Postoperative atrial fibrillation is associated with higher scores on predictive indices

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ABSTRACT

Objective: To compare the performance of the CHADS VASc, POAF, and HATCH scoring systems to predict new-onset atrial fibrillation after cardiac surgery.

Methods: We conducted a single-center cohort study, performing a retrospective analysis of prospectively collected data. The study included consecutive patients undergoing cardiac surgery between January 2010 and December 2016. The primary outcome was the development of new-onset postoperative atrial fibrillation during hospitalization.

Results: A total of 3113 patients underwent cardiac surgery during the study period: coronary artery bypass graft surgery (45%), valve replacement (24%), combined procedure (revascularization-valve surgery) (15%), and other procedures (16%). Twenty-one percent ($n = 654$) presented postoperative atrial fibrillation. Median scores in patients with postoperative atrial fibrillation were significantly higher ($P < .001$). The CHA2DS2-VASc score demonstrated greater discriminative ability to predict the event (C -statistic, 0.77; 95% confidence interval [CI], 0.75-0.79) versus the POAF score and the HATCH score (C -statistic, 0.71; 95% CI, 0.69-0.73 and C -statistic, 0.70; 95% CI, 0.67-0.72, respectively). All 3 scores presented good calibration according to the Hosmer-Lemeshow test univariate and multivariable analysis demonstrated that the 3 scores were independent predictors of postoperative atrial fibrillation: CHA2DS2-VASc score odds ratio 1.87 (95% CI, 1.64-2.13), POAF score odds ratio 1.18 (95% CI, 1.01-1.36), and HATCH score odds ratio 1.62 (95% CI, 1.37-1.92).

Conclusions: The POAF, CHA2DS2-VASc, and HATCH scoring systems showed good discrimination and calibration to predict postoperative atrial fibrillation in patients undergoing cardiac surgery. Among them, the CHA2DS2-VASc score presented the best discriminative ability for postoperative atrial fibrillation and has the advantage of being easy to calculate. (J Thorac Cardiovasc Surg 2019;157:2279-86)

AUC-ROC for the CHA2DS2-VASc, POAF, and HATCH scores.

Central Message

Atrial fibrillation in the postoperative period of cardiac surgery is frequent, and influences morbimortality. It is important to be able to predict its occurrence with validated tools.

Perspective

This study demonstrates the ability of the CHA2DS2-VASc, HATCH, and POAF scoring systems to predict the development of atrial fibrillation after cardiac surgery, demonstrating their performance in terms of discrimination and calibration. The CHA2DS2-VASc score demonstrated the highest predictive ability.

See Commentary on page 2287.

Atrial fibrillation (AF) is the most common sustained arrhythmia after cardiac surgery. The prevalence reported in previous studies is between 20% and 40%, depending

on the definition and the method used for detection.^{1,2} Its incidence varies according to the type of surgery, and occurs in 40% to 50% of patients after valve surgery, either isolated or combined, and in almost 30% of patients during the postoperative period of coronary artery bypass graft (CABG) surgery.^{3,4}

Postoperative AF is known to be associated with adverse outcomes for patients and for the health care system, including higher short- and long-term mortality rates, increased length of hospital stay, and greater hospitalization costs.^{3,5-7}

Previous studies have identified multiple clinical, anatomic, and molecular risk factors that could influence

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Abbreviations and Acronyms

AF	= atrial fibrillation
AUC-ROC	= area under the curve-receiver operating characteristic
CABG	= coronary artery bypass graft
COPD	= chronic obstructive pulmonary disease
CPB	= cardiopulmonary bypass
HF	= heart failure
HT	= hypertension
HL	= Hosmer-Lemeshow

the development of postoperative AF.⁸⁻¹⁰ The most relevant risk factors include age, heart failure, rheumatic heart disease, chronic kidney failure, and chronic obstructive pulmonary disease (COPD).^{11,12} Once these risk factors were identified, many models were created and validated to predict the development of postoperative AF to improve the efficacy of preventive measures by limiting prophylaxis to patients with high risk for postoperative AF, minimizing the global burden of complications associated with these therapies.^{13,14}

The POAF,¹⁵ CHA2DS2-VASc,¹⁶ and HATCH scores¹⁷ are used to predict new-onset AF after cardiac surgery. Other models presented modest predictive capacity,^{18,19} and others predicted the occurrence of AF in low-risk patients; for example, including only CABG surgery, and excluding patients with renal and cardiac failure.^{12,20,21}

The CHA2DS2-VASc score was initially introduced to predict the risk of embolic stroke in patients with AF.¹⁶ This bedside prediction score is based on variables that are easy to remember.^{22,23} Patients with CHA2DS2-VASc scores ≥ 2 are at high risk for ischemic stroke. However, multiple studies with small number of participants have investigated the use of the CHA2DS2-VASc score to predict postoperative AF,²⁴⁻²⁸ and only 1 recent published study compared the predictive ability of CHA2DS2-VASc with other scoring systems (ie, POAF score and Atrial Fibrillation Risk Index), showing limited ability to predict postoperative AF in patients undergoing cardiac surgery.²⁹

The HATCH score was developed by De Vos and colleagues¹⁷ and it includes clinical parameters that can be easily calculated. The authors identified independent variables for the development of persistent AF after 1-year follow-up in patients with paroxysmal AF and found that the HATCH score was the most important predictor of AF progression.³⁰ This score was validated to predict AF after catheter ablation.³¹ Each item of the HATCH score is associated with long-term left atrial

enlargement, and is therefore important for the development of postoperative AF. For these reasons, the HATCH score is a valuable tool to predict postoperative AF, and a study performed in 2016 suggested it could be a useful tool.³¹ In contrast, POAF score is the only scoring system that was specifically created and validated to predict postoperative AF.¹⁵

Currently, there are no studies comparing these scoring systems in our setting. The aim of our study was to compare the performance of the CHA2DS2-VASc, POAF, and HATCH scoring systems to predict the development of AF after cardiac surgery in our setting.

METHODS

We conducted a single-center cohort study, performing a retrospective analysis of prospectively collected data. The study included consecutive patients undergoing cardiac surgery between January 2010 and December 2016. Patients with previous AF or other atrial arrhythmias were excluded. The primary outcome was the development of new onset postoperative AF during hospitalization. Postoperative AF was defined as in previous studies, as any documented AF episode lasting >30 seconds recorded either by continuous telemetry throughout hospitalization or on a 12-lead electrocardiogram performed daily and when the patient reported experiencing symptoms. All patients had continuous telemetry monitoring at least during the first 48 hours by an offsite central monitor unit, and once identified, every arrhythmia event was confirmed by a cardiologist.

Risk Scoring Systems

Scores were calculated for each patient, as follows:

CHA2DS2-VASc score. Age ≥ 75 years, 2 points; 65 to 74 years, 1 point; female sex, 1 point; history of heart failure (HF), 1 point; hypertension (HT), 1 point; stroke/transient ischemic attack, 2 points; diabetes, 1 point; and peripheral vascular disease, 1 point.^{22,23}

POAF score. Age, 60 to 69 years, 1 point; 70 to 79 years, 2 points; ≥ 80 years, 3 points; COPD, 1 point; glomerular filtration rate <15 mL/min/1.73 m² on dialysis, 1 point; emergency operation, 1 point; preoperative intra-aortic balloon pump, 1 point; left ventricular ejection fraction $<30\%$, 1 point; and any heart valve surgery, 1 point.¹⁵

HATCH score. HT, 1 point; age ≥ 75 years, 1 point; stroke or transient ischemic attack, 2 points; COPD, 1 point; and HF, 2 points.^{17,31}

Statistical Analysis

Quantitative data are expressed as mean $\pm$ standard deviation and were compared with 2-sample *t* tests for independent samples, whereas dichotomous variables were reported as absolute values and proportions. Differences in proportion were compared using a χ^2 test or Fisher exact test, as appropriate. Ordinal data and continuous variables inconsistent with normal distribution are expressed as median and interquartile range (IQR), and were compared with the Mann-Whitney *U* test. Variables significantly associated with postoperative AF after univariate analysis ($P < .05$) listed in Table 1 were entered in a multivariable logistic regression model with backward elimination to identify the independent predictors of postoperative AF, and each score was insert in different time. The variables that were independently

TABLE 1. Characteristics of study participants with and without atrial fibrillation (AF)

Characteristic	With postoperative AF (n = 654)	Without postoperative AF (n = 2459)	P value
Age (y)	71.5 ± 8.7	64.7 ± 12.4	<.001
Male sex	449 (68)	1892 (77)	<.001
Body mass index	27 (24-30)	27 (25-30)	.1
Additive European system for cardiac operative risk evaluation score	7 (5-8)	4 (2-6)	<.001
Current smoker and former smoker	322 (49)	1356 (55)	.007
Diabetes	140 (21.4)	569 (23.1)	.3
Hypertension	492 (75.2)	1742 (70.8)	.02
Peripheral vascular disease	11 (1.7)	54 (2.2)	.4
Chronic kidney failure (CrCl < 15)	10 (1.5)	23 (0.9)	.1
Peripheral vascular disease	220 (33)	819 (33)	.8
Chronic obstructive pulmonary disease	58 (9)	128 (5.2)	<.001
Cerebrovascular disease	32 (5)	102 (4)	.4
Left ventricular ejection fraction <30%	44 (6.7)	72 (2.9)	<.001
Heart failure	99 (15.1)	174 (7.1)	<.001
Previous intra-aortic balloon pump	15 (2.3)	36 (1.5)	.1
Urgent surgery	210 (32)	715 (29)	.1
Type of surgery			<.001
Coronary artery bypass graft	205 (31.3)	1204 (49)	
Valve surgery	224 (34.3)	519 (21.1)	
Coronary artery bypass graft + valve surgery	137 (20.9)	340 (13.8)	
Other	88 (13.5)	396 (15.9)	
Inotropic agents	69 (10.6)	133 (5.5)	<.001
Cardiopulmonary bypass	427 (65)	1221 (49)	<.001
Cardiopulmonary bypass time (min)	94 (71-123)	97 (67-129)	.4
Hospital stay (d)	10 (6-16)	6 (5-10)	<.001

Values are presented as mean ± standard deviation, median (interquartile range), or n (%). AF, Atrial fibrillation; CrCl, creatine clearance.

associated with postoperative AF were presented as odds ratios (ORs) along with the 95% confidence intervals (CIs). An OR was considered statistically significant if its 95% CI exceeded 1, with *P* value < .05.

Calibration and Discrimination

The models were evaluated in terms of their 2 components: discrimination and calibration. Calibration was assessed using the Hosmer-Lemeshow (HL) goodness-of-fit test, which evaluates the difference between the real rate observed and the rate predicted by the model in different risk groups, a *P* value > .05 indicates that the model is best fit for the data and thus predicts the probability of developing postoperative AF. We calculated the area under the curve-receiver operating characteristic (AUC-ROC) to assess the predictive value of the scores, and the Youden index was used to determine the cut-off point of each scale with the highest sensitivity and specificity.

Ethical Considerations

Committee on Ethics and Research approval was obtained with waiver of consent for retrospective review of previously collected, de-identified data.

RESULTS

A total of 3113 patients undergoing cardiac surgery between 2010 and 2016 were consecutively included: 45% underwent CABG surgery, 24% underwent valve replacement, 15% underwent combined procedures (eg, revascularization-valve surgery), and 16% underwent other procedures (eg, aortic surgery, septal myectomy, or pulmonary endarterectomy). In 52.9% of procedures, cardiopulmonary bypass (CPB) was used, and only 2.2% of the CABG surgeries were on-pump surgical procedures. The baseline characteristics of the population are described in Table 1.

Twenty-one percent of patients (n = 654) presented postoperative AF. CPB was more frequently used and its duration was statistically longer in the postoperative AF group (median, 85 minutes [IQR, 0-118 minutes] vs 35 minutes [IQR, 250-107 minutes]).

These patients were older (71.5 ± 8.7 years vs 64.7 ± 12.4 years) and had more comorbidities (additive

TABLE 2. Calculation of median score, area under the curve-receiver operating characteristic (AUC-ROC), and odds ratio (OR) and 95% confidence interval (CI)

Score	Median (interquartile range)		P value
	With postoperative atrial fibrillation	Without postoperative atrial fibrillation	
CHA2DS2-VASc score	3 (3-4)	2 (1-3)	<.001
POAF score	3 (2-4)	2 (1-3)	<.001
HATCH score	2 (1-3)	1 (1-2)	<.001
	Univariate analysis		P value
	OR	95% CI	
CHA2DS2-VASc score	2.31	2.13-2.51	<.001
POAF score	1.84	1.71-1.98	<.001
HATCH score	1.94	1.79-2.11	<.001
	AUC-ROC		95% CI
	AUC-ROC		
CHA2DS2-VASc score	0.77		0.75-0.79
POAF score	0.71		0.69-0.73
HATCH score	0.70		0.67-0.72

OR, Odds ratio; CI, confidence interval.

European System for Cardiac Operative Risk Evaluation score 7 vs 4; $P < .001$) compared with those without postoperative AF, and the presence of HT, COPD, left ventricle dysfunction, and HF was more frequent. The rate of current smokers and male sex was lower (49% vs 55% [$P < .007$] and 68% vs 77% [$P < .001$], respectively).

The use of preoperative beta blockers was similar in both groups ($P = .063$) with no significant differences in the rest of the drugs used.

FIGURE 1. Area under the curve-receiver operating characteristic for the CHA2DS2-VASc, POAF, and HATCH scores.

In postoperative AF patients, hospital stay was longer (median, 10 vs 6 days; $P < .001$), the use of inotropic drugs during the postoperative period was more common (10.6% vs 5.5%; $P < .001$), and in-hospital mortality was higher (9% vs 3.7%; $P < .001$).

CHA2DS2-VASc Score

Median CHA2DS2-VASc score was 3 (IQR, 3-4) in patients with postoperative AF and 2 (IQR, 1-3) in those without it ($P < .001$) (Table 2). The prevalence of postoperative AF increased with higher CHA2DS2-VASc scores (Figure 1). The probability of developing AF increased as the score was 1 point higher (OR, 2.6; 95% CI, 2.4-2.9). The AUC-ROC was 0.77 (95% CI, 0.75-0.79) (Figure 1). The best cut-off point to predict postoperative AF was ≥ 3 . With a sensitivity of 80% (95% CI, 76.85%-83.12%); specificity 69% (95% CI, 67.31%-71.00%); and positive and negative predictive value of 39% and 91.8%, respectively. The test showed good calibration (HL test $P = .088$) (Figure 2 and Table 3).

POAF Score

Median POAF score was 3 (IQR, 2-4) in patients with postoperative AF and 2 (IQR, 1-3) in those without the event ($P < .001$).

The AUC-ROC was 0.71 (95% CI, 0.69-0.73) (Figure 1). The best cut-off point to predict postoperative AF was ≥ 2 . With a sensitivity of 62% (95% CI, 58.39%-65.96%); specificity 70% (95% CI, 67.80%-71.48%); and positive and negative predictive value of 35% and 87%, respectively. The probability of developing AF increased as the

FIGURE 2. Calibration plot for each score. AF, Atrial fibrillation.

score was 1 point higher (OR, 1.18; 95% CI, 1.018-1.36). The test showed good calibration (HL test $P = .75$) (Figure 2 and Table 3).

HATCH Score

Median HATCH score was 2 (IQR, 1-3) in patients with postoperative AF and 1 (IQR, 1-2) in those without it ($P < .001$).

The AUC-ROC was 0.70 (95% CI, 0.67-0.72) (Figure 1). The best cut-off point to predict postoperative AF was ≥ 1 , with a sensitivity of 58% (95% CI, 53.75%-61.47%); specificity 76% (95% CI, 74.60%-78.00%); and positive and negative predictive value of 40% and 87%, respectively. The probability of developing AF increased as the score was 1 point higher (OR, 1.62; 95% CI, 1.37-1.92). The test showed good calibration (HL test $P = .21$) (Figure 2 and Table 3).

The univariate analysis identified the following factors associated with postoperative AF: sex, age, use of CPB, COPD, smoking habits, HT, left ventricle dysfunction, high additive European system for cardiac operative risk evaluation score (>5), type of surgery, and use of inotropic drugs. At multivariable analysis, the CHA2DS2-VASc, POAF, and HATCH scoring systems were predictors of AF ($P = .05$), but the highest OR was achieved by the CHA2DS2 VASc score: 1.87 as the score was 1 point higher (95% CI, 1.64-2.13; $P < .001$). Other variables associated were female sex and age; and for the POAF score, the presence of HT and HF for the regression model (Table 4).

DISCUSSION

This study demonstrates the ability of the CHA2DS2-VASc, HATCH, and POAF scoring systems to predict the development of AF after cardiac surgery, demonstrating their performance in terms of discrimination and calibration, and the ability to determine those patients with low probability of presenting AF after cardiac surgery, with high negative predictive values. The CHA2DS2-VASc score demonstrated the highest predictive ability. Although other factors such as age and sex are clearly associated with the development of postoperative AF, the usefulness of the CHA2DS2-VASc should be noted because it is a simple bedside tool and easy to remember.

Postoperative AF occurred in 21% of patients in this study, a number that is lower than reported previously.^{15,25,29} An explanation for this could be that most of the surgeries included in our study were CABG, and only 2% of these were performed with CPB, compared with other studies where its use was significantly higher.^{12,20,26,31}

As in other studies,^{11,12,18,20,32} patients with postoperative AF presented more comorbidities, expressed as a higher additive European System for Cardiac Operative Risk Evaluation score, more cardiovascular risk factors, and higher prevalence of pulmonary diseases. There was no difference in the use of beta blockers during the preoperative period.

Several previous retrospective studies have demonstrated the independent association between the CHA2DS2-VASc score and the incidence of postoperative AF, but in all cases the studies recruited small samples. In addition, ours is the first study analyzing the score in a Latin American population, and was validated and compared with other scoring systems.

In a retrospective study, Borde and colleagues²⁷ evaluated 729 patients after CABG surgery in India, and demonstrated an association between postoperative AF and a CHA2DS2-VASc score ≥ 3 with an OR of 3.68. As opposed to our experience, they did not include combined procedures or valve surgeries.

In a prospective study, Chua and colleagues²⁴ analyzed only 277 patients undergoing CABG surgery or valve

TABLE 3. Contingency table for Hosmer-Lemeshow test

Deciles	CHA2DS2-VASc score			
	Without postoperative AF		With postoperative AF	
	Observed	Expected	Observed	Expected
1	282	288.491	14	7.509
2	400	395.862	13	17.138
3	304	296.875	16	23.125
4	224	223.673	24	24.327
5	352	342.593	45	54.407
6	283	286.855	79	75.145
7	249	251.887	99	96.113
8	183	191.357	124	115.643
9	181	180.408	240	240.592
POAF score				
1	333	329.522	10	13.478
2	329	330.505	19	17.495
3	447	451.677	64	59.323
4	176	182.482	36	29.518
5	261	258.181	52	54.819
6	269	263.288	87	92.712
7	117	116.965	48	48.035
8	232	227.261	115	119.739
9	294	298.120	223	218.880
HATCH score				
1	166	176.913	166	176.913
2	72	60.862	72	60.862
3	8	8.346	8	8.346
4	180	171.685	180	171.685
5	86	94.194	86	94.194

AF, Atrial fibrillation.

surgery. The Kaplan-Meier analysis indicated a higher rate of postoperative AF based on CHADS2 and CHA2DS2-VASc scores >2 . The AUC-ROC was 0.87, which is higher than found in our study. Finally, Kashani and colleagues²⁶

TABLE 4. Multivariable analysis to predict postoperative atrial fibrillation

	Multivariable analysis	
	Odds ratio	
	(95% confidence interval)	P value
CHA2DS2-VASc score	1.87 (1.64-2.13)	$<.001$
POAF score	1.18 (1.018-1.36)	.048
HATCH score	1.62 (1.37-1.92)	$<.001$
Age*	1.03 (1.01-1.05)	$<.001$
Female	1.75 (1.37-2.22)	$<.001$
Hypertension	1.86 (1.41-2.31)	$<.001$
Heart failure	1.96 (1.38-2.61)	$<.001$

*By year of age.

made a retrospective evaluation of 2385 patients who underwent CABG surgery or valve surgery. At multiple-regression analysis, high-risk patients (score ≥ 2) had a significantly greater probability of developing postoperative AF compared with the low-risk group (OR, 5.21; $P < .0001$), with an AUC that was lower than the one determined in our study (0.65) and a sensitivity of 74%. In this study, the incidence of postoperative AF was lower (15%) than reported in international registries; therefore, the sample may not be representative.

The discriminative ability of the HATCH score in patients undergoing CABG surgery was only evaluated by Emren and colleagues³¹ who compared this score with the CHA2DS2-VASc score. Unlike our findings, the HATCH score presented higher predictive ability with an AUC of 0.77 versus 0.71 for the CHA2DS2-VASc score.

The POAF score was the only scoring system that was created and validated to predict postoperative AF using 7 variables identified in a multivariable analysis.¹⁵ The score

was applied to patients undergoing CABG surgery or valve surgery. The discriminative ability of the score was moderate, with an AUC of 0.66 in the original cohort and of 0.65 in the validation cohort. Both cohorts presented good calibration.

Recently, the predictive ability of the POAF score, the CHA2DS2-VASc, and the Atrial Fibrillation Risk Index was compared in patients undergoing nonemergent CABG surgery or valve surgery. The incidence of postoperative AF was remarkably higher, near 34%, with poor discrimination and calibration for the 3 scoring systems, with AUC-ROC for prediction of postoperative AF < 0.6.²⁹

The advantage of these scoring systems lies on the possibility of predicting the development of postoperative AF in low-risk patients and thus, avoiding unnecessary treatment with beta blockers or amiodarone. The use of the score can also warn an attending physician during the preoperative evaluation of the necessity of indicating prophylaxis with drugs to prevent postoperative AF. The scores can predict postoperative AF from the moment a patient is admitted to a cardiovascular recovery unit to facilitate preventive measures such as drug therapy or dual site atrial pacing.

As far as limitations of this study, we should mention the retrospective nature and the fact that it was conducted in a high-complexity cardiovascular center; therefore, the sample may not be representative of other centers in our country. However, the results can be extrapolated due to the size of the cohort and the number variables included. Another limitation is that not all patients had the same duration of continuous telemetry. All had at least 48 hours, but more severely ill patients continued monitoring for longer. Therefore, it could have underdiagnosed asymptomatic AF, especially in patients who required less monitoring time.

CONCLUSIONS

The POAF, CHA2DS2-VASc, and HATCH scoring systems showed good discrimination and calibration to predict postoperative AF in cardiac surgery patients. Among them, the CHA2DS2-VASc score presented the best discriminative ability for postoperative AF and has the advantage of being easy to calculate, constituting a useful tool to identify low-risk patients during the preoperative period.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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