RESEARCH ARTICLE

DETERMINANTS OF POSTOPERATIVE ATRIAL FIBRILLATION: A RETROSPECTIVE EVALUATION OF POSTOPERATIVE ATRIAL FIBRILLATION IN CARDIAC SURGERY

Tariq Shaheed, DO[1]; Jake Martinez, DO[1]; Amanda Frugoli, DO[1,2]; Weldon Zane Smith, PhD[3]; Ian Cahatol, DO[1]; Omid Fatemi, MD[4]

[1]Department of Internal Medicine, Community Memorial Hospital, Ventura, California
[2]Department of Graduate Medical Education, Community Memorial Hospital, Ventura, California
[3]California State University Channel Islands, Camarillo, California
[4]Department of Cardiology, Community Memorial Health System, Ventura, California

KEYWORDS:

Arrhythmia

Atrial fibrillation

Cardiac surgery

Postoperative atrial fibrillation

Introduction: Atrial fibrillation is the most common postoperative arrhythmia and is associated with increased length of stay, cost, morbidity and mortality.[1–4] The incidence of postoperative atrial fibrillation for noncardiac, nonthoracic surgeries ranges from 0.4% to 26%.[5] The incidence increases to 20%–50% in cardiac surgery, occurring in approximately 30% of isolated coronary artery bypass grafting (CABG), approximately 40% of isolated valve surgeries and up to 50% of CABG plus valve surgeries.[6–8] Our aim was to identify risk factors that may predispose patients to postoperative atrial fibrillation and compare the efficacy of previously developed prediction tools to a new bedside prediction tool. We sought to develop a bedside screening tool using 4 easily identifiable variables: body mass index, age, congestive heart failure and hypertension (BACH). We predicted that our model would compare similarly to previously developed and validated prediction models but would be easier to use.

Methods: We retrospectively identified 672 patients without a history of atrial fibrillation who had undergone cardiac surgery from July 2011 to December 2018. The risk factors for atrial fibrillation were evaluated alongside previously developed prediction tools. Using logistic regression, *t* tests and receiver operator characteristic (ROC) analysis, we compared previously used risk stratification scores of CHA_2DS_2-VASc, CHARGE-AF and age. We also compared our proposed BACH risk prediction tool to our population and compared it against CHA_2DS_2-VASc, CHARGE-AF and age. In a subpopulation analysis of 259 people, we evaluated if left atrial size was an independent risk factor for the development of postoperative atrial fibrillation.

Results: A total of 131 patients—approximately 20%—developed postoperative atrial fibrillation. CHA_2DS_2-VASc had the lowest area under the curve (AUC) and did not perform as well at classifying patients with postoperative atrial fibrillation as the other 3 predictors. CHARGE-AF, age by itself and age per 5 years performed relatively similarly to one another. ROC was greatest for age alone (ROC area .634, 95% CI: .581–.688), followed by CHARGE-AF (ROC area .631, 95% CI: .577–.684), and finally CHA_2DS_2-VASc (ROC area .564, 95% CI: .509–.619). A logistic model was fit for the BACH variables (continuous versions of body mass index, age, congestive heart failure and hypertension). The model achieved good fit, $\chi^2(671, N=672)=633.029$, $P=.816$, Nagelkerke $R^2=.070$. However, only the predictors of age and prior heart failure were found to be significant. For BACH, the C-statistic (and AUC) for the model was .645 (95% CI: .601, .707), which was marginally better than age alone. All the models that were fit using ROC analyses were not statistically different from one another in terms of performance. No statistical significance was found between the 2 groups for preoperative left atrial size.

Conclusion: These findings suggest that age may be the highest risk factor for postoperative atrial fibrillation. The bedside prediction tool BACH compared slightly better than age alone but was not statistically different from the other prediction tools' performance. The BACH prediction tool is easy to use, includes only 4 factors that are readily available at the bedside and improves prediction over age alone.

CORRESPONDENCE:
Ian Cahatol, DO | icahatol@cmhshealth.org

 Print ISSN: 1877-573X
DOI: doi:10.33181/13062

INTRODUCTION

Atrial fibrillation is the most common postoperative arrhythmia and is associated with increased mortality and significant morbidity including increased risk of stroke, myocardial infarction and persistent congestive heart failure.[1–3] Additionally, it leads to an increase in healthcare resources including cost, prolonged intensive care unit stay and length of hospital stay.[2,4] In various studies it has been linked to an average increased length of stay of 3 days and an increase in total hospital cost of nearly $10,000.[9] The incidence of postoperative atrial fibrillation for noncardiac, nonthoracic surgeries ranges from 0.4% to 26%.[5] The incidence increases to 20%–50% in cardiac surgery, occurring in up to 30% of isolated coronary artery bypass grafting (CABG), approximately 40% of isolated valve surgeries, and up to 50% of CABG plus valve surgeries.[6–8,10]

Given the high frequency of postoperative atrial fibrillation combined with the associated increase in mortality, morbidity and healthcare costs, significant efforts have been made to predict patients who are at the highest risk. These efforts are to attempt to decrease postoperative atrial fibrillation occurrence by using prophylactic antiarrhythmics. Over the past 2 decades, numerous studies have attempted to decrease the occurrence of postoperative atrial fibrillation with beta blockers, amiodarone, sotalol, magnesium, digoxin and non-dihydropyridine calcium channel blockers with inconsistent results. Beta blockers and amiodarone have shown the most promising results in decreasing postoperative atrial fibrillation.[9,11–16] Unfortunately these treatments are associated with increased side effects. Prophylactic use of beta blockers has been associated with hypotension, bradycardia, and pulmonary edema due to its suppression of myocardial inotropy. These risks are amplified in beta blocker–naive patients.[17,18] Amiodarone is also associated with hypotension and bradycardia in addition to QT prolongation and pulmonary, hepatic and thyroid toxicity.[14,19] In the past few years, Skiba *et al* completed a prospective, randomized, single-blind, controlled pilot study in patients undergoing elective cardiac surgery to receive either standard therapy, metoprolol or amiodarone. They were able to identify that perioperative metoprolol but not amiodarone was associated with a significant reduction in postoperative atrial fibrillation.[20] This blanket prophylactic study also demonstrated the significance of bradycardia, as 40% were unable to be assigned treatment due to bradycardia.[20]

Although these studies have demonstrated the possibility of decreasing postoperative atrial fibrillation, they have also shown risks and decreased efficacy when using a blanket prophylaxis strategy. As a result, many studies have attempted to identify predictors of post–cardiac surgery atrial fibrillation. These have been developed in attempts to determine which patients would have the greatest benefit of a prophylaxis strategy while mitigating the possible medication side effects.[21–27] Ferreira *et al* also found that larger left atrial diameter is an independent risk factor for postoperative atrial fibrillation. This was also supported by Osranek *et al*, who suggested that left atrial volume was a strong and independent predictor of postoperative atrial fibrillation.[28] Although supported by few studies, the left atrial size or volume has not consistently been demonstrated to be an independent risk factor. Left atrial size or volume has not been included in any of the previously published risk calculators. Despite the high number of trials and development of multiple risk calculators, advanced age has consistently been shown to be the most significant risk factor for increased risk of postoperative atrial fibrillation.[4,6–9,21,22,27] Other predictive tools have been studied and shown to be somewhat predictive; however, few have shown to be better than age alone. In a recent large study comparing the CHA_2DS_2-VASc score, Cohorts for Heart and Aging Research in Genomic Epidemiology (CHARGE)-AF score, and a risk model for predicting postoperative atrial fibrillation following cardiac operations (POAF score) with age, only CHARGE-AF performed better than age alone in the prediction of postoperative atrial fibrillation. Despite the large number of studies, there remains no consensus of who or how to prophylactically treat in order to decrease occurrence of postoperative atrial fibrillation. In this study, we investigated the ability of CHARGE-AF, CHA_2DS_2-VASc, BACH (body mass index [BMI], age, congestive heart failure and hypertension) and age to predict new-onset postoperative atrial fibrillation in a community setting after cardiac surgery.

METHODS

This single center retrospective study identified 672 patients without a prior history of atrial fibrillation who underwent cardiac surgery including CABG, aortic or mitral valve surgery, or any combination of these from July 2011 to December 2018 in a community hospital in California. The study used electronic health information combined with data from the Society of Thoracic Surgeons cardiothoracic database. Postoperative atrial fibrillation development was determined by ICD billing codes. This included development of atrial fibrillation any time in the postoperative inpatient treatment period. Any length or burden of atrial fibrillation was included. Additional subpopulation was developed using ICD billing codes for atrial fibrillation, and manual chart review was completed on 259 patients to obtain echocardiogram metrics for left atrial size.

The data was then used to identify age in addition to calculating the CHARGE-AF and CHA_2DS_2-VASc scores.[29,30] Preoperative intra-aortic balloon pump utilization (IABP) was not available on many patients and was unable to be included in the analysis for risk factor. This precluded the ability to evaluate POAF score against the prior studies and our proposed bedside tool, BACH. BACH was developed as a historical tool that could be used at the bedside prior to surgery to determine if these factors combined could be used to predict new-onset postoperative atrial fibrillation. The CHARGE-AF tool uses 10 different variables and barely outperforms age alone; this is more cumbersome in beside use. We hypothesized that we could use BACH variables with similar performance. This study was approved by the institutional review board.

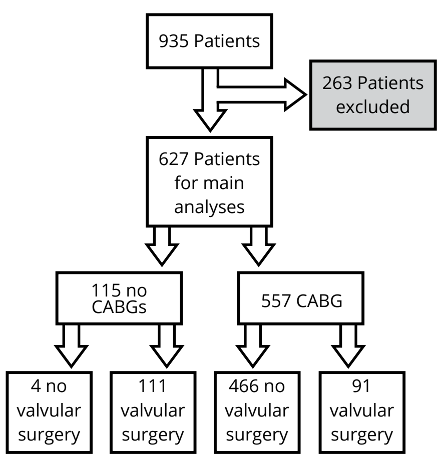
Study data

Patient data was obtained from a single hospital's electronic health record (EHR) system combined with data provided to the Society of Thoracic Surgeons cardiothoracic database. The data was then used to identify age, in addition to calculating CHARGE-AF and CHA_2DS_2-VASc scores.[29,30]

INCLUSION AND EXCLUSION

Inclusion criteria were all patients older than 18 who underwent cardiac surgery including CABG, valvular or both, July 2011–December 2018. Exclusion criteria included those with any history of atrial fibrillation preoperatively. In total, there were 263 of 935 patients excluded from the cohort analysis due to missing information or prior history of atrial fibrillation. Of the remaining 672 patients, 115 did not undergo CABG, while 557 did, and 202 patients had valvular surgery, while 470 did not. Of the patients who did not undergo CABG, 4 had no valvular surgery, while 111 did, and of the patients who did undergo CABG, 466 had no valvular surgery, while 91 did. A visual breakdown of patients is provided in Figure 1.

FIGURE 1:



STATISTICAL ANALYSES

To investigate demographic differences, chi-square tests of independence were performed to test for differences in the discrete variables of patients: sex; diabetes; current smoker status; hypertension; whether patients were taking antihypertension medication; and whether patients had a stroke, congestive heart failure or myocardial infarction in the past. Independent-samples *t* tests were performed to test for differences in continuous demographic variables of patients: age, BMI, height, weight, preoperative blood pressure (systolic and diastolic), the 2 risk scores (CHA_2DS_2-VASc, CHARGE-AF), and preoperative left atrial size (pre-op LA size). Pre-op LA size was measured for only a portion of the sample: 259 patients.

To investigate how well different scores could identify postoperative atrial fibrillation, receiver operator characteristic (ROC) curve analyses were performed for age, $CCHA_2DS_2$-VASc and CHARGE-AF. Logistic regression was performed with the variables used in the formation of CHARGE-AF scores to determine how well the prediction model worked in the current sample. Afterward, another logistic regression was performed using uncategorized versions of the categorical variables used in the CHARGE-AF model (age, weight, height, systolic blood pressure and diastolic blood pressure). Finally, the BACH model proposed in this study (age, BMI, congestive heart failure and hypertension defined using systolic and diastolic blood pressure) was fit to the data to investigate its predictive power.

A combination of the variables used to create CHARGE-AF and CHA_2DS_2-VASc scores were included in ROC analyses to determine whether better classification could be achieved in the current sample. In addition to the ROC analyses, logistic regression models were fit on the variables included in CHA_2DS_2-VASc and CHARGE-AF, as well as a combination of the variables, including potential confounding variables, used to create the risk scores to determine the most important predictors of postoperative atrial fibrillation.

RESULTS

Demographic analyses

Demographics of the 672 patients in the study cohort were summarized in Table 1. Incidence of postoperative atrial fibrillation was 19.5%. A total of 131 patients developed postoperative atrial fibrillation and 541 did not. The 2 groups of patients were quite similar to one another, only statistically differing on a few variables. Regarding discrete variables, only history of prior congestive heart failure significantly differed between groups, $\chi^2(1, N=672)=4.028$, $P=0.045$, $\Phi=0.07$. Despite being statistically significant, the relationship between heart failure and postoperative atrial fibrillation was rather weak.

For the continuous variables, age and the 2 risk scores were statistically significant. For age, $t(670)=-4.694$, $P<.001$, $d=0.46$, and Levene's test of homogeneity of variance was non-significant, $P=.577$, suggesting the variances were the same in both groups. The groups differed by 4.761 years (95% CI: −6.749, −2.773) on average. The effect size of the difference between the 2 groups was medium in size.[25] For CHA_2DS_2-VASc, $t(670)=-2.175$, $P=.030$, $d=0.21$, and Levene's test was nonsignificant, $P=.753$. The groups differed by 0.502 points (95% CI: −0.723, −0.280), a small effect size. Finally, for CHARGE-AF, $t(670)=-4.450$, $P<.001$, $d=0.44$, and Levene's test was nonsignificant, $P=.513$. The groups differed by 0.502 points (95% CI: −0.723, −0.280), a medium effect size.

No statistical significance was found between the 2 groups for pre-op LA size, $t(96.85)=-0.276$, $P=.730$, $d=0$. Levene's test of homogeneity of variance was significant, $P=.004$, suggesting the variances were different between groups, so a correction for heterogeneity of variance was performed. Additionally, an independent-samples Mann-Whitney *U* test also found nonsignificance, $P=.709$. The difference of 0.035 cm (95% CI: −0.233, −0.164) was negligible.

TABLE 1:

Patient characteristics

CHARACTERISTIC	POST-OP AFIB (N=131, 19.5%)	NO POST-OP AFIB (N=541, 80.5%)	*P* VALUE
Age, mean + SD, years	70.9±10.33	66.2±10.437	<.0001*
Body mass index, mean ± SD, kg/m²	28.6±5.1	28.6±5.0	.968
Height, mean ± SD, cm	173.4±10.4	171.4±10.3	.057
Weight, mean ± SD, kg	86.2±18.0	84.2±17.1	.242
Sex			.680
Female	32 (24.4)	123 (22.7)	
Male	99 (75.6)	418 (77.3)	
Diabetes	46 (35.1)	230 (42.5)	.122
Current smoker	16 (12.2)	82 (15.2)	.392
Hypertension	98 (74.8)	440 (81.3)	.094
Antihypertensive medication	110 (84.0)	484 (89.5)	.078
Stroke TIA	9 (0.07)	41 (0.08)	.782
Congestive heart failure	19 (0.15)	47 (0.09)	.045*
Prior MI	56 (42.7)	206 (38.1)	.325
Preoperative blood pressure, mean ± SD, mm Hg			
Systolic	135.9±23.5	136.4 ± 22.7	.819
Diastolic	71.1±15.0	73.6 ± 14.4	.064
Pre-op LA size (n=259)			.730
N	48	211	
Mean ± SD, cm	4.1±0.6	4.0±0.8	
Risk scores			
CHA_2DS_2-VASc			.030*
Mean ± SD	3.8±1.9	3.4±1.8	
Median (IQR)	4.0 (3.0)	3.0 (3.0)	
CHARGE-AF		< .0001*	
Mean ± SD	13.4±1.1	12.9±1.2	
Median (IQR)	13.6 (1.6)	13.0 (1.6)	

Note: * denotes $P<.05$. For continuous variables, the *P* value represents that of an independent-samples t-test.
For discrete variables, the *P* value represents that of a chi-square test of independence.

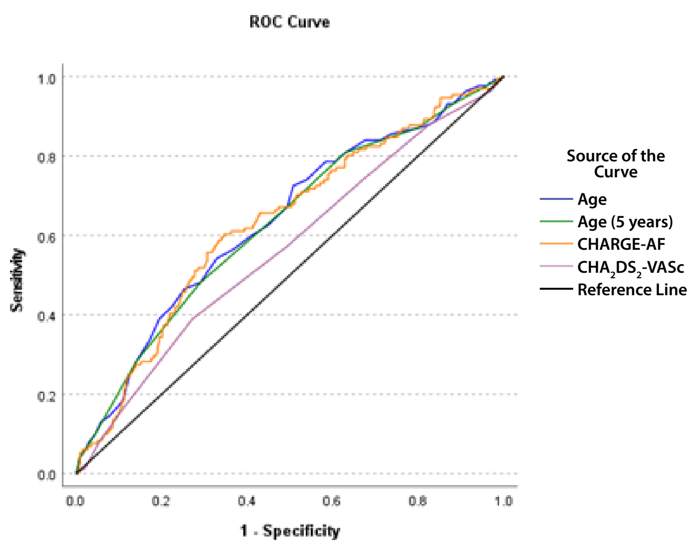
Abbreviations: afib, atrial fibrillation; SD, standard deviation; TIA, transient ischemic attack; MI, myocardial infarction; LA, left atrial; IQR, interquartile range.

Receiver operator characteristic curve analyses

To investigate whether the scores accurately classified patients, ROC analyses using CHA_2DS_2-VASc and CHARGE-AF scores, age by itself, and age per 5 years were entered into the area under the curve (AUC) analyses using 131 individuals who experienced postoperative atrial fibrillation and 541 who did not. A comparison of the ROC curves for each of these 4 analyses can be found in Figure 2. AUC was significant for all 4 analyses. For CHA_2DS_2-VASc, the AUC was .564 (P=.24, 95% CI: .509, .619), for CHARGE-AF, the AUC was .631 (P<.001, 95% CI: .577, .684), for age by 5 years the AUC was .627 (P<.001, 95% CI: .573, .681), and for age by itself, the AUC was .634 (P<.001, 95% CI: .581, .688). AUC=.5 represents chance accuracy, while AUC=1 indicates perfect accuracy.[31] CHA_2DS_2-VASc had the lowest AUC and did not perform as well at classifying patients with postoperative atrial fibrillation status as the other 3 predictors. CHARGE-AF, age by itself and age per 5 years performed relatively similarly to one another.

FIGURE 2:

Graphic representation of ROC analyses



Logistic regression analyses

CHARGE-AF

A logistic regression analysis was performed using the predictors from the CHARGE-AF score to determine how the model fit for the sample in the current study, and its results are displayed in Table 2. The model achieved good fit, $\chi^2(661, N=672)=622.126$, P=.884, Nagelkerke R^2=.094. The C-statistic for the model was .675 (95% CI: .624, .726). Although the model achieved good fit, many predictors were found to be nonsignificant. Only age, antihypertensive medication use and prior congestive heart failure were significant predictors.

TABLE 2:

Logistic regression with CHARGE-AF

PREDICTOR	ß	S.E.	SIG.	OR
Age (5 yr)	0.247	0.056	.000**	1.280
Height (10 cm)	0.095	0.114	.404	1.100
Weight (15 kg)	0.181	0.101	.075	1.198
Systolic BP (20 mm Hg)	0.035	0.102	.732	1.035
Diastolic BP (10 mm Hg)	−0.109	0.880	.212	0.897
Current smoker	0.63	0.315	.842	1.065
Antihypertensive medication use	−0.669	0.305	.028*	0.512
Diabetes	−0.299	0.223	.181	.742
Congestive heart failure	0.711	0.310	.022*	2.036
Myocardial infarction	0.351	0.212	.099	1.420
Constant	−6.447	2.112	.002	.002
Note. * is significant at the .05 level and ** at .001.				

CHARGE-AF UNCATEGORIZED

A logistic regression analysis was also performed using uncategorized predictors from the CHARGE-AF score (using continuous versions of age, weight, height, systolic blood pressure, and diastolic blood pressure rather than categorized versions) to attempt to form a better prediction model for postoperative atrial fibrillation. Results from this model are displayed in Table 3. Using the CHARGE-AF model achieved good fit, $\chi^2(661, N=672)=617.833$, $P=.884$, Nagelkerke $R^2=.104$. The C-statistic for the model was .689 (95% CI: .638, .739). However, only the predictors of antihypertensive medication, prior heart failure and age were found to be significant.

BACH

A logistic model was fit for the BACH variables (using continuous versions of age, BMI, systolic blood pressure, and diastolic blood pressure along with congestive heart failure), to attempt to create a better bedside prediction model for postoperative atrial fibrillation. Results from this model are displayed in Table 4. The model achieved good fit, $\chi^2(671, N=672)=633.029$, $P=.816$, Nagelkerke $R^2=.070$. However, only the predictors of age and prior heart failure were found to be significant. Figure 3 displays an ROC analysis comparing the BACH model to just using age. For BACH, the C-statistic (and AUC) for the model was .645 (95% CI: .601, .707), which was marginally better than age alone, but again all of the models fit using ROC analyses were not statistically different from one another in terms of performance.

TABLE 3:

Logistic regression using uncategorized CHARGE-AF predictors

PREDICTOR	ß	S.E.	SIG.	OR
Age	0.053	0.011	.000**	1.054
Height	0.013	0.012	.257	1.014
Weight	0.013	0.007	.075	1.013
Systolic BP	0.001	0.005	.791	1.001
Diastolic BP	−0.012	0.009	.187	0.988
Current smoker	0.086	0.316	.785	1.090
Antihypertensive medication use	−0.688	0.307	.025*	0.502
Diabetes	−0.297	0.225	.186	0.743
Congestive heart failure	0.740	0.313	.018*	2.096
Myocardial infarction	0.362	0.213	.090	1.437
Constant	−7.304	2.156	.001	.001
Note. * is significant at the .05 level and ** at .001. Variables in bold differ from the previous model in that they were included as continuous rather than discrete. Abbreviations: BP, blood pressure.				

TABLE 4:

Logistic regression using BACH predictors

PREDICTOR	ß	S.E.	SIG.	OR
Age	0.048	0.011	.000**	1.049
BMI	0.017	0.020	.377	1.018
Systolic BP	−0.001	0.005	.914	0.999
Diastolic BP	−0.009	0.009	.308	0.991
Congestive heart failure	0.701	0.302	.021*	2.105
Constant	−4.535	1.173	.000**	0.011
Note. * is significant at the .05 level and ** at .001. Abbreviations: BMI, body mass index; BP, blood pressure.				

FIGURE 3:

ROC curves comparing age and BACH

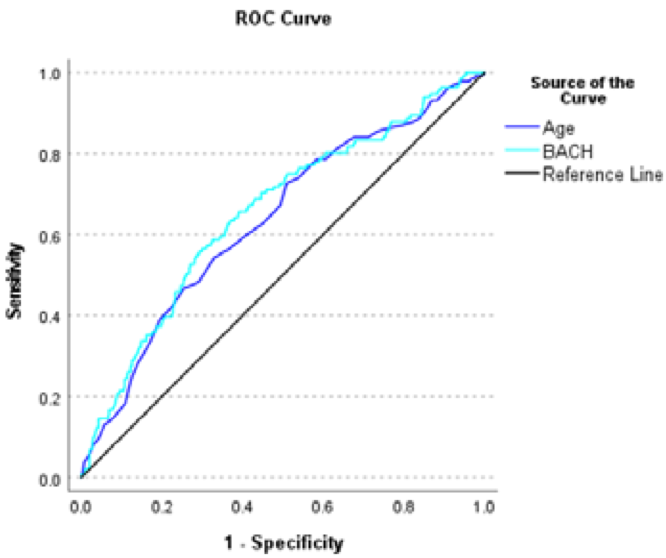
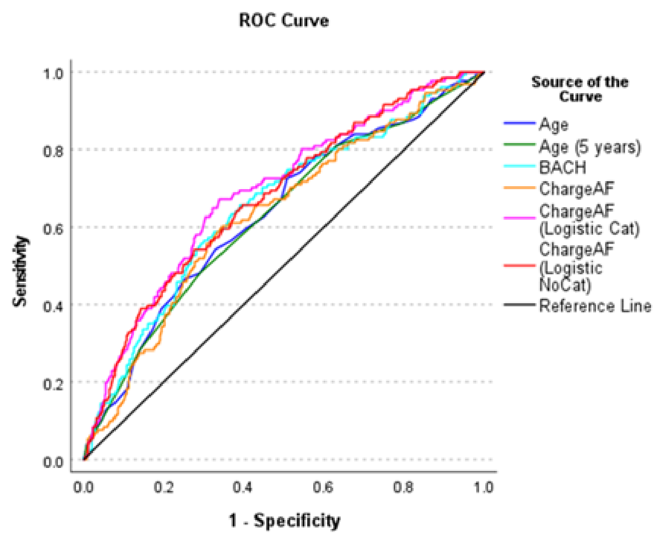


FIGURE 4:

ROC curves comparing prediction model



Investigating a better model

Using the CHARGE-AF model with continuous versions of each variable, additional predictors were investigated to determine whether a better predictive model could be built using readily available variables. The inclusion of CHA_2DS_2-VASc predictors such as prior stroke/transient ischemic attack ($\chi^2(1)=0.259$, $P=.611$), vascular disease ($\chi^2((1)=0.048$, $P=.827$), and gender ($\chi^2(1)=1.271$, $P=.260$), failed to statistically improve the model based on chi-square difference tests.

To determine whether the model would benefit from the inclusion of BMI instead of having height and weight separately, model comparisons were performed between nested models. First, a base model including all variables from Table 3 besides height and weight was fit. Next, BMI was introduced as a predictor. The inclusion of BMI did not significantly improve the model, $\chi^2(1)=2.129$, $P=.145$. Height and weight were added into the base model, which resulted in a significant improvement to the model, $\chi^2(2)=9.369$, $P=.009$. This suggests that despite not being significant predictors, height and weight were important for the overall performance of the model. This was true for height and weight by themselves, but not when combined into BMI.

ROC analyses using CHARGE-AF, age, age by 5 years, the logistic model using CHARGE-AF variables, the logistic model using CHARGE-AF variables without categorizing age, weight, height, systolic blood pressure and diastolic blood pressure, and BACH showed that overall the final model, utilizing uncategorized variables, was more successful than others. However, all models performed quite similarly to one another as seen in Figure 4.

The ROC analysis for age along with the computation of Youden's *J* to balance sensitivity and specificity found that the age of 66 was the ideal cut point between those at greater risk for developing postoperative atrial fibrillation.[32] Similarly, the use of Youden's *J* with age by 5 years found the age of 65 as an ideal cut point.

Overall, the CHA_2DS_2-VASc and CHARGE-AF criteria performed relatively poorly in this sample compared to previous studies.[26] The BACH model did not significantly improve over CHARGE-AF, and age by itself performed similarly to the more complex models. Although prediction could be improved by fitting a logistic regression to obtain new coefficients for CHARGE-AF, and prediction could be further improved by using continuous variables rather than categorized ones, the improvements were considered marginal.

DISCUSSION

The incidence of postoperative atrial fibrillation for this cohort was 19.5%, which is similar to previously published literature. This information is supportive and also helps illustrate the burden of this arrhythmia postoperatively. The overall goal of this investigation was to determine predictors of atrial fibrillation and evaluate prediction tools in a community setting. During this process we evaluated if left atrial size would be an independent risk factor. Based on this review using a subpopulation of patients, we determined left atrial size was not an independent risk factor. This is similar to some prior studies but contrary to others.[28,33]

Our primary investigation compared the performance of well-known predictive tools CHARGE-AF, CHA_2DS_2-VASc and age in a community hospital patient population undergoing cardiac surgery. We also developed a bedside prediction tool using historical data that is readily available and easy to use, consisting of only 4 factors. Unfortunately, the previously developed POAF calculator was excluded from our study due to inadequate numbers/missing data of preoperative intra-aortic balloon pump placement in our cohort.[24] However, the POAF calculator has been compared to CHARGE-AF and age alone in a study of 9416 consecutive patients by Pollock *et al*, revealing it to be less predictive of postoperative atrial fibrillation than CHARGE-AF and age but slightly better than CHA_2DS_2-VASc.[27] Additionally, preoperative intra-aortic balloon pump placement does not apply to patients undergoing elective cardiac surgery.

Our evaluation and comparison of CHARGE-AF, age and CHA_2DS_2-VASc revealed each of these risk stratification tools showed statistically significant differences in the group of patients who developed postoperative atrial fibrillation. The difference was larger in CHARGE-AF and age when compared to CHA_2DS_2-VASc. Interestingly, age was a better predictor of postoperative atrial fibrillation when compared to the aforementioned tools in our cohort. The findings of Pollock *et al* were similar in that they found age and CHARGE-AF to be the best predictors. In their evaluation, however, they found that CHARGE-AF was slightly better than age alone. Logistic regression showed a history of congestive heart failure and increasing age in this sample resulted in increased risk of postoperative atrial fibrillation. These predictors alone, or in combination, did not prove to be a better predictive model when compared to age alone, CHARGE-AF or BACH.

Our bedside prediction tool, BACH, compared similarly to the previously developed prediction tools. ROC analyses using CHARGE-AF; age; age by 5 years; the logistic model using CHARGE-AF variables; the logistic model using CHARGE-AF variables without categorizing age, weight, height, systolic blood pressure and diastolic blood pressure; and BACH all showed that overall, the final model—utilizing uncategorized variables—was more successful than others. For BACH, the C-statistic (and AUC) for the model was .645 (95% CI: .601, .707), which was marginally better than age alone. When compared using all the models that were fit using ROC analysis, BACH was not statistically different in terms of performance. In review of the BACH model, age and prior heart failure were the strongest predictors. Although the BACH model did not improve the prediction, surprisingly, it had similar success with fewer variables. Although the variables needed to calculate the CHARGE-AF score are readily available in the electronic health record, simplifying the prediction score to the 4 variables in the BACH score may improve physician utilization and standardization.

Based on our findings and the importance of age in all of the previously studied prediction tools, including our BACH tool, we attempted to further clarify what age would be the ideal cutoff for classification of patients as high risk. An ROC analysis for age, along with the computation of Youden's *J* to balance sensitivity and specificity, found that the age of 66 was the ideal cut point between those at greater risk for developing postoperative atrial fibrillation and those who are not.[32] Further studies are needed to look at the potential use of age alone in predicting postoperative atrial fibrillation; the ideal age cutoff that would make a patient "high risk"; and continued efforts to identify a better predictive model, which can then possibly lead to firm guidelines of who should be considered high risk and receive prophylactic arrhythmias per the 2019 American College of Cardiology/American Heart Association/Heart Rhythm Society guidelines.

A consensus postoperative atrial fibrillation prediction tool remains elusive. Multiple prediction tools have been developed with varying predictive capabilities and consistency. Given the findings in both our study and the larger recent study by Pollock *et al*, it seems that age may be the most useful predictor of postoperative atrial fibrillation.[27] Additionally, adding variables does not improve prediction, and in our setting, the 4 variables of BACH performed similarly.

STRENGTHS AND LIMITATIONS

As with other retrospective analysis, there is risk for confounding as well as selection bias, which are the limitations of such study design. Some patients had to be excluded from analysis due to lacking data in IABP use and sex. Thus, the POAF score had to be excluded from this analysis. Researchers attempted to limit the effects of confounding variables by using case matched controls with an equal number of all variables in both groups. This study's cohort was relatively small when compared to a CHARGE-AF derivation cohort of over 26,000 participants, and it was geographically limited to a single center in Southern California, whereas CHARGE-AF utilized 3 separate cohorts.[29] The percentage of women included was 23.1%, which reflects the clinical practice of a single surgical group and somewhat limits generalizability. Our findings are similar to Pollock *et al*, which demonstrated CHARGE-AF and age as better predictors than the POAF bedside score.[29]

Strengths of the study include that patients who had pre-existing atrial arrhythmias were excluded from analysis. Some of the previously published prediction models included patients with preoperative history of atrial fibrillation, which calls into question the incidence of new-onset atrial fibrillation in these study cohorts.[24] Our study cohort included only patients without known preoperative atrial fibrillation who developed it during hospital stay, which is the population who have been shown to have longer length of stay and are at higher risk of perioperative stroke.[1–4] Our ROC analysis independently validates BACH, CHARGE-AF and age alone as potential tools for prediction of atrial fibrillation, adding evidence to previously reported studies.

Despite many studies, postoperative atrial fibrillation remains difficult to predict. As per the 2019 AHA/ACC/HRS guidelines, beta blockers should be continued if already prescribed, and preoperative administration of amiodarone is reasonable for prophylactic therapy in patients at high risk for developing postoperative atrial fibrillation.[34] The lack of a consensus on how to quantify high risk highlights the need for a reliable and easy-to-use method of identifying those at high risk. This is particularly important to prevent blanket prophylaxis with medical therapies that have been shown to have significant adverse side effects.[14,17–19]

CONCLUSION

Our analysis suggests increasing age, BACH and CHARGE-AF are the best predictors of determining patients at higher risk of postoperative atrial fibrillation. Increasing age alone carried the most weight in our study and thus may be considered to identify high-risk patients preoperatively. Further studies need to be performed to confirm these findings as well as utilize the BACH method in a randomized controlled trial for prevention of this dangerous and costly arrhythmia.

Funding and Disclosures: None of the authors or contributors to this study have any financial gain or sponsorship for this study. This study had no financial support.

Data Availability Statement: The data utilized for this research is part of the Society of Thoracic Surgeons Cardiothoracic Database and included the specific data contributed from our community hospital July 2011–December 2018. The specific data can be obtained from contacting our corresponding author to have access to the de-identified information if access is granted by the institutional review board at Community Memorial Hospital.

REFERENCES:

1. Almassi GH, Schowalter T, Nicolosi AC, *et al*. Atrial fibrillation after cardiac surgery: a major morbid event? *Ann Surg*. 1997;226:501–511. doi:10.1097/00000658-199710000-00011
2. Villareal RP, Hariharan R, Liu BC, *et al*. Postoperative atrial fibrillation and mortality after coronary artery bypass surgery. *J Am Coll Cardiol*. 2004;43:742–748. doi:10.1016/j.jacc.2003.11.023
3. Saxena A, Dinh DT, Smith JA, Shardey GC, Reid CM, Newcomb AE. Usefulness of postoperative atrial fibrillation as an independent predictor for worse early and late outcomes after isolated coronary artery bypass grafting (multicenter Australian study of 19,497 patients). *Am J Cardiol*. 2012;109:219–225. doi:10.1016/j.amjcard.2011.08.033
4. Mathew JP, Fontes ML, Tudor IC, *et al*. A multicenter risk index for atrial fibrillation after cardiac surgery. *JAMA*. 2004;291:1720–1729. doi:10.1001/jama.291.14.1720
5. Joshi KK, Tiru M, Chin T, Fox MT, Stefan MS. Postoperative atrial fibrillation in patients undergoing non-cardiac non-thoracic surgery: A practical approach for the hospitalist. *Hosp Pract* (1995). 2015;43(4): 235–244. doi:10.1080/21548331.2015.1096181
6. Matthew JP, Parks R, Savino JS, *et al*. Atrial fibrillation following coronary artery bypass graft surgery: predictors, outcomes, and resource utilization. *JAMA*. 1996;276(4):300–306. doi:10.1001/jama.1996.03540040044031
7. 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
8. Echahidi N, Pibarot P, O'Hara G, Mathieu P. Mechanisms, prevention, and treatment of atrial fibrillation after cardiac surgery. *J Am Coll Cardiol*. 2008;51(8):793–801. doi:10.1016/j.jacc.2007.10.043
9. Mitchell LB, Exner DV, Wyse DG, *et al*. Prophylactic oral amiodarone for the prevention of arrhythmias that begin early after revascularization, valve replacement, or repair: PAPABEAR: A randomized controlled trial. *JAMA*. 2005;294(24):3093–3100. doi:10.1001/jama.294.24.3093
10. Sabzi F, Zokaei AH, Moloudi AR. Predictors of atrial fibrillation following coronary artery bypass grafting. *Clin Med Insights Cardiol*. 2011;5:67–75. doi:10.4137/CMC.S7170
11. Thein PM, White K, Banker K, Lunny C, Mirzaee S, Nasis A. Preoperative use of oral beta-adrenergic blocking agents and the incidence of new-onset atrial fibrillation after cardiac surgery. A systematic review and meta-analysis. *Heart Lung Circ*. 2018;27(3):310–321. doi:10.1016/j.hlc.2017.08.026
12. Tamura T, Yatabe T, Yokoyama M. Prevention of atrial fibrillation after cardiac surgery using low-dose landiolol: a systematic review and meta-analysis. *J Clin Anesth*. 2017;42:1–6. doi:10.1016/j.jclinane.2017.07.009
13. Ji T, Feng C, Sun L, *et al*. Are beta-blockers effective for preventing post-coronary artery bypass grafting atrial fibrillation? Direct and network meta-analyses. *Ir J Med Sci*. 2016;185(2):503–511. doi:10.1007/s11845-016-1447-1
14. Arsenault KA, Yusuf AM, Crystal E, *et al*. Interventions for preventing post-operative atrial fibrillation in patients undergoing heart surgery. *Cochrane Database Syst Rev*. 2013;2013(1):CD003611. doi:10.1002/14651858.CD003611.pub3
15. Bagshaw SM, Galbraith PD, Mitchell LB, Sauve R, Exner DV, Ghali WA. Prophylactic amiodarone for prevention of atrial fibrillation after cardiac surgery: a meta-analysis. *Ann Thorac Surg*. 2006;82(5):1927–1937. doi:10.1016/j.athoracsur.2006.06.032
16. Aasbo JD, Lawrence AT, Krishnan K, Kim MH, Trohman RG. Amiodarone prophylaxis reduces major cardiovascular morbidity and length of stay after cardiac surgery: a meta-analysis. *Ann Intern Med*. 2005;143(5): 327–336. doi:10.7326/0003-4819-143-5-200509060-00008
17. Merrit RE, Shrager JB. Prophylaxis and management of atrial fibrillation after general thoracic surgery. *Thorac Surg Clin*. 2012;22(1):13–23. doi:10.1016/j.thorsurg.2011.08.016
18. Bayliff CD, Massel DR, Inculet RI, *et al*. Propranolol for the prevention of postoperative arrhythmias in general thoracic surgery. *Ann Thorac Surg*. 1999;67(1):182–186. doi:10.1016/s0003-4975(98)01226-0
19. 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
20. Skiba MA, Pick AW, Chaudhuri K, *et al*. Prophylaxis against atrial fibrillation after cardiac surgery: beneficial effect of perioperative metoprolol. *Heart Lung Circ*. 2013;22(8):627–633. doi:10.1016/j.hlc.2012.12.017
21. Mathew JP, Fontes ML, Tudor IC, *et al*. A multicenter risk index for atrial fibrillation after cardiac surgery. *JAMA*. 2004;291(14):1720–1729. doi:10.1001/jama.291.14.1720
22. Silva RG, Lima GG, Guerra N, Bigolin AV, Petersen LC. Risk index proposal to predict atrial fibrillation after cardiac surgery. *Rev Bras Cir Cardiovasc*. 2010;25(2):183–189. doi:10.1590/s0102-76382010000200009
23. Chua SK, Shyu KG, Lu MJ, *et al*. Clinical utility of CHADS2 and CHA_2DS_2-VASc scoring systems for predicting postoperative atrial fibrillation after cardiac surgery. *J Thorac Cardiovasc Surg*. 2013;146(4):919–926.e1. doi:10.1016/j.jtcvs.2013.03.040
24. 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
25. Borde D, Gandhe U, Hargave N, Pandey K, Mathew M, Joshi S. Prediction of postoperative atrial fibrillation after coronary artery bypass grafting surgery: is CHA_2DS_2-VASc score useful? *Ann Card Anaesth*. 2014;17(3):182–187. doi:10.4103/0971-9784.135841

26. Yin L, Ling X, Zhang Y, *et al*. CHADS2 and CHA_2DS_2-VASc scoring systems for predicting atrial fibrillation following cardiac valve surgery. *PLoS One*. 2015;10(4):e0123858. doi:10.1371/journal.pone.0123858

27. Pollock B, Filardo G, da Graca B, *et al*. Predicting new-onset post-coronary artery bypass graft atrial fibrillation with existing risk scores. *Ann Thorac Surg*. 2018;105(1):115–121. doi:10.1016/j.athoracsur.2017.06.075

28. Osranek M, Fatema K, Qaddoura F, *et al*. Left atrial volume predicts the risk of atrial fibrillation after cardiac surgery: a prospective study. *J Am Coll Cardiol*. 2006;48(4):779–786. doi:10.1016/j.jacc.2006.03.054

29. Alonso A, Krijthe BP, Aspelund T, *et al*. Simple risk model predicts incidence of atrial fibrillation in a racially and geographically diverse population: the CHARGE-AF consortium. *J Am Heart Assoc*. 2013;2(2):e000102. doi:10.1161/JAHA.112.000102

30. Lip GY, Nieuwlaat R, Pisters R, Lane DA, Crijns HJ. 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

31. Alemayehu D, Zou KH. Applications of ROC analysis in medical research: recent developments and future directions. *Acad Radiol*. 2012;19(12):1457–1464. doi:10.1016/j.acra.2012.09.006

32. 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

33. Mathew JP, Parks R, Savino JS, Friedman AS, *et al*. Atrial fibrillation following coronary artery bypass graft surgery: predictors, outcomes, and resource utilization. Multicenter Study of Perioperative Ischaemia Research Group. *JAMA*.1996;276(4):300–306. PMID: 8656542

34. 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):e199–e267. doi:10.1161/CIR.0000000000000041