JAFIB

Featured Review

Journal of Atrial Fibrillation

www. jafib.com

Hybrid Therapy for Atrial Fibrillation - Optimizing Treatment Strategies

Laurent Pison, MD,[1] Mark La Meir, MD, PhD,[2] Harry J. Crijns, MD, PhD[1]

[1]*Department of Cardiology, Maastricht University Medical Center and Cardiovascular Research Institute Maastricht, Maastricht, the Netherlands.* [2]*Department of Cardiac Surgery, UZ Brussel Center for Cardiovascular Diseases, Brussels, Belgium.*

Abstract

Endocardial atrial fibrillation (AF) ablation techniques enable one to characterize the underlying substrate in order to tailor the ablation procedure but these ablation lesions are not always transmural nor long lasting. Surgical AF ablation techniques, on the other hand, create reliable linear lesions but the lesion set is based on empirical assumptions rather than specific patient characteristics. Performed in combination, both approaches seem to be complementary as they overcome their mutual shortcomings. Several hybrid or convergent ablation strategies with the use of various energy sources have been described. Medium and long term results are encouraging, especially in challenging settings such as persistent AF and failed endocardial catheter ablations..

Introduction

According to the most recent Heart Rhythm Society(HRS)/ European Heart Rhythm Society(EHRA)/European Cardiac Arrhythmia Society (ECAS) consensus statement, both the endocardial and stand alone surgical AF ablation approach can be considered in patients with symptomatic AF refractory or intolerant to at least one Vaughan-Williams class 1 or 3 antiarrhythmic drug (AAD) but the current evidence supporting surgical ablation is mainly based on expert consensus and clinical experience. The indication to perform an endocardial ablation in this kind of patients, however, is driven by results from randomized clinical trials and/or meta-analyses.[1]

As the strengths of both techniques seem to overcome their mutual weaknesses, several groups tried to combine both approaches in the hope to further improve results of AF ablation.

This review article will first briefly review the current status of endocardial and surgical ablation techniques in order to better understand the rationale for a hybrid or convergent concept. The second part will focus on the several aspects of the hybrid AF ablation with the emphasis on techniques, follow-up and outcomes.

Endocardial AF Ablation

The cornerstone of endocardial AF ablation is an ablation strategy that targets the pulmonary vein (PV) and/or PV antrum whereby electrical isolation of the PV should be the goal.[1] The one-year success rate of this approach is greater than 80% in patients with paroxysmal AF.[2] Nowadays, unipolar radiofrequency (RF) is the most frequently used energy source to perform PV isolation. Cryoablation and laser are two alternatives.[3,4] Whatever energy source used, the most frequent reason for AF recurrence after PV isolation remains PV reconduction.[5] Long-term results of catheter ablation for paroxysmal AF are somewhat disappointing: in a recently published prospective study, sinus rhythm was maintained in only 46% of patients after the initial procedure without AAD during a median follow-up period of 5 years.[6] As AF progresses from paroxysmal to persistent and longstanding persistent AF, the atrial substrate itself plays an increasingly important role in the maintenance of the arrhythmia.[7] This may explain why PV isolation alone results in success rates of less than 25% in patients with persistent AF.[8] To improve these results, one needs to modify the atrial substrate by creating linear lesions and/or ablating complex fractionated atrial electrograms (CFAE). Ablation procedures combining PV isolation with linear lesions and/ or CFAE ablation in patients with (longstanding) persistent AF, seem to result in better outcomes than PV isolation alone but there is an important variation in success rates ranging from 11% to 75% and the incidence of iatrogenic atrial tachycardias after these procedures is substantial (up to 40%).[9,10] The creation of linear lesions was inspired by the surgical Cox-maze procedure for AF.[11] These linear

Disclosures:
Parikshit S. Sharma Has nothing to declare, David J. Callans consults for Biosense, St. Jude, Medtronic.

Corresponding Author:
Laurent Pison, MD
Department of Cardiology
Maastricht University Medical Center and Cardiovascular Research Institute
Maastricht
PO Box 5800
Maastricht
The Netherlands.

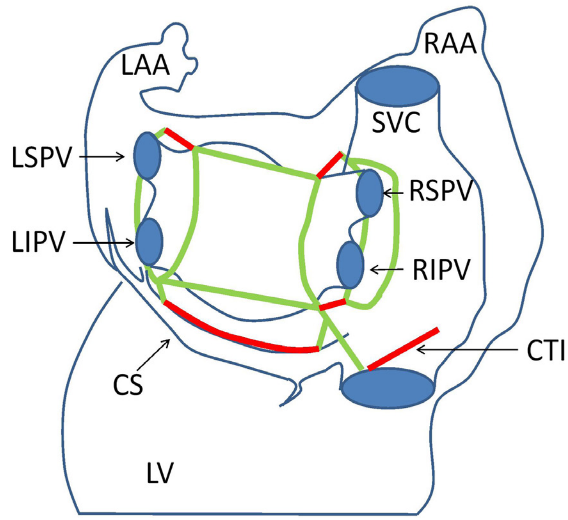

Figure 1: Posterior view of the heart with schematic representation of epicardial (green) and endocardial (red) ablation lines as applied by Kiser et al. and Gehi et al. See text for details.CTI = endocardial cavotricuspid isthmus ablation line, CS = coronary sinus, LAA = left atrial appendage, LIPV = left inferior pulmonary vein (PV) , LSPV = left superior PV, LV = left ventricle, RAA = right atrial appendage, RIPV = right inferior PV, RSPV = right superior PV, SVC = superior vena cava.

lesions are thought to prevent sustained multiple re-entry circuits by compartmentalization of the atria. The two most frequently deployed linear lesions, are the roofline connecting both superior PVs and the mitral isthmus line going from the left inferior PV to the mitral annulus. However, performing these linear lesions can sometimes be very challenging and incomplete lines may act as a substrate for macro-re-entrant circuits.[12] In 2004, Nademanee et al reported a one year success rate of 87% in patients with persistent AF (4% with AAD) and 78% in patients with longstanding persistent AF (11% with AAD) after CFAE (defined as fractionated electrograms with 2 or more deflections and a mean cycle length shorter than 120 ms) ablation only.[13] However, those results could not be reproduced by other groups and the electrophysiological mechanisms underlying CFAEs are still a source of debate.[14-16] Sites demonstrating high-dominant frequency seem to be as well interesting ablation sites. In an animal model, these sites correspond to functional reentry and are called rotors.[17] Recently, localized rotors have been visualized in human AF by computational mapping and ablation of these rotors results in acute termination of AF or substantial organization of the arrhythmia.[18,19] This discovery holds the potential for an important step towards a tailored substrate ablation approach, especially in patients with persistent AF.

Surgical AF Ablation

The gold standard for the surgical treatment of AF is the Cox-maze III procedure, also known as the "cut-and-sew" maze. This operation involves the creation of numerous incisions in both atria that would direct the sinus impulse propagation through the atria while interrupting macro-re-entrant circuits.[20] This procedure results in impressive long term success rates with 92% of patients free from symptomatic AF and 80% off AAD.[21] Postoperative care was standardized and included regular follow-up appointments with ECG monitoring. Importantly, the use of holter monitors, pacemaker interrogation, implantable monitoring devices, were not routine and therefore the results most likely overestimate the success. Another advantage of the surgical approach, is the possibility of removing the left atrial appendage (LAA) which may help to decrease the risk for stroke, especially in patients with a contraindication for warfarin.[22] According to the HRS/EHRA/ECAS expert consensus statement on catheter and surgical ablation of AF, stand-alone AF surgery should be considered for symptomatic AF patients who are refractory or intolerant to at least one Class 1 or 3 AAD, prefer a surgical approach or have failed one or more attempts at catheter ablation.[1] Nevertheless, the Cox-maze III procedure did not gain widespread implementation due to its complexity and technical challenge. As an alternative to the surgical incisions of the cut-and-sew maze and in an effort to simplify the procedure, several groups replaced these incisions with linear lines of ablation. In 2004, Damiano et al. introduced the Cox-maze IV procedure during which bipolar RF devices were used to isolate the PVs and create linear lesions.[23] This procedure can be performed through a small thoracotomy but it still requires cardiopulmonary bypass. There appears to be no difference between the Cox-maze III and IV procedure in terms of the rate of freedom from AF at 3, 6, and 12 months.[24] The last decade has been marked by a quest for new surgical ablation devices using unipolar and bipolar RF, microwave, laser, cryoablation or high-frequency ultrasound, that would enable the cardiac surgeon to perform a curative lesion epicardially on the beating heart without the need for cardiopulmonary bypass.[25] Unfortunately, none of the currently existing energy sources is able to guarantee reliable, transmural lesions in each and every patient. Another shortcoming of the epicardial surgical approach, is the inability to map and selectively ablate any re-entrant or focal tachycardia occurring during surgical AF ablation. Current techniques for the minimally invasive surgical treatment of stand-alone AF, result in success rates (defined as freedom from any AF episode longer than 30 seconds off AAD) at 12 months from 65% to 92% in paroxysmal AF and from 67% to 80% in persistent AF.[25]

The Hybrid AF Ablation Procedure: the Best of Two Worlds

Given the current knowledge about etiology and pathophysiology of AF, an optimal ablation procedure for this arrhythmia would[1] isolate the PVs permanently,[2] define the specific properties of the underlying atrial electrical substrate in order to customize the subsequent ablation strategy,[3] always create completely transmural linear lesions, and[4] be minimally invasive. To date, neither the endocardial approach nor the surgical ablation procedure on its own is able to meet all these criteria. However, both techniques seem to be complementary as, performed in combination (hence the nomenclature "hybrid" or "convergent" procedure), they bear the potential to overcome their respective shortcomings. The epicardial surgical approach seems to result in superior transmurality of the lesions, resulting in longlasting PV isolation and permanent conduction block.[26] The endocardial AF ablation procedure on the other hand, using multipolar catheters and three-dimensional electroanatomical mapping systems, is the most efficacious setting to guide substrate modification and ablation of atrial tachycardias known to occur during the stepwise ablation of persistent AF.[27]

There appears to be a wide variation in the possible combinations of epicardial surgical and transvenous endocardial techniques, lesion sets, and follow-up used for hybrid or convergent AF ablation

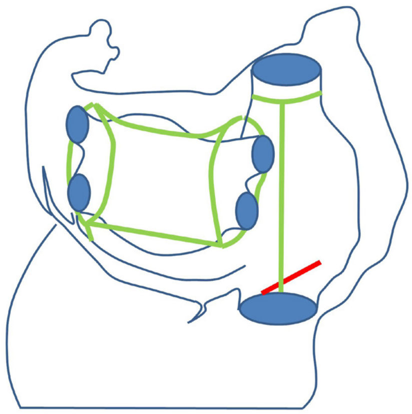

Figure 2: Posterior view of the heart with schematic representation of epicardial (green) and endocardial (red) ablation lines as applied by Pison et al. See text for details.

procedures (Table 1 and 2).[28]

In 2010, Kiser et al. reported on a series of 28 patients with persistent or longstanding persistent AF (mean AF duration 8 years, and mean left atrial size 5.3cm) who had failed medical management and underwent a combined surgical epicardial RF ablation and electrophysiological endocardial ablation.[29] The surgical part of the procedure was performed using a transdiaphragmatic pericardioscopic approach via an incision below the xiphoid process. Linear epicardial lesions were created with an irrigated, unipolar RF ablation device to isolate the PV, the posterior wall of the left atrium (LA), and the ligament of Marshall (Fig. 1). In addition to this, three other linear lesions were performed: from the inferior left PV to the coronary sinus (CS), from the right inferior PV towards the inferior right atrium near the Thebesian valve and onto the inferior vena cava. Because of the pericardial reflections, the epicardial linear lesions had to completed endocardially at the superior right and left PV and at the inferior right PV. To do so during the same procedure, the electrophysiologist gained access to the LA after a transseptal puncture via a femoral venous approach and ablated these zones. The next step was to prove isolation of the PVs and posterior LA using a multipolar circular catheter placed endocardially. If high-frequency electrical activity was mapped at the endocardial surface of the CS, this was subsequently ablated. Finally, the cavotricuspid isthmus (CTI) was ablated endocardially with confirmation of bidirectional block. If sinus rhythm was not attained at the end of the procedure, the patient underwent cardioversion. The procedure was complicated by symptomatic pericardial effusion requiring percutaneous drainage in 2 patients and 1 patient had phrenic nerve paresis. Antiarrhythmic drugs were initiated after the procedure at the discretion of the electrophysiologist but discontinued by 3 months. Follow-up was performed with a 24-hour Holter at 3 months, and 24-hour or 7-day Holter at 6 months. At 3 months 87% of patients were in sinus rhythm, but only 43% were free of AF and AADs. At 6 months, 84% were in sinus rhythm, and 76% were free of AF and AAD.

Table 1: Hybrid AF ablation: baseline characteristics

First author	Number of patients	Age (years)	LA diameter (cm)	CA (%)	Par AF N (%)	Pers AF N (%)	LS Pers AF N (%)
Kiser	28	ns	5.3	0	0	5(18)	23(82)
Gehi	101	63±10	5.1±1.0	36(36)	17(17)	47(46)	37(37)
Pison	26	57±9	4.3±0.5	11(44)	15(57)	10(38)	1(5)
Muneretto	24	63±9	5.0±0.8	ns	0	3(12)	21(88)
Gersak	50	56±11	4.8±0.5	ns	3(6)	8(16)	39(78)
mahapatra	15	59±2	5.2±1.0	15(100)	0	9(60)	6(40)
Krul	31	57	4.7±0.7	14(45)	16(52)	13(42)	2(6)

Age and left atrial (LA) diameter expressed as mean ± SD. See text for details.
AF = atrial fibrillation, CA = catheter ablation, LS = longstanding, N = number, ns = not specified, Par = paroxysmal, Pers = persistent

Gehi et al. described a cohort of 101 consecutive patients who underwent a transdiaphragmatic pericardioscopic, hybrid epicardial-endocardial AF ablation procedure.[30] Patients were considered for this procedure if they had (1) paroxysmal or persistent AF and failed prior endocardial catheter ablation with concomitant class 1 or class 3 AAD therapy, (2) persistent AF with dilated LA or structural heart disease, or (3) longstanding persistent AF. The epicardial surgical part of the procedure was performed with the same device and lesion set as described by Kiser et al.[29] The subsequent endocardial approach, which was performed during the same procedure, deployed comparable lesions to what has been reported by Kiser et al. except for the fact that CFAEs also were targeted. If AF organized into either atrial flutter (AFL) or atrial tachycardia during this stepwise approach, these arrhythmias were mapped and ablated. The endocardial endpoints of this procedure were entrance and exit block of the PVs, entrance block of the LA posterior wall, and block across mitral isthmus and CTI. Patients who remained in AF at the end of this procedure were cardioverted. A class 1 or class 3 AAD was initiated in all patients postoperatively and not stopped before 6 weeks. There were 6 major complications: 2 deaths, 2 rebleedings requiring reoperation and 2 pericardial tamponades. Patients were followed with 24-hour Holter monitoring at 3, 6 and 12 months. Recurrence of AF was defined as any episode of AF lasting more than 30 seconds off all AADs. Recurrences occurring prior to the 3-month follow-up were not taken into consideration. Overall, 12-month arrhythmia-free survival after a single hybrid procedure off AAD was 68% and 73% including repeat endocardial ablation.

We published in 2012 our initial experience with long-term follow-up of minimally invasive epicardial bilateral PV isolation and linear lesions in combination with endocardial proof of conduction block and endocardial touch-up if indicated in a single AF ablation procedure in a cohort of 26 consecutive patients.[31] Inclusion criteria were previously failed catheter ablation, LA volume ≥ 29 ml/m2, persistent or longstanding persistent AF, or patient preference for a hybrid procedure. The first steps of this procedure consisted of gaining endocardial access to the LA with a transseptal puncture via femoral venous approach and thoracoscopic isolation of the PVs as ipsilateral pairs using a bipolar RF clamp (Fig. 2). If AF didn't terminate or was still inducible after PV isolation, a roof line and an inferior line were created with a bipolar RF linear pen device. By making those linear lesions, the posterior LA was isolated which is also known

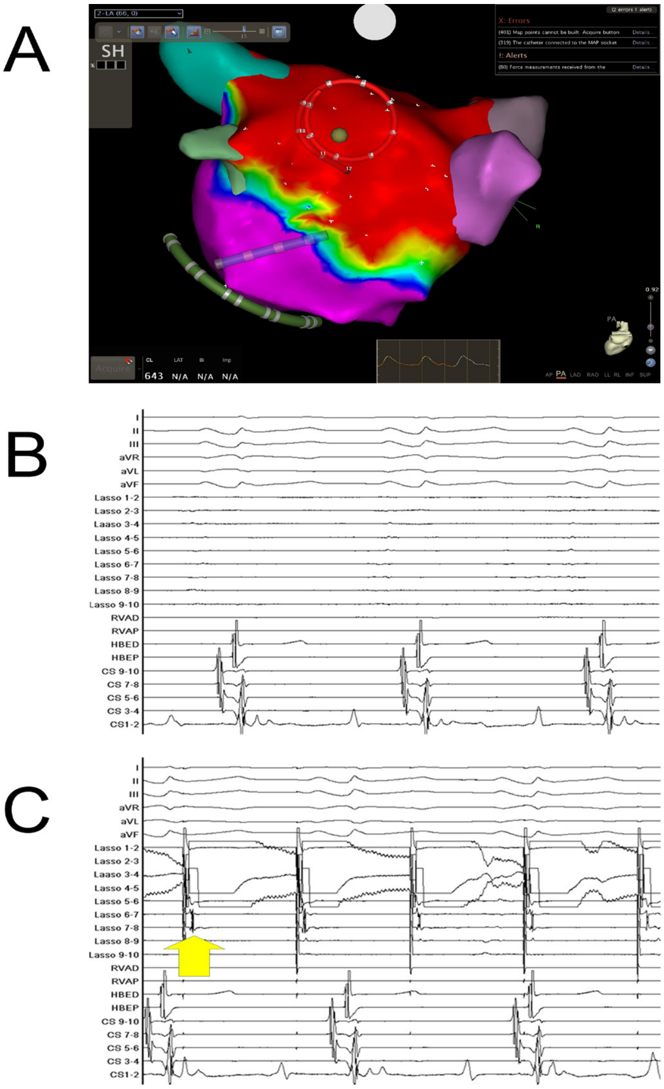

Figure 3: Box lesion with bidirectional block Panel A: posterior-anterior view of the left atrium. The box lesion is visualized in red (voltages < 0.15mV). A circular mapping catheter (Lasso catheter) is placed endocardially in the middle of the box lesion. Panel B: the endocardial Lasso catheter tracings show only far field signals which indicates entrance block. Panel C: pacing from the Lasso catheter results in local capture (arrow) without conduction to the rest of the left atrium which indicates exit block.

as a box lesion (Fig. 3). If entrance and exit block were not reached within this box lesion, the conduction gaps were identified and ablated endocardially with a cooled tip RF catheter. This was needed in 5 patients (23%). If the right atrium was dilated, 2 additional epicardial linear lesions were deployed: 1 encircling the superior vena cava (SVC), the other connecting both caval veins. If AF persisted at this point, a left isthmus linear lesion was created using a bipolar RF pen device but in all cases endocardial touch-up was necessary to obtain bidirectional block. In patients with known typical AFL or if this arrhythmia became apparent during the procedure, the CTI was ablated endocardially and the endpoint was bidirectional block. The ganglionated plexi (GP) were not selectively ablated. No deaths or conversions to cardiopulmonary bypass were reported. After the procedure, patients reinitiated their pre-operative AAD regimen. Acenocoumarol and AADs were discontinued after the 6-month monitoring visit confirmed the absence of any atrial arrhythmia. The patients underwent a 7-day continuous Holter monitoring at 3, 6, 9, and 12 months. According to current guidelines, success was defined as no episode of AF/AFL/atrial tachycardia (AT) lasting more than 30 seconds off AAD after the 3-month blanking period. One-year success was 93% for patients with paroxysmal AF and 90% for patients with persistent AF.

Several groups analyzed the feasibility and effectiveness of a staged hybrid procedure. This means that the epicardial surgical and transvenous endocardial approach are performed in 2 separate procedures with an interval of at least several days.

Muneretto et al performed a staged hybrid AF ablation procedure in 24 consecutive patients with lone persistent or longstanding persistent AF.[32] The mean LA dimension was 50 mm and the mean AF duration was 83 months. The surgical procedure was performed first and consisted of a monolateral, right-sided, thoracoscopic approach to deliver a continuous lesion encircling 'en bloc' the ostium of all PVs and the posterior wall of the LA (Fig. 4). This lesion was applied using a internally cooled, RF monopolar device with suction adherence. Once the box lesion had been completed, the presence of entrance and exit block was assessed using a quadripolar catheter placed in the middle of the lesion epicardially and a decapolar CS catheter. Bidirectional block was achieved in 88% of the patients. At the time of the surgical procedure, all patients were equipped with an implantable subcutaneous loop recorder. No surgical complications were reported. The endocardial ablation procedure was performed 30 to 45 days after surgery. In 21% of the patients, bidirectional block could not be confirmed at the level of the box lesion due to gaps which were subsequently closed using endocardial ablation catheters. In 62% of patients, additional endocardial lesions were deployed at sites of focal triggers for AF, CFAE and CTI. During follow-up the implantable loop recorder was interrogated monthly. In this study, AF recurrence was defined as the presence of AF with a duration longer than 5 minutes. At a mean follow-up of 28 months, 87% of the patients had no AF recurrence and 75% were off AAD.

In a recent paper, Gersak et al. reported the outcomes of a convergent AF ablation procedure in 50 patients with mainly persistent or longstanding persistent AF.[33] In 34 patients, the endocardial part of the procedure was performed during the same session. In the remaining 16 patients (32%), this was done at least two months after epicardial ablation (staged manner). In all patients the epicardial surgical ablation was performed first. The posterior surface of the heart was accessed via an endoscopically created, transdiaphragmatic pericardial window. The epicardial LA lesions were created without dissecting the pericardial deflections and using a vacuum irrigated unipolar RF electrosurgical device with a 3 cm long directional ablation electrode. Linear epicardial lesions were placed around the PVs, at the roof of the LA, over the ligament of Marshall, close to the CS and over areas of GP (Fig. 5). In all patients, a subcutaneous loop recorder was implanted. In 34 patients, the endocardial part of the procedure was performed during the same session. In the remaining 16 patients, this was done at least two months after epicardial ablation. Percutaneous access to the LA was obtained through a conventional transseptal puncture and endocardial lesions were applied to connect the epicardial linear lesions along the pericardial reflections using a saline irrigated ablation catheter. Isolation of the PVs was checked endocardially. In all patients, amiodarone was initiated after the

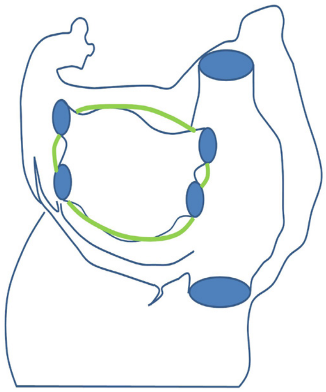

Figure 4: Posterior view of the heart with schematic representation of epicardial (green) and endocardial (red) ablation lines as applied by Muneretto et al. See text for details.

procedure. At 12 months, 75% of patients were in sinus rhythm off AAD and at 24 months this was the case in 67% of patients. Major complications were observed in 5 patients (10%): 2 procedural deaths due to atrioesophageal fistulas, 1 stroke, 1 pericardial effusion and 1 excessive bleeding necessitating blood transfusion.

Mahapatra and colleagues matched 15 patients with persistent or longstanding persistent AF who underwent a sequential hybrid ablation procedure and had previously failed at least 1 catheter ablation and 1 AAD to 30 patients who had failed at least 1 catheter ablation and were scheduled for a repeat catheter ablation only. (34) The epicardial surgical ablation was performed with a bilateral thoracoscopic approach, using a bipolar RF clamp and a bipolar unidirectional RF ablation device (Fig. 6). Surgical ablation included isolation of the PVs and SVC, creation of a roof line, mitral isthmus line, GP ablation, ligament of Marshall ablation, and LAA exclusion. All patients were then loaded on amiodarone intravenously. Approximately 4 days later, patients underwent an endocardial ablation procedure. After confirmation of SVC isolation, CTI and CS ablation was performed and isoproterenol was administered. If AFL was induced, it was mapped and ablated. Once sinus rhythm was restored, PV isolation and block across linear lesions were assessed. If AF was induced, CFAEs were ablated after validation of PV isolation and completeness of linear lesions. There were no acute complications. Amiodarone was continued until 3 months. In the 30 patients from the catheter-alone control group, the ablation strategy included, at a minimum, antral PV isolation, roof line and CTI line. Patients were followed with 7-day Holter at 3,6, and 12 months and 24-hour Holter at 9,18 and 24 months. The primary endpoint was event free survival of any atrial arrhythmia longer than 30 seconds off AAD. After a mean follow-up of 20.7±4.5 months, 87% of patients in the sequential hybrid ablation group were free of any atrial arrhythmia off AAD, compared to 53% in the control group.

The feasibility of a completely epicardial hybrid procedure has also been investigated. Krul et al. performed thoracoscopic PV isolation, GP ablation and linear lesions (only in nonparoxysmal AF patients) in combination with epicardial assessment of conduction block during the same procedure in 31 patients (15 persistent or longstanding persistent AF).[35] Surgery was performed through 3

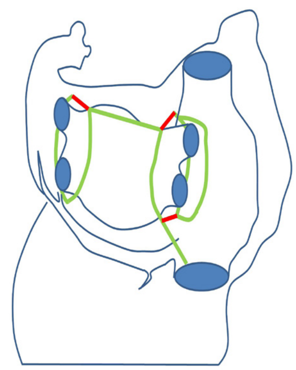

Figure 5: Posterior view of the heart with schematic representation of epicardial (green) and endocardial (red) ablation lines as applied by Gersak et al. See text for details.

Table 2: Hybrid AF ablation: procedural characteristics and endpoints

First author	Access	Epicardial energysource	Endocardial energysource	GP	LAA	Follow-up	Endpoint	Succes percentage (%)
Kiser	TD	Irrigated unipolar RF	ns	no	no	24-hour or 7-day Holter at 6 months	No AF off AAD	761
Gehi	TD	Irrigated unipolar RF	Noncooled 8-mm or cooled 3.5-mm tip	no	no	24-hour Holter at 3, 6, and 12 months	No episode of AF > 30 seconds off AAD	731
Pison	TOB	Bipolar RF	Cooled 3.5-mm tip	no	yes	7-day Holter at 3, 6, 9, and 12 months	No episode of AF/AFL/AT > 30 seconds off AAD	PAF 93, Pers AF 90
Muneretto	TOM	Irrigated unipolar RF	ns	no	no	Monthly interrogation of ILR	No episode of AF > 5 minutes off AAD or AF burden > 0.5%	751
Gersak	TP	Irrigated unipolar RF	Cooled 3.5-mm tip	no	no	Interrogation of ILR at 6, 12, and 24 months	SR off AAD	671
mahapatra	TOB	Bipolar RF	Noncooled 5-mm or cooled 3.5-mm tip	yes	yes	7-day Holter at 3, 6, and 12 months	No episode of AF/AFL/AT > 30 seconds off AAD	871
Krul	TOB	Bipolar RF	no	yes	Yes	24-hour Holter every 3 months during 2 years	No episode of AF/AFL/AT > 30 seconds off AAD	PAF 92, Pers AF 80

1Global success percentage, 2Succes percentage for patients with paroxysmal AF (PAF) en persistent AF (Pers AF). See text for details.
AAD = antiarrhythmic drugs, AF = atrial fibrillation, AFL = atrial flutter, AT = atrial tachycardia, GP = ganglionated plexi, ILR = implantable loop recorder, LAA = left atrial appendage, ns = not specified, TOB = thoracoscopic bilateral, TOM = thoracoscopic monolateral, TP = transdiaphragmatic pericardioscopic, SR = sinus rhythm

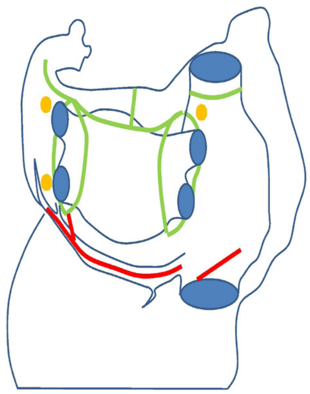

Figure 6: Posterior view of the heart with schematic representation of epicardial (green) and endocardial (red) ablation lines as applied by Mahapatra et al. Orange dots represent epicardial ganglionated plexi ablation. See text for details

ports bilaterally. The GPs were localized and subsequently ablated with a bipolar RF pen (Fig. 7). The PVs were isolated using a bipolar RF clamp and a custom-made multi electrode was positioned on the epicardial surface of those PVs to assess conduction block. In patients with persistent AF, 3 additional linear lesions were deployed on the LA: superior line, inferior line and trigone line (between the superior line and left fibrous trigone). Electrical isolation of the box and conduction block across the trigone line were tested using the same custom-made multi electrode. The LAA was removed with an endoscopic stapling device. During this procedure, 3 patients had a sternotomy because of uncontrolled bleeding. Three months after the procedure, AADs were discontinued. Oral anticoagulants were stopped at 6 months in patients with a CHADS2 score ≤ 1 and in

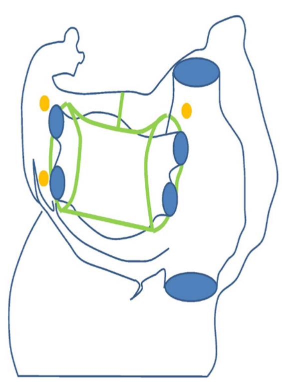

Figure 7: Pulmonary Vein Isolation to treat AF: An example using advanced imaging

sinus rhythm off AAD. Patients were followed up with a 24-hour Holter every 3 months. The primary endpoint was freedom from episodes of AF/AFL/AT lasting more than 30 seconds without the use of AAD after 12 months. Eighty-six percent of the patients reached this primary endpoint.

Discussion

The hybrid or convergent AF ablation procedure combines the best aspects of minimally invasive AF surgery and electrophysiology. This multidisciplinary approach makes it possible to create and evaluate an extensive biatrial lesion set, without sternotomy or cardiopulmonary bypass. To date, the number of patients who underwent a hybrid AF ablation remains small but, especially in patients with persistent and longstanding persistent AF, one-year success rates off AAD are promising. However, different hybrid or convergent ablation strategies, various energy sources and divergent definitions of success are being used which makes it quite difficult to compare outcomes. It is therefore not clear which lesions or lesion sets are needed and what is the best endpoint for this kind of procedures. The only lesion they all have in common is PV isolation. Isolation of the posterior wall of the LA is also a preferred target as ectopy initiating AF frequently arises in this part of the LA.[36] The added value of GP ablation is still an area of debate. In an animal model, Damiano et al. demonstrated functional reinnervation within a period of 4 weeks.[37] The concern has been raised that if this reinnervation is non-uniform, this could create a new substrate for AF that was not originally present in a given patient. Another advantage of the hybrid approach, is the possibility to exclude the LAA as this is the site of most of the clot formation that eventually leads to thromboembolic events in patients with non-valvular AF.[38] In addition, there may be a small number of patients with recurrent AF owing to a trigger nestled in the LAA, which could be eliminated with exclusion of this appendage.[39] Combining the epicardial surgical and the endocardial approach in one single procedure makes it possible to perform an endocardial touch-up whenever epicardial lesions are not completely transmural. Other advantages are [1] the anatomic guiding for those touch-up lesions by the surgeon showing the cardiologist where the epicardial lesions are exactly located and [2] the immediate add on endocardial lesion and the already deployed surgical lesions add up to form a firm transmural lesion. However, organizing this kind of procedures requires robust logistical capacities as both the cardiac surgeon and electrophysiologist need to be in the same room at the same time. Another important concern is that performing an endocardial ablation immediately after epicardial ablation rather than staging endocardial ablation at a later date, may limit endocardial mapping due to edema or transient injury caused by epicardial ablation. However, considering the long term results of the combined approach this probably is not a true problem. Whether to perform a hybrid AF ablation in a given patient rather than a standard endocardial procedure, remains a difficult question as long as we don't have results of prospective randomized trials at our disposal. Current data suggest to reserve this kind of procedures for patients with persistent or longstanding persistent AF with a dilated LA or after a failed endocardial approach. The significant complication rate in some series is likely the effect of a learning curve as this kind of procedures requires a specific technical expertise concerning the epicardial surgical aspect. In order to further improve widespread acceptance and implementation of these hybrid techniques, major complications should be restricted to a minimum.

Conclusions:

Hybrid or convergent AF ablation procedures integrate the advantages of both cardiology and cardiac surgery. The surgeon is able to perform PV isolation epicardially, deploy a number of linear ablation lines and exclude the LAA. The electrophysiologist can realize endocardial validation of those epicardial lesions and perform endocardial (touch-up) ablation where necessary. There is a wide variation in surgical techniques and lesion sets. Although the number of patients treated so far is relatively small, the medium and long-term follow-up results are encouraging.

References:

1. Calkins H, Kuck KH, Cappato R, Brugada J, Camm AJ, Chen SA, Crijns HJ, Damiano RJ, Jr., Davies DW, DiMarco J, Edgerton J, Ellenbogen K, Ezekowitz MD, Haines DE, Haissaguerre M, Hindricks G, Iesaka Y, Jackman W, Jalife J, Jais P, Kalman J, Keane D, Kim YH, Kirchhof P, Klein G, Kottkamp H, Kumagai K, Lindsay BD, Mansour M, Marchlinski FE, McCarthy PM, Mont JL, Morady F, Nademanee K, Nakagawa H, Natale A, Nattel S, Packer DL, Pappone C, Prystowsky E, Raviele A, Reddy V, Ruskin JN, Shemin RJ, Tsao HM, Wilber D. 2012 hrs/ehra/ecas expert consensus statement on catheter and surgical ablation of atrial fibrillation: Recommendations for patient selection, procedural techniques, patient management and follow-up, definitions, endpoints, and research trial design: A report of the heart rhythm society (hrs) task force on catheter and surgical ablation of atrial fibrillation. Developed in partnership with the european heart rhythm association (ehra), a registered branch of the european society of cardiology (esc) and the european cardiac arrhythmia society (ecas); and in collaboration with the american college of cardiology (acc), american heart association (aha), the asia pacific heart rhythm society (aphrs), and the society of thoracic surgeons (sts). Endorsed by the governing bodies of the american college of cardiology foundation, the american heart association, the european cardiac arrhythmia society, the european heart rhythm association, the society of thoracic surgeons, the asia pacific heart rhythm society, and the heart rhythm society. Heart Rhythm 2012;9:632-696 e621.
2. Thomas SP, Sanders P. Catheter ablation for atrial fibrillation. Heart, lung & circulation 2012;21:395-401.
3. Andrade JG, Khairy P, Guerra PG, Deyell MW, Rivard L, Macle L, Thibault B, Talajic M, Roy D, Dubuc M. Efficacy and safety of cryoballoon ablation for atrial fibrillation: A systematic review of published studies. Heart Rhythm 2011;8:1444-1451.
4. Gerstenfeld EP. New technologies for catheter ablation of atrial fibrillation. Current treatment options in cardiovascular medicine 2011;13:393-401.
5. Callans DJ, Gerstenfeld EP, Dixit S, Zado E, Vanderhoff M, Ren JF, Marchlinski FE. Efficacy of repeat pulmonary vein isolation procedures in patients with recurrent atrial fibrillation. Journal of cardiovascular electrophysiology 2004;15:1050-1055.
6. Ouyang F, Tilz R, Chun J, Schmidt B, Wissner E, Zerm T, Neven K, Kokturk B, Konstantinidou M, Metzner A, Fuernkranz A, Kuck KH. Long-term results of catheter ablation in paroxysmal atrial fibrillation: Lessons from a 5-year follow-up. Circulation 2010;122:2368-2377.
7. Katritsis D, Merchant FM, Mela T, Singh JP, Heist EK, Armoundas AA. Catheter ablation of atrial fibrillation the search for substrate-driven end points. Journal of the American College of Cardiology 2010;55:2293-2298.
8. Oral H, Knight BP, Tada H, Ozaydin M, Chugh A, Hassan S, Scharf C, Lai SW, Greenstein R, Pelosi F, Jr., Strickberger SA, Morady F. Pulmonary vein isolation for paroxysmal and persistent atrial fibrillation. Circulation 2002;105:1077-1081.
9. Brooks AG, Stiles MK, Laborderie J, Lau DH, Kuklik P, Shipp NJ, Hsu LF, Sanders P. Outcomes of long-standing persistent atrial fibrillation ablation: A systematic review. Heart Rhythm 2010;7:835-846.
10. Rostock T, Drewitz I, Steven D, Hoffmann BA, Salukhe TV, Bock K, Servatius H, Aydin MA, Meinertz T, Willems S. Characterization, mapping, and catheter ablation of recurrent atrial tachycardias after stepwise ablation of long-lasting persistent atrial fibrillation. Circ Arrhythm Electrophysiol 2010;3:160-169.
11. Shen J, Bailey M, Damiano RJ, Jr. Surgery for lone atrial fibrillation: Present state-of-the-art. Innovations (Philadelphia, Pa 2009;4:248-255.
12. Jais P, Hocini M, O'Neill MD, Klein GJ, Knecht S, Sheiiro M, Arentes L, Kodali S, Clementy J, Haissaguerre M. How to perform linear lesions. Heart Rhythm 2007;4:803-809.
13. Nademanee K, McKenzie J, Kosar E, Schwab M, Sunsaneewitayakul B, Vasavakul T, Khunnawat C, Ngarmukos T. A new approach for catheter ablation of atrial fibrillation: Mapping of the electrophysiologic substrate. Journal of the American College of Cardiology 2004;43:2044-2053.
14. Oral H, Chugh A, Good E, Wimmer A, Dey S, Gadeela N, Sankaran S, Crawford T, Sarrazin JF, Kuhne M, Chalfoun N, Wells D, Frederick M, Fortino J, Benloucif-Moore S, Jongnarangsin K, Pelosi F, Jr., Bogun F, Morady F. Radiofrequency catheter ablation of chronic atrial fibrillation guided by complex electrograms. Circulation 2007;115:2606-2612.
15. Viles-Gonzalez JF, Gomes JA, Miller MA, Dukkipati SR, Koruth JS, Eggert C, Coffey J, Reddy VY, d'Avila A. Areas with complex fractionated atrial electrograms recorded after pulmonary vein isolation represent normal voltage and conduction velocity in sinus rhythm. Europace 2013;15:339-46.
16. Lau DH, Maesen B, Zeemering S, Verheule S, Crijns HJ, Schotten U. Stability of complex fractionated atrial electrograms: A systematic review. Journal of cardiovascular electrophysiology 2012;23:980-987.
17. Mandapati R, Skanes A, Chen J, Berenfeld O, Jalife J. Stable microreentrant sources as a mechanism of atrial fibrillation in the isolated sheep heart. Circulation 2000;101:194-199.
18. Narayan SM, Krummen DE, Rappel WJ. Clinical mapping approach to diagnose electrical rotors and focal impulse sources for human atrial fibrillation. Journal of cardiovascular electrophysiology 2012;23:447-454.
19. Shivkumar K, Ellenbogen KA, Hummel JD, Miller JM, Steinberg JS. Acute termination of human atrial fibrillation by identification and catheter ablation of localized rotors and sources: First multicenter experience of focal impulse and rotor modulation (firm) ablation. Journal of cardiovascular electrophysiology 2012;23:1277-1285.
20. Cox JL, Canavan TE, Schuessler RB, Cain ME, Lindsay BD, Stone C, Smith PK, Corr PB, Boineau JP. The surgical treatment of atrial fibrillation. Ii. Intraoperative electrophysiologic mapping and description of the electrophysiologic basis of atrial flutter and atrial fibrillation. The Journal of thoracic and cardiovascular surgery 1991;101:406-426.
21. McCarthy PM, Gillinov AM, Castle L, Chung M, Cosgrove D, 3rd. The cox-maze procedure: The cleveland clinic experience. Seminars in thoracic and cardiovascular surgery 2000;12:25-29.
22. Prasad SM, Maniar HS, Camillo CJ, Schuessler RB, Boineau JP, Sundt TM, 3rd, Cox JL, Damiano RJ, Jr. The cox maze iii procedure for atrial fibrillation: Long-term efficacy in patients undergoing lone versus concomitant procedures. The Journal of thoracic and cardiovascular surgery 2003;126:1822-1828.
23. Shen J, Bailey MS, Damiano RJ, Jr. The surgical treatment of atrial fibrillation. Heart Rhythm 2009;6:S45-50.
24. Lall SC, Melby SJ, Voeller RK, Zierer A, Bailey MS, Guthrie TJ, Moon MR, Moazami N, Lawton JS, Damiano RJ, Jr. The effect of ablation technology on surgical outcomes after the cox-maze procedure: A propensity analysis. The Journal of thoracic and cardiovascular surgery 2007;133:389-396.
25. La Meir M, Gelsomino S, Luca F, Pison L, Colella A, Lorusso R, Crudeli E, Gensini GF, Crijns HG, Maessen J. Minimal invasive surgery for atrial fibrillation: An updated review. Europace 2013;15:170-182.
26. Bugge E, Nicholson IA, Thomas SP. Comparison of bipolar and unipolar radiofrequency ablation in an in vivo experimental model. Eur J Cardiothorac Surg 2005;28:76-80; discussion 80-72.
27. Knecht S, Veenhuyzen G, O'Neill MD, Wright M, Nault I, Weerasooriya R, Miyazaki S, Sacher F, Hocini M, Jais P, Haissaguerre M. Atrial tachycardias encountered in the context of catheter ablation for atrial fibrillation part ii: Mapping and ablation. Pacing Clin Electrophysiol 2009;32:528-538.
28. Pison L, Dagres N, Lewalter T, Proclemer A, Marinskis G, Blomstrom-Lundqvist C. Surgical and hybrid atrial fibrillation ablation procedures. Europace 2012;14:939-941.

29. Kiser AC, Landers M, Horton R, Hume A, Natale A, Gersak B. The convergent procedure: A multidisciplinary atrial fibrillation treatment. The heart surgery forum 2010;13:E317-321.
30. Gehi AK, Mounsey JP, Pursell I, Landers M, Boyce K, Chung EH, Schwartz J, Walker TJ, Guise K, Kiser AC. Hybrid epicardial-endocardial ablation using a pericardioscopic technique for the treatment of atrial fibrillation. Heart Rhythm 2013;10:22-28.
31. Pison L, La Meir M, van Opstal J, Blaauw Y, Maessen J, Crijns HJ. Hybrid thoracoscopic surgical and transvenous catheter ablation of atrial fibrillation. Journal of the American College of Cardiology 2012;60:54-61.
32. Muneretto C, Bisleri G, Bontempi L, Cheema FH, Curnis A. Successful treatment of lone persistent atrial fibrillation by means of a hybrid thoracoscopic-transcatheter approach. Innovations 2012 (Philadelphia, Pa;7:254-258.
33. Gersak B, Pernat A, Robic B, Sinkovec M. Low rate of atrial fibrillation recurrence verified by implantable loop recorder monitoring following a convergent epicardial and endocardial ablation of atrial fibrillation. Journal of cardiovascular electrophysiology 2012;23:1059-1066.
34. Mahapatra S, LaPar DJ, Kamath S, Payne J, Bilchick KC, Mangrum JM, Ailawadi G. Initial experience of sequential surgical epicardial-catheter endocardial ablation for persistent and long-standing persistent atrial fibrillation with long-term follow-up. The Annals of thoracic surgery 2011;91:1890-1898.
35. Krul SP, Driessen AH, van Boven WJ, Linnenbank AC, Geuzebroek GS, Jackman WM, Wilde AA, de Bakker JM, de Groot JR. Thoracoscopic video-assisted pulmonary vein antrum isolation, ganglionated plexus ablation, and periprocedural confirmation of ablation lesions: First results of a hybrid surgical-electrophysiological approach for atrial fibrillation. Circ Arrhythm Electrophysiol 2011;4:262-270.
36. Chen SA, Hsieh MH, Tai CT, Tsai CF, Prakash VS, Yu WC, Hsu TL, Ding YA, Chang MS. Initiation of atrial fibrillation by ectopic beats originating from the pulmonary veins: Electrophysiological characteristics, pharmacological responses, and effects of radiofrequency ablation. Circulation 1999;100:1879-1886.
37. Sakamoto S, Schuessler RB, Lee AM, Aziz A, Lall SC, Damiano RJ, Jr. Vagal denervation and reinnervation after ablation of ganglionated plexi. The Journal of thoracic and cardiovascular surgery 2010;139:444-452.
38. Blackshear JL, Odell JA. Appendage obliteration to reduce stroke in cardiac surgical patients with atrial fibrillation. The Annals of thoracic surgery 1996;61:755-759.
39. Di Biase L, Burkhardt JD, Mohanty P, Sanchez J, Mohanty S, Horton R, Gallinghouse GJ, Bailey SM, Zagrodzky JD, Santangeli P, Hao S, Hongo R, Beheiry S, Themistoclakis S, Bonso A, Rossillo A, Corrado A, Raviele A, Al-Ahmad A, Wang P, Cummings JE, Schweikert RA, Pelargonio G, Dello Russo A, Casella M, Santarelli P, Lewis WR, Natale A. Left atrial appendage: An underrecognized trigger site of atrial fibrillation. Circulation 2010;122:109-118.