The Convergent Atrial Fibrillation Ablation Procedure: Evolution of a Multidisciplinary Approach to Atrial Fibrillation Management

Karan Wats,1 Andy Kiser,2 Kevin Makati,3 Nitesh Sood,4 David DeLurgio,5 Yisachar Greenberg1 and Felix Yang1

1. Maimonides Medical Center, Brooklyn, New York, NY, US; 2. St Clair Cardiovascular Surgical Associates, Pittsburgh, PA, US; 3. Tampa Cardiac Specialists, Lutz, FL, US; 4. Southcoast Health, Fall River, MA, US; 5. Emory Saint Joseph’s Hospital, Atlanta, GA, US

Abstract
The treatment of AF has evolved over the past decade with increasing use of catheter ablation in patients refractory to medical therapy. While pulmonary vein isolation using endocardial catheter ablation has been successful in paroxysmal AF, the results have been more controversial in patients with long-standing persistent AF where extrapulmonary venous foci are increasingly recognised in the initiation and maintenance of AF. Hybrid ablation is the integration of minimally invasive epicardial ablation with endocardial catheter ablation, and has been increasingly used in this population with better results. The aim of this article was to analyse and discuss the evidence for the integration of catheter and minimally invasive surgical approaches to treat AF with specific focus on convergent ablation and exclusion of the left atrial appendage using a surgically applied clip.

Keywords
AF, ablation, convergent procedure, AtriClip

Disclosure: AK, KM, NS, DO, YG and FY received consulting fees from Atricure. All other authors have no conflicts of interest to declare.

Acknowledgement: The authors contributed equally.

Received: 11 December 2019 Accepted: 9 April 2020 Citation: Arrhythmia & Electrophysiology Review 2020;9(2):88–96.

DOI: https://doi.org/10.15420/aer.2019.20

Correspondence: Felix Yang, Cardiology, 1st Floor Professional Building, 953 49th St, Brooklyn, NY 11219, US. E: fyang@maimonidesmed.org

Open Access: This work is open access under the CC-BY-NC 4.0 License which allows users to copy, redistribute and make derivative works for non-commercial purposes, provided the original work is cited correctly.

AF is the most commonly encountered atrial arrhythmia in clinical practice. Restoration of normal sinus rhythm through catheter- and surgically based approaches has been increasingly used as technologies and outcomes have improved.1 Success rates for AF ablation vary greatly depending on the duration of AF (more successful for paroxysmal AF, less successful in persistent AF and even less so for long-standing persistent AF). The persistent AF population represents a challenging cohort that frequently require multiple ablation procedures to maintain sinus rhythm.2 Additionally, the left atrial appendage (LAA) has been implicated as an independent driver of AF arrhythmogenesis, as well as a site responsible for thromboembolism, and this in turn has increased interest in LAA management.3 In this article, we discuss how the convergent AF procedure and external surgical LAA ligation can be performed through a multidisciplinary approach to manage conventional treatment-refractory persistent AF patients.

The substrate in paroxysmal AF appears to largely originate from the pulmonary veins, and as a result, pulmonary vein isolation (PVI) has demonstrated effectiveness in eliminating AF recurrence in the majority of patients.4,5 Nevertheless, the success rates for ablation of paroxysmal AF ablation still warrants improvement. The FIRE and ICE trial yielded an approximate 65% freedom from atrial arrhythmias off antiarrhythmics in both the cryoballoon and the radiofrequency ablation arms at 18 months.6

Even more recently, the Cryoballoon versus Irrigated Radiofrequency Catheter Ablation: Double Short versus Standard Exposure Duration (CIRCA-DOSE) trial reported only a 51–54% freedom from atrial arrhythmias at 1 year with loop recorder data utilising the latest iterations of contact force-sensing ablation catheters and the second-generation cryoballoon.7 If one excludes asymptomatic and shorter-lived recurrences, the successful elimination of AF increases to around 80% for both ablation devices. However, PVI alone does not address AF and other atrial arrhythmias originating from regions outside the pulmonary veins. Frequent extra-PV targets of AF ablation include the posterior left atrium, superior vena cava, ligament of Marshall, coronary sinus, crista terminalis and the left atrial appendage.8,9

Patients with persistent AF are thought to have arrhythmogenic substrate outside the pulmonary veins, thus explaining poor outcomes in studies with ablation strategies limited to PVI. Substract and Trigger Ablation for Reduction of AF Trial Part II (STAR AF II) compared the strategies of pulmonary vein isolation, PVI with ablation of complex fractionated electrograms and PVI plus linear ablation, and the freedom from AF at 18 months was 59%, 49% and 46%, respectively.10 Freedom from any atrial arrhythmias off antiarrhythmic therapy was even lower. The pathophysiological mechanisms for persistent and also long-standing persistent AF are frequently more complex than those of paroxysmal AF.

Although still considered a cornerstone of persistent AF ablation, PVI alone does not sufficiently maintain normal sinus rhythm in this
population. In the post-STAR AF II era, operators have struggled to address the persistent AF population. In addition to PVI, a variety of supplemental procedures have found clinical application, such as roof and mitral isthmus lines, posterior wall isolation, rotor mapping, ablation of autonomic ganglia, ablation of low-voltage fibrotic regions, high-dose isoproterenol to elicit focal triggers, vein of Marshall alcohol ablation and left atrial appendage isolation.\textsuperscript{13,15} Unfortunately, no catheter-based approach has consistently yielded a high rate of success in persistent patients.

**Surgical Ablation**

The first cut-and-sew maze procedure was performed in 1987.\textsuperscript{14} Subsequent revisions culminating in the Cox maze III and Cox maze IV have yielded high success rates, maintaining sinus rhythm in 80–90% of patients off antiarrhythmic therapy.\textsuperscript{19} However, the surgical maze procedure requires cardiopulmonary bypass and is associated with significantly higher morbidity compared with a catheter-based approach. Minimally invasive epicardial approaches have attempted to replicate the efficacy of the Cox maze procedure, but with less morbidity. In a pooled analysis of minimally invasive epicardial approaches, only 43% of patients with long-standing persistent AF maintained sinus rhythm, as compared with 75% in paroxysmal AF.\textsuperscript{20} In comparison, single-procedure freedom from atrial arrhythmias ± antiarrhythmics for catheter-based ablation of long-standing persistent AF was reported to be ~52% at 1 year by Ganesan et al., and ~37% after one or two procedures in the Hamburg experience.\textsuperscript{21,22}

The advantage of surgical ablation lies in the surgeon’s ability to directly visualise and ablate the target structures of interest. In addition to endocardial access, the surgeon also has direct access to epicardial structures, such as the ligament of Marshall and ganglionic plexi, that may serve as drivers of persistent AF. Direct visualisation enables ablation while avoiding complications involving the phrenic nerve and the oesophagus.\textsuperscript{23} Moreover, the surgeon can exclude the left atrial appendage, which eliminates associated AF triggers while potentially reducing the patient’s risk of stroke.\textsuperscript{24}

The AF Catheter Ablation Versus Surgical Ablation Trial (FAST) trial compared bilateral thoracoscopic epicardial ablation with endovascular catheter ablation randomising 124 patients with drug refractory AF to either surgical PVI using a bipolar radiofrequency (RF) clamp, LAA staple with additional ganglionated plexi ablation, ligament of Marshall, and optional linear ablations lines or endovascular ablation with atrial PVI and additional linear ablation. The overall freedom from AF at 12 months was 66% in the surgical arm, as compared with 37% in the catheter ablation arm. The difference was notable even in patients with persistent AF (56% versus 36%; p=0.341). The surgical arm, however, was associated with more procedural complications.\textsuperscript{25}

While the cut-and-sew maze creates a definitive scar to isolate and compartmentalise the regions of the atria, less invasive iterations of the maze procedure depends on achieving transmurality, contiguity and durability of the lesions created with RF or cryotherapy. Validation of the lesion set is not readily performed surgically, in contrast to that of catheter-based approaches. Additionally, the surgical environment in most institutions does not provide access to electrophysiological manoeuvres, such as comprehensive lesion validation and non-pulmonary vein trigger mapping. The lack of electrophysiological testing during surgical ablation may explain the varied and poor AF-free outcomes despite extensive lesion sets being performed.

**Hybrid Ablation**

The desire to create durable transmural lesions, close the appendage, validate the lesions set and address additional arrhythmic substrate has led to the concept of hybrid ablation. Centres have emerged embracing this multidisciplinary approach, and integrate the expertise of electrophysiologists and surgeons. Unfortunately, much of the hybrid experience comes from single-centre observation studies that vary in surgical technique, as well as the endocardial ablation strategy.\textsuperscript{26–28}

Hybrid surgical approaches predominately involve either bilateral thoracoscopic using bipolar RF clamps or a unilateral thoracoscopic approach through the right chest alone.\textsuperscript{29,27} The surgeon utilises RF energy tools to create block across linear lesions in both atria. The catheter-based portion of the procedure usually follows, validating the surgical work, and addressing additional substrate, triggers and creation of a cavotricuspid isthmus line.

Mahapatra et al. first described their experience with a staged hybrid ablation for patients with persistent AF who had failed antiarrhythmic drug therapy and at least one attempt at catheter ablation.\textsuperscript{25} Using bilateral thoracoscopic, they created bilateral antral PVI lesions and isolated the superior vena cava, connected the veins with a roof line, created lesions connecting the right and left superior PVs to the non-coronary commissure of the aortic valve, and a lesion connecting the left superior PV to the LAA followed by LAA closure. Catheter ablation was performed 3–5 days later. They compared these patients with a matched catheter ablation-alone group and found higher freedom from atrial arrhythmia off antiarrhythmic drugs in the hybrid group at 20 months of follow-up (87% versus 53%; p<0.04). There were no complications in this report. Other hybrid procedures followed with single-centre observational reports using variable ablation lesions with sinus rhythm rates, off antiarrhythmic drugs, ranging from 37% to 86%.\textsuperscript{27–31}

**Posterior Wall Isolation**

With the failure of rotor mapping, complex fractionated atrial electrogram ablation and simple linear ablation, there is increasing interest in the isolation of the posterior wall. Cardiac MRI data have implicated the posterior wall as a region with a high prevalence of atrial fibrosis.\textsuperscript{25} Additionally, the varied myocardial fibre orientation of the posterior wall and the high prevalence of autonomic ganglionic plexi may also contribute to the AF substrate.\textsuperscript{32,34} Debunking of the posterior wall perhaps reduces the AF substrate to a critical level at which AF cannot sustain. This critical mass hypothesis, first suggested in observational studies by Garrey et al. more than a century ago and reproduced in animal studies more recently by Lee et al., may explain the success of ablation lesion strategies that effectively compartmentalise the atria.\textsuperscript{35,36}

The current strategies for posterior wall isolation using catheter ablation include a single-ring approach, pulmonary vein isolation and box lesion set or obliteration of posterior wall potentials. The single-ring approach is similar to the Cox maze III procedure, which involves isolating the pulmonary veins and posterior wall, but has had variable success rates, and due to difficulty in achieving complete block in the roof portion of the circle, recurrent conduction can occur and compromise isolation of the posterior wall.\textsuperscript{27} Pulmonary vein isolation and a box lesion set uses double circles around the veins as anchors for posterior wall isolation, and an additional roof line to connect the superior PVs and a low posterior line to connect the inferior veins. This technique also showed only modest success rates in observational trials.\textsuperscript{28} Endocardial homogenisation of the posterior wall signals may
Convergent AF Ablation

Address the shortcomings of linear ablation, but potentially increases the rate of atrioesophageal fistula. Concern about atrioesophageal fistula frequently limits the amount of ablation that an operator can deliver to the posterior wall. Current catheter-based strategies to address posterior wall substrate include high-power, short-duration application of radiofrequency energy to theoretically limit deep ablation; real-time temperature monitoring; oesophageal deviation; and cryoballoon across the posterior space. Despite the endocardial energy used, oesophageal injury during posterior wall catheter ablation can occur, and although the occurrence of an atrioesophageal fistula is of low relative frequency, the high mortality of this complication necessitates standardised ablation protocols and close post-procedural surveillance.

The posterior wall of the left atrium may also have epicardial connections. This may explain the variability in success with posterior box lesion sets. Multiple reports have demonstrated the ability to have endocardial electrical isolation, yet persistent posterior wall activity. Because endocardial catheter ablation alone has limited epicardial efficacy, related to energy penetration restrictions, supplemental epicardial ablation to achieve definitive posterior wall isolation has gained attention.

Convergent Ablation

The convergent procedure is a form of hybrid AF ablation that utilises a pericardioscopic approach from the upper abdomen. As such, the convergent approach distinguishes itself as a compliment to catheter ablation rather than a complex surgical procedure. The convergent procedure simplifies the lesion set to focus on an effective endocardial and epicardial posterior wall and pulmonary vein isolation (Figure 1), involving an epicardial approach, there may also be utility in the ablation of ganglioneurated plexi and epicardial fat in the surgical lesion set. Pericardioscopy provides laparoscopic access to the pericardium and epicardial space. Under direct visualisation, the Epi-Sense® (Atricure, Mason, OH, US) unipolar vacuum-assisted linear RF ablation catheter uses vacuum to suck the atrial tissue into apposition with the RF coil. Saline continuously irrigates the electrode to improve energy penetration and limit char. The pericardioscopic access provides optimal access to the posterior left atrium and posterior pulmonary vein antrums. It also enables direct electrocardiogram evaluation before, during and after the procedure to help confirm a complete lesion set. This immediate and comprehensive lesion approach is more difficult with other hybrid procedures.

Endocardial ablation follows the epicardial procedure to confirm lesion integrity and supplement the epicardial procedure, which can be performed during the same setting or in a staged fashion – each approach offering distinct advantages.

A concomitant approach has the advantage of providing immediate endocardial confirmation of posterior isolation and provides timely feedback to the surgeon. The concomitant approach requires efficient schedule coordination between the surgeon, electrophysiologist and the staff to offer the patient a same-day procedure. Simultaneous epicardial mapping of the posterior wall scar utilising 3D mapping systems can be performed to demonstrate gaps and allow for surgeons to create additional epicardial lesions. During a staged procedure, the surgeon performs the epicardial procedure, which includes pulmonary vein isolation and posterior wall isolation followed by catheter ablation after days to weeks. This approach offers convenience to both the electrophysiologist and surgeon. Additionally, it gives time for reconnections to develop by the time endocardial ablation is performed, and gaps in the epicardial ablation can be addressed.

Evidence for Convergent Ablation

Kiser et al. reported the initial convergent procedure experience in 28 patients with persistent or long-standing persistent AF. The patients underwent concomitant epicardial radiofrequency ablation and transeptal endocardial ablation to exclude the entire posterior left atrium and isolate the PVs. They reported no deaths. At ≤6 months follow-up, freedom from AF and antiarrhythmic drugs was 76%.

Since then, other observational studies with ≥12 months follow-up have reported similar results of success (Table 1), with freedom from AF at 12 months ranging 73–88% and patients in sinus rhythm ranging 52–88%. Gersak et al. reported the longest follow-up on convergent procedures, with 81% of patients being free from AF at 4 years.

Among comparison studies of convergent versus endocardial-only ablation, Edgerton et al. in 2009 initiated a prospective study that enrolled 24 patients to a hybrid approach and 35 patients to catheter ablation only. Their hybrid group underwent surgical ablation through a pericardioscopic approach followed immediately by endocardial catheter ablation. They used a unipolar radiofrequency device to perform PVI, posterior box, ablate the ligament of Marshall (without dissection) and the lateral right atrium. The endocardial portion entailed verification and completion of epicardial lines, ablation in the coronary sinus, isolation of the LAA, and ablation of complex fractionated atrial electrograms. At 12-month follow-up, the hybrid group had lower arrhythmia-free survival (24% versus 63%; p<0.001). The complication rates were significantly higher in the hybrid group (21% versus 3%; p=0.036), including three deaths, one tamponade and one phrenic nerve palsy in the hybrid group compared with one
Table 1: Convergent Procedure Studies

| Studies                                    | Type     | Year       | Type of AF                              | Timeframe of Treatment | No. of Patients | Timing | Concomitant/Stage | Mortality Complications Follow-up | Freedom from AF ± Antiarrhythmics (%) | Freedom from any Atrial Arrhythmia ± Antiarrhythmics (%) | Freedom from any Atrial Arrhythmia off Antiarrhythmics (%) |
|--------------------------------------------|----------|------------|-----------------------------------------|------------------------|-----------------|--------|-------------------|-----------------------------------|----------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|
| Transabdominal without AtriClip           | Kiser et al. | 2011       | PAF, PsAF, LSPAF                         | Jan 2009-May 2010      | 65              | Concomitant      | -                  | -                   | 88%                                                               | 83%                                                          | -                                                            |
|                                            | Zembala et al. | 2012      | PsAF, LSPAF                              | Aug 2009-Dec 2011     | 27              | Staged           | -                  | -                   | 3%                                                               | 10%                                                          | -                                                            |
|                                            | Gehi et al. | 2013       | PAF, PsAF, LSPAF                         | Jan 2009-Dec 2011     | 101             | Concomitant      | -                  | -                   | 0%                                                               | 6%                                                           | 12 months                                                  |
|                                            | Civello et al. | 2013    | PAF, PsAF, LSPAF                         | May 2010-Dec 2011     | 104             | Concomitant      | -                  | -                   | 0%                                                               | 6%                                                           | 12 months                                                  |
|                                            | Thosani et al. | 2013    | PsAF, LSPAF                              | Jun 2010-Feb 2013     | 43              | Concomitant      | -                  | -                   | 0%                                                               | 0%                                                           | -                                                            |
|                                            | Gersak et al. | 2014      | PsAF, LSPAF                              | Jan 2010-Dec 2011     | 73              | Concomitant      | -                  | -                   | 0%                                                               | 7%                                                           | 12 months                                                  |
|                                            | Edgerton et al. | 2016  | LSPAF                                    | –                    | 24              | Concomitant      | -                  | -                   | 14%                                                              | 7%                                                           | 24 months                                                  |
|                                            | Gersak et al. | 2016      | PAF, PsAF, LSPAF                         | Jan 2009-Jul 2013     | 76              | Concomitant & staged | -                  | -                   | 0%                                                               | 12%                                                          | 48 months                                                  |
|                                            | Zembala et al. | 2017    | PsAF, LSPAF                              | Jul 2009-Dec 2014     | 90              | Staged           | -                  | -                   | 1%                                                               | 8%                                                           | 12 months                                                  |
|                                            | Kress et al. | 2017      | PsAF, LSPAF                              | Jun 2010-Aug 2014     | 64              | Concomitant      | -                  | -                   | 1.6%                                                             | 7.8%                                                          | 16 months                                                  |
|                                            | Jan et al. | 2018      | PAF                                       | Jan 2013-Jun 2015     | 24              | Concomitant      | -                  | -                   | 0%                                                               | 12.5%                                                        | 30.5 months                                                |
|                                            | Gulkarov et al. | 2019  | LSPAF                                    | Oct 2013-Mar 2017     | 31              | Concomitant      | -                  | -                   | 0%                                                               | 12.9%                                                        | 24 months                                                  |
|                                            | Gegechkori et al. | 2019 | PsAF, LSPAF                              | Jan 2014-Aug 2016     | 59              | Concomitant      | -                  | -                   | 0%                                                               | 1.6%                                                         | 12 months                                                  |
|                                            | Sabzwari et al. | 2019    | LSPAF                                    | Feb 2015-Sept 2017    | 30              | –                | 0%                   | -                  | 0%                                                               | 0%                                                           | 12 months                                                  |
|                                            | Gegechkori et al. | 2019  | PsAF, LSPAFA                              | Aug 2016-Oct 2019     | 64              | Concomitant      | -                  | -                   | 0%                                                               | 7.8%                                                         | 12 months                                                  |
|                                            | Tonks et al. | 2019      | PAF, PsAF, LSPAF                         | Feb 2016-May 2017     | 36              | Concomitant (32/36) | -                  | -                   | 0%                                                               | 16.7%                                                        | 12 months                                                  |

LSPAF = longstanding persistent AF; PAF = paroxysmal AF; PsAF = persistent AF.
Electrophysiology and Ablation

Table 2: Convergent Procedure Complications

| Complications                  | Number | Percentage |
|--------------------------------|--------|------------|
| Atrioesophageal fistula        | 6/884  | 0.7%       |
| Pericardial effusion           | 10/884 | 1.1%       |
| Pericardial tamponade          | 9/884  | 1.0%       |
| Cardiac death                  | 2/884  | 0.2%       |
| Unexplained death              | 2/884  | 0.2%       |
| Major bleeding                 | 12/884 | 1.4%       |
| Hematemesis                    | 1/884  | 0.1%       |
| Stroke                         | 7/884  | 0.8%       |
| TIA                            | 2/884  | 0.2%       |
| Pleural effusion               | 3/884  | 0.3%       |
| Lung injury                    | 1/884  | 0.1%       |
| Pulmonary vein stenosis        | 1/884  | 0.1%       |
| Transient phrenic nerve palsy  | 3/884  | 0.3%       |
| Groin/puncture site complications | 2/884 | 0.2%       |
| Infection                      | 1/884  | 0.1%       |

TIA = transient ischaemic attack.

In 2011, Kiser et al. evaluated these published and the non-published, but early reported, outcomes and complications of the convergent procedure while examining the predicate iterations of the pericardioscopic approach. Improvements to the convergent procedure have reduced procedural complexity while further reducing complications (Table 2). Unlike the original description of complicated device manipulation over wires and within the transverse sinus, the procedure was modified in 2012 to keep the epicardial ablation catheter in a straight configuration. The resulting epicardial lesion set sought to homogenise the posterior LA wall rather than create a convoluted linear box lesion. (Figure 2) The procedure also moved to a subxiphoid approach in 2015 (Figure 3). This change eliminated the rare complication of bowel herniation into the thoracic space via the transabdominal, transdiaphragmatic approach, while still allowing the surgeon sufficient access to the posterior left atrium. These changes have enhanced efficacy, as well as the safety profile of the procedure.

Concomitant LAA Exclusion Using the AtriClip

The LAA has been implicated in the initiation and perpetuation of AF, particularly in the persistent AF population. The Effect of Empirical Left Atrial Appendage Isolation on Long-term Procedure Outcome in Patients With Persistent or Long-standing Persistent Atrial Fibrillation Undergoing Catheter Ablation (BELIEF) trial examined patients who had long-standing AF and randomised them to ablation with LAA isolation versus ablation without LAA isolation (NCT01362738). Single-procedure freedom at 12 months with LAA isolation was 56% versus 28% without isolation (p=0.001). While endocardial isolation of the LAA is possible, multiple procedures are frequently required to create lasting LAA electrical isolation. A consequence of electrical isolation appears to be an increased incidence of LAA thrombus secondary to mechanical standstill of the appendage. While this may be addressed with a WATCHMAN implant,
The convergent procedure has evolved from the hybrid ex-maze’s (left panel) complex epicardial (blue lines) and endocardial (green lines) linear ablation set to the current convergent lesion set (right panel), which involves epicardial homogenization of the posterior wall (blue lines), followed by endocardial ablation (red dots) to complete the pulmonary vein isolation and a cavotricuspid isthmus line. IVC = inferior vena cava; LA = left atrium; PA = pulmonary artery; RA = right atrium; SVC = superior vena cava. Source: Reproduced with permission from AtriCure.

Source: Reproduced with permission from AtriCure.
concomitant endocardial AF ablation and WATCHMAN implantation is cost prohibitive due to reimbursement constraints.

The AtriClip has been utilised in >200,000 patients, predominantly in open-chest surgical procedures to close the appendage. Retrospective data demonstrate that the AtriClip closure is safe, durable and leads to a reduction in thromboembolic events.62–65 Acute and long-term closure rates have been >95% with residual stumps >10 mm in only 0–5% of cases.66–68 The AtriClip began to be placed through a left thoracoscopic approach in 2012, and convergent procedures began incorporating the AtriClip in 2017 (Figure 4).69–72 As the convergent procedure already enlists the assistance of the surgeon, the thoracoscopic addition of the AtriClip is able to be performed in the same procedure setting in a cost-effective manner.

The AtriClip seeks to address the LAA as an electrical source of AF triggers and the mechanical risk for stroke. Studies have demonstrated that the AtriClip achieves acute electrical isolation of the appendage, which has earned it a US Food and Drug Administration indication.70 Additional benefits of incorporating a left thoracoscopic approach to LAA management include the ability to epicardially ablate the vein of Marshall, which may allow for easier creation of a lateral mitral isthmus line.

While recent reports have demonstrated favourable outcomes with the addition of the AtriClip to the convergent procedure, further studies are required.71,72 Outcomes from the LAA Ligation Adjunctive to PVI for Persistent or Longstanding Persistent AF (aMAZE) trial (NCT02513797), which investigates the antiarrhythmic effect of closing the LAA with the AtriClip, began to be placed through a left thoracoscopic approach in 2012, and convergent procedures began incorporating the AtriClip in 2017 (Figure 4).69–72 As the convergent procedure already enlists the assistance of the surgeon, the thoracoscopic addition of the AtriClip is able to be performed in the same procedure setting in a cost-effective manner.

Future Direction

The Epi/Endo Ablation For Treatment of Persistent Atrial Fibrillation (AF) (CONVERGE) trial (NCT01984346) is an investigational device-exempt, prospective, multicentre, open-label, randomised controlled pivotal study to evaluate the safety and efficacy of the Epi-Sense AF Guided Coagulation System (Atricure) for the treatment of symptomatic persistent and long-standing persistent AF in patients refractory to medical therapy. The primary objective is to demonstrate the superiority of the convergent procedure compared with stand-alone endocardial radiofrequency catheter ablation. A total of 153 patients have been randomised in a two-to-one manner to the convergent procedure or endocardial-only ablation and followed for a minimum of 1 year.

Unlike other catheter ablation trials for persistent AF, CONVERGE imposed no limits on the duration of AF and allows left atrial sizes up to 6 cm. As a result, the CONVERGE trial is the only ablation trial thus far to include a substantial portion of patients with long-standing persistent AF. The study finished enrolment in August 2018, and 12-month follow-up for primary effectiveness was completed in August 2019. The results are expected to be reported in 2020. If positive, the CONVERGE trial would mark a major milestone by confirming a superior method for ablation of persistent and long-standing persistent AF. Future trials utilising the convergent procedure are necessary to assess the use of endocardial cryoablation as an alternative to endocardial RF ablation, and to assess the incremental benefit of LAA exclusion and electrical silencing.

Conclusion

The convergent procedure as practiced today has evolved from its original design as a modification of the Cox maze linear lesion set to its current lesion protocol, which prioritises homogenisation of the posterior wall substrate through the pericardium to dovetail the electrophysiologist’s endocardial wide area circumferential pulmonary vein isolation.73 With iterative procedural refinements in the epicardial access, catheter manipulation and oesophageal protection, the rate of procedural complications has significantly declined. In summary, the convergent hybrid ablation affords endocardial pulmonary vein isolation, epicardial posterior wall isolation and left atrial appendage management via external ligation in either a single or staged procedural setting.74

With a cumulative experience in >10,000 patients to date, the convergent procedure now has an established position in the vast array of procedures directed at managing non-paroxysmal AF.
4. Haissaguerre M, Jaïs P, Shah DC, et al. Spontaneous initiation of atrial fibrillation. N Engl J Med 1998;339:654–9. https://doi.org/10.1056/NEJM199809033391003; PMID: 9725923.

8. Shah D, Haissaguerre M, Jais P, Hocini M. Nonpulmonary vein catheter ablation of the ganglionated plexi. Heart Rhythm 2011;8:1631–5. https://doi.org/10.1016/j.hrthm.2011.08.035; PMID: 21954992.

12. Kim JS, Shin SY, Na JO, et al. Does isolation of the left atrial appendage for the prevention of embolic stroke and left atrial appendage thrombus formation after catheter and surgical ablation of atrial fibrillation: a case series and literature review. J Cardiovasc Electrophysiol 2016;27:524–30. https://doi.org/10.1111/jce.13687; PMID: 26294590.

16. Delliturri A, Chiba S, Brichkov I, Sherwinter D. Laparoscopic epicardial mapping and ablation for refractory atrial fibrillation: a case series and literature review. Arch Med Sci 2015;11:358–66. https://doi.org/10.5114/ams.2015.53960; PMID: 28144262.

20. Khalil AS, Schellhaas R, de Groot J, et al. Relation of atrial flutter electroanatomic substrate with the anatomical borders of the appendage. J Cardiovasc Electrophysiol 2017;28:1166–72. https://doi.org/10.1111/jce.13571; PMID: 28015829.

24. Port JL, Dalen JE, Lip GYH, et al. Anticoagulation for atrial fibrillation: The 2016 guidelines. Circulation 2016;133:1238–84. https://doi.org/10.1161/CIR.0000000000000437; PMID: 26904015.

28. Gehi AK, Mounsey JP, Pursell I, et al. Hybrid epicardial-endocardial ablation using a percutaneous technique for the treatment of atrial fibrillation. N Engl J Med 2012;366:2044–54. https://doi.org/10.1056/NEJMoa1208535; PMID: 22686463.

32. Caliskan E, Eberhard M, Falk V, et al. Incidence and characteristics of left atrial appendage occlusion. Circ Arrhythm Electrophysiol 2013;6:1552–8. https://doi.org/10.1161/CIRCEP.111.961862; PMID: 23892241.

36. Gera P, Zembala M, Molhert D, et al. European experience of the convectorient atrial fibrillation ablation catheter. Thorac Dis 2017;9:e767–70. https://doi.org/10.21037/thoracdis.2017.08.48; PMID: 29222551.

40. Løvås B, Sivertsen EC, Bøvik H, et al. Electrical isolation of the left atrial anterior wall and septum for treatment of persistent atrial fibrillation: preliminary experience. J Interv Cardiovasc Pathol 2018;4:893–901. https://doi.org/10.1007/s40601-017-0049-3; PMID: 30766499.
64. Caliskan E, Sahin A, Yilmaz M, et al. Epicardial left atrial appendage AtriClip occlusion reduces the incidence of stroke in patients with atrial fibrillation undergoing cardiac surgery. *Eur J Cardiothorac Surg* 2017;52:1015-14. https://doi.org/10.1093/ejcts/ezw507; PMID: 29016813.

65. Ailawadi G, Gaedisch MK, Harvey RC, et al. Exclusion of the left atrial appendage with a novel device: early results of a multicenter trial. *Thorac Cardiovasc Surg* 2015;63:520-6. https://doi.org/10.1055/s-0035-1560229; PMID: 26189378.

66. Maredia M, Wei D, Allosme S, et al. Stand-alone totally thoracoscopic left atrial appendage exclusion using a novel clipping system in patients with high risk of stroke-initial experience and literature review. *Kardiochir Torakochirurgia Pol* 2015;12:298. https://doi.org/10.5114/kitp.2015.56777; PMID: 26866543.

67. Smirniotis P, Arora P, Zitara J, et al. Residual echocardiographic and computed tomography findings after thoracoscopic exclusion of the left atrial appendage using the AtriClip PRO device. *Int J Cardiovasc Imaging* 2018;34:813-20. https://doi.org/10.1007/s10728-018-0019-0; PMID: 29722468.

68. Smith NE, Joseph J, Morgan J, et al. Initial experience with minimally invasive surgical exclusion of the left atrial appendage with an epicardial clip. *Innovations* 2017;12:28-32. https://doi.org/10.1097/imi.0000000000000339; PMID: 28129318.

69. Beder K, Werner S, Kotlyar E, et al. Left atrial appendage epicardial clip (AtriClip): essentials and post-procedure management. *J Airway Manag* 2019;11. https://doi.org/10.4022/jaam.2019; PMID: 31934360.

70. Steiner C, Staffil J, Elmiron M, et al. Epicardial left atrial appendage clip occlusion also provides the electrical isolation of the left atrial appendage. *J Thorac Cardiovasc Surg* 2012;143:1346-8. https://doi.org/10.1016/j.jtcvs.2012.01.016; PMID: 22647971.

71. Geggelbor N, Yang F, Miller A, et al. Comparison of hybrid ablation for persistent atrial fibrillation with and without left atrial appendage closure: Report of 1 year follow up (abstract). Presented at Venice Arrhythmias 2019, Venice, Italy, 3-5 October 2019.

72. Tankski J, Lantzi E, Malise A, et al. Short and intermediate term outcomes of the Convergent Procedure: initial experience in a tertiary referral center. *Ann Thorac Cardiovasc Surg* 2019;25:415-21. https://doi.org/10.5701/actccs.19-00714; PMID: 31459813.

73. Lee RI, Lakshminredy D, Mittal S, et al. Percutaneous alternative to the Maze procedure for the treatment of persistent or long-standing persistent atrial fibrillation (UWAPAZ trial): rationale and design. *Am Heart J* 2015;170:1184-94. https://doi.org/10.1016/j.ajh.2015.09.016; PMID: 26678460.

74. Lee LS. Subxiphoid minimally invasive epicardial ablation (convergent procedure) with left thoracoscopic closure of the left atrial appendage: Operative Techniques in Thoracic and Cardiovascular Surgery 2018;23:152-65. https://doi.org/10.1053/j.optechstcvs.2019.04.002; PMID: 31374587.

75. Umbran V, Verhage C, Chieca G, et al. One-stage approach for hybrid atrial fibrillation treatment. *Arrhythm Electrophysiol Rev* 2017;3:215-6. https://doi.org/10.1540/apr.1.17.36.2; PMID: 29308637.

76. Cveklo KC, Smith CA, Boeddeker W. Combined endocardial and epicardial ablation for symptomatic atrial fibrillation: single center experience in 100+ consecutive patients. *Journal of Innovations in Cardiovascular Management* 2013;1-7.

77. Jan M, Zelek J, Gerask ZM, et al. Comparison of treatment outcomes between convergent procedure and catheter ablation for paroxysmal atrial fibrillation evaluated with implantable loop recorder monitoring. *Card Electrophysiol* 2018;29:84-90. https://doi.org/10.1111/cpe.13820; PMID: 29722468.

78. Gulbaro I, Weng B, Kovâlê M, et al. Convergent ablation for persistent atrial fibrillation: single center experience. *J Card Surg* 2019;34:1037-43. https://doi.org/10.1111/jocs.14204; PMID: 31374587.

79. Sabzwari SRA, Jang J, Mehla N, et al. Convergent ablation for the treatment of long-standing persistent atrial fibrillation – a single center experience. Presented at American Heart Association Scientific Sessions, Philadelphia, PA, 16-18 November 2019.