary artery pressure; PASP: systolic pulmonary artery pressure; PADP: diastolic pulmonary artery pressure; CVP: central venous pressure.

and uFRAC (OR: 2.68 (1.12–6.39) were found to be independent predictors of POAF (Table 3). As can be seen from Table 3, multivariate analyses for the three prediction models showed that age, sex, LAE, uLAT, and uFRAC were independent predictors of POAF.

**Prediction models**

The apparent best model for the prediction of POAF was M3 using the atrial-derived electrogram parameters uLAT and uFRAC, together with age and BMI (Figure 5 and Supplementary Figure 1). This model had the highest ROC area both with and without cross-validation as follows: AUC 0.796 (95% CI 0.698–0.894) and AUC 0.837 (95% CI 0.750–0.923), respectively (Table 4). Furthermore, calibration plots revealed a reasonable risk assessment of the M3 model (Supplementary Figure 1). Table 5 shows the ability of the M3 model to predict the outcome POAF when calculated from the optimal cutoff point of the model (cutpoint = −0.13585592). The M3 model had a sensitivity
of 73% with a cutpoint determined by maximizing the Youden index. As shown in Figure 5, the sensitivity of 73% would correspond to a specificity of approx. 60–65% for M2, whereas we have calculated a specificity of 80.6% for M3. Although the M3 model seemingly had a higher AUC score, it performed in a statistically similar manner to that of the ECG-clinical model combining the PR interval, QRS duration, LAE and patient age and the model using only the clinical measurements of age, sex, and BMI.

**Discussion**

The present study found that variables derived from atrial electrograms together with age and BMI in a prediction model increased its ability to predict POAF. The two predictors, uLAT and uFRAC, were both strongly associated with the development of POAF, and they may therefore act as indicators of the underlying structural atrial changes, potentially related to increased fibrotic myocardial tissue in the atria. A strong relationship between atrial remodeling due

| Table 2. Electrocardiogram and atrial electrogram parameters. |
|---------------------------------------------------------------|
| **ECG**                                                      |
| PR, ms (SD)                                                  |
| Pdur, ms (SD)                                                |
| LAE, %                                                       |
| QRS, ms (SD)                                                 |
| aEG                                                          |
| uLAT (SD)                                                    |
| uFRAC, %                                                     |
| **No POAF (n = 62)**                                         |
| **POAF (n = 37)**                                            |
| **p Value**                                                  |
| 168.5 (27.2)                                                 | 173.4 (32.1)                         | .4231 |
| 108.8 (13.6)                                                 | 117 (14.3)                            | .0061 |
| 13 (21)                                                      | 15 (41)                               | .042  |
| 97.7 (22.4)                                                  | 103.9 (19.8)                          | .1636 |
| 38.2 (14.3)                                                  | 47.8 (16)                             | .0029 |
| 28 (45)                                                      | 25 (68)                               | .049  |

**Notes:** Data are presented as the mean ± standard deviation (SD) or as a count and percentage. Pdur: P-wave duration; LAE: left atrial enlargement (see Figure 2 for the ECG parameter definition); uLAT: unipolar local activation time; uFRAC: unipolar fractionation (see Figure 4 for the electrogram parameter definitions).

| Table 3. Univariable and multivariable regression analyses for odds of postoperative atrial fibrillation using the variables in the M1, M2, and M3 models. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Variable**                                                                 | **Univariable OR (95% CI)** | **p Value** |
| Clinical                                                                                                                                |                                                                 |            |
| Age                                                                      | 1.08 (1.03–1.13)             | .001        |
| Sex                                                                      | 2.46 (0.88–6.85)             | .085        |
| BMI                                                                      | 1.10 (1.01–1.21)             | .038        |
| ECG                                                                      |                                |            |
| PR, ms                                                                                   | 1.01 (0.99–1.02)             | .419        |
| Pdur, ms                                                                          | 1.04 (1.01–1.07)             | .009        |
| LAE, %                                                                  | 2.57 (1.05–6.30)             | .039        |
| QRS, ms                                                                           | 1.01 (0.99–1.03)             | .167        |
| Atrial electrogram                                                           |                                |            |
| uLAT                                                                   | 1.04 (1.01–1.07)             | .006        |
| uFRAC, %                                                              | 2.08 (1.12–3.69)             | .026        |

**Variable** | Multivariable OR (95% CI) | **p Value** |
| M1: age, sex, BMI                                                                                 |                                                                 |            |
| Age                                                                      | 1.09 (1.04–1.15)             | .001        |
| Sex                                                                      | 3.71 (1.16–11.82)             | .026        |
| BMI                                                                      | 1.09 (0.98–1.21)             | .111        |
| M2: age, PR, QRS, LAE                                                      |                                |            |
| Age                                                                      | 1.09 (1.04–1.16)             | <.001       |
| PR                                                                      | 0.98 (0.97–1.00)             | .136        |
| QRS                                                                    | 1.02 (0.99–1.04)             | .144        |
| LAE                                                                    | 4.06 (1.27–12.97)             | .018        |
| M3: age, BMI, uLAT, uFRAC                                                  |                                |            |
| Age                                                                      | 1.10 (1.04–1.16)             | .001        |
| BMI                                                                      | 1.10 (0.97–1.24)             | .123        |
| uLAT                                                                    | 1.05 (1.02–1.09)             | .003        |
| uFRAC                                                                   | 4.39 (1.50–12.81)             | .007        |

**Abbreviations:** BMI: body mass index; Pdur: P-wave duration; LAE: left atrial enlargement (see Figure 2 for ECG parameter definition); uLAT: unipolar local activation time; uFRAC: unipolar fractionation (see Figure 4 for electrogram parameter definitions).

**Figure 4.** Examples of the configuration of the electrograms depending on the outcome POAF. The figure shows how the variables local activation time (uLAT) and fractionation (uFRAC) were calculated.
to aging (used here as a measure of the left atrial size) and POAF has been reported in the literature [5,18]. Comparisons of the present findings with those of other studies confirmed that advanced age and BMI are independent predictors of POAF.

POAF is the most common complication after cardiac surgery, and it is most likely related to a combination of predisposing factors as well as reactions to the surgical procedure. The pathophysiology behind the development of POAF has not been fully established, but an increasing number of studies have confirmed that structural and electrical changes can be detected in patients prone to POAF [19–22].

The variables used in the prediction model developed in the present study are easy to collect in daily routines involved in patient care. The atrial-derived measurements used in the prediction model are applicable even when the temporary electrodes are not placed in the exact same place on the heart. This is because obstructive barriers to

![Figure 5](image_url)  
**Figure 5.** Receiver operating characteristic curves for multivariable POAF prediction models. The best prediction model for POAF was the atrial-clinical model using the atrial electrogram parameters uLAT and uFRAC, together with age and BMI. (A) Model without cross-validation. (B) Model with 10-fold cross-validation.

**Table 4.** Area under the curve for the prediction models.

| Model Type                  | Variable(s)                  | AUC     | [95% CI]          |
|-----------------------------|------------------------------|---------|-------------------|
| Clinical model:             | age, sex, BMI                | 0.748   | 0.646 0.849       |
| With cross-validation       |                              | 0.723   | 0.623 0.823       |
| ECG-clinical model:         | PR interval, QRS-dur, LAE, age| 0.762   | 0.658 0.866       |
| With cross-validation       |                              | 0.716   | 0.607 0.825       |
| Atrial ECG-clinical:        | age, BMI, uLAT, uFRAC        | 0.837   | 0.750 0.923       |
| With cross-validation       |                              | 0.796   | 0.698 0.894       |

Abbreviations: AUC: area under the curve; BMI: body mass index; CI: confidence interval; ECG: electrocardiogram; QRS-dur: QRS duration; LAE: left atrial enlargement; uLAT: local activation time; uFRAC: presence of fractionation of the electrograms.
wavefront propagation, such as fibrosis in the atria, most often are not localized to a single focal point but instead are more diffuse and thus cover the entire epicardial surface. It is also unlikely that fractionation was caused by wavefront collision or irregular re-entries in the atria because the morphology of the P-waves indicates a regular sinus rhythm.

This study supports evidence from previous observations of electrocardiographic measures for the prediction of POAF. Chandy et al. [23] found an association with increased P-wave dispersion and POAF. Gu et al. [7] showed a good predictive value of different ECG parameters in combination with the clinical characteristics of patients for predicting POAF with an AUC of 0.780 (0.696; 0.865). We observed a similar AUC in our population (AUC 0.716 (0.606;0.826) with the same model, but a larger AUC (0.837) was obtained for the model including atrial electrograms. Thus, compared to earlier prediction models of ECG

| Outcome of M3: atrial-clinical | Positive | Negative | Row total |
|-------------------------------|----------|----------|-----------|
| Positive                      | 27 (TP)  | 12 (FP)  | 39 (TP + FP) |
| Negative                      | 10 (FN)  | 50 (TN)  | 60 (FN + TN) |
| Column total                  | 37 (TP + FN) | 62 (FP + TN) | N = 99 (TP + TN + FP + FN) |
| Accuracy: (TP / TN) / (TP + TN + FP + FN) = 78% |
| Sensitivity: TP / (TP + FN) = 73% |
| Specificity: TN / (TN + FP) = 80.6% |
| Positive predictive value: TP / (TP + FP) = 69.2% |
| Negative predictive value: TN / (TN + FN) = 83.3% |

TP: true positive; FP: false positive; TN: true negative; FN: false negative.

**Limitations**

There were several limitations to this study. Due to the small sample size, the following results may have occurred: (1) overfitting of the model, which was not captured in the cross-validation; (2) selection bias, in which the most comorbid/complicated procedures/patients were excluded from evaluation and furthermore, that only two ICU beds had the software installed in the monitors enabling the recording of data; and (3) distortion of the data due to different procedures in both elective and acute patients. Most likely, the ECG and electrogram characteristics in patients with chronic valvular lesions will differ from those in patients with coronary artery disease with regard to atrial remodeling and ventricular dysfunction and it may be advantageous to study the prediction model in patients undergoing the same type of surgery. Furthermore, there may be patients with incidents of POAF not captured via early postoperative telemetry or after discharge, which could underestimate the incidence rate of POAF. However, the composition and incidence of POAF are probably applicable to most cardiac surgery centers and we have no reason to believe that the patients were systematically excluded because of the availability of the software in the monitors, and hence skew the applicability of the risk score.

Although the present study must be viewed as a hypothesis-generating study that requires further validation studies, these results suggested that atrial-derived electrogram recordings may be of assistance in predicting POAF. Additional studies with larger study populations are necessary to test and externally validate the model.

**Conclusion**

We demonstrated that measurements from atrial electrograms may be helpful in identifying patients at risk of POAF in cardiac surgery. Further studies are needed to validate the use of the prediction model before implementation in a clinical setting.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data underlying this article cannot be shared publicly due to patient privacy. The data will be shared on reasonable request to the corresponding author.

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