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CLINICAL PRACTICE GUIDELINE

The Society of Thoracic Surgeons 2023 Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation

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The Society of Thoracic Surgeons 2023 Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation incorporate the most recent evidence for surgical ablation and left atrial appendage occlusion in different clinical scenarios. Substantial new evidence regarding the risks and benefits of surgical left atrial appendage occlusion and the long-term benefits of surgical ablation has been produced in the last 5 years. Compared with the 2017 clinical practice guideline, the current update has an emphasis on surgical ablation in first-time, nonemergent cardiac surgery and its long-term benefits, an extension of the recommendation to perform surgical ablation in all patients with atrial fibrillation undergoing first-time, nonemergent cardiac surgery, and a new class I recommendation for left atrial appendage occlusion in all patients with atrial fibrillation undergoing first-time, nonemergent cardiac surgery. Further guidance is provided for patients with structural heart disease and atrial fibrillation being considered for transcatheter valve repair or replacement, as well as patients in need of isolated left atrial appendage management who are not candidates for surgical ablation. The importance of a multidisciplinary team assessment, treatment planning, and long-term follow-up are reiterated in this clinical practice guideline with a class I recommendation, along with the other recommendations from the 2017 guidelines that remained unchanged in their class of recommendation and level of evidence.

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EXECUTIVE SUMMARY

In 2017, The Society of Thoracic Surgeons (STS) published the Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation.[1] This document provides a Clinical Practice Guidelines update, incorporating new evidence generated since 2017. Institute of Medicine standards were used to prepare this 5-year update, and a comprehensive literature search was conducted to identify and include all new data. Over the last 5 years, substantial new evidence, including data from randomized clinical trials, has been generated primarily about the management of the left atrial appendage in patients with a history of atrial fibrillation. Further, several large national databases have studied the association of surgical ablation and longer-term outcomes in patients with atrial fibrillation undergoing concomitant cardiac surgery procedures.

After a review of all new data and confidential voting, the consensus of the writing group was to give a stronger recommendation for the obliteration of the left atrial appendage in patients with atrial fibrillation undergoing concomitant cardiac surgical procedures and to expand the recommendation of surgical ablation to patients with

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atrial fibrillation with any first-time nonemergent concomitant procedure.

Lastly, guidance for patients with atrial fibrillation and valvular heart disease being considered for transcatheter valve repair or replacement has been added to this version of the Clinical Practice Guidelines (Table 1). The remaining recommendations were adopted from the 2017 Clinical Practice Guidelines without further modification (Table 2). The complete recommendations of the 2023 STS Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation are summarized in Table 1.

BACKGROUND

In 2017, the STS published a comprehensive clinical practice guideline for the surgical treatment of patients with atrial fibrillation.[1] That document summarized the relevant literature at the time, classified outcome results, and provided clinically applicable recommendations. In accordance with the Institute of Medicine standards, Clinical Practice Guidelines are due for an update after 5 years to ensure guidelines reflect the current body of evidence and state of knowledge. Over the last 5 years, additional evidence supporting the use of surgical ablation (a landmark trial on the benefits of left atrial appendage occlusion/obliteration in patients with atrial fibrillation) and ongoing developments in the treatment of patients with structural heart disease, who often present with atrial fibrillation, warrant the revisitation of the 2017 recommendations.

Atrial fibrillation is a substantial public health concern with an increasing incidence and high prevalence in the general population.[2,3] It is particularly common among patients with other cardiovascular pathologies, especially those with valvular heart disease.[4] From 30% to 50% of patients undergoing surgical or transcatheter aortic valve replacement present with atrial fibrillation, which has been associated with a worse prognosis after the valve replacement, including worse procedural outcomes, bleeding events, and

TABLE 1 The Society of Thoracic Surgeons 2023 Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation Recommendations

Recommendations	COR	LOE
Recommendations for mitral valve operations		
Surgical ablation for atrial fibrillation is recommended for first-time nonemergent concomitant *mitral operations* to restore sinus rhythm and improve long-term outcomes.	I	A
Recommendations for operations other than mitral valve surgery		
Surgical ablation for atrial fibrillation is recommended for any first-time nonemergent concomitant *nonmitral operation* to restore sinus rhythm and improve long-term outcomes.	I	B-NR
Recommendations regarding stand-alone surgical ablation		
Surgical ablation for symptomatic atrial fibrillation in the absence of structural heart disease refractory to class I/III antiarrhythmic drugs, catheter-based therapy, or both, is reasonable as a primary stand-alone procedure to restore sinus rhythm.	IIa	B-NR
Surgical ablation for symptomatic persistent or longstanding persistent atrial fibrillation in the absence of structural heart disease is reasonable as a stand-alone procedure using the Cox maze III/IV lesion set as the preferred procedure.	IIa	B-NR
Surgical ablation for symptomatic atrial fibrillation in the setting of left atrial enlargement (≥4.5 cm) or more than moderate mitral regurgitation by pulmonary vein isolation alone is not recommended.	III	C
Recommendations for concomitant left atrial appendage management		
Left atrial appendage obliteration for atrial fibrillation is recommended for all first-time nonemergent cardiac surgery procedures, with or without concomitant surgical ablation, to reduce morbidity from thromboembolic complications.	I	A
Recommendations regarding stand-alone left atrial appendage management		
Isolated surgical left atrial appendage obliteration may be considered in patients with longstanding persistent atrial fibrillation, a high stroke risk, and contraindications for or failure of long-term oral anticoagulation.	IIb	B-NR
Recommendations for patients being considered for transcatheter valve therapies		
For patients with symptomatic valve disease and atrial fibrillation, who are deemed of low to intermediate surgical risk, surgical valve repair or replacement with concomitant surgical ablation and left atrial appendage occlusion is reasonable over isolated transcatheter valve repair or replacement alone to restore sinus rhythm and improve long-term outcomes.	IIa	B-NR
Recommendations for all patients with atrial fibrillation		
Multidisciplinary heart team assessment and treatment planning as well as long-term follow-up using periodic continuous electrocardiographic monitoring for rhythm assessment, are recommended to optimize patient outcomes.	I	C

COR, class of recommendation; LOE, level of evidence.

TABLE 2 Updated and New Recommendations in The Society of Thoracic Surgeons 2023 Clinical Practice Guidelines for the Surgical Treatment of Atrial Fibrillation

STS 2017 Clinical Practice Guidelines	COR	LOE	STS 2023 Clinical Practice Guidelines	COR	LOE
Recommendations for mitral valve operations:					
Surgical ablation for atrial fibrillation can be performed without additional risk of operative mortality or major morbidity and is recommended at the time of concomitant mitral operations to restore sinus rhythm.	I	A	Surgical ablation for atrial fibrillation is recommended for first-time nonemergent concomitant *mitral operations* to restore sinus rhythm and improve long-term outcomes.	I	A
Recommendations for operations other than mitral valve surgery:					
Surgical ablation for atrial fibrillation can be performed without additional operative risk of mortality or major morbidity and is recommended at the time of concomitant isolated aortic valve replacement, isolated coronary artery bypass graft surgery, and aortic valve replacement plus coronary artery bypass graft operations to restore sinus rhythm.	I	B-NR	Surgical ablation for atrial fibrillation is recommended for any first-time nonemergent concomitant *nonmitral operation* to restore sinus rhythm and improve long-term outcomes.	I	B-NR
Recommendations for concomitant left atrial appendage management:					
It is reasonable to perform left atrial appendage excision or exclusion in conjunction with surgical ablation for atrial fibrillation for longitudinal thromboembolic morbidity prevention.	IIa	C	Left atrial appendage obliteration for atrial fibrillation is recommended for all first-time nonemergent cardiac surgery procedures, with or without concomitant surgical ablation, to reduce morbidity from thromboembolic complications.	I	A
At the time of concomitant cardiac operations in patients with atrial fibrillation, it is reasonable to surgically manage the left atrial appendage for longitudinal thromboembolic morbidity prevention.	IIa	C			
Recommendations regarding stand-alone left atrial appendage management:					
			Isolated surgical left atrial appendage obliteration may be considered in patients with longstanding persistent atrial fibrillation, a high stroke risk, and contraindications for or failure of long-term oral anticoagulation.	IIb	B-NR
Recommendations for patients being considered for transcatheter valve therapies:					
			For patients with symptomatic valve disease and atrial fibrillation, who are deemed of low to intermediate surgical risk, surgical valve repair or replacement with concomitant surgical ablation and left atrial appendage occlusion is reasonable over isolated transcatheter valve repair or replacement alone to restore sinus rhythm and improve long-term outcomes.	IIa	B-NR

COR, class of recommendation; LOE, level of evidence; STS, The Society of Thoracic Surgeons.

mortality at 2 years.[5-8] Considerations for managing atrial fibrillation and the left atrial appendage should therefore be commonplace in many areas now increasingly treated jointly by surgeons, interventional cardiologists, and electrophysiologists in a multidisciplinary fashion.

Numerous studies have investigated different energy sources, lesion sets, comprehensive procedural outcomes, and specific clinical indications. Although results of previous work have at times seemed unclear owing to procedural or electrophysiologic heterogeneity, a consistent clinical picture has emerged in the past decade. The success of surgical ablation is dependent on the lesion set and the tools used to create the lesions.

In patients with primary mitral regurgitation, surgical ablation resulting in sustained restoration of sinus rhythm has become an established method for eliminating long-term anticoagulation therapy in patients with atrial fibrillation. Thus, mitral repair and surgical ablation with the Cox maze procedure have become naturally complementary operations.[9,10] The rate of surgical ablation performed concomitantly in patients with atrial fibrillation at the time of mitral valve repair in the United States has risen from 52% to 61.5% over the last decade,[11,12] yet an opportunity exists to improve this rate further.

In a recent review of the STS Adult Cardiac Surgery Database, the adoption of surgical ablation and surgical left atrial appendage occlusion has not changed substantially in the last 5 years, again demonstrating substantial room for changes in cardiac surgery practice to align more with current guidelines. In 2022, only 43% of all patients with documented atrial fibrillation undergoing first-time, nonemergent cardiac surgery were treated with surgical ablation plus surgical left atrial appendage occlusion, whereas 30% received neither a

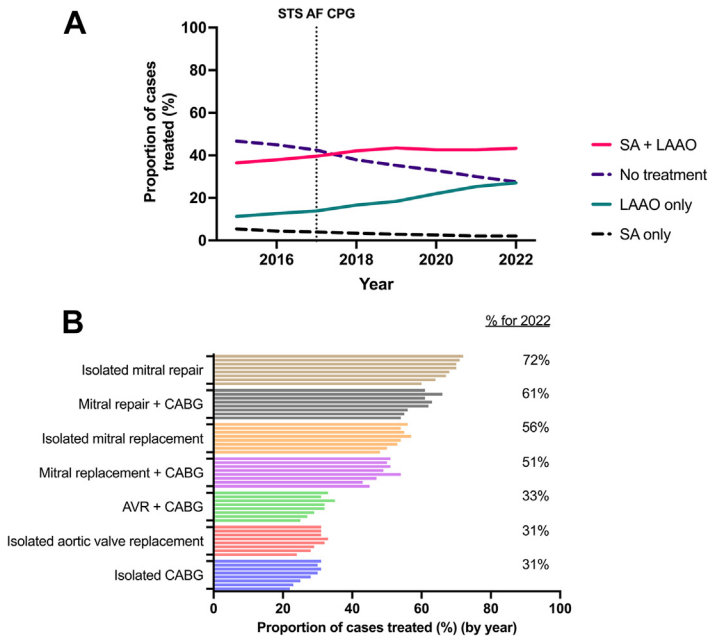

FIGURE 1 Adoption of surgical ablation and left atrial appendage occlusion at first-time, nonemergent heart surgery. (A) Shows the percentage of patients with documented atrial fibrillation undergoing first-time, nonemergent cardiac surgery being treated with surgical ablation (SA), SA + left atrial appendage occlusion (LAAO), LAAO alone, or no treatment. (B) Shows the adoption of complete treatment (SA + LAAO of atrial fibrillation in the same cohort) and by procedure type for each year between 2015 and 2022 (each year represented by one bar). The 2022 percentage of treatment is also listed numerically on the right-hand side of the figure. (AVR, aortic valve replacement; CABG, coronary artery bypass grafting; STS AF CPG, The Society of Thoracic Surgeons 2017 Clinical Practice Guidelines on the Surgical Treatment of Atrial Fibrillation.)

surgical ablation nor any left atrial appendage management (Figure 1). The undertreatment of atrial fibrillation, including left atrial appendage occlusion, is particularly evident among patients undergoing isolated coronary artery bypass grafting or aortic valve replacement, with generally greater treatment of both surgical ablation and left atrial appendage occlusion/obliteration among patients receiving a mitral valve procedure (Figure 1).[13] Clearly, this represents an area in need of further education and better implementation of guideline-recommended practice. Barriers to this process and potential solutions were recently identified in a survey across 2 statewide quality collaboratives.[14]

The gold standard of surgical ablation has remained the Cox maze procedure and its iteration, based on the original work of Dr Cox. Over the years, the operation evolved into the Cox maze III, or the "cut-and-sew" maze,[15] which has been applied extensively in clinical practice.[16] Modifications of the atrial lesion sets evolved as new energy sources were developed,[17,18] and Damiano and associates[19,20] used a combination of radiofrequency energy and cryoablation to replace several of the maze III cut-and-sew lesions, calling this facilitated procedure the Cox maze IV. The safety and effectiveness of the Cox maze III/IV procedure have been substantiated by several studies, regardless of the chosen energy source for ablation or the surgical access.[21-23]

Similarly, in select atrial fibrillation patients in whom the absence of moderate or more severe structural heart disease has been documented conclusively by appropriate imaging, enabling technologies have stimulated a resurgence of interest in epicardial surgical ablation performed as a stand-alone procedure or in combination with staged hybrid catheter-based ablation.[24,25] Based on the performance and durable rhythm success even in patients with longstanding, persistent atrial fibrillation, adoption of surgical ablation as a stand-alone procedure, especially using minimally invasive and robotic-assisted techniques, has increased.[26-28] A study of the STS Adult Cardiac Surgery Database investigating the results of stand-alone surgical therapy for isolated atrial fibrillation between 2011 and 2017 noted a 7% annual growth rate in stand-alone surgical ablation, with a 4% annual increase in the number of centers performing these procedures.[29]

As with the previous Clinical Practice Guidelines version, this guideline assessed the optimal application of surgical ablation and management of the left atrial appendage to provide recommendations for 3 operation categories in clinical practice: primary open atrial operations, primary closed atrial operations, and stand-alone operations for atrial fibrillation.[1] The aim of this effort was to distill the existing literature into recommendations in the field of *surgical ablation* for atrial fibrillation, whereby an element of heterogeneity exists in studied patient populations, concomitant operations, disease stages (paroxysmal to long-standing persistent atrial fibrillation), surgical techniques (eg, on-pump vs off-pump), ablation methods (lesion set and energy source), and studied end points and their ascertainment.

A substantial body of literature on the efficacy and effectiveness of surgical ablation has been produced by individuals, institutions, and trials subscribing to the importance of complete electric isolation of the left atrium and/or a complete biatrial maze procedure. Yet, significant contemporary evidence for the association of surgical ablation and left atrial appendage management with improved outcomes is also derived from large observational cohorts, which do not discern different ablation methods, or clinical trials permitting different techniques of left atrial appendage management, therefore precluding statements and recommendations that are specific to different surgical techniques. The complete list of recommendations of the clinical practice guidelines presented herein is provided in Table 1, and

recommendations that are new or changed from the 2017 Clinical Practice Guidelines are provided in Table 2.

METHODOLOGY

The STS Workforce on Evidence-Based Surgery assembled a writing group in 2022 to update the 2017 Clinical Practice Guidelines from a roster of new and previous writing group members. A balanced, unbiased writing group was assembled, emphasizing clinical experience and scientific background. All members were asked to declare all industry collaboration or support and any other potential conflict of interest pertaining to atrial fibrillation, surgical ablation, or left atrial appendage management. The full details of the disclosures of interests for each author are provided (Supplemental Table 1).

The guideline writing committee reviewed the literature published on surgical ablation and left atrial management published since 2017. In concordance with the 2017 Clinical Practice Guidelines version, operations were classified as concomitant surgical ablation associated with primarily open atrial operations (ie, mitral valve repair or replacement), concomitant surgical ablation at the time of primary closed atrial operations (ie, aortic valve replacement, coronary artery bypass grafting, or aortic valve replacement plus coronary artery bypass grafting), and surgical ablation or left atrial appendage occlusion performed as a stand-alone operative procedure. Literature searches focused on randomized controlled trials and meta-analyses but also used registries, observational and descriptive studies, reviews, and expert opinion.

LITERATURE REVIEW AND RECOMMENDATIONS

A comprehensive literature search was conducted in the MEDLINE and Embase databases. Formal search results were limited to papers published on human subjects in English between January 1, 2017, and January 1, 2023, using the same search algorithm as detailed previously.[1] A manual examination of the identified studies supplemented the literature search. More than 1143 results were obtained. Papers were excluded if they were case reports, were population-based studies covering only incidence and risk factors for atrial fibrillation, had a primary focus on nonsurgical procedures, or sought to identify potential outcomes or markers not within the focus of this guideline. A total of 35 relevant new articles met the inclusion criteria and were analyzed in detail by the writing group. Observational studies were appraised using the Newcastle-Ottawa scale (Supplemental Table 2). Appraisals of randomized clinical trials and meta-analyses used checklists modeled after those recommended by the Center on Evidence Based Medicine, and all extracted and reviewed data were compiled in the form of evidence tables.

Select meta-analyses were conducted where data from multiple studies were deemed adequate and reasonably similar to justify the pooling of estimates using random effect models (long-term outcomes with surgical ablation; concomitant left atrial appendage occlusion). Only published meta-analyses were included in the main guideline document. Meta-analyses conducted by the task force are in the Supplemental Materials (Supplemental Figures A-H).

All authors reviewed all data. Considering prior evidence included in the 2017 Clinical Practice Guidelines and the new evidence, recommendations were formulated and reviewed by all members consistent with Institute of Medicine standards for guideline development.[30,31] A modified Delphi consensus process and anonymous electronic voting was used to approve the final recommendations (Supplemental Table 3). The recommendations are graded according to the American College of Cardiology/American Heart Association Recommendation System.[32] The manuscript was presented to and approved by the STS Workforce on Evidence-Based Surgery, the STS Council on Quality and Research, and the STS Executive Committee.

1. MITRAL VALVE OPERATIONS AND CONCOMITANT SURGICAL ABLATION.

Mitral valve replacement or repair, in combination with other procedures or not, is the most common surgery requiring the opening of the left atrium and, with that, providing an opportunity to complete a concomitant left atrial surgical ablation for atrial fibrillation. Patients with mitral valve disease have a high incidence of atrial fibrillation at the time of presentation for surgery, ranging from 20% to 42%,[33,34] and therefore is the population that predominantly has been studied in randomized clinical trials and observational studies of surgical ablation. Isolated or combined mitral valve procedures also continue to be the operations with the greatest adoption of surgical ablation for patients with atrial fibrillation (Figure 1). On the other hand, high baseline risk, reoperation, and concerns about a prolonged ischemic time seem to be factors in the decision not to perform ablation,[14] despite evidence that worse risk profiles are not a contraindication to surgical ablation. On the basis of available data, current ablation techniques are safe and should be applied during open left atrial procedures, even for high-risk patients.[35-39]

Several randomized clinical trials of mitral patients have established surgical ablation as an effective intervention to reduce the prevalence of early postoperative atrial fibrillation by more than 50%.[40-43] In addition, randomized clinical trials and

meta-analyses predominantly including mitral patients have consistently shown a substantial reduction in atrial fibrillation burden at the 1-year follow-up,[44-46] with some studies extending early success into the longer-term.[47,48] In the Cardiothoracic Surgical Trials Network randomized clinical trial, 260 patients with persistent or long-standing persistent atrial fibrillation underwent pulmonary vein isolation, a biatrial maze procedure, or no ablation during concomitant mitral valve surgery. Ablation resulted in significant higher freedom from atrial fibrillation at 12 months (63% vs 29%), a higher risk of permanent pacemaker implantation, and lower mortality (6.8% vs 8.7%), although this did not reach statistical significance.[46]

Duration of atrial fibrillation, left atrial size, and advanced patient age all influence success rates.[49-51] Equally good results are achieved for rheumatic mitral valve disease as for other etiologies.[52-55] The literature also supports the existence of a learning curve with improving outcomes as experience increases.[56] In most studies, patients achieving sinus rhythm demonstrate improved symptoms as well as quality of life. Irrespective of survival benefit, evidence of improved long-term quality of life appears to be documented as one of the consistent and compelling benefits of effective surgical ablation for atrial fibrillation.[57-59]

Demonstrating a causal survival benefit in mitral patients after surgical ablation is difficult because these patients typically are younger and healthier than other patients with atrial fibrillation requiring cardiac surgery.[60,61] Furthermore, the follow-up of existing randomized clinical trials is insufficient to document long-term outcomes. The well-established association of atrial fibrillation with morbidity and mortality through various mechanisms would suggest that elimination of atrial fibrillation and restoration of physiologic cardiac excitation would result in better survival, and improving conversion rates is therefore essential for manifesting the full potential of surgical ablation.

A propensity-matched study demonstrated significant survival benefits after surgical ablation with successful restoration of sinus rhythm.[62] This result was observed in the overall population and in the paroxysmal atrial fibrillation groups.[63] Similar survival benefits were published by an international registry.[64] Several studies have documented better recovery of left ventricular function after successful sinus rhythm restoration, and left atrial size usually decreases.[65,66] Surgical ablation also may be associated with superior long-term freedom from stroke compared with nontreatment,[67-69] although a low but persistent stroke potential continues.[70]

There is also increasing evidence for the long-term benefits of surgical ablation in patients undergoing mitral valve surgery and other concomitant procedures. Recently, a national registry study from the Republic of Poland including 3568 patients undergoing mitral valve surgery with a median follow-up of 5 years showed reduced all-cause mortality with surgical ablation (hazard ratio, 0.82; 95% CI, 0.7-0.96).[71] Similar long-term survival benefits were found in an institutional study of patients with rheumatic mitral valve disease by Kim and associates.[69] monitoring 1229 patients for more than 5 years, as well as by several national registry studies from Taiwan, Korea, Poland, and the United States, including mitral valve, coronary artery bypass grafting, and other procedures (Supplemental Figure D).[72,73]

Variables that are consistently found to be associated with lower rates of conversion to sinus rhythm after surgical ablation include large left atrium, advanced age, cumulative atrial fibrillation burden, a less extensive ablation procedure, in particular, omission or incompleteness of the left posterior wall isolation, and the coronary sinus lesion.[17,48,64,74-77] The safety of surgical ablation in patients undergoing concomitant mitral valve procedures is well established. Institutional data from various centers[60] focusing on mitral valve patients and STS database analyses, including other concomitant procedures, consistently show no increase in major morbidity or mortality with adding surgical ablation to the procedure.[11]

Most recently, a comprehensive analysis of the STS database, including patients undergoing mitral valve surgery for primary mitral regurgitation, showed excellent short-term morbidity and mortality outcomes that were not increased with the addition of surgical ablation.[78] The analysis of the STS database also showed a potential association of surgical ablation with the observation of renal dysfunction. The same was found in a recent institutional analysis that observed an increased risk of acute kidney injury (odds ratio, 1.89; 95% CI, 1.12-3.18; $P = .017$) independent of the length of time on cardiopulmonary bypass.[79] However, there was not an increased risk of permanent dialysis, nor did the higher incidence of acute kidney injury impact the survival benefit seen with surgical ablation.[79] Despite these observed associations, a direct causal link between surgical ablation and acute kidney injury has yet to be established in the literature.

Studies with several years of follow-up have described an association between surgical ablation and the need for permanent pacemaker implantation. In the STS database, patients who underwent concomitant surgical ablation with coronary artery bypass grafting, valve surgery, or a combination thereof had a greater likelihood of requiring a permanent pacemaker (7.8% vs 5.9%; risk-adjusted odds ratio, 1.33; 95% CI, 1.24-1.43; $P < .0001$).[78] The same pattern was suggested in an

observational study of mitral valve surgery patients undergoing concomitant surgical ablation or not, which reported no increase in mortality or major operative risk with surgical ablation but a 2-fold to 3-fold higher incidence of pacemaker implantation among patients undergoing ablation vs patients undergoing mitral valve surgery alone.[60] In recent studies evaluating a broader spectrum of patients, including multivalve procedures, the reported need for early pacemaker implantation associated with surgical ablation has spanned a wide range from 1.6%[80] to 14%.[81]

The substantial variability in pacemaker implantation after surgical ablation is likely explained by differences in surgical technique and practice patterns leading to pacemaker implantation, such as proactive evaluation for sick sinus syndrome, which is associated with the duration of atrial fibrillation. Several studies with 2 or more years of follow-up cited previously evaluated the association of surgical ablation with the long-term risk of requiring permanent pacemaker implantation, showing an increase in permanent pacemaker implantation over time (Supplemental Figure H).

Recommendations for mitral valve operations:

1. **Surgical ablation for atrial fibrillation is recommended for first-time nonemergent concomitant *mitral operations* to restore sinus rhythm and improve long-term outcomes.**
   - **Class of recommendation: I**
   - **Level of evidence: A**

2. SURGICAL ABLATION DURING CONCOMITANT CLOSED-ATRIAL NONMITRAL VALVE SURGERY. In patients with structural, nonmitral heart disease and patients with coronary artery disease, atrial fibrillation is common and associated with an increased risk of early and late mortality and morbidity.[82-85] Preexisting atrial fibrillation at the time of surgical aortic valve replacement is strongly associated with increased cardiovascular morbidity and all-cause mortality.[84,86,87] Furthermore, surgical ablation at the time of coronary artery bypass grafting, valve procedures, aortic procedures, and combinations thereof have been associated with improved outcomes, including long-term survival.[67,77,88] In patients with aortic stenosis specifically, the benefits of surgical aortic valve replacement plus surgical ablation over transcatheter aortic valve replacement alone have also been demonstrated.[89] Surgical ablation concomitant with procedures without a structural indication for left atriotomy is inherently different because added procedural surgical decision making is required. One can certainly perform left and right atriotomies and full biatrial lesion sets as with left atriotomy procedures. However, many surgeons have preferred less invasive approaches, such as with epicardial surgical ablation procedures, given concerns about prolonging the ischemic time or perceived increase in risk with more extensive surgical ablation,[14] occasionally perhaps without full consideration of the pathophysiology of atrial fibrillation.

An early study of the Cox maze III procedure in coronary artery bypass grafting patients with atrial fibrillation produced a 98% sinus rhythm rate at 5 years.[90] As in the mitral valve population, cumulative atrial fibrillation burden and left atrial size were predictors of ablation failure.[91-93] A single randomized study of 35 patients with paroxysmal atrial fibrillation having isolated coronary artery bypass grafting vs coronary artery bypass grafting with concomitant pulmonary vein isolation (PVI) is available.[94] At 18 months, 89% of patients in the PVI group were atrial fibrillation-free vs 47% in the coronary artery bypass grafting-only group.

In surgical aortic valve replacement patients with atrial fibrillation, freedom from atrial fibrillation off antiarrhythmic drugs is better with surgical ablation than without.[95-97] However, it is important to note that in these specific patient cohorts, rhythm end point recovery seems to approximate 50% to 80% with PVI alone[98] compared with >90% with full open atrial biatrial maze procedures.[90,99] In a prospective study, surgical ablation for persistent atrial fibrillation in coronary artery bypass grafting or aortic valve replacement patients was safe.[93] In a review of 9 studies examining ablation efficacy, restoration of sinus rhythm after surgical ablation was not significantly different for aortic valve replacement plus coronary artery bypass grafting subgroups compared with surgical ablation with concomitant mitral operations.[61,97]

A meta-analysis of 16 randomized clinical trials evaluated primarily mitral valve procedures but also incorporated other cardiac operations.[44] Isolated aortic valve replacement and coronary artery bypass grafting operations both demonstrated a higher prevalence of sinus rhythm in the surgical ablation groups at the 1-year follow-up. There were no significant differences between the ablation and no-ablation groups regarding mortality, pacemaker implantation, and neurologic events.

An earlier meta-analysis focusing on persistent atrial fibrillation at the time of valve surgery incorporated randomized and nonrandomized studies, and surgical ablation was deemed safe and effective.[47] Surgical ablation was associated with modestly longer operative times, but hospital lengths of stay were similar. A recent network meta-analysis including 2031 patients undergoing a broad range of concomitant procedures suggested greater effectiveness with more extensive ablation, including open left atrial or biatrial maze vs PVI

alone.[100] However, this study showed no further improvement in conversion to sinus rhythm with a biatrial maze. The left atrial maze was also not associated with increased operative morbidity or mortality compared with PVI alone. The network meta-analysis did suggest increased mortality with the addition of the right atrial maze; importantly, the individuals included in the biatrial maze group underwent more complex procedures and were higher-risk patients.

A series of national database analyses have recently investigated the association of concomitant surgical ablation in a broad variety of patients and long-term mortality, stroke, or thromboembolism, rehospitalization related to atrial fibrillation or heart failure, as well as permanent pacemaker implantation.[1-8] A national registry study from Taiwan, including nearly 7000 patients undergoing coronary artery bypass grafting, valve, and aortic procedures, demonstrated a significant reduction in all-cause mortality, stroke, and thromboembolism over 5 years.[67] Similarly, a study from the Korean national registry, the Polish national registry, and 5 studies based on Medicare or multi-institutional United States data have shown a reduction in mortality with 2- to 6.7-year median follow-up time.[1-5] In most studies, the signal for stroke and thromboembolism is less clear but seems to favor surgical ablation numerically.[1] In the most recent analysis of 100,000 Medicare beneficiaries, surgical ablation was associated with reduced 3-year mortality and a significant reduction in stroke with surgical ablation when compared with left atrial appendage occlusion alone.[101] Although these studies were not randomized, their sample size and use of rigorous analytic techniques and sensitivity analyses lend evidentiary credibility to these important findings. On the basis of these data, a pooled estimate of studies with long-term follow-up, the advantage of surgical ablation over no ablation past the 2-year mark was as follows: all-cause mortality (hazard ratio [HR], 0.77; 95% CI, 0.69-0.86) (Figure 2), stroke (HR, 0.69; 95% CI, 0.64-0.75), and thromboembolism (HR, 0.68; 95% CI, 0.63-0.74) (Supplemental Figures E, F).

The addition of surgical ablation to any concomitant, nonemergent nonmitral cardiac surgery procedure can be considered safe based on currently available evidence.[78,102] As outlined in the section on mitral valve procedures, surgical ablation in the nonmitral population has been associated with an increased risk of perioperative renal dysfunction and permanent pacemaker implantation. However, the same studies did not find an increased risk of dialysis, and the better survival with ablation prevailed in these patients despite the risk.[78,79] Of the large number of studies that have investigated the difference between surgical ablation and no surgical ablation in a heterogenous surgical population, none has demonstrated an obvious association of surgical ablation with short-term major morbidity or mortality.

A 2014 randomized study compared coronary artery bypass grafting plus a Cox maze III/IV procedure and coronary artery bypass grafting with PVI to coronary artery bypass grafting alone and reported no in-hospital mortality or difference in major morbidity.[95] Several smaller observational studies, using various analytic methods to adjust for bias in their comparison, have compared outcomes of surgical aortic valve replacement or surgical aortic valve replacement with or without coronary artery bypass grafting, with and without surgical ablation, and did not show a significant difference in operative morbidity or mortality.[103,104] In the longer-term, surgical ablation is associated with an increased incidence of permanent pacemaker implantation but improved long-term survival. Pooling the effect estimates from 3 studies with at least 2 years of follow-up and reported permanent pacemaker implantation information suggests that the long-term mortality benefit of surgical ablation is at the cost of an increased chance of requiring a permanent pacemaker (HR, 1.38; 95% CI, 1.22-1.57) (Supplemental Figure H).

Recommendations for operations other than mitral valve surgery

1. **Surgical ablation for atrial fibrillation is recommended for any first-time nonemergent concomitant *nonmitral operation* to restore sinus rhythm and improve long-term outcomes.**
   - **Class of recommendation: I**
   - **Level of evidence: B-NR**

3. STAND-ALONE SURGICAL ABLATION FOR ATRIAL FIBRILLATION. The presence of symptomatic atrial fibrillation refractory to at least 1 class I or III antiarrhythmic drug has been established in several prior societal guidelines as the primary indication for ablation in stand-alone patients.[1,105] Often, most patients also have had at least 1 unsuccessful catheter-based ablation before referral for stand-alone surgical ablation.[105]

One systematic review suggested the efficacy of bipolar radiofrequency plus cryoablation (Cox maze IV) to complete the lesion set was equivalent to the Cox maze III technique for stand-alone surgical ablation, if both were applied meticulously.[97,106] Most surgical studies of surgical ablation in stand-alone patients have used minimally invasive approaches, including direct visualization, thoracoscopy, and robotic-assisted procedures. Thoracoscopic off-pump radiofrequency PVI plus left atrial appendage amputation has been studied in several studies.[107-112] For the 60% to 80% of patients who attain the rhythm end point, antiarrhythmic and anticoagulant agents are eventually discontinued, with associated

improved quality of life.[113] In most series, paroxysmal cases had a higher conversion rate than persistent atrial fibrillation.[114]

Many of these reports do not always adhere to continuous electrocardiographic monitoring to support the primary rhythm end point. Whether as the first procedure or after failed catheter ablation, surgical approaches in most of the studies was found to be more successful in restoring and maintaining sinus rhythm than catheter-based ablation,[24,115-120] but at the cost of higher periprocedural morbidity. One exception to this was a small study randomizing 52 patients with paroxysmal atrial fibrillation to transcatheter PVI or thoracoscopic surgical PVI isolation plus left atrial appendage occlusion, showing 56% freedom of atrial fibrillation at 2 years in the transcatheter arm vs 29% freedom in the surgical arm, although this difference did not reach statistical significance and the findings are relatively fragile, given the small sample size.[121]

Isolated PVI has not performed as well as minimally invasive versions of the full on-pump endocardial maze procedure.[122-124] Similarly, ganglionic ablation has been minimally efficacious and is no longer considered as an additive application to surgical ablation.[125] In a randomized clinical trial, additional ganglionic ablation did not result in greater procedural success but significantly increased major morbidity, including bleeding, sinus node dysfunction, and need for permanent pacemaker implantation.[58,126]

Most studies suggest the relative superiority of extended left atrial and biatrial lesion sets over PVI, with more extensive ablation patterns producing the best atrial fibrillation conversion rates.[96,127] Surgeons should be aware that incomplete lesion sets can be proarrhythmic and have been implicated in the induction of atypical macro-reentrant atrial flutter.[128]

Similarly, studies using a hybrid minimally invasive PVI or various methods and techniques of left atrial posterior wall ablation, followed by interval catheter-based mapping and focal ablation completion, have been studied for several years, producing encouraging but mixed short-term results in limited clinical trials or registry experience.[110,123,129-131] Recently, a series of randomized clinical trials have produced more robust data demonstrating the superiority of a hybrid ablation approach over catheter-based ablation alone.

There has been substantial heterogeneity in the definition and application of hybrid atrial fibrillation procedures, but in general, the percutaneous endocardial technique is combined with a minimally invasive epicardial nonsternotomy ablation that does not include cardiopulmonary bypass.[132] A systematic review of durable sinus conversion and complications from hybrid procedure or catheter ablation revealed that at 12 months or more, the hybrid procedure achieved a significantly higher rate of freedom from atrial arrhythmias, with and without the use of antiarrhythmic drugs, compared with atrial fibrillation catheter ablation alone in patients with persistent or long-standing persistent atrial fibrillation.[133]

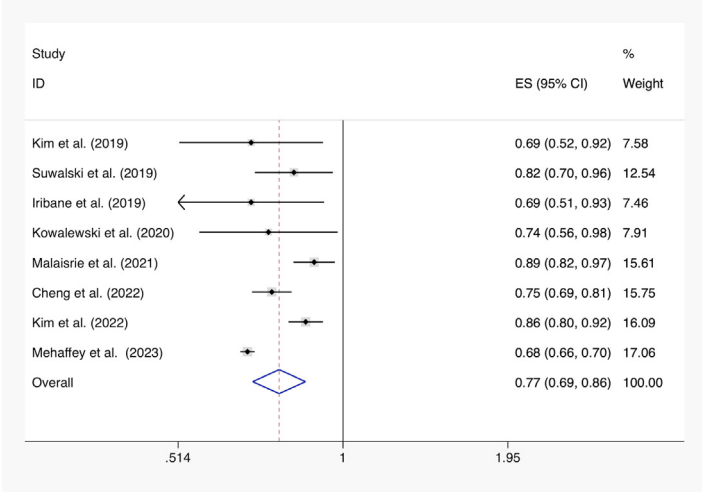

FIGURE 2 Association surgical treatment of atrial fibrillation with all-cause mortality. Studies with a follow-up of ≥2 years (median follow-up range, 2.6-6.7 years; n = 8 studies) and the pooled effect estimate for all-cause mortality associated with surgical ablation of atrial fibrillation is shown (estimate [ES], 0.77; 95% CI, 0.69-0.86). The size of the solid squares denotes the mean difference, and the horizontal lines represent the 95% CIs. The diamond denotes the weighted mean difference, and the lateral tips of the diamond indicate the associated CIs.

The Combined Endoscopic Epicardial and Percutaneous Endocardial Ablation Versus Repeated Catheter Ablation in Persistent and Longstanding Persistent Atrial Fibrillation (CEASE-AF) randomized clinical trial comparing hybrid ablation against catheter ablation alone in patients with persistent atrial fibrillation showed significantly higher effectiveness with hybrid ablation (71% vs 39%), with no significant difference in major complications at 30 days.[25] Similarly, the Hybrid Versus Catheter Ablation in Persistent AF (HARTCAP-AF) and the Convergence of Epicardial and Endocardial Ablation for the Treatment of Symptomatic Persistent AF (CONVERGE) trials, both randomized clinical trials in patients with persistent atrial fibrillation, demonstrated the superiority of the hybrid ablation strategy (89% and 65% success at 12 months) over catheter ablation (41% and 37%), with comparable adverse events in both groups.[24,134] The benefit of hybrid ablation over catheter ablation alone is further documented by several meta-analyses.[135-137]

Considering the totality of the evidence, more complete lesion sets, particularly a biatrial Cox maze III/IV

procedure, applied through a minimally invasive approach, may provide the greatest benefit overall.[28] An increasing number of stand-alone surgical ablation studies using cryoablation and a minimally invasive thoracoscopic or robotic-assisted approach have recently shown improved outcomes in safety and effectiveness, with >90% of patients being free from atrial fibrillation at 1 year and ≥80% at 5 years of follow up.[26,138-142] Notably, these results were achieved at established, high-volume centers despite including many patients with long-standing persistent atrial fibrillation. These were not always documented by continuous electrocardiographic monitoring to support the rhythm end points. Because left atrial size is a risk factor for ablation failure, atrial reduction procedures may have benefit, although this remains controversial and without strong evidence.[141-144]

Given stronger longitudinal evidence of efficacy and longitudinal freedom from atrial fibrillation, antiarrhythmic drugs, as well as oral anticoagulation after a full biatrial Cox maze, the field awaits more homogeneous or randomized evidence on hybrid or epicardial ablation procedures that adhere to the concept of the Cox maze lesion set. Epicardial ablation with atypical lesions remains exploratory until more robust evidence becomes available.

In a 2013 systematic review by Krul and associates[145] that compiled results from 23 observational studies with 752 patients who underwent minimally invasive stand-alone procedures, operative mortality was 0.4%. Complication rates attributed to surgery were just 3.2%. Analysis of stand-alone procedures recorded in the STS National Database showed an operative mortality rate of 0.74%. The complication rate was considerably higher at 16.43%, although major morbidities, such as stroke (0.72%), renal failure (2.45%), and bleeding (0.99%), were low. Pacemakers were implanted in 1.03% of patients.[146] More recent series have shown even lower morbidity and zero mortality in consecutive cases.[26,138,139]

Recommendations regarding stand-alone surgical ablation

1. **Surgical ablation for symptomatic atrial fibrillation in the absence of structural heart disease refractory to class I/III antiarrhythmic drugs, catheter-based therapy, or both, is reasonable as a primary stand-alone procedure to restore sinus rhythm.**
   - **Class of recommendation: IIa**
   - **Level of evidence: B-NR**
2. **Surgical ablation for symptomatic persistent or longstanding persistent atrial fibrillation in the absence of structural heart disease is reasonable as a stand-alone procedure using the Cox maze III/IV lesion set as the preferred procedure.**
   - **Class of recommendation: IIa**
   - **Level of evidence: B-NR**
3. **Surgical ablation for symptomatic atrial fibrillation in the setting of left atrial enlargement (≥4.5 cm) or more than moderate mitral regurgitation by pulmonary vein isolation alone is not recommended.**
   - **Class of recommendation: III**
   - **Level of evidence: C**

4. LEFT ATRIAL APPENDAGE MANAGEMENT. Left atrial appendage occlusion/obliteration is one part of the comprehensive surgical management of atrial fibrillation, and its aim is to reduce early and late risk of stroke. Initial observational studies have suggested atrial appendage management is associated with >50% reduction in thromboembolic morbidity and a modest survival benefit.[76] In most series of surgical ablation, left atrial appendage management has become a routine component; in fact, the Cox maze operation is only complete with left atrial appendage occlusion/obliteration. Complete left atrial appendage obliteration is recommended in all surgical ablation subsets.

Several observational studies have addressed the question of concomitant left atrial appendage occlusion in various cardiac surgery populations, suggesting a benefit of left atrial appendage occlusion for the prevention of ischemic stroke, other thromboembolic complications, as well as all-cause mortality. A large study by Friedman and associates[147] of 10,524 Medicare beneficiaries with atrial fibrillation undergoing a variety of elective cardiac surgery procedures showed an association of left atrial appendage occlusion with lower all-cause mortality (HR, 0.88; 95% CI, 0.79-0.55) and thromboembolic complications (HR, 0.67; 95% CI, 0.56-0.81) over a median follow-up of 2.6 years. Similar results were found in an isolated coronary artery bypass grafting cohort of 4210 Medicare beneficiaries with atrial fibrillation.[148] Several smaller institutional studies of patients undergoing valve procedures, coronary artery bypass grafting, and combinations thereof were unable to demonstrate the same effect convincingly, possibly due to a much smaller sample size and shorter follow up.[88,149]

A third Medicare data study evaluated left atrial appendage occlusion in 8590 patients with and without atrial fibrillation undergoing coronary artery bypass grafting and/or valve procedures.[149] The authors reported the effect estimate of left atrial appendage occlusion for all-cause mortality and stroke in the overall cohort and separately for those patients with and without atrial fibrillation. Both in the complete cohort

and the atrial fibrillation cohort, left atrial appendage occlusion was associated with a significantly reduced mortality (relative risk [RR], 0.71; 95% CI, 0.6-0.84) and stroke (RR, 0.73; 95% CI, 0.56-0.96) with a greater effect size and tighter CIs in the atrial fibrillation cohort. In the no-atrial fibrillation cohort, left atrial appendage occlusion had no effect on mortality and stroke, but it was associated with a significantly increased risk of atrial fibrillation-related hospitalizations during follow-up, presumably related to a higher incidence of new-onset postoperative atrial fibrillation seen in patients with no prior history of atrial fibrillation receiving left atrial appendage occlusion.

Multiple institutional studies also investigated the association of left atrial appendage occlusion in all comers, with varying prevalence of atrial fibrillation (ranging from 25% to 53%) and using different cohorts and definitions of thromboembolic complications, some exclusively including populations with mandatory oral anticoagulation (eg, mechanical mitral valve replacement or left ventricular assist devices), and with all studies reporting a correlation between left atrial appendage occlusion and reduced incidence in thromboembolic complications.[148-151]

Furthermore, 6 meta-analyses have been published on the association of left atrial appendage occlusion and various outcomes over the past 5 years alone.[152-156] The meta-analysis, including the largest number of patients (n = 40,107), showed a substantially lower incidence of stroke (RR, 0.68; 95% CI, 0.57-0.82) and thromboembolic complications (RR, 0.63; 95% CI, 0.53-0.76).[155] Qualitatively and quantitatively, very similar results for all-cause mortality, stroke, and thromboembolic complications were found by the 5 other meta-analyses across different time periods, follow-up durations, and case-mix, even including left ventricular assist device populations.

In these observational studies, management of the left atrial appendage by resection, epicardial stapling, clip application, or endoatrial double-layer longitudinal suture closure has been studied extensively. Stapling only has had poor outcomes, with most patients having a residual stump and recanalization of the appendage, which can be thrombogenic.[157,158] Complications from surgical left atrial appendage occlusion are rare but most frequently are related to the manipulation of the appendage, causing bleeding, and incorrect placement of the epicardial clip, leaving a residual stump or potentially impinging the circumflex coronary artery.[159]

Robust randomized data of concomitant left atrial appendage occlusion in patients with atrial fibrillation has only recently become available with the publication of the long-term outcomes of the Left Atrial Appendage Closure During Open Heart Surgery (LAACS) randomized clinical trial and a landmark trial by Whitlock and colleagues[160] and Madsen and colleagues.[161] LAACS was a relatively small study (n = 186) of patients with predominantly no history of atrial fibrillation (87%), showing no statistically significant reduction in stroke (RR, 0.62; 95% CI, 0.27-1.43) and mortality (RR, 0.78; 95% CI, 0.44-1.39) at 6 years of follow-up.

The larger Left Atrial Appendage Occlusion Study III (LAAOS III) randomized clinical trial enrolled 4770 patients with atrial fibrillation undergoing concomitant cardiac surgery procedures to receive left atrial appendage occlusion or not with routine use of oral anticoagulation postoperatively and a mean follow-up of 3.8 years. Permissible methods of left atrial appendage occlusion in this trial included amputation and closure (preferred), stapler closure, double-layer linear closure from within the atrium in participants undergoing minithoracotomy (this approach required transesophageal echocardiographic confirmation of the occlusion), or closure with an epicardial clip. Approximately one-third of patients also underwent a surgical ablation procedure, 92% of the individuals received the allocated left atrial appendage management, and 77% were compliant with oral anticoagulation at 3 years. Despite ongoing oral anticoagulation in most of the patients, left atrial appendage occlusion significantly reduced the primary end point (ischemic stroke or systemic thromboembolism), primarily driven by a reduction in stroke (RR, 0.66; 95% CI, 0.52-0.84). However, in LAAOS III, the benefits of left atrial appendage occlusion did not include a decrease in all-cause mortality. A secondary analysis of LAAOS III further found the reduction in thromboembolic complications with left atrial appendage occlusion was independent of the use of oral anticoagulation.[162]

Recommendations for concomitant left atrial appendage management:

1. **Left atrial appendage obliteration for atrial fibrillation is recommended for all first-time nonemergent cardiac surgery procedures, with or without concomitant surgical ablation, to reduce morbidity from thromboembolic complications.**
   - **Class of recommendation: I**
   - **Level of evidence: A**

5. STAND-ALONE LEFT ATRIAL APPENDAGE OCCLUSION. As previously stated, the safety and efficacy of surgical left atrial appendage occlusion/obliteration were primarily established in patients undergoing concomitant surgical procedures, such as coronary artery bypass grafting or valve repair or replacement. Epicardial occlusion of the left atrial appendage occlusion has been popularized and facilitated by the development of dedicated devices and several studies required for their regulatory approval.[163]

Left atrial appendage occlusion using a clip has been found to be safe, effective with a ≥95% success rate of complete left atrial appendage occlusion based on cardiac computed tomographic imaging, and reproducible in most hands.[164-166] Several case series and larger observational studies have investigated the safety and effectiveness of isolated left atrial appendage occlusion performed without the use of cardiopulmonary bypass and by a thoracoscopic approach, showing reasonable short- and long-term outcomes.[166-168]

Endocardial devices for appendage occlusion may not always be anatomically feasible or appropriate, given unique aspects of appendage anatomy. In a small study comparing surgical against percutaneous left atrial appendage occlusion in a cohort of patients with atrial fibrillation and increased risk of thromboembolic and bleeding complications treated by a heart team, procedural complications, hospital stay, completeness of left atrial appendage occlusion, and neurologic complications were comparable between the 2 strategies.[168] This was despite higher CHA_2DS_2VASc (Congestive heart failure, Hypertension [blood pressure >140/90 mm Hg or treated hypertension on medication], Age ≥75 years, Diabetes mellitus, prior Stroke or transient ischemic attack or thromboembolism, Vascular disease, Age 65-74 years, Sex category [ie, female sex]) and HAS-BLED (Hypertension, Abnormal renal/liver function, Stroke, Bleeding history or predisposition, Labile international normalized ratio, Elderly, Drugs/alcohol concomitantly) scores in the surgical group and ongoing anticoagulation (dual antiplatelet therapy for 3 months and single antiplatelet therapy after that) in the percutaneous left atrial appendage occlusion group vs no anticoagulation in the surgical group. Other studies have suggested a higher incidence of bleeding complications with percutaneous left atrial appendage occlusion and longer length of stay with surgical left atrial appendage occlusion.[169]

The safety of complete suspension of anticoagulation (including antiplatelet therapy) was also described in a small cohort of consecutive patients with high bleeding and stroke risk.[170] The benefit of complete suspension of anticoagulation that is possible with surgical left atrial appendage occlusion may be of particular benefit in patients with the highest bleeding risk or those requiring invasive procedures that cannot be performed safely with ongoing anticoagulation.

Contemporary data of percutaneous left atrial appendage occlusion shows a high degree of left atrial appendage patency and peridevice leaks, which have been associated with an increased risk of thromboembolism. In a recent meta-analysis of 48 studies investigating residual leaks after percutaneous left atrial appendage occlusion, peridevice leak was seen on transesophageal echocardiography in 26.1% of patients and in 57.3% of patients when computed tomography was used as the diagnostic study. Peridevice leak was associated with a higher risk of thromboembolism (odds ratio, 2.04; 95% CI, 1.03-1.22) compared with no peridevice leak, suggesting a large proportion of patients may have to continue anticoagulation.[171]

A meta-analysis including 6 studies of surgical left atrial appendage occlusion showed a low incidence of complications, perioperative mortality, and stroke rates at 1 year of follow-up and no substantial difference compared with the percutaneous left atrial appendage occlusion approach.[172] However, none of these studies have randomized patients between the 2 treatment options, and other limitations with the included studies suggest the comparison between strategies must be interpreted with caution.

A prospective registry is currently evaluating the comparative effectiveness of thoracoscopic surgical left atrial appendage occlusion, percutaneous left atrial appendage occlusion, and a hybrid approach (LARIAT device, SentreHEART) in 400 patients with a high thromboembolic and bleeding risk (Stand-alone Left Atrial Appendage Occlusion for Thromboembolism Prevention [SALAMANDER]; NCT05144958).[173] Randomized controlled trials between surgical left atrial appendage occlusion and percutaneous left atrial appendage occlusion, as well as between surgical left atrial appendage occlusion and oral anticoagulation, including direct thrombin or factor Xa inhibitors, are currently missing. Adequately powered randomized clinical trials are needed to inform better which patients with relative or absolute contraindications for novel oral anticoagulation truly benefit from surgical left atrial appendage occlusion and how it compares with other anticoagulation regimens (eg, single antiplatelet therapy). Further, more research is needed to define the best method to document the completeness of left atrial appendage occlusion postoperatively and the optimal anticoagulation strategy after surgical left atrial appendage occlusion, especially when the exclusion of the left atrial appendage occlusion trabeculation may not be complete.

Recommendations regarding stand-alone left atrial appendage management:

1. **Isolated surgical left atrial appendage obliteration may be considered in patients with longstanding persistent atrial fibrillation, a high stroke risk, and contraindications for or failure of long-term oral anticoagulation**.
   - **Class of recommendation: IIb**
   - **Level of evidence: B-NR**

6. PATIENTS WITH ATRIAL FIBRILLATION UNDER CONSIDERATION FOR TRANSCATHETER VALVE REPAIR OR REPLACEMENT. With the rapid development of technology and expansion of indications for transcatheter treatment of structural heart disease, an increasing number of patients with atrial fibrillation will be considered for transcatheter aortic valve replacement, transcatheter mitral or tricuspid replacement or edge-to-edge repair, or other technology. Although some of this technology continues to be restricted to patients of prohibitive or high surgical risk, transcatheter aortic valve replacement has become mainstream and is widely applied without clarity on indications and considerations regarding concomitant cardiac pathology.[174]

As mentioned in the previous sections, the prevalence of atrial fibrillation is high among patients with structural heart disease, often causally related, and a marker of increased short- and long-term morbidity and mortality. Furthermore, several valvular pathologies are known to progress with the persistence of atrial fibrillation, notably mitral and tricuspid regurgitation. A specific entity of atrioventricular valve insufficiency has been established in patients with persistent atrial fibrillation, resulting in a type I dilated annulus and valve dysfunction (atrial functional mitral/tricuspid regurgitation).[175] In these cases, atrial fibrillation is not only a "bystander" but may also be the very cause of valve dysfunction and may necessitate an intervention for the treatment strategy to have curative and not solely palliative intentions. Nonetheless, transcatheter edge-to-edge repair has been promoted as a therapy for this subset of patients.[175]

In the transcatheter aortic valve replacement landmark trials, between one-third and one-half of the patients presented with atrial fibrillation at enrollment. This incidence is higher than in most contemporary surgical aortic valve replacement cohorts, because the patients enrolled in these trials tended to be older and sicker. However, in the 2 most recent studies, enrolling only low-surgical risk patients, 15% to 18% of patients had atrial fibrillation at baseline, most of whom in either arm did not receive treatment,[176,177] despite substantial evidence that atrial fibrillation is highly treatable with surgical ablation, which does not increase short-term morbidity and mortality but has been associated with improved long-term survival and a substantially reduced risk of thromboembolic complications when combined with left atrial appendage occlusion (see Sections 2 and 4).

Untreated atrial fibrillation in patients with aortic stenosis is associated with significantly worse outcomes, including mortality, stroke, vascular complications, and repeat hospitalizations. Further, atrial fibrillation after transcatheter aortic valve replacement is an independent predictor of late bleeding complications, cardiovascular events, and mortality beyond 1 year of follow-up.[5,178,179] A large study of Medicare beneficiaries demonstrated that patients with aortic stenosis and atrial fibrillation benefit greatly from a surgical strategy (surgical aortic valve replacement plus surgical ablation) resulting in reduced all-cause mortality (HR, 0.65; 95% CI, 0.53-0.79), permanent pacemaker implantation (HR, 0.62; 95% CI, 0.44-0.87), bleeding (HR, 0.63; 95% CI, 0.039-1.00), and rehospitalization for heart failure (HR, 0.49; 95% CI, 0.36-0.65) compared with transcatheter aortic valve replacement alone.[89]

Neither randomized clinical trials nor registry data clearly document the prevalence of atrial fibrillation among patients receiving transcatheter edge-to-edge repair. On the basis of the general population and body of knowledge, it is safe to assume that atrial fibrillation is highly prevalent among patients being considered for transcatheter edge-to-edge repair, posing an indication for ablation and left atrial appendage occlusion. Detailed data on the outcomes of patients with atrial fibrillation undergoing transcatheter mitral valve repair and the impact of atrial fibrillation on these outcomes are currently not available. A recent, comprehensive review of surgical outcomes with surgical mitral valve repair from the STS database demonstrated the very low risk of mitral valve repair surgery overall as well as the safety of adding surgical ablation and left atrial appendage occlusion to these procedures without an increase in the short-term risk of morbidity and mortality.

Although the benefits of restoration of sinus rhythm and/or left atrial appendage occlusion may not outweigh the risk of surgery in certain populations that are at high risk for surgical treatment or have a short life expectancy, consideration for a surgical treatment plan of the valve pathology, along with surgical ablation and left atrial appendage occlusion, should be part of every heart team discussion with all patients presenting with atrial fibrillation and structural heart disease.

Recommendations for patients being considered for transcatheter valve therapies:

1. **For patients with symptomatic valve disease and atrial fibrillation, who are deemed of low to intermediate surgical risk, surgical valve repair or replacement with concomitant surgical ablation and left atrial appendage occlusion is reasonable over isolated transcatheter valve repair or replacement alone to restore sinus rhythm and improve long-term outcomes.**
   - **Class of recommendation: IIa**
   - **Level of evidence: B-NR**

7. ADDITIONAL CONSIDERATIONS FOR PATIENTS WITH ATRIAL FIBRILLATION. Most patients undergoing surgical ablation are administered perioperative class I or III antiarrhythmic drugs, such as amiodarone,[180] and these are often continued for 2 to 3 months after surgical ablation.[181] Most patients who achieve stable sinus rhythm after surgical ablation eventually can discontinue all antiarrhythmic agents.[115] A good follow-up is essential,[182] and at least periodic 24-hour Holter monitoring should be routine. Atrial fibrillation recurrence should prompt consideration for catheter-based assessment and possible ablation.[183] Substantial gaps of knowledge still exist regarding the management of antiarrhythmic drugs after catheter or surgical ablation for atrial fibrillation. The improvement of symptoms associated with atrial fibrillation is the goal of antiarrhythmic medication. Therefore, the choice to continue long-term antiarrhythmic medication must take patient preferences, potential adverse effect risks, and symptom burden during follow-up into account. In some studies after catheter ablation, antiarrhythmic therapy doubled sinus rhythm maintenance when compared with no therapy; nevertheless, the research currently available makes it challenging to arrive at specific recommendations.

Similar challenges exist for the use of anticoagulation after surgical ablation and left atrial appendage occlusion. Balancing the risk of postoperative bleeding, oral anticoagulation is often initiated early postoperatively in patients after atrial fibrillation surgery because of the endothelial damage caused during ablation. Some centers have adopted single-antiplatelet therapy with no oral anticoagulation after surgical ablation and left atrial appendage occlusion, reporting stroke rates of less than 1%.[184] Regarding long-term oral anticoagulation strategy, there are no randomized or robust observational data available to guide specific recommendations. Currently, factors to consider in the decision to use oral anticoagulation or not after surgical ablation and left atrial appendage occlusion are documented freedom from atrial fibrillation, completeness of left atrial appendage occlusion, and the patient's bleeding risk and stroke risk (CHA_2DS_2-VASc score). Anticoagulation management after surgical ablation and left atrial appendage occlusion certainly is an area in need of further research.

Multidisciplinary collaboration between cardiothoracic surgeons having clinical interest and experience with surgical ablation and electrophysiologists experienced in the pharmacologic and catheter-based management of atrial fibrillation can enhance patient outcomes.[168] Monitoring at regular intervals by the cardiac surgeon, electrophysiologist, or both, is important to ensure appropriate postoperative management and optimization of results. After surgical ablation, it is suggested that patients be longitudinally monitored for a minimum of 1 year by the surgeon of the multidisciplinary heart team. The measure of success in surgical ablation is freedom from atrial fibrillation and antiarrhythmic drugs at 1 year.

There is no literature specifically addressing the clinical questions surrounding surveillance and follow-up after surgical ablation. However, as outlined previously, studies delineating the differences in long-term outcomes, including effectiveness of sinus conversion, survival benefit, or the need for a permanent pacemaker, extend to 5 years of follow-up and beyond. To detect the late recurrence of atrial fibrillation and the development of new conduction abnormalities, continued surveillance for up to 5 years is suggested.

Recommendations for all patients with atrial fibrillation:

1. **Multidisciplinary heart team assessment and treatment planning as well as long-term follow-up using periodic continuous electrocardiographic monitoring for rhythm assessment are recommended to optimize patient outcomes.**
   - **Class of recommendation: I**
   - **Level of evidence: C**

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An Essential Update But Are the 2023 Surgical Treatment of Atrial Fibrillation Guidelines Enough?

INVITED COMMENTARY:

The surgical management of atrial fibrillation (AF) has evolved significantly since the last publication of The Society of Thoracic Surgeons (STS) first guidelines on the surgical treatment of AF in 2017 by Badhwar and colleagues.[1] At the time, concomitant surgical ablation had a class I recommendation on the basis of restoring sinus rhythm alone, and left atrial appendage occlusion (LAAO) received a class IIA recommendation given the limited evidence.[1] In this issue of *The Annals of Thoracic Surgery*, Wyler von Ballmoos and colleagues[2] present the much-needed updated 2023 STS AF guidelines. Concomitant LAAO was upgraded to a class IA recommendation on the basis of the landmark Left Atrial Appendage Occlusion Study III (LAAOS III) randomized controlled trial (RCT).[3] Concomitant surgical ablation remained class I, but the wording is stronger to encompass the entire spectrum of cardiac surgery on the basis of improving late outcomes rather than just restoring sinus rhythm alone. Wyler von Ballmoos and colleagues[2] must be congratulated for tackling such an important topic. AF affects the long-term outcomes of our patients, and as surgeons, we must be advocates and leaders in the treatment of this important disease process. However, we also believe that these guidelines are limited in addressing 3 specific contemporary issues in the field of surgical AF.

First, current Medicare-STS database analysis still reveals that concomitant AF is severely undertreated but also that off-pump surgical treatment of *standalone* AF is increasing. Since the publication of the 2017 guidelines, 3 RCTs (Epicardial and Endocardial