Ablation of atrial fibrillation during coronary artery bypass grafting: Late outcomes in a Medicare population

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ABSTRACT

Background: This study compares outcomes of patients with preoperative atrial fibrillation undergoing coronary artery bypass grafting (CABG) with or without concomitant atrial fibrillation ablation in a nationally representative Medicare cohort.

Objectives: This study examined early and late outcomes in CABG patients with a preoperative history of atrial fibrillation to determine the correlation between surgical atrial fibrillation ablation to mortality and stroke or systemic embolization.

Methods: In the Medicare-linked Society of Thoracic Surgeons database, 361,138 patients underwent isolated CABG from 2006 to 2013; 34,600 (9.6%) had preoperative atrial fibrillation; 10,541 (30.5%) were treated with surgical ablation (ablation group), and 23,059 were not (no ablation group). Propensity score matching was performed using a hierarchical mixed model. Long-term survival was summarized using Kaplan-Meier curves and Cox regression models with robust variance estimation. The stroke or systemic embolization incidence was modeled using the Fine-Gray model. Median follow-up was 4 years.

Results: Long-term mortality in propensity score-matched CABG patients (mean age 74 years; Society of Thoracic Surgeons risk score, 2.25) receiving ablation versus no ablation was similar (log-rank $P = .30$). Stroke or systemic embolization occurred in 2.2% versus 2.1% at 30 days and 9.9% versus 12.0% at 5 years (Gray $P = .0091$). Landmark analysis from 2 to 5 years showed lower mortality (hazard ratio, 0.89; 95% confidence interval 0.82–0.97; $P = .0358$) and lower risk of stroke or systemic embolization (hazard ratio, 0.73; 95% confidence interval, 0.61–0.87; $P = .0006$) in the ablation group.

Conclusions: Concomitant ablation in CABG patients with preoperative atrial fibrillation is associated with lower stroke or systemic embolization and mortality in patients who survive more than 2 years. (J Thorac Cardiovasc Surg 2021;161:1251–61)

Surgical ablation of AF in CABG patients is associated with lower mortality at 5 years.

CENTRAL MESSAGE

Concomitant AF treatment during coronary artery bypass surgery is associated with fewer stroke and systolic embolic events as well as higher survival in patients who survive 2 years beyond surgery.

PERSPECTIVE

Treating AF during cardiac surgery is a class I indication in patients with a suitable perioperative risk. Ablation in CABG patients with preoperative AF is associated with lower stroke and systemic embolization and mortality in patients who survive 2 years. AF ablation was associated with a higher operative mortality in patients with a CHA₂DS₂-VASc score of 7 to 9.

See Commentaries on pages 1262 and 1263.

The incidence of preoperative atrial fibrillation (AF) in patients undergoing coronary artery bypass grafting (CABG) ranges from 5% to 10%.^{1,2} Preoperative AF is an

independent risk factor for worse perioperative outcomes and decreased long-term survival in patients who undergo CABG when compared with patients without preoperative

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Supported by institutional funding from Northwestern University, Chicago Ill.

Read at the 98th Annual Meeting of The American Association for Thoracic Surgery, San Diego, California, April 28-May 1, 2018.

Received for publication April 23, 2019; revisions received Oct 15, 2019; accepted for publication Oct 23, 2019; available ahead of print Nov 29, 2019.

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0022-5223/\$36.00

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<https://doi.org/10.1016/j.jtcvs.2019.10.159>

Abbreviations and Acronyms

AF	= atrial fibrillation
CABG	= coronary artery bypass grafting
CHA ₂ DS ₂ -VASc	= congestive heart failure, hypertension, age ≥ 75 years, diabetes, stroke, vascular disease, age 65 to 74 years, sex category
CIF	= cumulative incidence function
CMS	= Centers for Medicare and Medicaid Services
K-M	= Kaplan-Meier
LAA	= left atrial appendage
PS	= propensity score
STS	= Society of Thoracic Surgeons

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AF.² A national database study confirmed that preoperative AF is associated with worse long-term survival, and higher risk of stroke or systemic embolization after CABG.¹

Although AF ablation during CABG in patients with preoperative AF has been associated with higher freedom from AF,³⁻⁵ single-center studies have shown improvement in clinical outcomes after AF ablation during other cardiac surgery⁶⁻¹⁰ but few in a dedicated CABG cohort.³ In this study, we sought to examine early and late outcomes in CABG patients with a preoperative history of AF to determine the association between surgical AF ablation and mortality and stroke or systemic embolization.

METHODS

Data were obtained from the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (versions 2.52, 2.61, and 2.73) on patients who were discharged between January 1, 2006, and December 31, 2013, and could be linked to Centers for Medicare and Medicaid Services (CMS) data using a validated deterministic matching algorithm.¹¹ Medicare recipients aged ≥ 65 years, with preoperative AF, undergoing isolated CABG as a first cardiac surgery were included in this study. After exclusions, the study population consisted of 34,600 patients with preoperative AF: 24,059 (69.5%) in the no surgical ablation (no ablation) group and 10,541 (30.5%) in the ablation group (Figure 1).

End Points

The primary outcome was all-cause mortality after CABG using STS registry data for in-hospital deaths and the linked Medicare Denominator

File for postdischarge deaths.¹² The secondary outcomes were stroke or systemic embolization (ie, stroke, hemorrhagic stroke, transient ischemic attack, or systemic arterial embolism)¹³ and in-hospital major morbidity.

Incident stroke or systemic embolization was defined by using STS registry data to account for in-hospital strokes and Medicare Part A data to identify subsequent re-hospitalizations with stroke or systemic embolization as a primary diagnosis (International Classification of Diseases, ninth revision codes: 433.1, 434.x1, 430, 431, 432.0, 432.1, 432.9, 444.x, and 435.x).

In-hospital major morbidity, a previously defined composite,^{14,15} referred to any of the following postprocedure complications: permanent stroke, new cases of renal failure, prolonged ventilation (ie, ventilation longer than 24 hours after surgery), reoperation for cardiac reasons (ie, graft dysfunction, bleeding, valve dysfunction, or other), and deep sternal wound infection.

Statistical Analysis

Patients treated in a given hospital share some commonalities inherent to that hospital (compared with patients treated elsewhere) that may influence how they were treated and thus influence their outcomes above and beyond the effects of treatment itself. Therefore, propensity scores (PS) for surgical ablation were determined using a hierarchical mixed model that includes both patient and hospital characteristics as well as a random intercept (with hospitals as random effects) to holistically capture and control for any confounding due to inherent hospital-related commonalities. Patient variables were based in the validated American College of Cardiology Foundation and the Society of Thoracic Surgeons Collaboration on the Comparative Effectiveness of Revascularization Strategies model¹⁶ for predictors of long-term mortality after CABG (Table 1). We also included region (ie, Northeast, West, South, or Midwest), hospital teaching status, hospital average annual volume of CABG in patients aged 65 and older and preoperative medications: aspirin, beta-blockers, angiotensin-converting enzyme inhibitors, statins, and anticoagulants. Consistent with the validated STS risk models,¹⁶ missing values (<3%) were imputed with relevant groups-specific medians for continuous variables and most common category for categorical ones.

A 1-to-1 optimal matching algorithm was used to obtain a matched sample to overcome differences in potential confounders between the 2 study groups. To assess balance, we compared the distribution of baseline characteristics before and after matching. Absolute values of standardized mean differences <10% suggest adequate balance.¹⁷ Before matching, the standardized differences ranged between -23 and 14, whereas in the matched sample, they ranged between -1.7 and 2.4, which indicates that balance was achieved after matching (Figure 2). Because use versus nonuse of ablation could be influenced by unmeasured confounders that cannot be adjusted for using registry variables, we tested the association between ablation and the falsification end point of fracture. In addition, to account for possible residual confounding, we use multivariate Cox-regression analysis in the matched sample (same covariates as in the American College of Cardiology Foundation and the Society of Thoracic Surgeons Collaboration on the Comparative Effectiveness of Revascularization Strategies model¹⁶) for long-term outcomes. Results were virtually the same as univariate Cox model (Table E1). A null association between the exposure (ablation) and a falsification suggested balance among unmeasured confounders.

The study groups were summarized before and after matching using medians and interquartile ranges (25th and 75th percentiles) for continuous variables and frequency counts and percentages for categorical variables and in-hospital outcomes. Differences in distributions between groups were evaluated with Wilcoxon and Pearson χ^2 tests, respectively.

For in-hospital outcomes, we computed odds ratios and 95% confidence intervals (CIs) for the overall and matched sample using generalized estimated equations logistic regression to account for hospital clustering of patients.

Time-to-event analysis was used to compare long-term survival and stroke or systemic embolization occurrence by group. For survival, patient follow-up was censored at the end of study period (January 1, 2014).

FIGURE 1. Flow diagram of the study cohort. The Society of Thoracic Surgeons (STS) database was queried for patients undergoing isolated coronary artery bypass graft (CABG) between 2006 and 2013. Exclusions and numbers of patients removed are shown on the left. This resulted in 34,600 patients with preoperative atrial fibrillation (AF) who were divided into those with or without surgical ablation during the CABG procedure. CV, Cardiovascular; CMS, Centers for Medicare and Medicaid Services; PCI, percutaneous coronary intervention.

Product-limit Kaplan-Meier (K-M) survival and failure estimates were computed for each group in the unmatched and matched samples and compared via log-rank tests. Cox proportional hazard regression models were used to compute hazard ratios for ablation versus no ablation in both samples. Because patients from a given hospital share commonalities compared to patients from different hospitals, we used a robust sandwich variance estimation to account for hospital clustering of patients and computed 95% CIs accordingly. The proportional hazard assumption was tested using log-log survival plots (log[-log] survival vs log-time) and interactions between study groups and log-time. Although the assumption was met in the overall sample, both methods suggested a marginal violation of the assumption in the matched sample, with curves crossing 2 years after surgery and a statistically significant interaction with time ($P = .01$). Given these results, hazard ratios (HRs) were computed in the unmatched and matched samples for the overall follow-up period, but we also performed a landmark analysis at 2 years to explore earlier versus later effects of surgical ablation in survival. Both, K-M survival curves and HRs were computed for each period.

For stroke or systemic embolization and the falsification end point of fracture, death was considered a competing risk. Follow-up was censored at death date, end of fee-for-service date, or end of study period, whichever came first. Date for in-hospital strokes postprocedure was not available and surgery date was assigned as the event date (23% of all strokes). For regression analysis, the Fine and Gray method was used to calculate the subdistribution HRs. The proportional hazards assumption (accounting for

competing risk of death) was tested by plotting Schoenfeld residuals^{18,19} for each treatment group versus log-time and also with interaction terms between study groups and log-time in regression models. Results suggested a violation of the assumption in the matched sample (P value for interaction with log-time in the matched sample was .0064 for stroke or systemic embolization). Therefore, a landmark analysis at 2 years was performed and cumulative incidence function curves and subdistribution HRs were computed for each period.

All tests were 2-sided. Analyses were performed using SAS (version 9.4, SAS Institute Inc, Cary, NC).

RESULTS

Patient and Operative Characteristics

Compared with patients treated with ablation, patients in the no ablation group were older, had a higher incidence of renal failure (glomerular filtration rate <30 or undergoing dialysis), diabetes, chronic lung disease, lower ejection fraction, and New York Heart Association functional class IV, incidence of dyslipidemia, and hypertension was similar. After PS matching, the groups were statistically similar except for fewer myocardial infarctions in the ablation group (40.4%) compared with the no ablation group

TABLE 1. Baseline and operative characteristics of patients with preoperative atrial fibrillation in the no surgical ablation and surgical ablation groups

Variable	Unmatched			Propensity score matched		
	No ablation (n = 24,059)	Ablation (n = 10,541)	P value	No ablation (n = 9771)	Ablation (n = 9771)	P value
Age (y)	75 (71, 80)	74 (70, 78)	<.0001	74 (69, 79)	74 (70, 78)	.1049
Female	6920 (29)	2561 (24)	<.0001	2370 (24)	2439 (25)	.2729
Body mass index	28.10 (25, 32)	28.61 (25, 33)	.954	28 (25, 32)	28 (25, 32)	.9893
Height (cm)	173 (165, 180)	175 (168, 180)	<.0001	175 (168, 180)	175 (168, 180)	.6838
Race						
Other	428 (1.8)	208 (2.0)	<.0001	174 (1.8)	176 (1.8)	.9835
Asian	283 (1.2)	102 (1.0)		102 (1.0)	99 (1.0)	
Hispanic	548 (2.3)	138 (1.3)		130 (1.3)	138 (1.4)	
Black	751 (3.1)	217 (2.1)		204 (2.1)	210 (2.2)	
White	21,952 (91.2)	9848 (93.4)		9132 (93.5)	9122 (93.4)	
Missing	97 (0.4)	28 (0.3)		29 (0.3)	26 (0.3)	
Current smoking	3111 (12.9)	1160 (11.0)	<.0001	1126 (11.5)	1108 (11.3)	.6857
Diabetes	9903 (41.2)	4164 (39.5)	<.0001	3832 (39.2)	3844 (39.3)	.8209
Hypertension	21,615 (89.8)	9417 (89.3)	.1523	8695 (89.0)	8728 (89.3)	.4477
Dyslipidemia	19,776 (82.4)	8687 (82.2)	<.0001	8102 (83.0)	8063 (82.5)	.4132
Peripheral vascular disease	5355 (22.3)	1837 (17.4)	<.0001	1758 (18.0)	1760 (18.0)	.9783
Renal failure*	1625 (6.8)	423 (4.0)	<.0001	434 (4.4)	452 (4.6)	.5319
Glomerular filtration rate	61 (49, 74)	65 (53, 75)	<.0001	64.7 (52, 80)	64.7 (52, 75)	.2077
Chronic lung disease			<.0001			.2990
Severe	1644 (6.8)	552 (5.2)		533 (5.5)	532 (5.0)	
Moderate	2179 (9.1)	788 (7.5)		707 (7.2)	733 (7.5)	
Cerebrovascular disease	5735 (23.8)	2204 (20.9)	<.0001	2098 (21.5)	2077 (21.3)	.5540
Transient ischemic attack	1620 (6.7)	653 (6.2)	.0627	651 (6.7)	608 (6.2)	.2103
Previous carotid surgery	1739 (7.2)	583 (5.5)	<.0001	554 (5.7)	557 (5.7)	.9262
Carotid stenosis >75%	964 (4.0)	319 (3.0)	<.0001	315 (3.2)	305 (3.1)	.6832
Immunosuppressive treatment	993 (4.1)	342 (3.2)	<.0001	306 (3.1)	318 (3.3)	.6272
Preoperative myocardial infarction			<.0001			.0015
≤6 h	47 (0.2)	12 (0.1)		8 (0.1)	12 (0.1)	
>6 h but <24 h	212 (0.9)	43 (0.4)		43 (0.4)	42 (0.4)	
Between 1 and 21 d	7476 (31.1)	2211 (21.0)		2031 (20.8)	2130 (21.8)	
No myocardial infarction	11,850 (49.3)	6350 (60.2)		5696 (58.3)	5822 (59.6)	
Coronary artery disease						
Left main ≥50%	8713 (36.2)	3360 (31.9)	<.0001	3174 (32.5)	3173 (32.5)	.9838
3 vessels	18,524 (77.0)	7946 (75.4)	.0043	7443 (76.2)	7416 (75.9)	.8993
2 vessels	4720 (19.6)	2225 (21.1)		1993 (20.4)	2014 (20.6)	
1 vessel	815 (3.4)	370 (3.5)		335 (3.4)	341 (3.5)	
Left ventricular ejection fraction ≥55%	10,761 (46)	4971 (48.2)	<.0001	4631 (48.8)	4570 (47.8)	.4303
NYHA functional class IV	1796 (25)	608 (22.5)	.0001	578 (23.1)	573 (22.5)	.6947
Aortic stenosis, moderate or severe	1124 (4.7)	383 (3.6)	<.0001	347 (3.6)	362 (3.7)	.5651
Urgent procedure	14,303 (59.5)	5366 (50.9)	<.0001	5040 (51.6)	5047 (51.7)	.9202

(Continued)

TABLE 1. Continued

Variable	Unmatched		<i>P</i> value	Propensity score matched		<i>P</i> value
	No ablation (n = 24,059)	Ablation (n = 10, 541)		No ablation (n = 9771)	Ablation (n = 9771)	
CHA ₂ DS ₂ -VASc score			<.0001			0.138
1-3	9560 (65.5)	5028 (34.5)		4608 (50.1)	4574 (49.8)	
4-6	13,145 (72.1)	5088 (27.9)		4805 (50.1)	4785 (49.9)	
7-9	1354 (76.1)	425 (23.9)		358 (46.5)	412 (53.5)	
STS mortality risk score†	2.84 (1.6, 4.6)	2.19 (1.4, 3.6)	<.0001	2.25 (1.4, 3.7)	2.3 (1.4, 3.7)	.9239
Predicted major morbidity	19.34 (13.8, 28)	16.58 (12.1, 23.4)	<.0001	16.77 (12.2, 23.9)	16.8 (12.3, 23.8)	.9303
Predicted stroke	1.72 (1.2, 2.6)	1.44 (1.02, 2.13)	<.0001	1.46 (1, 2.2)	1.47 (1, 2.2)	.7821
Predicted renal failure	4.69 (2.7, 9)	3.92 (2.33, 7.25)	<.0001	3.92 (2.3, 7.5)	3.97 (2.4, 7.4)	.3675
Predicted prolonged ventilation	11.87 (8.1, 18.3)	9.89 (6.9, 14.7)	<.0001	10.05 (7.1, 15.1)	10 (7, 15)	.9011
Predicted deep sternal wound infection	0.39 (0.25, 0.64)	0.35 (0.24, 0.56)	<.0001	0.35 (0.24, 0.57)	0.35 (0.24, .056)	.5853
Predicted reoperation	6.98 (5.5, 9.3)	6.22 (5, 8.1)	<.0001	6.28 (5.1, 8.2)	6.28 (5.06, 8.13)	.8795
Cardiopulmonary bypass time (min)	90 (70, 115)	107 (84, 136)	<.0001	90 (70, 115)	108 (85, 137)	<.0001

Values for continuous variables are presented as median (first quartile, third quartile); for variables with discrete distributions, values are n (%). NYHA, New York Heart Association, CHA₂DS₂-VASc, congestive heart failure, hypertension, age ≥75 years, diabetes, previous stroke/transient ischemic attack-vascular disease, age 65-74 years, sex category; STS, Society of Thoracic Surgeons. *Glomerular filtration rate <30 or receiving dialysis. †STS risk scores use the 2007 model.

(41.7%) (Table 1). Mean cardiopulmonary bypass time was longer in the ablation group (113 ± 43 minutes vs 95 ± 36 minutes; *P* < .0001) for the unmatched and matched groups. There were no data available on the ablation lesion sets or management of the left atrial appendage (LAA).

Perioperative Results

In the unmatched analysis, in-hospital outcomes were not statistically different. In the matched analysis, patients in the ablation group had greater in-hospital mortality, prolonged ventilation, and new renal failure compared with the no ablation group. Subanalysis of the operative mortality showed that patients with higher Congestive heart failure, hypertension, age ≥75 years, diabetes, stroke, vascular disease, age 65-74 years, sex category (CHA₂DS₂-VASc) scores revealed higher operative mortality in patients with a CHA₂DS₂-VASc score of 7 to 9, and the lowest operative mortality in the ablation group with a CHA₂DS₂-VASc score of 1 to 3 (Table 2).

Long-term Results: Mortality and Stroke or Systemic Embolization

In the unmatched analysis, the 1-year overall K-M failure estimates (mortality incidence) was 10.8% (95% CI, 10.2%-11.4%) in the ablation group compared with 13.3% (95% CI, 12.9%-13.8%) in the no ablation group. The 5-year overall mortality was 29.9% (95% CI, 28.8%-31.0%) in the ablation group compared with 37.1% (95% CI, 36.3%-37.8%) in the no ablation group. The HR for mortality (Figure 3, A) was 0.78 (95% CI, 0.74-0.82). The 1-year CIF for stroke or systemic embolization was 3.7% (95% CI, 3.4%-4.2%) in the ablation group

compared with 4.4% (95% CI, 4.1%-4.7%) in the no ablation group. The 5-year overall stroke or systemic embolization (Figure 4, A) was 8.8% (95% CI, 8.2%-9.5%) in the ablation group compared with 10.7% (95% CI, 10.2%-11.2%) in the no ablation group. The HR was 0.84 (95% CI, 0.77-0.91).

After PS matching, the 1-year overall mortality incidence was 11.1% (95% CI, 10.5%-11.7%) in the ablation group compared with 10.6% (95% CI, 10.0%-11.3%) in the no ablation group. The 5-year overall mortality was 30.2% (95% CI, 29.1%-31.4%) in the ablation group compared with 31.7% (95% CI, 30.6%-32.9%) in the no ablation group (log-rank *P* = .303) (Figure 3, B). The 1-year CIF for stroke or systemic embolization was 3.8% (95% CI, 3.4%-4.2%) in the ablation group compared with 3.9% (95% CI, 3.5%-4.3%) in the no ablation group. The 5-year overall stroke or systemic embolization was 8.8% (95% CI, 8.1%-9.5%) in the ablation group compared with 10.5% (95% CI, 9.7%-11.2%) in the no ablation group (log-rank *P* = .009) (Figure 4, B).

Landmark Analysis at 2 Years: Mortality and Stroke or Systemic Embolization

After PS matching, the difference in 2-year mortality was not statistically significant between ablation and no ablation groups (HR, 1.00; 95% CI, 0.93-1.08; log-rank *P* = .59). Among patients surviving past 2 years, mortality was lower in the ablation group (HR, 0.89; 95% CI, 0.82-0.97; log-rank *P* = .04) (Figure 3, C and D).

Similarly, the difference in 2-year incidence of stroke or systemic embolization was not statistically significant between ablation and no ablation groups (HR, 0.96; 95%

FIGURE 2. Propensity score-match assessment of balance before and after matching. A 1-to-1 optimal matching algorithm was used to overcome differences in potential confounders between the 2 study groups. We compared the distribution of baseline characteristics before (*blue squares*) and after matching (*triangles*). Before matching, the standardized differences ranged between -23 and 14 , whereas in the matched sample, they ranged between -1.7 and 2.4 , which indicates balance was achieved. *NYHA*, New York Heart Association, *CABG*, coronary artery bypass graft.

CI, 0.84- 1.10; Gray test $P = .50$). Among patients surviving past 2 years, incidence of stroke or systemic embolization was lower in the ablation group (HR, 0.73; 95% CI, 0.61-0.87; Gray test $P = .0005$) (Figure 4, C and D).

DISCUSSION

This is the largest contemporary study of ablation in CABG patients compared with those who had untreated AF. In this study ablation was associated with a small but statistically significant higher operative mortality. In

TABLE 2. In-hospital outcomes by surgical ablation group in unmatched and propensity score-matched patients

Variable	Unmatched			Propensity score matched				
	No ablation group (n = 24,059)	Ablation group (n = 10,541)	P value	No ablation group (n = 9771)	Ablation group (n = 9771)	P value	Odds ratio (95% confidence interval)	P value
In-hospital mortality	799 (3.3)	327 (3.1)	.2910	245 (2.5)	309 (3.2)	.0058	1.27 (1.07-1.51)	.0072
Operative mortality	962 (4.0)	390 (3.7)	.1012	304 (3.1)	372 (3.8)	.0165	1.21 (1.02-1.42)	.0244
CHA ₂ DS ₂ -VASC 1-3	242 (3.0)	107 (2.5)		95 (2.4)	99 (0.2)			
CHA ₂ DS ₂ -VASC 4-6	633 (5.7)	244 (5.5)		195 (4.7)	236 (5.7)			
CHA ₂ DS ₂ -VASC 7-9	87 (7.6)	39 (10.7)		15 (4.9)	37 (10.5)			
Composite morbidity	4756 (19.8)	2043 (19.38)	.4104	1690 (17.3)	1912 (19.6)	<.0001	1.16 (1.08-1.25)	<.0001
Reoperation for bleeding/ tamponade, graft, valve, other cardiac reason	936 (3.9)	445 (4.2)	.1497	386 (4.0)	420 (4.3)	.2224	1.09 (0.95-1.25)	.2145
Deep sternal wound infection	103 (0.4)	44 (0.4)	.8891	44 (0.5)	37 (0.4)	.4371	0.84 (0.54-1.30)	.4359
Permanent stroke	474 (2.0)	191 (1.8)	.3226	161 (1.7)	181 (1.9)	.2761	1.13 (0.91-1.39)	.2757
Prolonged ventilation	3326 (13.8)	1398 (13.3)	.1610	1104 (11.3)	1314 (13.5)	<.0001	1.22 (1.12-1.33)	<.0001
New renal failure	1371 (6.0)	664 (6.5)	.0838	480 (5.1)	617 (6.5)	<.0001	1.32 (1.16-1.49)	<.0001

Values are presented as n (%) unless otherwise noted. CHA₂DS₂-VASC, congestive heart failure, hypertension, age ≥ 75 years, diabetes, previous stroke/transient ischemic attack-vascular disease, age 65-74 years, sex category.

subanalysis of these patients, we determined the highest operative mortality was in the ablation group with CHA₂DS₂-VASC scores of 7 to 9 and the lowest mortality was also in the ablation group in patients with a CHA₂DS₂-VASC score of 1 to 3. Additionally, perioperative morbidity including prolonged ventilation and new renal failure was also higher. However, 2-year mortality did not differ by use versus nonuse of ablation. In patients who survived past 2 years, stroke or systemic embolization and mortality were lower in the ablation group (Figure 5).

A previous single-center series demonstrated a reduction in stroke after concomitant surgical AF ablation during cardiac surgery.²⁰ This current analysis is the first to show a long-term stroke or systemic embolization was lower after AF ablation in a CABG-only cohort. Because neither atria are opened routinely in CABG, the addition of AF ablation requires either omission of endocardial lesions or alteration of the CABG operation to allow for atrial access required for the Cox-maze procedure.²¹ Although the exact lesion set is unknown in this dataset (data unavailable until 2014), many patients may have received an incomplete ablation set of the Cox-maze procedure, causing an underestimation of the efficacy of AF ablation.

The effect of AF ablation on operative mortality and long-term survival has not been established in CABG patients. A previous study of Medicare patients with preoperative AF undergoing CABG showed that the addition of AF ablation was associated with an increase in 30-day mortality that was not statistically significant (adjusted odds ratio, 1.15; $P = .19$).²² However, another study of STS-CMS linked patients with preoperative AF demonstrated ablation

was associated with lower perioperative mortality,²³ but analyzed patients undergoing multiple cardiac operations, including mostly mitral valve surgery. A similar study, compiling data from 7 centers, found improved long-term survival in patients with AF who had concomitant ablation during CABG, valve, or CABG plus valve procedures.²⁴

Our study found that the HR for AF ablation and mortality was not proportional over time, and that survival curves crossed at 2 years. Therefore, AF ablation was associated with a small, statistically significant higher operative mortality that was mitigated over time and became equivalent through 2 years, and per the landmark analysis, significantly lower in patients surviving past 2 years. Moreover, patients with lower CHA₂DS₂-VASC scores had lower operative mortality when undergoing AF ablation, which is consistent with previous reports. On the other hand, patients with high CHA₂DS₂-VASC scores had lower operative mortality if AF ablation was performed, suggesting an important risk-benefit consideration.

Guidelines for the treatment of AF recommend concomitant ablation during CABG (class 1) in whom acceptable perioperative safety is expected.²⁵ Our study supports the recommendations that AF ablation should be performed during CABG in most patients with preoperative AF because after 2 years it is associated with lower stroke and mortality. Future guideline recommendations should take into account higher risk patients (eg, very elderly patients, high CHA₂DS₂-VASC). Our study also reveals that many patients did not get treatment of AF during CABG surgery suggesting underuse of surgical ablation of AF. The maze procedure has become less complex with modification of lesions, application of energy sources like cryotherapy

FIGURE 3. Mortality outcomes of patients in 6-year follow-up. A, Unadjusted overall data. B, Adjusted matched data. Mortality risk was similar between groups in the adjusted group ($P = .303$). Landmark analysis results for patients surviving past 2 years. C, Unmatched data. D, Matched data. Patients who had surgical ablation of atrial fibrillation had a lower risk of death ($P = .0358$).

and radio frequency, and devices to close the LAA.²⁶ Unfortunately, there were no data available on the LAA, although some variation of LAA closure is typical with AF ablation. Recent data regarding LAA closure in a population of elderly patients from the STS database showed a lower risk of readmission for thromboembolism over 3 years in patients who did have surgical occlusion of the LAA.²⁷ The evolution of these changes are not completely reflected in this current dataset; continued advancements may further

lower the perioperative risks, improve the efficacy of AF ablation, and reduce AF under treatment.

There has been ongoing study of whether percutaneous coronary intervention and CABG are equivalent.²⁸ Our data raise an important treatment implication for patients with coronary artery disease and AF. The improved late survival and lower risk of stroke and thromboembolic events shown in our study should be considered when evaluating patients with coronary artery disease with concomitant AF and perhaps tip the treatment strategy toward surgery,

FIGURE 4. Stroke or systemic embolization outcomes of patients in 6-year follow-up. A, Unadjusted overall data. B, Adjusted matched data. Landmark analysis results for patients surviving beyond 2 years. C, Unmatched data. D, Matched data. Patients who had surgical ablation of atrial fibrillation had a lower risk of stroke or systemic embolic event ($P = .0005$).

especially in younger patients who may benefit the most. See [Video 1](#) for a discussion of the paper.

Study Limitations

The linkage between STS and CMS Medicare database was incomplete and may have led to unintended bias. We analyzed the unlinked subjects who could not be linked and found no significant differences in baseline characteristic with the linked subjects. This analysis is most generalizable to patients aged 65 years or older who are most susceptible to the added risks associated with extended operating times. Finally, absent from this study (due to

lack of data availability) is the type and duration of preoperative AF (paroxysmal vs persistent), the AF lesions sets, and LAA management. Incomplete lesion sets of the Cox-maze procedure potentially lowered the effectiveness of AF ablation, and the omission of surgical LAA closure (associated with reduced risk of thromboembolism)²⁷ both bias results to the null hypothesis.

CONCLUSIONS

AF ablation in CABG patients with preoperative AF is associated with lower stroke or systemic embolization at

FIGURE 5. Patients undergoing isolated coronary artery bypass surgery with a history of preoperative atrial fibrillation (AF) may benefit from concomitant AF ablation. The Cox-maze IV maze lesion set is shown. However, detailed lesion set information was not available in our study. Although early stroke and mortality were similar, stroke or systemic embolization and mortality for patients surviving more than 2 years was lower. CABG, Coronary artery bypass graft.

5 years. The small but statistically significant higher perioperative risk should be considered in patients with vulnerabilities to increased operating time required for AF ablation. Lower mortality was observed in patients surviving past 2 years. Patients with ablation of AF had a lower operative mortality in the low CHA₂DS₂-VASc scores group but higher operative mortality in those with CHA₂DS₂-VASc scores of 7 to 9, suggesting a risk–benefit consideration for high risk, elderly patients.

Webcast

You can watch a Webcast of this AATS meeting presentation by going to: https://aats.blob.core.windows.net/media/18May01/Theater%201%20Booth%20134/S84%20-%20Update%20of%20surgical%20Ablation/S84_1_webcast_123616894.mp4.

Conflict of Interest Statement

Dr McCarthy has received speaker fees from Atricure and Medtronic. Dr Friedman has received educational grants from Boston Scientific, Medtronic, and Abbott; research grants from National Cardiovascular Data Registry funded by the National Institutes of Health (T 32 training grant HL069749-13), Boston Scientific, Abbott, Medtronic, and Biosense Webster; and consulting fees from Abbott; in addition, he is supported by the Joseph C. Greenfield Jr, MD, Scholar in Cardiology Award. All other authors have nothing to disclose with regard to commercial support.

The authors thank Mr and Mrs Timothy Thoelecke for their financial support of the Bluhm Cardiovascular Institute, at Northwestern University, which made this project possible.

References

- Malaisrie SC, McCarthy PM, Kruse J, Matsouaka R, Andrei AC, Grau-Sepulveda MV, et al. Burden of preoperative atrial fibrillation in patients undergoing coronary artery bypass grafting. *J Thorac Cardiovasc Surg.* 2018;155:2358-67.e1.
- Saxena A, Virk SA, Bowman S, Chan L, Jeremy R, Bannon PG. Preoperative atrial fibrillation portends poor outcomes after coronary bypass graft surgery: a systematic review and meta-analysis. *J Thorac Cardiovasc Surg.* 2018;155:1524-33.

VIDEO 1. Dr James L. Cox discusses the role of atrial fibrillation ablation during coronary artery bypass graft surgery. Video available at: [https://www.jtcvs.org/article/S0022-5223\(19\)33073-9/fulltext](https://www.jtcvs.org/article/S0022-5223(19)33073-9/fulltext).

3. Damiano RJ Jr, Gaynor SL, Bailey M, Prasad S, Cox JL, Boineau JP, et al. The long-term outcome of patients with coronary disease and atrial fibrillation undergoing the Cox maze procedure. *J Thorac Cardiovasc Surg.* 2003;126:2016-21.
4. Akpinar B, Sanisoglu I, Guden M, Sagbas E, Caynak B, Bayramoglu Z. Combined off-pump coronary artery bypass grafting surgery and ablative therapy for atrial fibrillation: early and mid-term results. *Ann Thorac Surg.* 2006;81:1332-7.
5. Geidel S, Lass M, Krause K, Schneider C, Boczor S, Kuck KH, et al. Persistent atrial fibrillation ablation concomitant to coronary surgery. *Thorac Cardiovasc Surg.* 2011;59:207-12.
6. Lee R, McCarthy PM, Wang EC, Vaduganathan M, Kruse J, Malaisrie SC, et al. Midterm survival in patients treated for atrial fibrillation: a propensity-matched comparison to patients without a history of atrial fibrillation. *J Thorac Cardiovasc Surg.* 2012;143:1341-51.
7. Attaran S, Saleh HZ, Shaw M, Bond L, Pullan MD, Fabri BM. Comparing the outcome of on-pump versus off-pump coronary artery bypass grafting in patients with preoperative atrial fibrillation. *Interact Cardiovasc Thorac Surg.* 2011;13:288-92.
8. Ad N, Holmes SD, Massimiano PS, Pritchard G, Stone LE, Henry L. The effect of the Cox-maze procedure for atrial fibrillation concomitant to mitral and tricuspid valve surgery. *J Thorac Cardiovasc Surg.* 2013;146:1426-34.
9. McCarthy PM, Manjunath A, Kruse J, Andrei AC, Li Z, McGee EC Jr, et al. Should paroxysmal atrial fibrillation be treated during cardiac surgery? *J Thorac Cardiovasc Surg.* 2013;146:810-23.
10. Musharbash FN, Schill MR, Sinn LA, Schuessler RB, Maniar HS, Moon MR, et al. Performance of the Cox-maze IV procedure is associated with improved long-term survival in patients with atrial fibrillation undergoing cardiac surgery. *J Thorac Cardiovasc Surg.* 2018;155:159-70.
11. Jacobs JP, Edwards FH, Shahian DM, Haan CK, Puskas JD, Morales DL, et al. Successful linking of the Society of Thoracic Surgeons Adult Cardiac Surgery Database to Centers for Medicare and Medicaid Services Medicare data. *Ann Thorac Surg.* 2010;90:1150-6.
12. Mann AF, Durham S. Death information in the research identifiable Medicare data. Vol 2017. <https://www.resdac.org/articles/death-information-research-identifiable-medicare-data>. Accessed December 27, 2019.
13. D'Agostino RS, Jacobs JP, Badhwar V, Paone G, Rankin JS, Han JM, et al. The Society of Thoracic Surgeons Adult Cardiac Surgery Database: 2017 update on outcomes and quality. *Ann Thorac Surg.* 2017;103:18-24.
14. Shahian DM, Edwards FH, Ferraris VA, Haan CK, Rich JB, Normand SL, et al. Quality measurement in adult cardiac surgery: part 1—conceptual framework and measure selection. *Ann Thorac Surg.* 2007;83:S3-12.
15. O'Brien SM, Shahian DM, DeLong ER, Normand SL, Edwards FH, Ferraris VA, et al. Quality measurement in adult cardiac surgery: part 2—statistical considerations in composite measure scoring and provider rating. *Ann Thorac Surg.* 2007;83:S13-26.
16. Shahian DM, O'Brien SM, Sheng S, Grover FL, Mayer JE, Jacobs JP, et al. Predictors of long-term survival after coronary artery bypass grafting surgery: results from the Society of Thoracic Surgeons Adult Cardiac Surgery Database (the ASCERT study). *Circulation.* 2012;125:1491-500.
17. Austin PC. Using the standardized difference to compare the prevalence of a binary variable between two groups in observational research. *Commun Stat Simul Comput.* 2009;38:1228-34.
18. Fine JP, Gray RJ. A proportional hazards model for the subdistribution of a competing risk. *J Am Stat Assoc.* 1999;94:496-509.
19. Gray RJ. A class of K-sample tests for comparing the cumulative incidence of a competing risk. *Ann Stat.* 1988;16:1141-54.
20. Fukunaga S, Hori H, Ueda T, Takagi K, Tayama E, Aoyagi S. Effect of surgery for atrial fibrillation associated with mitral valve disease. *Ann Thorac Surg.* 2008;86:1212-7.
21. Cox JL, Churyla A, Malaisrie SC, Kruse J, Pham DT, Kisilitsina ON, et al. When is a maze procedure a maze procedure? *Can J Cardiol.* 2018;34:1482-91.
22. Rankin JS, Lerner DJ, Braid-Forbes MJ, Ferguson MA, Badhwar V. One-year mortality and costs associated with surgical ablation for atrial fibrillation concomitant to coronary artery bypass grafting. *Eur J Cardiothorac Surg.* 2017;52:471-7.
23. Badhwar V, Rankin JS, Ad N, Grau-Sepulveda M, Damiano RJ, Gillinov AM, et al. Surgical ablation of atrial fibrillation in the United States: trends and propensity matched outcomes. *Ann Thorac Surg.* 2017;104:493-500.
24. Iribarne A, DiScipio AW, McCullough JN, Quinn R, Leavitt BJ, Westbrook BM, et al. Surgical atrial fibrillation ablation improves long-term survival: a multi-center analysis. *The Ann Thorac Surg.* 2019;107:135-42.
25. Badhwar V, Rankin JS, Damiano RJ Jr, Gillinov AM, Bakaeen FG, Edgerton JR, et al. The Society of Thoracic Surgeons 2017 clinical practice guidelines for the surgical treatment of atrial fibrillation. *Ann Thorac Surg.* 2017;103:329-41.
26. Cox JL, Malaisrie SC, Kisilitsina ON, McCarthy PM. The electrophysiologic basis for lesions of the contemporary Maze operation. *J Thorac Cardiovasc Surg.* 2019;157:584-90.
27. Friedman DJ, Piccini JP, Wang T, Zheng J, Malaisrie SC, Holmes DR, et al. Association between left atrial appendage occlusion and readmission for thromboembolism among patients with atrial fibrillation undergoing concomitant cardiac surgery. *JAMA.* 2018;319:365-74.
28. Doenst T, Haverich A, Serruys P, Bonow RO, Kappetein P, Falk V, et al. PCI and CABG for treating stable coronary artery disease: JACC review topic of the week. *J Am Coll Cardiol.* 2019;73:964-76.

Key Words: atrial fibrillation, maze, ablation, coronary artery bypass grafting

TABLE E1. Independent Cox regression analysis for mortality and stroke or systemic embolism in the total cohort and propensity matched cohort

Variable	Unmatched unadjusted hazard ratio (95% confidence interval)	Unmatched regression adjusted hazard ratio (95% confidence interval)	Matched unadjusted hazard ratio (95% confidence interval)	Matched regression adjusted hazard ratio (95% confidence interval)
Mortality				
Ablation vs no ablation	0.78 (0.74-0.82)	0.95 (0.9-1)	0.97 (0.92-1.03)	0.95 (0.89-1.01)
Stroke or systemic embolism				
Ablation vs no ablation	0.84 (0.77-0.91)	0.89 (0.81-0.97)	0.87 (0.79-0.97)	0.86 (0.78-0.96)