The Texas Heart Institute® Journal

Clinical Investigation

Incidence, Risk Score Performance, and In-Hospital Outcomes of Postoperative Atrial Fibrillation After Cardiac Surgery

Matthew W. Segar, MD, MS[1]; Alexander Marzec, MD[2]; Mehdi Razavi, MD[1]; Karen Mullins, MSHS[3]; Joanna E. Molina-Razavi, MD[1]; Subhasis Chatterjee, MD[4,5]; Alexis E. Shafii, MD[4,5]; Jennifer R. Cozart, MD[4,5]; Marc R. Moon, MD[4,5]; Abdi Rasekh, MD[1]; Mohammad Saeed, MD[1]

[1]Department of Cardiology, The Texas Heart Institute, Houston, Texas
[2]Department of Medicine, Baylor College of Medicine, Houston, Texas
[3]Quality Cardiovascular Service Line, Baylor St Luke's Medical Center, Houston, Texas
[4]Division of Cardiothoracic Surgery, Baylor College of Medicine, Houston, Texas
[5]Department of Cardiovascular Surgery, The Texas Heart Institute, Houston, Texas

Abstract

Background: Postoperative atrial fibrillation (POAF) frequently complicates cardiac surgery. Predicting POAF can guide interventions to prevent its onset. This study assessed the incidence, risk factors, and related adverse outcomes of POAF after cardiac surgery.

Methods: A cohort of 1,606 patients undergoing cardiac surgery at a tertiary referral center was analyzed. Postoperative AF was defined based on the Society of Thoracic Surgeons' criteria: AF/atrial flutter after operating room exit that either lasted longer than 1 hour or required medical or procedural intervention. Risk factors for POAF were evaluated, and the performance of established risk scores (POAF, HATCH, COM-AF, CHA_2DS_2-VASc, and Society of Thoracic Surgeons risk scores) in predicting POAF was assessed using discrimination (area under the receiver operator characteristics curve) analysis. The association of POAF with secondary outcomes, including length of hospital stay, ventilator time, and discharge to rehabilitation facilities, was evaluated using adjusted linear and logistic regression models.

Results: The incidence of POAF was 32.2% (n = 517). Patients who developed POAF were older, had traditional cardiovascular risk factors and higher Society of Thoracic Surgeons risk scores, and often underwent valve surgery. The POAF risk score demonstrated the highest area under the receiver operator characteristics curve (0.65), but risk scores generally underperformed. Postoperative AF was associated with extended hospital stays, longer ventilator use, and higher likelihood of discharge to rehabilitation facilities (odds ratio, 2.30; 95% CI, 1.73-3.08).

Conclusion: This study observed a high incidence of POAF following cardiac surgery and its association with increased morbidity and resource utilization. Accurate POAF prediction remains elusive, emphasizing the need for better risk-prediction methods and tailored interventions to diminish the effect of POAF on patient outcomes.

Keywords: Atrial fibrillation; cardiac surgical procedures; outcome assessment, health care; risk assessment; thoracic surgery

Citation: Segar MW, Marzec A, Razavi M, Mullins K, Molina-Razavi JE, Chatterjee S, Shafii AE, Cozart JR, Moon MR, Rasekh A, Saeed M. Incidence, risk score performance, and in-hospital outcomes of postoperative atrial fibrillation after cardiac surgery. *Tex Heart Inst J*. 2023:50(5):e238221. doi:10.14503/THIJ-23-8221
Corresponding author: Matthew W. Segar, MD, MS, 6770 Bertner Ave, Houston, TX, 77030 (msegar@texasheart.org)

Introduction

Arrhythmias are common complications after cardiac surgery, with postoperative atrial fibrillation (POAF) being the most frequently observed arrhythmia.[1] The incidence rate of POAF ranges from 20% to 50%, depending on factors such as the type of surgery, patient population, and criteria used for diagnosis.[2,3] Notably, POAF has been associated with increased morbidity, mortality, and health care costs.[4] Patients who develop POAF are at a higher risk of experiencing complications such as stroke, heart failure (HF), and prolonged hospital stays.[5] Moreover, POAF has been linked to long-term adverse outcomes, including a greater risk of recurrence of AF/atrial flutter and increased mortality.[6] The accurate prediction of POAF can help guide therapy and facilitate targeted interventions to prevent its occurrence.[7] Several established risk scores, such as the POAF, HATCH, and COM-AF scores, have been developed to help identify patients at risk for developing POAF.[8-10] Early identification of patients at risk for POAF allows for the timely initiation of prophylactic measures, such as the use of β-blockers, amiodarone, or other antiarrhythmic drugs, which have been shown to reduce the incidence of POAF.[7,11] The comparative performance of each risk score, however—in addition to general AF risk scores, such as the Society of Thoracic Surgeons (STS) score and the congestive HF, hypertension, age ≥75 years, diabetes, stroke or transient ischemic attack, vascular disease, age 65-74 years, sex category (CHA_2DS_2-VASc) score—in predicting POAF is unknown.[12,13]

The present study examined the incidence of POAF, the accuracy of POAF risk scores, and in-hospital adverse outcomes of POAF among patients who underwent cardiac surgery in a large tertiary referral hospital.

Key Points

- The incidence of POAF in this study was 32.2% (n = 517) of 1,606 patients who underwent cardiac surgery. Patients who developed POAF were 7 years older on average than patients without POAF and had traditional cardiovascular risk factors, higher STS risk scores, and a greater likelihood of undergoing valve surgery.
- Risk scores demonstrated poor performance in predicting POAF, with the highest AUROC of 0.65 coming from the POAF risk score, though it showed greater utility in risk stratification for patients with scores of 5 or more.
- Development of POAF was associated with significantly longer hospital LOS, increased ventilator time, and greater odds of being discharged to rehabilitation facilities, thereby emphasizing the need for improved risk-prediction tools and targeted interventions to prevent or mitigate POAF's impact on patient outcomes.

Abbreviations and Acronyms

AF	atrial fibrillation
AUROC	area under the receiver operator characteristic curve
CHA_2DS_2-VASc	congestive heart failure, hypertension, age ≥75 years, diabetes, stroke or transient ischemic attack, vascular disease, age 65-74 years, sex category
COPD	chronic obstructive pulmonary disease
HF	heart failure
LOS	length of stay
POAF	postoperative atrial fibrillation
STS	Society of Thoracic Surgeons

Patients and Methods

Study Population

This study used deidentified data from patients undergoing cardiac surgery at Baylor St Luke's Medical Center, a large tertiary referral hospital, and data stored in the STS Adult Cardiac Surgery Database. The STS database is a national registry that was established in 1989 to collect and analyze clinical data on adult cardiac surgery procedures; it represents a collaboration between STS and more than 90% of the adult cardiac surgery centers in the United States, with the primary goal of improving the quality of patient care and outcomes.[13,14] The STS database's data collection methods are standardized and rely on a detailed set of data elements, definitions, and specifications that are updated periodically to reflect advances in surgical techniques and clinical practice.[14,15] The present study included data from patients undergoing cardiac surgery between January 4, 2016, and December 12, 2022. Participants who were on antiarrhythmic medications at baseline, had a history of AF, or had a prior history of supraventricular arrhythmias were excluded. The present study was considered exempt from institutional review board review by CommonSpirit Health Research Institute (IRB00009715).

Outcomes

The primary outcome of interest in this study was the development of POAF. Based on the STS database definition, POAF in this study occurred when a patient experienced AF/atrial fibrillation after exiting the operating room that either lasted longer than 1 hour or required a medical or procedural intervention (cardioversion, ablation, or medication); this definition excluded those patients already in AF at the start of surgery. In addition to the primary outcome of POAF, the study assessed several clinical outcomes of interest, including the total amount of time a patient was on a ventilator after surgery, the patient's length of stay (LOS) in the hospital, and whether the patient was discharged to a rehabilitation facility.

Risk Scores

This study evaluated several established risk scores for predicting POAF. The POAF score predicts the incidence of POAF based on variables including age, history of AF, and history of valvular heart disease, with scores ranging from 0 to 7.[8] The HATCH score predicts the risk of progression from paroxysmal to persistent AF, incorporating factors such as hypertension, age, previous transient ischemic attack or stroke, chronic obstructive pulmonary disease, and HF, with scores ranging from 0 to 5.[9] The COM-AF score estimates the risk of AF occurrence after cardiac surgery, taking into account variables such as age, sex, HF, hypertension, diabetes, and previous stroke, with scores ranging from 0 to 9.[10] The CHA_2DS_2-VASc score predicts the risk of stroke in patients with AF, incorporating factors such as congestive HF, hypertension, age, diabetes, previous transient ischemic attack or stroke, vascular disease, and sex, with scores ranging from 0 to 9.[12] Finally, the STS risk score, developed by the STS, predicts operative mortality and morbidity for patients undergoing cardiac surgery based on multiple preoperative factors, including demographics, medical history, and procedure type.[13] Scores range from 0 to 1 and are expressed as a percentage (0%-100%).

Statistical Analysis

Baseline characteristics were compared between patients who developed POAF and patients who did not. Continuous variables were compared using 1-way analysis of variance, while categorical variables were compared using the χ^2 test. The performance of the risk scores (POAF, HATCH, COM-AF, CHA_2DS_2-VASc, and STS) for predicting POAF was evaluated by calculating the area under the receiver operating characteristic curve (AUROC) and visualizing the results with ROC curves. The optimal cut point was determined using the ROC and the maximum value of the Youden index to calculate the sensitivity, specificity, positive predictive value, and negative predictive value of each risk score.[16] Finally, the association between POAF and secondary outcomes—including the patient's total time on a ventilator, hospital LOS, and whether they were discharged to a rehabilitation facility—was assessed using unadjusted and propensity score–adjusted models. Propensity score matching was used to mitigate the risk of confounders. Nearest-neighbor matching was employed, with matching across data points such as age; sex; race; body mass index; hemoglobin level; history of chronic obstructive pulmonary disease, diabetes, or cardiovascular disease; smoking status; left ventricular ejection fraction; estimated glomerular filtration rate; whether surgery was emergent or valve surgery; and the patient's surgeon. Factors were selected based on demographics, surgical characteristics, and variables included in the POAF and STS risk scores. Length of stay and time on ventilator were log-transformed to account for non-normal distributions. All analyses were performed using R software, version 4.1.2 (R Foundation for Statistical Computing), with 2-sided $P < .05$ indicating significance.

Results

Among the 2,208 candidate patients who underwent cardiac surgery between January 4, 2016, and December 12, 2022, 602 individuals were excluded based on the criteria of being on preoperative antiarrhythmics (n = 8), having a history of AF at baseline (n = 593), and having prior supraventricular arrhythmias (n = 1). Among the 1,606 participants in the analysis cohort, 517 (32.2%) developed POAF. Participants who developed POAF were older (mean age of 67 years for patients with POAF vs 60 years for patients without POAF; $P < .001$) and less likely to be smokers (11.6% vs 15.8%; $P = .03$) (Table I). Participants who developed POAF were more likely to have traditional cardiovascular risk factors, including hypertension (92.1% vs 87.6%; $P = .009$) and kidney disease (mean estimated glomerular filtration rate, 70 mL/min/1.73 m2 vs 74 mL/min/1.73 m^2; $P = .02$). Among surgical characteristics, patients who developed POAF were more likely to have undergone valve surgery (42.4% vs 32.0%; $P < .001$),

TABLE I. Baseline Characteristics of Patients With and Without POAF After Cardiac Surgery

	Patients without POAF (n = 1,089)	Patients with POAF (n = 517)	*P* value[a]
Demographics			
Age, mean (SD), y	60 (12)	67 (10)	<.001
Male sex, No. (%)	753 (69.1)	368 (71.2)	.44
Black race, No. (%)	181 (16.6)	64 (12.4)	.03
Hispanic ethnicity, No. (%)	239 (21.9)	79 (15.3)	.002
Current smoker, No. (%)	172 (15.8)	60 (11.6)	.03
Previous coronary artery bypass graft, No. (%)	28 (2.6)	18 (3.5)	.38
Previous valve surgery, No. (%)	76 (7.0)	44 (8.5)	.32
Myocardial infarction, No. (%)	324 (29.8)	154 (29.8)	.99
Heart failure, No. (%)	363 (33.3)	192 (37.1)	.14
Diabetes, No. (%)	431 (39.6)	196 (37.9)	.55
Stroke/transient ischemic attack, No. (%)	142 (13.0)	68 (13.2)	.99
Hypertension, No. (%)	954 (87.6)	476 (92.1)	.01
Peripheral vascular disease, No. (%)	183 (16.8)	86 (16.6)	.98
Chronic obstructive pulmonary disease, No. (%)	188 (17.3)	101 (19.5)	.29
Dialysis, No. (%)	83 (7.6)	42 (8.1)	.80
Body mass index, mean (SD)	29.3 (6.1)	29.7 (6.3)	.20
Serum creatinine, mean (SD), mg/dL	1.51 (1.93)	1.47 (1.78)	.66
Estimated glomerular filtration rate, mean (SD), mL/min/1.73 m^2	73 (27)	70 (25)	.02
Albumin, mean (SD), mg/dL	3.9 (0.5)	3.9 (0.4)	.64
Hemoglobin, mean (SD), g/dL	12.7 (2.2)	12.6 (2.1)	.62
Left ventricular ejection fraction, mean (SD), %	55 (11)	55 (11)	.57
β-blocker use, No. (%)	986 (90.5)	449 (86.8)	.03
Calcium channel blocker use, No. (%)	241 (22.1)	146 (28.2)	.009
Aspirin use, No. (%)	594 (54.5)	283 (54.7)	.99
Surgery characteristics			
Valve surgery, No. (%)	349 (32.0)	219 (42.4)	<.001
STS risk algorithm, median (IQR), %	1.34 (0.66-2.26)	1.76 (0.92-3.04)	<.001
Emergent, No. (%)	66 (6.1)	38 (7.4)	.38
Cardiogenic shock, No. (%)	32 (2.9)	28 (5.4)	.02
Discharge characteristics			
Amiodarone on discharge, No. (%)	6 (0.6)	9 (1.7)	.04
Anticoagulation on discharge, No. (%)	153 (14.0)	236 (45.6)	<.001
Time on ventilator, median (IQR), h	6 (5-17)	12 (5-22)	<.001
LOS, median (IQR), d	7 (5-9)	9 (7-14)	<.001
Discharged to rehabilitation facility, No. (%)	96 (8.8)	109 (21.1)	<.001
Died in hospital, No. (%)	36 (3.3)	23 (4.4)	.32

LOS, length of stay; POAF, postoperative atrial fibrillation; STS, Society of Thoracic Surgeons.

[a]$P < .05$ was considered statistically significant.

had a higher STS risk score (median score, 1.76% vs 1.34%; $P < .001$), and were more likely to be in cardiogenic shock (5.4% vs 2.9%; $P = .02$) (Table I).

The median (IQR) values for the POAF, HATCH, COM-AF, CHA_2DS_2-VASc, and STS risk scores were 3 (2-3), 2 (1-3), 3 (2-4), 3 (2-4), and 1.47% (0.72%-2.47%), respectively. The overall performance of the risk scores was variable, ranging from an AUROC of 0.56 for the HATCH risk score to 0.65 for the POAF risk score (Fig. 1A). Notably, the POAF risk score more accurately stratified patients' risk, with a POAF incidence of 51.5% among individuals with a score greater than or equal to 5 (Fig. 1B). The POAF risk score had the highest specificity, positive predictive value, and negative predictive value compared to the other 4 risk scores (Table II).

Finally, the association between POAF and clinical outcomes of interest was assessed. In unadjusted analysis, POAF was significantly associated with an increased log-LOS in days ($\beta = .38$ [95% CI, 0.30-0.46]; $P < .001$) and log-ventilator time in hours ($\beta = .40$ [95% CI, 0.26-0.53]; $P < .001$) as well as greater odds of being discharged to a rehabilitation facility (odds ratio, 2.67 [95% CI, 1.99-3.59]; $P < .001$) (Table III). All associations remained significant after propensity score matching, with a 1.5-day-longer LOS (log-LOS $\beta = .33$ [95% CI, 0.25-0.40]; $P < .001$), 1.4-hours longer on ventilator (log-ventilator $\beta = .29$ [95% CI, 0.18-0.40]; $P < .001$), and nearly 130% greater odds of being discharged to a rehabilitation facility (odds ratio, 2.30 [95% CI, 1.73-3.08]; $P < .001$) (Table III).

Discussion

The present study found that the incidence of POAF among the 1,606 patients who underwent cardiac surgery was 32.2% (n = 517). Substantial differences were observed between patients who developed POAF and patients who did not, with the POAF group being older; having traditional cardiovascular risk factors, such as a history of hypertension and kidney disease; having higher STS risk scores; and a having greater likelihood of undergoing valve surgery. Second, the overall performance of the risk scores was poor in predicting POAF, with the POAF risk score having the highest AUROC of 0.65; however, the POAF score demonstrated some utility in risk stratification, as patients with scores of 5 or greater had a 50% prevalence of POAF. The development of POAF was also associated with significantly longer hospital LOS and ventilator time as well as a greater likelihood of being discharged to a rehabilitation facility. These findings highlight the importance of identifying patients at risk for POAF because POAF is associated with increased patient morbidity and resource use.

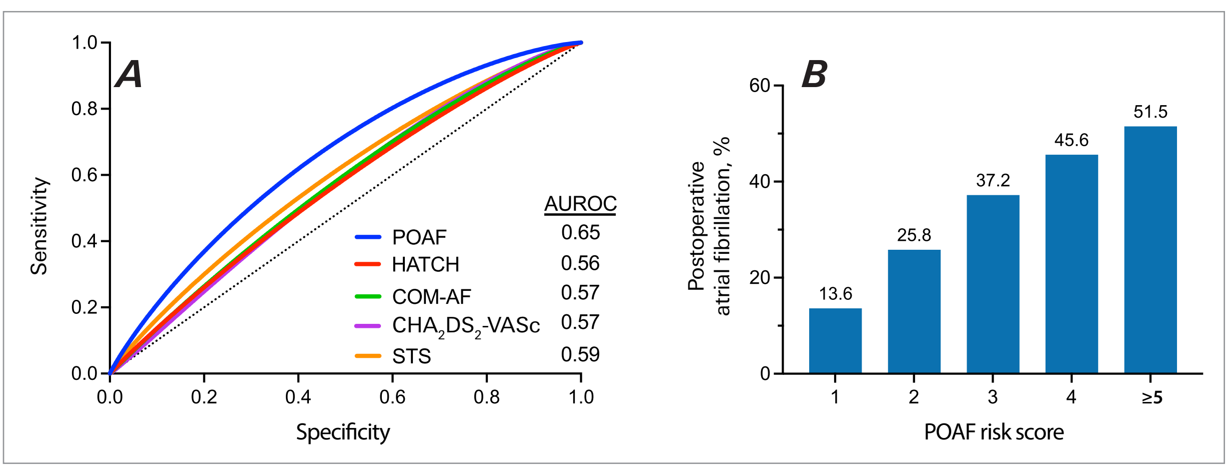

Fig. 1 A) Receiver operator characteristic curves of risk scores to predict POAF; **B**) incidence of POAF across POAF risk score strata.

AUROC, area under the receiver operator characteristic curve; CHA_2DS_2-VASc, congestive heart failure, hypertension, age ≥75 years, diabetes, stroke or transient ischemic attack, vascular disease, age 65-74 years, sex category; POAF, postoperative atrial fibrillation; STS, Society of Thoracic Surgeons.

TABLE II. Optimal Cut Points and Performance Metrics for Each Risk Score in Predicting POAF

Risk score	Cut point, ≥	Sensitivity	Specificity	Positive predictive value	Negative predictive value
POAF	3	0.56	0.67	0.78	0.42
HATCH	2	0.47	0.64	0.74	0.37
COM-AF	4	0.63	0.47	0.72	0.38
CHA_2DS_2-VASc	3	0.44	0.66	0.73	0.36
STS	1.74[a]	0.63	0.51	0.73	0.40

CHA_2DS_2-VASc, congestive heart failure, hypertension, age ≥75 years, diabetes, stroke or transient ischemic attack, vascular disease, age 65-74 years, sex category; POAF, postoperative atrial fibrillation; STS, Society of Thoracic Surgeons.

[a]STS score presented as a percentage, not an integer.

TABLE III. Association Between POAF and Adverse Clinical Outcomes

Outcome	Unadjusted estimate (95% CI)	*P* value[a]	Adjusted estimate (95% CI)[b]	*P* value[a]
Hospital LOS, d[c]	0.38 (0.30-0.46)	<.001	0.33 (0.25-0.40)	<.001
Total time on ventilator, h[c]	0.40 (0.26-0.53)	<.001	0.29 (0.18-0.40)	<.001
Odds of being discharged to a rehabilitation facility[d]	2.67 (1.99-3.59)	<.001	2.30 (1.73-3.08)	<.001

LOS, length of stay; POAF, postoperative atrial fibrillation.

[a]$P < .05$ was considered statistically significant.

[b]Adjusted associations were assessed using propensity score matching across age; sex; race and ethnicity; body mass index; hemoglobin level; history of chronic obstructive pulmonary disease, diabetes, and cardiovascular disease; smoking status; left ventricular ejection fraction; estimated glomerular filtration rate; whether the surgery was emergent or valve surgery; and the patient's surgeon.

[c]LOS and total time on ventilator were log-transformed and examined using linear regression.

[d]Whether a patient was discharged to a rehabilitation facility was examined using logistic regression and displayed as an odds ratio.

Despite advances in understanding the mechanisms and risk factors for POAF, it continues to be 1 of the most prevalent complications following cardiac procedures.[17,18] In this cohort, several risk factors were identified as being associated with the subsequent development of POAF, which is consistent with findings from previous epidemiological studies. Age, a well-established risk factor for both AF in general and POAF, was significantly higher among patients with POAF and the most critical risk factor for developing the complication.[6] Notably, preoperative β-blocker therapy was less frequently prescribed in patients who developed POAF. Though it is possible that these patients had more severe medical comorbidities that precluded the use of these agents, a protective effect in β-blockers against the development of POAF may explain in part the difference in β-blocker prescribing rates between the POAF and non-POAF groups.[19] Several medical comorbidities were significantly associated with POAF, including hypertension, chronic kidney disease, and cardiogenic shock; however, there was no significant difference in POAF incidence among patients with HF, chronic obstructive pulmonary disease, and kidney failure, despite these conditions being identified as independent risk factors in the POAF score.[7]

Numerous tools have been developed for predicting either POAF, such as the POAF and COM-AF risk scores, or complications from AF, such as the CHA_2DS_2-VASc, HATCH, and STS risk scores.[8-10,12,13] In the present study, all risk scores were observed to have relatively poor performance, except for the POAF-specific POAF risk score (AUROC = 0.65). Although accurately predicting POAF remains challenging, its effects on adverse patient outcomes are well documented. Patients undergoing cardiac surgery complicated by POAF face an increased risk of stroke, thromboembolism, myocardial infarction, and kidney failure.[5] In addition to short-term morbidity, POAF is associated with long-term adverse outcomes, including a 3-fold increase in AF recurrence and elevated rates of HF and overall mortality.[6] In the present study cohort, POAF was associated with increased hospital LOS, prolonged total ventilator hours, and nearly 130% greater odds of being discharged to a rehabilitation facility.

These findings emphasize the importance of accurately identifying patients at risk for POAF and developing effective prevention and treatment strategies. Early identification of patients at high risk can facilitate the timely initiation of prophylactic measures, such as β-blockers, amiodarone, or other antiarrhythmic drugs, which have demonstrated effectiveness in reducing the incidence of POAF.[20,21] Personalized interventions targeting modifiable risk factors, such as optimizing blood pressure control and managing diabetes, could further potentially minimize a patient's risk of developing POAF. Despite the suboptimal performance of the current risk prediction tools, this study highlights the potential for refining and combining these models to enhance POAF prediction. Future research should focus on incorporating novel biomarkers—such as circulating inflammatory markers, genetic predisposition, and other clinical variables—to improve the accuracy of risk-stratification models.[22] The application of advanced statistical and machine learning methods may also enable the development of more accurate and individualized risk prediction algorithms.[23]

The present study was not without limitations. First, the data were derived from a single tertiary referral hospital, which may limit the generalizability of its findings to other populations and settings. Second, it did not assess the duration of POAF. The clinical significance and implications of POAF may depend on the duration of the arrhythmia, and this study's analysis did not differentiate between transient and persistent episodes of POAF. Third, analysis was limited to the data available in the STS registry. It did not include other potentially relevant biomarkers or clinical factors that may influence the development of POAF, such as inflammatory markers, genetic predispositions, or echocardiographic parameters. The inclusion of additional variables could improve the predictive ability of the risk scores and provide further insights into the pathophysiology of POAF.

Conclusion

The present study identified a high incidence of POAF following cardiac surgery and its association with increased patient morbidity and resource utilization. Despite the existence of several risk scores, accurately predicting POAF remains challenging, and there is a need to improve these models. Future research should focus on refining risk-prediction tools and exploring targeted interventions to prevent or mitigate the impact of POAF on patient outcomes.

Article Information

Published: 27 October 2023

Author Contributions: All authors made substantial contributions to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and the drafting of the work or its critical revision for important intellectual content. All authors gave final approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of Interest Disclosure: Dr Segar reports speaker fees from Merck & Co., Inc. All other authors report no disclosures.

Funding/Support: None.

References

1. January CT, Wann LS, Alpert JS, et al; ACC/AHA Task Force Members. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on practice guidelines and the Heart Rhythm Society. *Circulation.* 2014;130(23):2071-2104. doi:10.1161/CIR.0000000000000040
2. LaPar DJ, Speir AM, Crosby IK, et al; Investigators for the Virginia Cardiac Surgery Quality Initiative. Postoperative atrial fibrillation significantly increases mortality, hospital readmission, and hospital costs. *Ann Thorac Surg.* 2014;98(2):527-533; discussion 33. doi:10.1016/j.athoracsur.2014.03.039
3. Bessissow A, Khan J, Devereaux PJ, Alvarez-Garcia J, Alonso-Coello P. Postoperative atrial fibrillation in non-cardiac and cardiac surgery: an overview. *J Thromb Haemost.* 2015;13(suppl 1):S304-S312. doi:10.1111/jth.12974
4. Aranki SF, Shaw DP, Adams DH, et al. Predictors of atrial fibrillation after coronary artery surgery. Current trends and impact on hospital resources. *Circulation.* 1996;94(3):390-397. doi:10.1161/01.cir.94.3.390
5. Villareal RP, Hariharan R, Liu BC, et al. Postoperative atrial fibrillation and mortality after coronary artery bypass surgery. *J Am Coll Cardiol.* 2004;43(5):742-748. doi:10.1016/j.jacc.2003.11.023
6. Mathew JP, Fontes ML, Tudor IC, et al; Investigators of the Ischemia Research and Education Foundation; Multicenter Study of Perioperative Ischemia Research Group. A multicenter risk index for atrial fibrillation after cardiac surgery. *JAMA.* 2004;291(14):1720-1729. doi:10.1001/jama.291.14.1720
7. Melduni RM, Schaff HV, Bailey KR, et al. Implications of new-onset atrial fibrillation after cardiac surgery on long-term prognosis: a community-based study. *Am Heart J.* 2015;170(4):659-668. doi:10.1016/j.ahj.2015.06.015
8. Mariscalco G, Biancari F, Zanobini M, et al. Bedside tool for predicting the risk of postoperative atrial fibrillation after cardiac surgery: the POAF score. *J Am Heart Assoc.* 2014;3(2):e000752. doi:10.1161/JAHA.113.000752
9. de Vos CB, Pisters R, Nieuwlaat R, et al. Progression from paroxysmal to persistent atrial fibrillation clinical correlates and prognosis. *J Am Coll Cardiol.* 2010;55(8):725-731. doi:10.1016/j.jacc.2009.11.040
10. Burgos LM, Ramirez AG, Seoane L, et al. New combined risk score to predict atrial fibrillation after cardiac surgery: COM-AF. *Ann Card Anaesth.* 2021;24(4):458-463. doi:10.4103/aca.ACA_34_20
11. Almassi GH, Schowalter T, Nicolosi AC, et al. Atrial fibrillation after cardiac surgery: a major morbid event? *Ann Surg.* 1997;226(4):501-511;discussion 511-513. doi:10.1097/00000658-199710000-00011
12. Lip GYH, Nieuwlaat R, Pisters R, Lane DA, Crijns HJGM. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: the Euro Heart Survey on Atrial Fibrillation. *Chest.* 2010;137(2):263-272. doi:10.1378/chest.09-1584
13. Shahian DM, O'Brien SM, Filardo G, et al; Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 1—coronary artery bypass grafting surgery. *Ann Thorac Surg.* 2009;88(1 suppl):S2-S22. doi:10.1016/j.athoracsur.2009.05.053
14. Jacobs JP, Haan CK, Edwards FH, et al. The rationale for incorporation of HIPAA compliant unique patient, surgeon, and hospital identifier fields in the STS database. *Ann Thorac Surg.* 2008;86(3):695-698. doi:10.1016/j.athoracsur.2008.04.075
15. Farjah F, Kaji AH, Chu D. Practical guide to surgical data sets: Society of Thoracic Surgeons (STS) national database. *JAMA Surg.* 2018;153(10):955-956. doi:10.1001/jamasurg.2018.0545
16. Youden WJ. Index for rating diagnostic tests. *Cancer.* 1950;3(1):32-35. doi:10.1002/1097-0142(1950)3:1<32::aid-cncr2820030106>3.0.co;2-3
17. Creswell LL, Schuessler RB, Rosenbloom M, Cox JL. Hazards of postoperative atrial arrhythmias. *Ann Thorac Surg.* 1993;56(3):539-549. doi:10.1016/0003-4975(93)90894-n
18. Andrews TC, Reimold SC, Berlin JA, Antman EM. Prevention of supraventricular arrhythmias after coronary artery bypass surgery. A meta-analysis of randomized control trials. *Circulation.* 1991;84(5 suppl):III236-III244.
19. Almassi GH, Pecsi SA, Collins JF, Shroyer AL, Zenati MA, Grover FL. Predictors and impact of postoperative atrial fibrillation on patients' outcomes: a report from the Randomized On Versus Off Bypass trial. *J Thorac Cardiovasc Surg.* 2012;143(1):93-102. doi:10.1016/j.jtcvs.2011.10.003
20. Daoud EG, Strickberger SA, Man KC, et al. Preoperative amiodarone as prophylaxis against atrial fibrillation after heart surgery. *N Engl J Med.* 1997;337(25):1785-1791. doi:10.1056/NEJM199712183372501
21. Kron J, Tan AY. Preventing postoperative atrial fibrillation: a stimulating new approach. *Circ Arrhythm Electrophysiol.* 2019;12(10):e007865. doi:10.1161/CIRCEP.119.007865
22. Turagam MK, Mirza M, Werner PH, et al. Circulating biomarkers predictive of postoperative atrial fibrillation. *Cardiol Rev.* 2016;24(2):76-87. doi:10.1097/CRD.0000000000000059
23. Karri R, Kawai A, Thong YJ, et al. Machine learning outperforms existing clinical scoring tools in the prediction of postoperative atrial fibrillation during intensive care unit admission after cardiac surgery. *Heart Lung Circ.* 2021;30(12):1929-1937. doi:10.1016/j.hlc.2021.05.101