Concomitant or stand-alone procedure

Current aspects of atrial fibrillation surgery

Christoph T. Starck[a], Jan Steffel[b], Tomas Holubec[c], Volkmar Falk[a]

[a] Clinic of Cardiac and Vascular Surgery, University Hospital Zurich, Switzerland
[b] Clinic of Cardiology, University Hospital Zurich, Switzerland
[c] Department of Cardiothoracic and Vascular Surgery, German Heart Institute, Berlin, Germand

Summary

Atrial fibrillation is the most common cardiac arrhythmia, with an increasing prevalence with rising age. Atrial fibrillation is associated with significant morbidity and mortality. Concomitant surgical ablation of atrial fibrillation in patients undergoing other cardiac surgical procedures is commonly practiced, with high success rates, short procedure times and a low additional operative risk profile. Minimally invasive stand-alone surgical procedures for atrial fibrillation are performed less frequently, even though they represent a valid therapeutic option for certain patients, with excellent results. Surgical procedures for atrial fibrillation treatment allow the excision or exclusion of the left atrial appendage, therefore eliminating a potential source of cerebral embolic events in the case of procedural failure to abolish atrial fibrillation. The hybrid approach, which combines the advantages of catheter and surgical ablation, is a promising approach for the future. This review focuses on surgical options in the curative treatment of atrial fibrillation.

Key words: Atrial fibrillation; surgical ablation; minimally invasive procedures; concomitant procedures

Introduction

Atrial fibrillation is the most common cardiac arrhythmia, with an increasing prevalence with increasing age. Atrial fibrillation increases the risk of stroke five-fold and leads to an enormous rise in healthcare costs [1].

James Cox and his coworkers did extensive research on the pathophysiology of atrial fibrillation, and based on their results they developed the Cox maze operation [2–4]. After two modifications the Cox maze III operation was introduced into clinical practice. This operation was a "cut-and-sew" technique with multiple incisions in the walls of both atria performed via median sternotomy with the help of extracorporeal circulation. Compared with the first and second procedures, the Cox maze III operation was associated with less arrhythmia recurrence, fewer pacemaker requirements and improved long-term sinus node and atrial transport function [5, 6]. Despite the fact that the Cox maze III procedure remains the gold standard in surgical treatment of atrial fibrillation, it never became widely used owing to long operative times and a challenging surgical technique [7, 8]. In 2002 the Cox maze IV operation was introduced. In this iteration most of the incisions were replaced with linear lines of bipolar radiofrequency ablation [9].

In 1998 Haissaguerre et al. published their results showing that in paroxysmal atrial fibrillation the arrhythmia is triggered by signals originating from the pulmonary veins. This finding led to the simplification of atrial fibrillation surgery by implementation of the pulmonary vein isolation approach [10]. Other studies showed the effectiveness of exclusively left atrial procedures in patients with chronic atrial fibrillation undergoing mitral valve surgery [11, 12].

The original "cut-and-sew" technique was further simplified by the introduction of cryo- and radiofrequency ablation instead of surgical incisions [13, 14]. Further alternative energy sources for surgical ablation were used to optimise and modify the surgical technique [15–18]. Because these modifications led to an easier procedure with shorter procedure times and less morbidity, the number of surgical ablation procedures, especially concomitant with other cardiac surgical operations, increased enormously [19].

Nowadays atrial fibrillation surgical ablation is mostly carried out as a concomitant procedure in patients who require other cardiac surgical procedures. In some cases surgical treatment of atrial fibrillation may also be performed in patients with lone atrial fibrillation (fig. 1).

Indications

According to the 2012 HRS/EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation, two indication classes have to be distinguished: concomitant or stand-alone atrial fibrillation surgery. Irrespective of the kind of atrial fibrillation (paroxysmal, persistent or long-standing

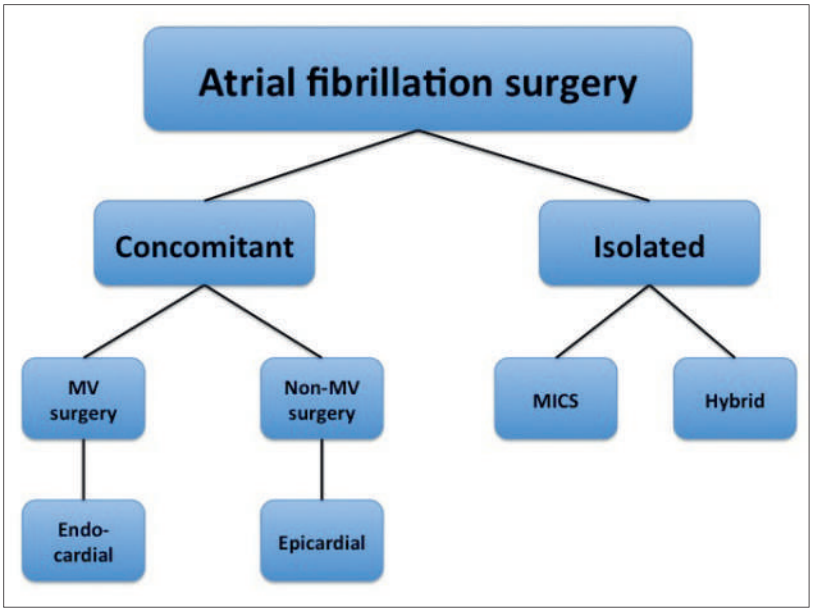

Figure 1: Schematic illustration of current practice of atrial fibrillation surgery. MICS = minimally invasive cardiac surgery; MV = mitral valve.

persistent), symptomatic atrial fibrillation refractory to, or associated with intolerance of, at least one class 1 or 3 antiarrhythmic medication is a class IIa-indication (level of evidence [LOE] C) for concomitant surgical ablation of atrial fibrillation. Symptomatic atrial fibrillation prior to initiation of antiarrhythmic drug therapy with a class 1 or 3 antiarrhythmic agent is in the case of paroxysmal and persistent atrial fibrillation a class IIa-indication (LOE C) and in the case of long-standing persistent a class IIb-indication (LOE C) for concomitant atrial fibrillation surgery.

In the case of stand-alone atrial fibrillation surgery, symptomatic atrial fibrillation (paroxysmal, persistent and long-standing persistent) refractory to or with intolerance of at least one class 1 or 3 antiarrhythmic medication is a class IIb-indication (LOE C) in the case of patients who have not had a failed catheter ablation but prefer a surgical approach or in the case of patients who have had one or more concomitant attempts at catheter ablation.

In patients with symptomatic atrial fibrillation prior to initiation of antiarrhythmic drug therapy with a class 1 or 3 antiarrhythmic agent, stand alone atrial fibrillation surgery is not recommended (class III, LOE C) [20].

Surgical approach

In the case of concomitant atrial fibrillation surgery, the surgical approach depends on the cardiac surgical procedure performed besides the surgical ablation. In the case of mitral valve surgery an endocardial left atrial approach is possible since atriotomy is required for the valve procedure. Extracorporeal circulation and cardioplegic cardiac arrest are mandatory. Depending on the surgical approach for the mitral valve operation the ablation is either carried out through a right lateral mini-thoracotomy or a median sternotomy [7, 8, 18, 19].

If aortic valve surgery or coronary artery bypass grafting is performed, atriotomy is not carried out and therefore an epicardial ablation approach is preferable. In case of off-pump coronary artery bypass grafting the epicardial ablation is performed without the help of extracorporeal circulation [21, 22].

If the surgical ablation of atrial fibrillation is carried out as a stand-alone procedure, the surgical approach should nowadays be minimally invasive and video-assisted. It is performed on a beating heart without the use of the extracorporeal circulation. The minimally invasive approach may be uni- or bilateral, depending on the ablation system used, the performed lesion set and left atrial appendage management [16, 23, 24].

As another interesting approach, especially in cases of stand-alone procedures, the hybrid approach should be mentioned. This approach is a combination of a minimally invasive surgical approach combined with electrophysiological mapping and endocardial catheter ablation. With the combination of a minimally invasive surgical epicardial ablation and an endocardial catheter ablation the limitations of both techniques are supposed to be overcome [25–28].

Lesion sets

In order to understand lesion sets for surgical ablation, it is important to understand the underlying pathophysiology. Atrial fibrillation is initiated by an event (trigger) and the presence of a predisposing substrate is maintaining the arrhythmia. Additional factors may act as modulators in the initiation or continuation of atrial fibrillation. Triggers and substrates can be located in both atria. However they are usually found in the pulmonary veins and the left atrium [21]. Triggers in the pulmonary veins characterise paroxysmal atrial fibrillation, whereas in persistent atrial fibrillation multiple macro re-entry circuits and atrial remodelling is responsible for the maintenance of the arrhythmia [29, 30]. This fact shows that one aspect of the choice of a lesion set is the existing type of atrial fibrillation. In patients with paroxysmal atrial fibrillation, a pulmonary vein isolation procedure might be sufficient, since mainly ectopic

foci in the pulmonary veins have to be addressed. In contrast, in cases of persistent atrial fibrillation a modification of the underlying substrates should be accomplished by linear ablation lines in the left atrium in addition to pulmonary veins isolation.

Another additional factor that can be considered during surgical ablation procedures is the isolation of autonomic ganglia after electrophysiological testing for ganglionic plexi activity [24]. Scherlag et al. were able to show that the activation of autonomic ganglia may serve as a mediator upon which the pulmonary vein triggers act to induce atrial fibrillation [31].

Isolation of the pulmonary veins is the key concept of all surgical ablation procedures. It can be performed easily via an endocardial as well as an epicardial approach. It can either be performed as one large "box lesion" encircling all four pulmonary veins or as bilateral pulmonary veins isolation with a pairwise isolation of the right and the left pulmonary veins. Whether the box lesion or the bilateral pulmonary veins isolation is the better approach is still not finally clarified, but several studies were able to show better results with the box lesion [9, 32].

Pulmonary veins isolation techniques essentially lead to trigger elimination; however, in patients with persistent atrial fibrillation this might not be enough to treat atrial fibrillation successfully, since substrates outside the pulmonary veins will exist. Therefore, additional linear ablation lines in the left atrium will be required. Creation of linear ablation lines in the left atrium with an endocardial approach is feasible and reproducible. In the case of an epicardial, beating heart approach linear ablation may be technical challenging to achieve [22]. A linear ablation with a bipolar radiofrequency clamp towards the mitral annulus puts nearby anatomical structures (coronary sinus, circumflex artery) at risk of damage and fails to create an ablation line that reaches the mitral annulus [33].

In summary, in patients with persistent atrial fibrillation a left atrial lesion set consisting of pulmonary veins isolation and additional ablation lines towards the ostium of the left atrial appendage as well as the mitral valve annulus is reasonable (fig. 2). In selected patients, mainly with longstanding-persistent atrial fibrillation and right atrial triggers as well as substrate, lesions in the right atrium might be required to improve the outcome of the ablation procedure [21].

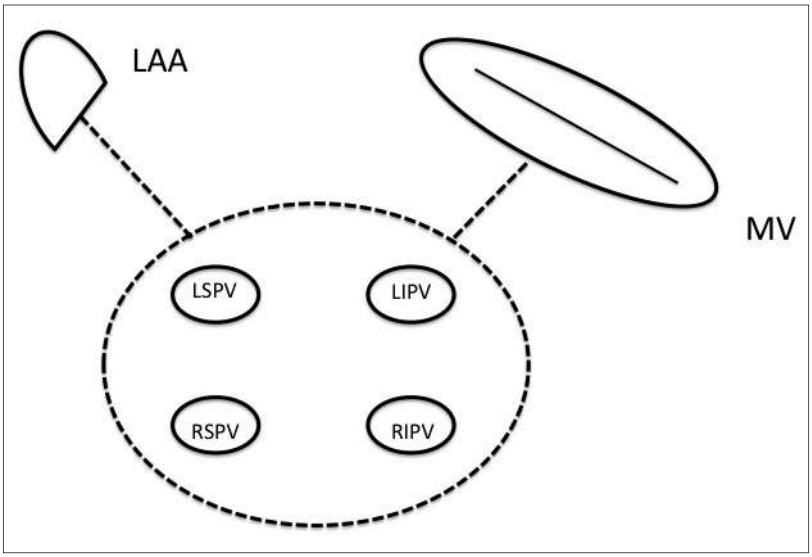

Figure 2: Schematic illustration of a surgical left atrial lesion set consisting of a "box lesion" (pulmonary veins isolation) and linear ablation lines to the orifice of the left atrial appendage and to the posterior mitral valve annulus. The exclusion or the excision of the left atrial appendage should also be performed in surgical ablation procedures. LAA = left atrial appendage; LIPV = left inferior pulmonary vein; LSPV = left superior pulmonary vein; MV = mitral valve; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein.

Left atrial appendage management and postoperative anticoagulation

One important advantage of surgical ablation procedures for atrial fibrillation over catheter ablation procedures is that the left atrial appendage can be easily excluded or excised (fig. 3). Therefore, even in case of procedural failure with the recurrence of atrial fibrillation, the left atrial appendage as a potential source of repeated cerebral embolic events is eliminated [24, 34]. Furthermore, it was shown that the left atrial appendage may be a site of atrial fibrillation initiation and that epicardial left atrial appendage clip occlusion leads to electrical isolation of the left atrial appendage, therefore eliminating this potential source of atrial fibrillation trigger signals [35, 36].

Several surgical techniques for left atrial appendage management exist. The left atrial appendage can either be excised or excluded. Excision means physical removal of the left atrial appendage with scissors or an amputating stapling device. In contrast, exclusion can be performed by closure of the orifice of the left atrial appendage with the appendage remaining attached. This can be achieved by suturing (running suture, pursestring or external ligation) or stapling [37]. Another way of exclusion is the application of an epicardial left atrial appendage clip [38].

Kanderian et al. examined the efficacy of surgical left atrial appendage closure by excision and exclusion. The overall rate of successful left atrial appendage closure was merely 40%, with excision showing

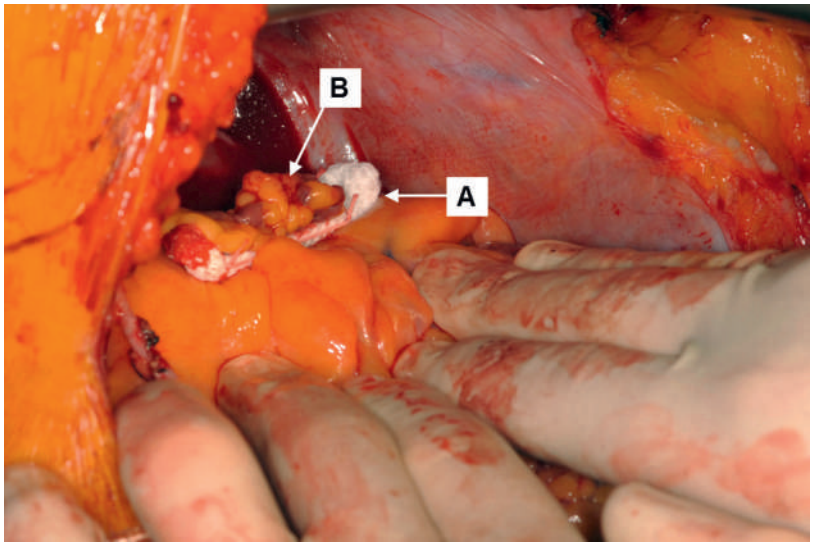

Figure 3: Intraoperative view of an applied left atrial appendage clip (AtriClip®, Atricure Inc., USA) in a concomitant surgical ablation procedure.
A = left atrial appendage clip; B = left atrial appendage.

higher success rates (73%) than suture exclusion (23%) and stapler exclusion (0%) [37]. Emmert et al. were able to show a 100% success rate of left atrial appendage closure with the epicardial left atrial appendage clip occlusion after a mean follow-up of 3.5 years [38]. On the basis of these studies the epicardial clip occlusion of the left atrial appendage should be the preferred surgical approach, since complete closure of the left atrial appendage is of utmost importance.

With regard to the question of anticoagulation after successful complete left atrial appendage closure, it is important to mention that there exists no reliable data that supports the discontinuation of oral anticoagulation in the absence of an absolute contraindication for oral anticoagulation and postoperative persistence of atrial fibrillation.

Based on the 2012 HRS/EHRA/ECAS expert consensus statement on catheter and surgical ablation of atrial fibrillation, oral anticoagulation should be continued for several months after surgical ablation of atrial fibrillation because of the relatively high incidence of early atrial tachyarrhythmias which occur after atrial fibrillation surgery. Anticoagulation may then be discontinued on a case-by-case basis after the documentation of the absence of symptomatic or asymptomatic atrial fibrillation episodes on follow-up electrocardiogram monitoring. Furthermore, a postoperative transthoracic echocardiogram should be obtained to rule out atrial stasis or thrombus prior to discontinuation of oral anticoagulation [20].

Results

Surgical ablation of atrial fibrillation, especially as a concomitant procedure to other cardiac surgical operations, is nowadays commonly performed. Reported success rates of both concomitant as well as stand-alone procedures mostly range between 60% and 80%, and the in-hospital mortality and periprocedural complication rate is low [8, 39–43].

Gillinov et al. studied the outcome of a surgical ablation procedure with bipolar radiofrequency as a concomitant procedure in 513 patients. They found that freedom from ablation failure was 72% at 12 months. An analysis of risk factors for ablation failure revealed three risk factors influencing ablation outcome: type and duration of atrial fibrillation, choice of lesion set in persistent atrial fibrillation and left atrial size [43].

Damiano et al. performed a prospective study on 282 patients who underwent the Cox maze IV procedure; 66% of the patients had a concomitant cardiac surgical procedure, the rest underwent a stand-alone atrial fibrillation operation. They were able to show rates of overall freedom from atrial fibrillation of 89%, 93% and 89% at 3, 6 and 12 months, respectively, postprocedure. There were no significant differences in success rates with regard to stand-alone versus concomitant maze operation ($p = 0.361$). They performed a multivariate logistic regression analysis of risk factors for failure after the Cox maze IV procedure and found left atrial diameter, early atrial tachycardias and failure to isolate the entire posterior left atrium to be predictors for procedural failure. Left atrial diameter was a significant predictor of failure with an odds ratio of 1.42 [9].

A meta-analysis of surgical ablation for atrial fibrillation during mitral valve surgery performed by Phan et al. revealed a significantly improved rate of sinus rhythm in the surgical ablation group. The meta-analysis, which included nine relevant randomised controlled trials comprising a total of 496 patients, showed, with regard to efficacy assessment, a sinus rhythm rate at 12 months of 75.5% in the surgical ablation group and 26% in the mitral valve only group ($p < 0.00001$). In patients with more than 12 months of follow-up success rates were 64.4% in the surgical ablation group versus 17.9% in the mitral valve only group ($p < 0.00001$). With regard to safety assessment 30-day all-cause mortality did not differ between the two groups (4.4% vs 2.2%; $p = 0.46$). The incidence of postoperative pacemaker implantations also did not reveal any significant differences (7.0% vs 7.5%; $p = 1.00$). The analysis of stroke rates revealed compa-

rable results between the groups (5.5% vs 3.9%; p = 0.45) [7].

Boersma et al. published the results of a prospective randomised clinical trial comparing catheter ablation for atrial fibrillation with stand-alone surgical ablation (FAST trial); 124 patients with drug refractory atrial fibrillation with left atrial dilatation and hypertension or failed catheter ablation were randomised to either catheter or surgical ablation. The primary endpoint was defined as freedom from left atrial arrhythmia lasting more than 30 seconds without antiarrhythmic medication. After 12 months the primary endpoint was met in 36.5% of the catheter ablation group and in 65.6% of the surgical ablation group (p = 0.0022). However the procedural adverse event rate was significantly higher in the surgical ablation group (23.0% vs 3.2%; p = 0.001) as well as the overall serious adverse event rate at 12 months (34.4% vs 15.9%; p = 0.027) [44].

Hybrid approach

As a result of suboptimal results with both catheter and surgical ablation a new concept of invasive treatment of atrial fibrillation was introduced in recent years – the hybrid approach. This approach is a combination of both surgical and catheter ablation of atrial fibrillation with the aim of optimising efficacy. [21, 26, 27]. La Meir et al. reported their experience with a hybrid procedure for atrial fibrillation treatment in 56 patients. They were able to show success rates of 92% at 2 years, 97% at 3 years and 95% at 4 years. These results are certainly promising and this approach needs to be further investigated in the future in order to evaluate whether the hybrid approach may become a standard treatment for lone atrial fibrillation.

Correspondence:
Christoph T. Starck, MD
Department of Cardiothoracic and Vascular Surgery
German Heart Institute Berlin
Augustenburger Platz 1
DE-13353 Berlin
Germany
starck[at]dhzb.de

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