Temporal trends and predictors of surgical ablation for atrial fibrillation across a multistate healthcare system

Scott C. Brancato, MD, FHRS,* Mansen Wang, MS,* Kateri J. Spinelli, PhD,* Maheer Gandhavadi, MD, FHRS,† Neil K. Worrall, MD, MA,‡ Eric J. Lehr, MD, PhD,§ Zach M. DeBoard, MD,‖ Torin P. Fitton, MD,* Alison Leiataua, MS,* Jonathan P. Piccini, MD, MHS, FHRS,¶ Ty J. Gluckman, MD, MHA*

*From the *Center for Cardiovascular Analytics, Research and Data Science (CARDS), Providence Heart Institute, Providence Research Network, Portland, Oregon, †Mercy General Hospital and Dignity Health Heart and Vascular Institute, Sacramento, California, ‡Providence Sacred Heart Medical Center and Children's Hospital, Spokane, Washington, §Swedish Heart and Vascular Institute, Seattle, Washington, ‖Providence Regional Medical Center Everett, Everett, Washington, and ¶Duke University Medical Center and Duke Clinical Research Institute, Durham, North Carolina.*

BACKGROUND Multiple class I and class IIa recommendations exist related to surgical ablation (SA) of atrial fibrillation (AF) in patients undergoing cardiac surgery.

OBJECTIVE Examine temporal trends and predictors of SA for AF in a large US healthcare system.

METHODS We retrospectively analyzed data from the Society for Thoracic Surgery (STS) Adult Cardiac Surgery Database for 21 hospitals in the Providence St. Joseph Health system. All patients with preoperative AF who underwent isolated coronary artery bypass graft (CABG) surgery, isolated aortic valve replacement (AVR), AVR with CABG surgery (AVR+CABG), isolated mitral valve repair or replacement (MVRr), and MVRr with CABG surgery (MVRr+CABG) from July 1, 2014, to March 31, 2020 were included. Temporal trends in SA were evaluated using the Cochran-Armitage trends test. A multilevel logistic regression model was used to examine patient-, hospital-, and surgeon-level predictors of SA.

RESULTS Among 3124 patients with preoperative AF, 910 (29.1%) underwent SA. This was performed most often in those undergoing isolated MVRr (n = 324, 44.8%) or MVRr+CABG (n = 75, 35.2%). Rates of SA increased over time and were highly variable between hospitals. Years since graduation from medical school for the primary operator was one of the few predictors of SA: odds ratio (95% confidence interval) = 0.71 (0.56–0.90) for every 10-year increase. Annual surgical (both hospital and operator) and AF catheter ablation volumes were not predictive of SA.

CONCLUSION Wide variability in rates of SA for AF exist, underscoring the need for greater preoperative collaboration between cardiologists, electrophysiologists, and cardiac surgeons.

KEYWORDS Surgical ablation; Atrial fibrillation; Cardiac surgery; Ablation trends; Guideline adherence

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Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in the United States.[1] Patients with AF face significantly increased risk of cardiovascular morbidity and mortality[1–3] and for those diagnosed with it prior to cardiac surgery, there is an increased likelihood of worse near-term and long-term outcomes.[4–7]

While use of a rhythm-control strategy in AF can improve symptoms and quality of life,[8] most randomized controlled trials have failed to demonstrate improvement in morbidity and mortality.[9–11] Recent exceptions to this include early use of a rhythm-control strategy in those diagnosed with AF within the last year[12] and catheter ablation of AF in patients with heart failure with reduced ejection fraction.[13] Surgical ablation (SA) of AF at the time of cardiac valve or coronary artery bypass graft (CABG) surgery has been associated with improved mid- and long-term survival in many observational studies.[14–16] In a 2018 meta-analysis of randomized controlled trials, however, SA of AF was not associated with improved clinical outcomes such as mortality and stroke.[17]

Address reprint requests and correspondence: Dr Scott C. Brancato, Center for Cardiovascular Analytics, Research and Data Science (CARDS), Providence Heart Institute, Providence St. Vincent Medical Center, 9427 SW Barnes Rd, Suite 594, Portland, OR 97225. E-mail address: scott.brancato@providence.org.

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KEY FINDINGS

- Rates of surgical ablation (SA) for atrial fibrillation (AF) in patients undergoing cardiac surgery increased over time in a large multistate healthcare system.
- Marked variability in the rate of SA for AF was found across hospitals and there was no correlation with procedural volume.
- A surgeon's years since medical school negatively predicted the likelihood of SA for AF.
- These findings highlight the need for increased collaboration and preoperative planning between cardiologists, electrophysiologists, and cardiac surgeons.

Multiple professional societies have issued guidance related to SA of AF for those undergoing cardiac surgery. In 2014, a class IIa indication was given to SA in selected patients undergoing cardiac surgery by the American College of Cardiology, American Heart Association, and Heart Rhythm Society.[8] In 2017, the Society of Thoracic Surgeons (STS) gave class I indications for SA of AF to patients undergoing mitral valve, aortic valve, or CABG surgery.[18] Finally, in 2017, a multisociety expert consensus statement gave class I indications to SA in patients with symptomatic AF undergoing mitral valve surgery and class IIa indications to SA in patients with symptomatic AF undergoing aortic valve, CABG, and combined surgeries.[1] Importantly, these guideline recommendations were largely based on moderate-quality evidence (level of evidence B).

While a 2014 study showed that the number of patients in the United States undergoing SA for AF has increased over time,[19] there is little contemporary data available about its use since 2014. Accordingly, this study sought to examine practice patterns and trends in the use of SA among patients undergoing adult cardiac surgery within a large integrated health system. We also sought to determine which patient, hospital, and surgeon factors predicted the use of SA. We hypothesized that, despite a rising rate of SA for AF, wide variability in its use was present across hospitals and operators.

Methods

Patient population and data source

We retrospectively analyzed data that were collected according to the STS Adult Cardiac Surgery Database (ACSD) specifications.[20] Procedures performed between July 1, 2014, and March 31, 2020 at 21 hospitals in the Providence St. Joseph Health (PSJH) system were included. Patients with preoperative AF (defined as either a recent [$\leq$30 days] or remote [>30 days] history of AF) who underwent isolated CABG surgery, isolated aortic valve replacement (AVR), AVR with CABG surgery (AVR+CABG), isolated mitral valve repair or replacement (MVRr), or MVRr with CABG surgery (MVRr+CABG) were selected for analysis (Supplemental Figure 1). Patients with emergent or salvage status and/or preoperative endocarditis were excluded. Patients undergoing reoperation, however, were included.

SA was defined by creation of any AF lesions among the 19 defined in the ACSD. Patients undergoing left atrial appendage obliteration or amputation without creation of an AF lesion were included in the no SA group. Based on variables included in the ACSD, a CHA_2DS_2-VASc score was calculated for each patient. Years since graduation from medical school for each surgeon was obtained via an internet search of public records. This study was approved by the PSJH institutional review board, with waiver of informed consent owing to the retrospective nature of the study and use of de-identified data. The research reported in this paper adhered to the STROBE guidelines.

Study aims

The primary aim was to examine temporal trends and variations in rates of SA for AF among 21 hospitals in the PSJH system. The secondary aim was to examine potential patient, hospital (annual surgical and AF catheter ablation volumes), and surgeon (annual surgical volume and years since training) predictors of SA. Finally, demographics, procedural characteristics, and in-hospital and 30-day outcomes were compared between those that did and did not undergo SA.

Statistical analysis

Baseline characteristics

Continuous variables were presented as mean and standard deviation (SD) or median and interquartile range (IQR), as appropriate based on normality of the data. Categorical variables were presented as counts and proportions. Demographic characteristics, relevant procedural risk factors, and outcomes were compared between groups (SA vs no SA) using t tests or Wilcoxon rank sum tests for continuous variables and χ^2 or Fisher exact tests for categorical variables.

Trends-over-time analysis

Temporal trends in the rate of SA for all hospitals and the 3 highest-volume hospitals were evaluated with the Cochran-Armitage trends test, with quarter-year of procedure as the unit of time. Additional analyses were performed to evaluate trends in SA for each of the 5 surgery types and for all surgery types combined.

Multilevel logistic regression model

To examine potential predictors of SA, a multilevel logistic regression model was built. Given clustering of patients by surgeon and clustering of surgeons by hospital, a 3-level model for hierarchical nested data was used.[21] First, a univariate analysis of each risk factor was performed. Any variable with a $P < .25$ was selected as a candidate for the multivariable analysis. Second, all candidates were put into a multivariable model. In this model, variables were removed if they had a $P > .10$ and were not a confounder (>20% change in any remaining parameter estimates) or if their inclusion

Table 1 Patient demographics

Variable	All	No SA	SA	*P* value
Patients	3124	2214 (70.9)	910 (29.1)	N/A
Age, years	72 [65–78]	72 [65–78]	71 [64–76]	.0001
Age ≥65	2396 (76.7)	1721 (77.7)	675 (74.2)	.0326
Female	843 (27.0)	564 (25.5)	279 (30.7)	.003
BMI				.6686
<18.5	28 (0.9)	23 (1.0)	5 (0.6)	
18.5–24.9	723 (23.1)	513 (23.2)	210 (23.1)	
25.0–29.9	1118 (35.8)	791 (35.7)	327 (35.9)	
30.0–34.9	749 (24.0)	538 (24.3)	211 (23.2)	
35.0–39.9	327 (10.5)	228 (10.3)	99 (10.9)	
≥40.0	179 (5.7)	121 (5.5)	58 (6.4)	
Race				.3275
White	2743 (90.1)	1958 (90.8)	785 (88.3)	
Black	31 (1.0)	21 (1.0)	10 (1.1)	
Native American	45 (1.5)	34 (1.6)	11 (1.2)	
Native Pacific	23 (0.8)	14 (0.7)	9 (1.0)	
Asian	114 (3.7)	78 (3.6)	36 (4.1)	
Other	104 (3.4)	67 (3.1)	37 (4.2)	
Ethnicity, Hispanic	124 (4.0)	98 (4.4)	26 (2.9)	.1241
CHF	999 (32.0)	757 (34.2)	242 (26.6)	.0001
NYHA class				.0014
I	76 (5.0)	53 (5.0)	23 (5.2)	
II	457 (30.2)	306 (28.7)	151 (33.8)	
III	448 (29.6)	337 (31.6)	111 (24.8)	
IV	238 (15.7)	182 (17.1)	56 (12.5)	
Hypertension	2637 (84.4)	1890 (85.4)	747 (82.1)	.0218
Diabetes	1111 (35.6)	849 (38.4)	262 (28.8)	.0001
CVD	754 (24.1)	545 (24.6)	209 (23.0)	.3277
Previous cardiac surgery	1401 (44.9)	1048 (47.4)	353 (38.8)	.0001
Previous CABG surgery	103 (3.3)	97 (4.4)	6 (0.7)	.0001
Previous valve surgery	207 (6.6)	186 (8.4)	21 (2.3)	.0001
Previous PCI	659 (21.1)	517 (23.4)	142 (15.6)	.0001
Previous MI	1112 (35.7)	866 (39.3)	246 (27.1)	.0001
Dialysis	111 (3.6)	90 (4.1)	21 (2.3)	.0158
CLD, moderate or severe	269 (8.7)	191 (8.7)	78 (8.6)	.9616
PVD	385 (12.3)	315 (14.2)	70 (7.7)	.0001
CHA_2DS_2-VASc score				
Male, ≥1	2245 (98.4)	1630 (98.8)	615 (97.5)	
Female, ≥2	836 (99.2)	563 (99.8)	273 (97.8)	
STS predicted risk of mortality, %	2.3 [1.2-4.3]	2.6 [1.4-4.6]	1.8 [0.9-3.4]	.0001
Left ventricle ejection fraction	55 [45-63]	55 [45-62]	58 [50-63]	.0001
Mitral insufficiency, moderate or severe	1198 (38.4)	750 (34.0)	448 (49.3)	.0001
Paroxysmal AF	2160 (69.1)	1548 (69.9)	612 (67.3)	.1427

Data presented as n (%) or median [IQR].

AF = atrial fibrillation; BMI = body mass index; CABG = coronary artery bypass graft; CHA_2DS_2-VASc = congestive heart failure, hypertension, age ≥75 years, diabetes mellitus, stroke, vascular disease, age 65–74 years, sex category; CHF = congestive heart failure; CLD = chronic lung disease; CVD = cerebrovascular disease; MI = myocardial infarction; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease; SA = surgical ablation; STS = Society of Thoracic Surgeons.

resulted in multicollinearity problems.[22] Finally, all variables that were not selected for the original multivariable model were added back one at a time and were retained if there was a $P < .10$. Model fit statistics, Akaike information criterion and Bayesian information criterion, were also considered in the model selection criteria. Age and sex, as common controlling variables, were kept in the model regardless of their *P* values.

Model results are presented as odds ratios (OR) and 95% confidence intervals (CI). For the time categories, 2017-Q1 was selected as the reference category to match the timing of the STS guideline.[18] A multilevel logistic regression model was chosen to allow for analysis of the quarter-year time variable, differences among hospitals, and differences among surgeons using the same model.

Missing data rates were <1% for all variables except STS predicted mortality risk (1.9%), patient race (2.7%), and New York Heart Association (NYHA) class (51.6%). Missing values were omitted from the related analyses. Because missing rates were high for NYHA class, this variable was excluded from the logistic regression models. P values less than .05 were considered statistically significant. All analyses were performed using SAS 9.4 software (SAS Institute, Cary, NC) and RStudio version 1.2.5001 (RStudio Team [2020].

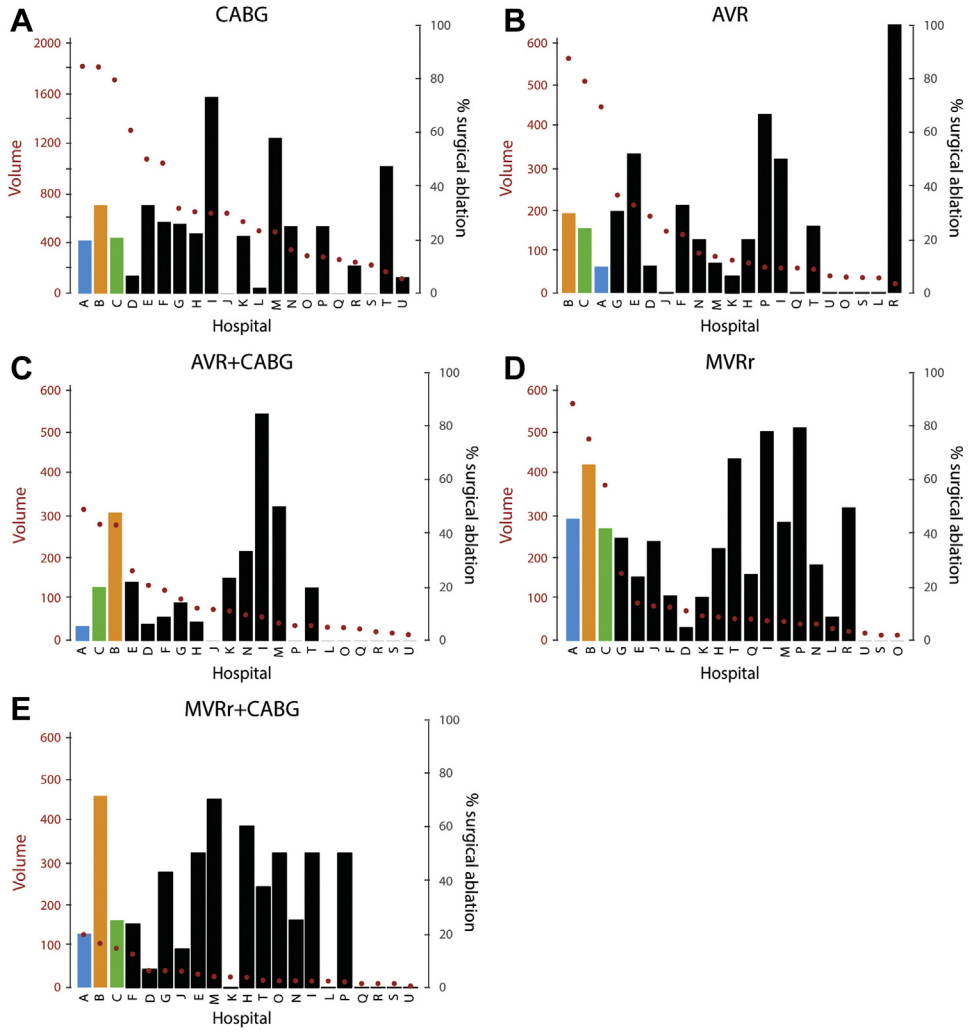

Figure 1 Surgery volumes and percent surgical ablation (SA) by hospital. Total surgery volumes (*red markers*, left y-axis) and percent SA (*bars*, right y-axis) for each hospital for the following: **A:** isolated coronary artery bypass graft (CABG); **B:** isolated aortic valve replacement (AVR); **C:** AVR+CABG; **D:** mitral valve repair or replacement (MVRr); and **E:** MVRr+CABG surgery. In each panel, the 3 highest-volume hospitals are coded as A (*blue*), B (*orange*), and C (*green*).

RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. http://www.rstudio.com/). Figures were produced using RStudio and edited in Adobe Illustrator 2019.

Results

Baseline and in-hospital characteristics

During the study period, 29,620 patients were captured in the STS ACSD by our health system, of which 5654 (19%) had preoperative AF (Supplemental Figure 1). After applying exclusion criteria, 3124 patients with preoperative AF remained, of which 910 (29.1%) underwent SA. Of patients with SA lesion set information recorded in the ACSD, 97% had pulmonary vein isolation performed (n = 841), with 95% having additional lesion sets created (n = 799) (Supplemental Table 1). As a percentage of total cases, SA was most often performed in those that underwent mitral valve surgery, either as isolated MVRr (n = 324, 44.8%) or MVRr+CABG (n = 75, 35.2%) (Supplemental Table 2). Although more patients underwent SA for isolated CABG surgery, this involved a smaller percentage of total cases (n = 333, 23.6%).

Patients that underwent SA were slightly younger; were more often female; had higher rates of mitral insufficiency and lower rates of heart failure, diabetes, peripheral vascular disease, previous cardiac surgeries and procedures, previous myocardial infarction; and had a lower NYHA class (Table 1). Most procedural characteristics were not significantly different between groups (Supplemental Table 2). In-hospital and 30-day outcomes were not significantly different as well (Supplemental Table 3).

Rates of surgical ablation

Rates of SA varied greatly across all 5 surgery types and there was no correlation with annual surgical volume (Figure 1). For all surgical types combined, rates of SA increased from 7.5% in the third quarter of 2014 to 40.9% in the first quarter of 2020 ($P < .0001$) (Figure 2). This trend was noted for all surgery types except isolated AVR ($P = .35$). The greatest

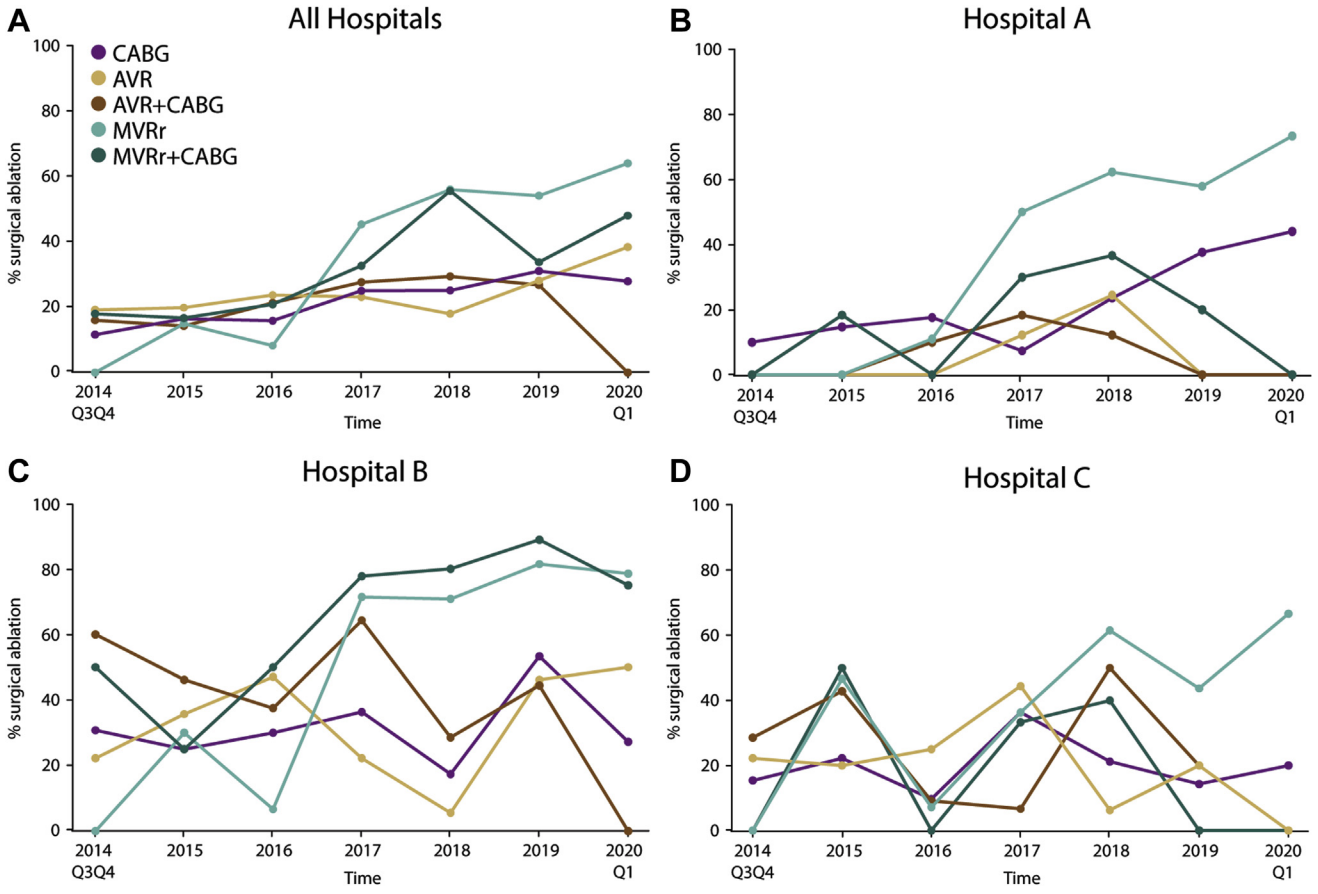

Figure 2 Surgical ablation trends over time. Percent surgical ablation (SA) over time for each surgery type, for all hospitals (**A**) and the 3 highest-volume hospitals (**B–D**), as coded in Figure 1. Abbreviations as in Figure 1.

increases in SA were noted in those undergoing MVRr and MVRr+CABG, with rates of 66.7% and 50.0% at the end of the study period, respectively. The overall combined rates of SA for AF over the entire study period were 42.6% and 23.4% for mitral valve and non–mitral valve surgeries, respectively.

Independent predictors of surgical ablation

After nonsignificant variables were removed, 12 risk factors remained in the final multilevel regression model: age, body mass index (BMI), sex, diabetes, previous cardiac surgery, previous CABG surgery, previous valve surgery, previous myocardial infarction, STS predicted mortality risk, surgical procedure type, surgery date, and years since medical school graduation for the primary operator (Supplemental Table 4). Annual hospital surgery volume, primary operator surgery volume, and hospital AF catheter ablation volume were not significant predictors in the univariate or multivariable models and thus were not included in the final model. A BMI $\geq$25.0 was the only patient characteristic significantly associated with increased odds of SA (Figure 3). Patients with either previous CABG or valve surgery had significantly lower odds of SA: CABG surgery OR (95% CI) = 0.22 (0.08–0.61); valve surgery OR (95% CI) = 0.15 (0.08–0.27). Every 10-year increase in the primary operator's years since medical school graduation decreased the odds of SA by 29% (95% CI: 10%–44%). Compared to MVRr+CABG surgery, isolated CABG surgery, isolated AVR, and AVR+CABG had significantly lower odds of SA (Figure 4). Quarter-years prior to 2017-Q1 also saw lower odds of SA (Figure 4). Estimations of individual hospital-level and surgeon-level random effects are presented in Supplemental Tables 5 and 6.

Discussion

To better understand the use of SA for AF among patients undergoing cardiac surgery, we looked at practice patterns involving 97 cardiothoracic surgeons across 21 hospitals within a single healthcare system. We first noted that rates of SA in this population rose over the study period, with a distinct increase in 2017. Second, we identified few strong predictors of SA. While hospital volume, surgeon volume, and AF catheter ablation volume failed to predict SA, the number of years since a surgeon completed medical school, the type and timing of surgery, and a limited number of patient factors were predictive. Finally, rates of SA and the type of ablation performed were highly variable, both within and across hospitals.

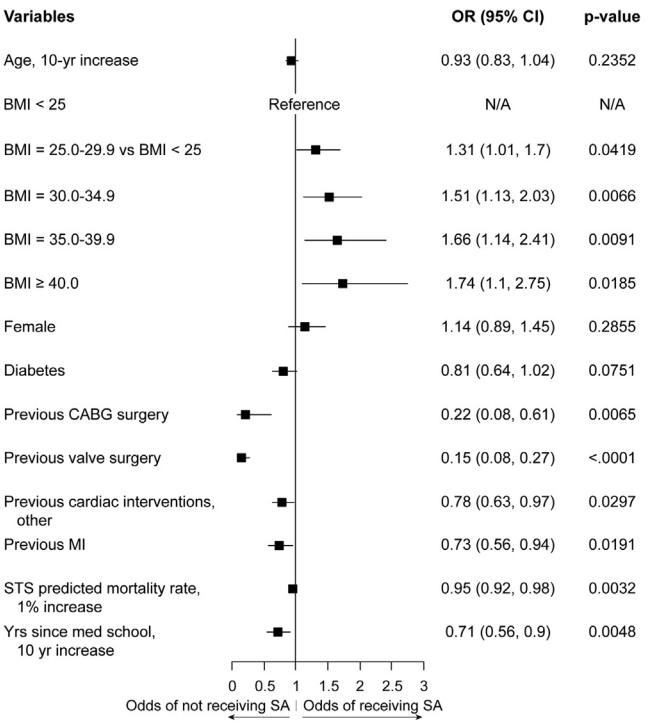

Figure 3 Predictors of surgical ablation (SA): patient and surgeon characteristics. Forest plot showing patient and surgeon variables that were included in the final logistic regression model. BMI = body mass index; CABG = coronary artery bypass graft; CI = confidence interval; MI = myocardial infarction; OR = odds ratio; STS = Society of Thoracic Surgeons; Yr = year.

Similar to that previously reported,[19] we noted a temporal increase in SA, with an analysis period extending nearly 6 years later. In our study, the largest increases in SA occurred in 2017, driven disproportionately by its use in mitral valve surgery. This is consistent with 2017 guidance issued by both the STS and HRS.[1,18] In these documents, the strongest support for SA of AF was in patients undergoing mitral valve procedures.

While a previous single-center report showed a positive relationship between surgeon experience and likelihood of the surgeon to perform SA, surgeon experience was defined by the number of SAs performed by the operator.[23] Given that the outcome of interest was directly correlated with the predictor variable in the statistical model, it is difficult to interpret conclusions from this analysis. In contrast, we defined surgeon experience as total surgical volume and did not find a relationship between surgeon experience and the likelihood of SA. We similarly found that higher hospital surgical volumes and catheter ablation volumes were not predictive of SA. This was somewhat unexpected, as it was anticipated that clinicians at these hospitals might be more likely to recommend SA at the time of cardiac surgery.

Interestingly, we did find a relationship between years since medical school and the likelihood of performing SA—surgeons who graduated more recently were more likely to perform SA. This relationship between years since training and adoption of certain guideline-recommended interventions has also been observed in other cardiac procedures that are underutilized.[24] While the interplay between surgeon experience, years in practice, and clinical outcomes has been the subject of previous investigation for other types of cardiac surgery,[25,26] the association between surgeon characteristics and adherence to guideline recommendations has been less well studied in cardiovascular surgery. This contrasts with surgical oncology, where hospital and surgeon volume, a surgeon's subspecialty, and the number of years

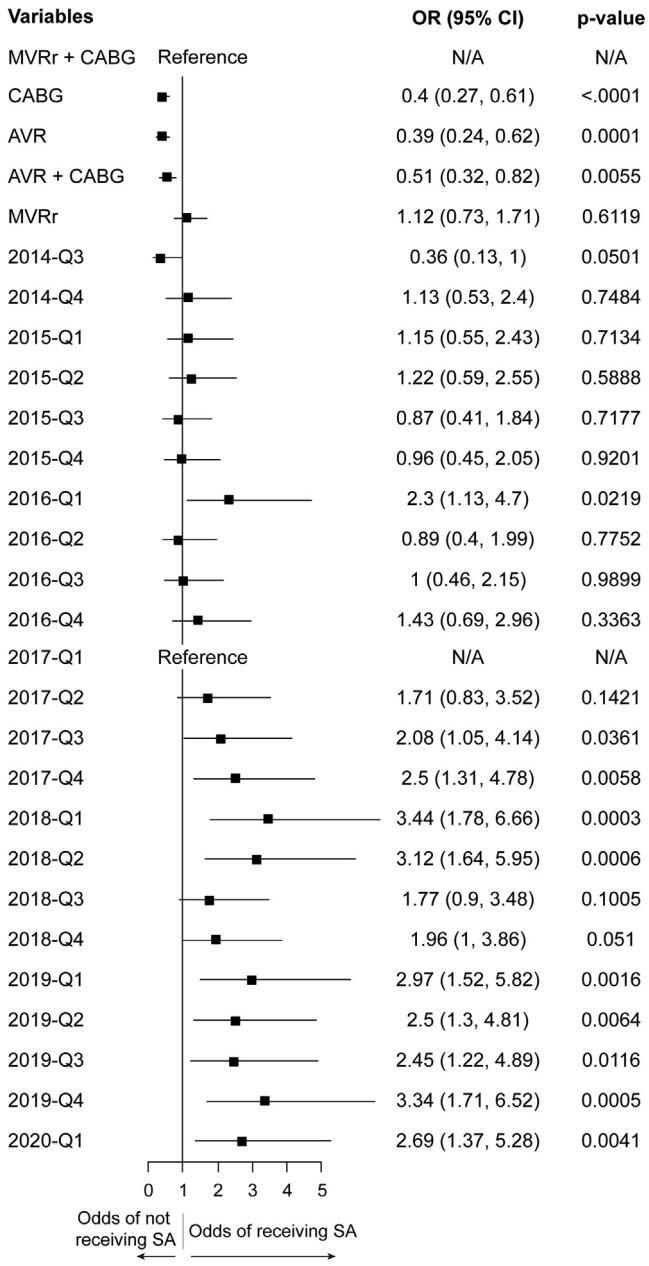

Figure 4 Predictors of surgical ablation: surgery type and timing of surgery. Forest plot showing surgery type and time variables that were included in the final logistic regression model. N/A = not applicable; Q = quarter. Additional abbreviations as in Figures 1 and 3.

in practice have been shown to correlate with guideline adherence.[27–29] Because the ACSD has limited data about the primary operator, further assessment of clinician-specific factors that may have influenced rates of SA for AF could not be performed.

Other observed predictors of SA were the type of surgery and the year in which it was performed. Patients undergoing mitral valve surgeries were 2.3 times more likely to undergo SA compared to non–mitral valve surgeries. In addition, patients undergoing surgery in 2017 or later were 2.5 times more likely to receive SA compared to earlier years. Certain factors, including BMI and previous cardiac surgery, influenced the odds of SA, while other factors such as patient age, the CHA_2DS_2-VASc score, and the STS risk score were not predictive.

The overall rate of SA for AF in our study was lower than that previously reported (29% vs 48%),[19] despite a higher observed prevalence of preoperative AF (19% vs 13%). In addition, among the 3 highest-volume hospitals in our cohort, rates of SA were highly variable for the 5 types of surgery evaluated. Similar variability in practice was observed in lower-volume hospitals and in the type of SA performed. While pulmonary vein isolation was utilized 97% of the time, there was significant heterogeneity in the number of lesions created (Supplemental Table 1). This may reflect prior guidelines, which have traditionally reviewed various approaches for SA without providing specific recommendations as to which lesion procedures should be performed.[1,18]

Findings from this study underscore the need to re-explore ways in which cardiac surgery patients with AF are evaluated in the preoperative setting. Benefit is likely to come from improved preoperative communication between key stakeholders (eg, cardiac surgeons, cardiologists, and electrophysiologists), not only to determine whether SA is warranted, but also to guide the intraoperative AF treatment plan. Such a process could mirror the heart team approach, which has become the standard for patients with structural heart disease being considered for intervention.[30] Alternatively, it could follow processes utilized by hospitals that perform hybrid procedures combining epicardial and endocardial ablation, where multidisciplinary engagement is regularly utilized to guide preprocedural planning.[31,32]

There also exists an opportunity to harmonize guidance issued by professional societies to ensure a more consistent approach to SA of AF. For example, the HRS consensus statement strongly recommends SA for patients with symptomatic AF at the time of cardiac surgery,[1] whereas the STS guidelines endorse SA without specifying symptom status.[18] Reconciling even these small differences could help, as subtle differences in recommendations between guidelines has been identified as a barrier to implementation.[33]

It is also important to consider other factors that influence outcomes when considering SA of AF. These include left atrial size and duration of AF.[34,35] Revisiting these outcomes is particularly important given recent results from the EAST-AFNET 4 trial, which demonstrated improved cardiovascular outcomes at 5 years with early institution of a rhythm-control strategy among patients diagnosed with AF during the prior year.[12] Higher risk of pacemaker implantation and postoperative atrial flutter should also inform treatment considerations, as both have been observed to occur at higher rates among patients undergoing SA of AF.[36] This is particularly true in patients undergoing biatrial lesion sets, as reported in a 2018 meta-analysis of SA studies.[17] This meta-analysis also found that while concomitant SA improved freedom from AF, it did not affect other clinical outcomes such as mortality or stroke. Importantly, these studies have been limited by modest patient enrollment and limited follow-up.

Limitations

First, given the study's observational design, it is possible that unmeasured confounders influenced the results. Second, while our study represents a large contemporary analysis involving 21 hospitals across 6 states, the observed results may not be reflective of practice patterns elsewhere in the United States. Third, our population was predominantly white (90%); as such, our findings may not be generalizable to other populations with greater racial and ethnic diversity. Fourth, we excluded cases with missing documentation related to preoperative AF (0.2% of cases) or SA (4.7% of cases), which may have introduced bias. Given the large sample size, we nonetheless believe that the results reflect an accurate comparison between groups even after excluding these cases. Finally, clinical variables that may inform the decision to perform SA, including left atrial size and type (symptomatic vs asymptomatic) and duration of AF, as well as some details about the ablation, were not available in the ACSD. Indeed, an ~5% missing rate for SA underscores the need for improved documentation related to SA in the ACSD. Future studies examining utilization and drivers of SA for AF, linked to clinical datasets and longer-term outcomes, are warranted.

Conclusion

Although rates of SA for AF have increased over time, its use in our healthcare system remains highly variable. Based on current guideline recommendations, there is significant opportunity to increase use of SA among patients undergoing cardiac surgery. Future availability of higher-quality evidence may also help to increase use of SA. Strong consideration should be given to team-based preoperative planning to more optimally address intraoperative treatment of this condition.

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Authorship: All authors attest they meet the current ICMJE criteria for authorship.

Patient Consent: This study was approved by the PSJH institutional review board, with waiver of informed consent owing to the retrospective nature of the study and use of de-identified data.

Ethics Statement: This study was approved by the PSJH institutional review board, with waiver of informed consent owing to the retrospective nature of the study and use of de-identified data. The research reported in this paper adhered to the STROBE guidelines.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hroo.2021.12.003.

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