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Hybrid dual stage closed chest ablation of persistent atrial fibrillation

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SOUHRN

Hybridní ablace (hybrid ablation, HABL) fibrilace síní jako kombinace endoskopické, minimálně invazivní, epikardiální ablace při zavřeném hrudníku spolu s přesností endokardiální metody vedené systémem CARTO byla zavedena ve snaze překonat limitace současných možností léčby pacientů s perzistující fibrilací síní (persistent atrial firbrillation, PSAF) a dlouhodobě perzistující fibrilací síní (long-standing persistent atrial fibrillation, LSPAF). Smyslem toho monocentrického, prospektivního klinického registru bylo zhodnotit bezpečnost a proveditelnost i účinnost HABL u pacientů s PSAF a LSPAF jeden rok po výkonu. V období od července 2009 do prosince 2014 byla HABL provedena celkem u devadesáti (n = 90) pacientů (PSAF, n = 39 a LSPAF, n = 51). Průměrná délka incidence fibrilace síní byla 4,5 ± 3,7 roku. Šest měsíců po ablaci bylo 78 % pacientů v sinusovém rytmu. Dvanáct měsíců po výkonu bylo v sinusovém rytmu 86 % pacientů a 62,3 % v sinusovém rytmu bez podávání antiarytmik skupin I/III. Na základě těchto výsledků lze usuzovat, že u pacientů s perzistující a dlouhodobě perzistující fibrilací síní je třeba uvažovat o kombinaci epikardiální a endokardiální radiofrekvenční ablace, protože se jedná a bezpečnou a účinnou metodu obnovy sinusového rytmu.

ABSTRACT

The hybrid ablation (HABL) of atrial fibrillation which combines endoscopic, minimally invasive, closed chest epicardial ablation with endocardial CARTO-guided accuracy was introduced to overcome limitations of current therapeutic options for patients with persistent (PSAF) and long-standing persistent atrial fibrillation (LSPAF). The purpose of this single-centre, prospective clinical registry was to evaluate procedural safety and feasibility as well as effectiveness of the HABL in patients with PSAF and LSPAF 1-year post-procedure. From July 2009 to December 2014, ninety (n = 90) patients with PSAF (n = 39) and LSPAF (n = 51) underwent HABL. Mean AF duration was 4.5 ± 3.7 years. At 6 months post-procedure 78% patients were in SR. At 12 months post-procedure 86% patients were in SR and 62.3% in SR and of class I/III AADs. These results suggest that combination of epicardial and endocardial RF ablation should be considered as a treatment option for patients with persistent and long-standing persistent atrial fibrillation as it is safe and effective in restoring sinus rhythm.

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Introduction

Atrial fibrillation (AF), with the prevalence of approximately 2%, is the most common cardiac arrhythmia which has become the crucial public health problem. One of the reasons can be found in western countries population aging [1]. In addition to the fact that AF is an independent risk factor of death [2], this arrhythmia may also increase the risk of many comorbidities [3].

Anti-arrhythmic drug (AAD) therapy remains the first line treatment of symptomatic AF, however, it can be associated with adverse side effects and insufficient effectiveness in substantial number of patients. In case of conservative approach failure, current guidelines recommend catheter ablation which in recent years became standardized treatment option in those patients [4,5]. Catheter ablation which is primarily designed to pulmonary vein (PV) isolation is well established, safe and effective in sinus rhythm (SR) restoration [5]. However invasive treatment of non-paroxysmal forms of AF, especially long-standing persistent, became one of the challenges nowadays. Effectiveness of ablation in this group is unsatisfactory and results from complex, not fully-understood pathophysiology of this disease. In patients with persistent AF, enlarged atria and structural heart disease, posterior wall has become an area of pathologic remodelling which can lead to conduction abnormalities as slowing or heterogeneity of conduction and presence of functional block lines [6]. Effectiveness of the stand-alone PVs isolation in non-paroxysmal AF is worse comparing to paroxysmal AF and there is a great need of implementation additional strategies to achieve better results [4].

Proposed in 80's by J. Cox surgical MAZE technic was one of the first attempt of procedural AF treatment. It is based on intraoperative mapping studies which proved the presence of multiple, macro-reentrant circuits of often unstable and short-lasting propagation. The concept of the procedure is to create multiple strategically placed incisions and then sewing the muscle of left and right atrium to interrupt all potentially developed macro-reentrant circuits. Lesions are created in the pattern of maze which provides proper propagation of sinus impulse and effective activations of atrial muscle without conducting to the PVs which are also isolated. Surgical ablation can be done as a part of complex cardiac surgery or as a stand-alone procedure [5]. Despite of high effectiveness, this method is nowadays used very rarely because of their big invasiveness expressed as need of sternotomy and extracorporeal circulatory support as well as frequent incidences of major complications [7]. Those disadvantages can be avoided by using minimally invasive surgical endoscopic epicardial ablation. This so-called Cox-Maze IV procedure can be performed using epicardial electrodes and without cardiopulmonary by-pass. This procedure seems to give comparable results comparing to standard "cut and sew" technic and is proved safe [8]. Developing of equipment lets reach posterior wall of LA and PVs both through transthoracic and transabdominal approach.

Hybrid ablation (HABL), which is combination of initial minimally invasive, epicardial (surgical) ablation followed by endocardial (catheter) ablation, is expected to overcome the challenges of individual procedures. Such approach gives hope to be most efficacious in avoiding lesions gaps and consequently providing the most effective treatment of AF. HABL is a therapeutic option for patients who underwent multiple unsuccessful catheter ablations because of symptomatic, antiarrhythmic drug-resistant atrial fibrillation. While data from centres which provide such treatment shows promising results of this method [8–12], it is not clear what is an optimal surgical approach and endocardial lesion set [13]operative approaches and perioperative care differ per center. In this review, an overview of findings from published studies on hybrid ablations is given, and related topics are discussed (e.g., one- and two-stage approaches, lesion sets, and patient management.

In this paper we would like to present our experience with dual-stage closed-chest HABL procedure using transabdominal access which allows for unrestricted ablation of posterior left atrium and subsequent CARTO-guided endocardial ablation to complete isolation lines and test entry and exit blocks [14].

Material and methods

Registry description

This is a single center, clinical registry which aim was to evaluate safety and effectiveness of HABL in long-term observation as well as feasibility of the procedure.

Safety was defined as occurrence of major adverse cardiac events including death, myocardial infarction, stroke, major bleeding or any procedure-related life-threatening event that occurred during the procedure or throughout the observation period. Effectiveness was defined according to HRS/EHRA/ECAS consensus as freedom from AF measured by lack of atrial tachyarrhythmia > 30 s as documented by a 7-day Holter monitoring at 12 months post procedure [5]. Also, SR maintenance off AADs or without any intervention (e.g. cardioversion or repeat ablation) was evaluated. Feasibility was defined by the percent of patients who completed HABL according to study protocol and the percent of procedures requiring a conversion to a sternotomy.

Consecutive patients with drug-refractory, symptomatic, persistent AF (PSAF) or long-standing PSAF (LSPAF) were screened for study eligibility by a Heart Team consisting of cardiac surgeon and electrophysiologist.

Group description

From July 2009 to December 2014, a total of ninety PSAF (43%) and LSPAF (57%) patients underwent the HABL. Table 1 summarizes patient demographics and baseline clinical characteristics of the registry population. Mean age of enrolled patients was 54.8 years ± 9.80 years (range 28–75 years) and 78% were male. Mean AF duration was 4.5 ± 3.7 years (range 1–20 years) and a mean European Heart Rhythm Association (EHRA) class 2.6. In 64.4% patients restoration of SR was attempted either by electrical cardioversion only (21.1%), endocardial catheter ablation only (20.0%), or both (23.3%) prior to the HABL. Of the 39 patients who had previous catheter ablation 56.4% patients had two or more catheter ablations. Left ventricular ejection fraction (LVEF) equal to or less than 35%

was diagnosed in 14.4% of patients. Hypertension and diabetes were present in 66.8% and 13.3% of the patients, respectively. Amiodarone-induced hyperthyroidism was present in 14.4% of patients. Pulmonary anomalies were observed in 26.7% of the patients.

Convergent and staged approach

The initial six procedures were performed in the electrophysiological (EP) lab, as a single procedure, with epicardial ablation via a minimal surgical access preceding the endocardial ablation via a percutaneous access. Patients were then extubated on the table, and transferred to the Cardiac Surgery Intensive Care Unit (CSICU), and discharged home 7–8 days post procedure. After the initial six procedures, due to reimbursement issues, the convergent procedure was performed in stages with the epicardial ablation procedure completed first and the percutaneous ablation procedure performed when the patient was readmitted 15–20 days later. Initially, the epicardial ablation procedure was performed in the operating theatre (OR) equipped with a portable C-arm, and later in the hybrid suite. Patients were extubated in the OR, transferred to the CSICU or to the floor on post-operative day 1, and discharged home on the 3rd–5th post-operative day.

Epicardial ablation — surgical procedure

Surgical and percutaneous procedures followed standard practice [15]. Patients were anaesthetised using the TIVA technique together with short acting muscle relaxants.

Fig. 1 – Radiofrequency epicardial ablation device in the dedicated cannula

Two independent temperature probes (Medtronic, USA) were inserted into the oesophagus. A midline abdominal small 2–3 cm incision was made 1–2 cm subxyphoid, through which a 10-mm laparoscopic port was inserted. Once the peritoneum was accessed, CO_2 insufflation was initiated and two 5 mm working ports were inserted in the left and right subcostal area. The central tendon of the diaphragm was identified and incised as an inverted T (3–4 cm) with a harmonic scalpel (Ethicon, USA). The pericardium was subsequently entered and the laparoscopic ports removed. A cannula designed for pericardioscopic access (nContact Surgical, Morrisville, NC, USA – Fig. 1) was then placed inside the pericardial sac. The cannula

| Table 1 – Patients characteristics	
Baseline characteristics	
Male (%)	78
Age (years); mean (SD)	54.8 (9.8)
Body mass index (kg/m^2); mean (SD)	48.6 (9.7)
Hypertension (%)	66.8
Diabetes mellitus (%)	13.3
Amiodarone-induced hyperthyroidism (%)	14.4
CHA$_2$DS$_2$-VASc	1.7 (1.2)
NYHA	2.0 (0.5)
EHRA	2.6 (0.6)
LVEF (%); mean (SD)	48.6 (9.7)
LA diameter (mm); mean (SD)	45 (6)
Pulmonary veins anomalies (%)	26.7
AF type (%)	
Paroxysmal	0
Persistent	43
Long-standing persistent	57
AF duration (years); average (SD)	4.5 (3.7)
Previous catheter ablation alone (%)	20
Previous two or more catheter ablations (%)	56.4
Previous cardioversion alone (%)	21.1
Previous ablation and cardioversion (%)	23.3
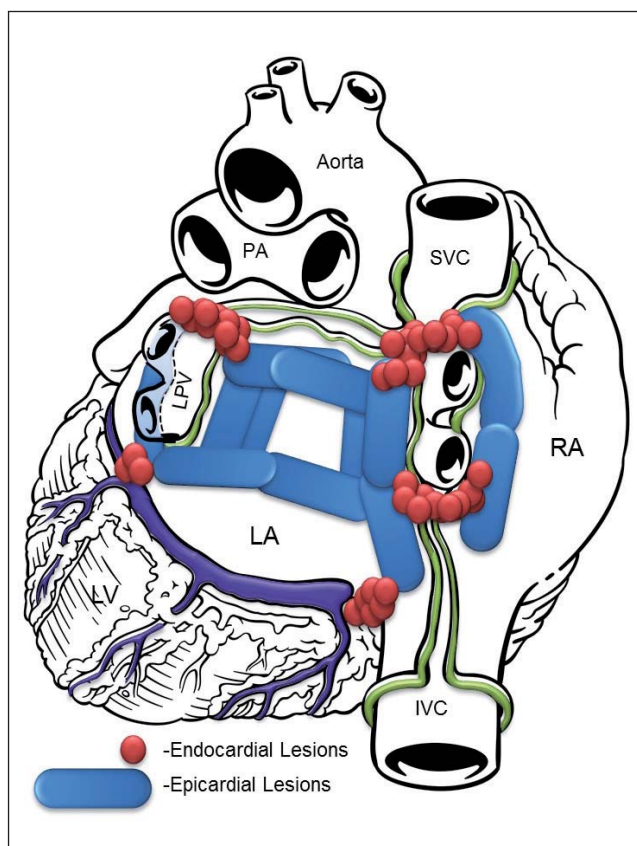
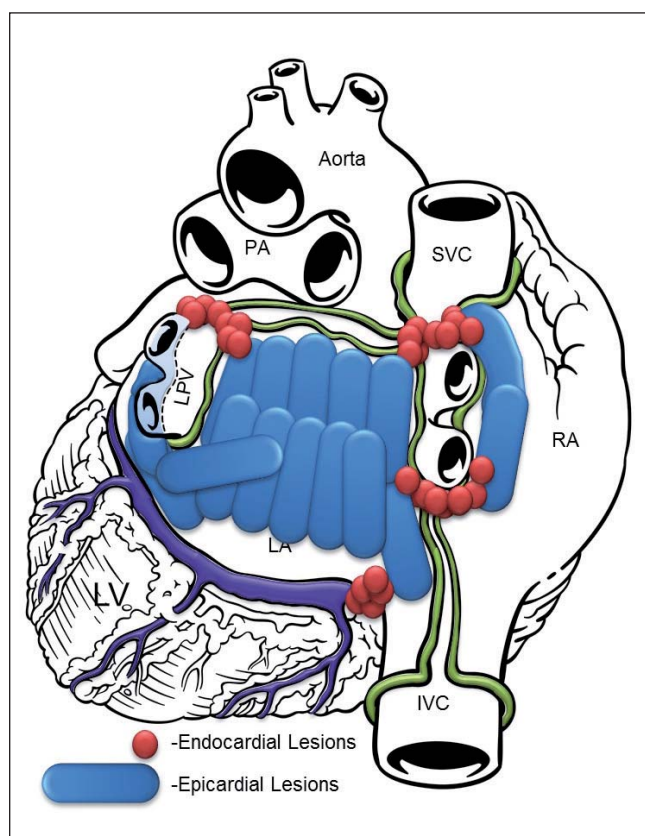**Fig. 2 – Lesion pattern A created mostly in PSAF patients**

Fig. 3 – Lesion pattern B created mostly in LSPAF patients

Fig. 4 – CARTO mapping of the left atrium post-convergent procedure

with an endoscope was pushed into the oblique sinus to visualize the posterior wall of the left atrium (LA) and pulmonary veins (PVs). An irrigated, unipolar radiofrequency ablation device (VisiTrax nContact Surgical, Morrisville, NC, USA) was passed through the cannula. Linear lesions (90 s each, 30 W power) were created. Due to the evolution of the surgical technique and our understanding of the AF pathology (LA fibrosis), the lesion pattern evolved over time. Patients with PSAF were more likely to receive pattern A (Fig. 2), while patients with LSPAF and with a history of endocardial ablations were treated more aggressively with lesion pattern B (Fig. 3). All applications on the posterior wall of the left atrium were performed under fluoroscopic guidance to visualize the relation between the ablating electrode and the oesophagus. Temperature probes were positioned to match the position of the ablating electrode. 50 ml of 30 °C 0.9% saline was injected into the pericardium prior to RF energy application to submerge the ablating electrode and reduce temperature spread. When all lesions had been created, a small drain was placed behind the LA and passed through one of the 5 mm endoscopic ports. The midline fascia was closed with interrupted permanent sutures. Skin and port incisions were closed using absorbable sutures.

Endocardial ablation — percutaneous procedure
Endocardial ablation procedures were performed using the Seldinger technique to introduce two sheaths via peripheral veins. A 10-polar 6F electrode, which served as the reference, was introduced into the coronary sinus via
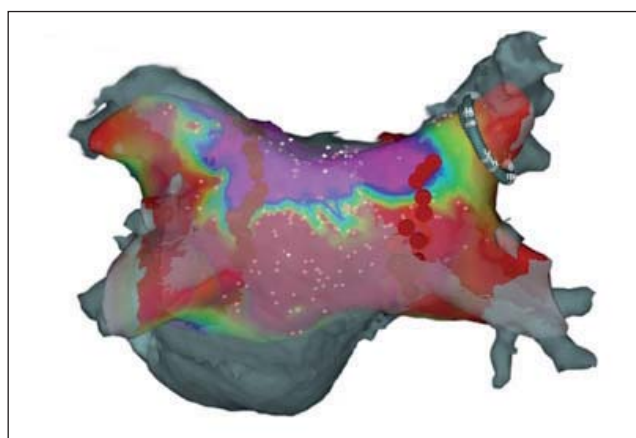
the right internal jugular vein. Subsequently, a Brockenbrough needle and a Mullins-type transseptal sheath were both positioned in the upper right atrium and a transseptal puncture was performed under the guidance of intracardiac pressures recorded from the tip of the needle. Immediately after the puncture, a single bolus of 10,000 U heparin was administered. Additional doses of heparin were administrated to maintain active clothing time between 300–350 s. Then 8F Navi-Star irrigated-tip ablation electrode (Biosense Webster, Diamond Bar, CA, USA) was introduced into LA. With the use of electro-anatomical mapping system (CARTO, Biosense Webster), an isopotential map of the LA was created to identify areas showing electrical activity within the PV ostia and in the region of the LA isthmus. Electrical silence was indicated if the amplitudes of bipolar atrial electrograms were < 0.05 mV. Once identified and marked on the map, areas with persistent conductivity were subsequently ablated using RF applications limiting the power to 40 W and the application time to 60 s. Finally, the electrical isolation of the veins was verified by stimulating the pulmonary ostia with a cycle length of 500 ms (Figure 4).

Postoperative management
All patients were prescribed the same postoperative pharmacological protocol: intravenous infusion of Amiodarone (Cordarone, 600 mg/50 ml 2ml/h) together with IV heparin (25,000 IU/50 ml 2 ml/h; ACT ≈ 180s) was initiated one hour post-surgery and continued for 48 hours. Potassium was supplemented to achieve levels in the range of 4.5–4.7. Warfarin (VKA) treatment was initiated on postoperative day two to maintain the international normalized ratio (INR) 2.5–3.5 in all patients who underwent the HABL in a single setting. Patients who underwent the staged procedure were discharged either on low molecular weight heparin (LMWH Clexane, 1 mg/kg twice daily) or novel oral anticoagulant (NOAC) – Rivaroxaban (Xarelto, Bayer, 1× 20 mg), and were continued on their prescribed therapy until readmission for the endocardial ablation portion of the procedure. Upon completion of the stage II, patients were discharged either on VKA or NOAC, depending on preoperative regime or patient preferences. For the first 3 months, patients were prescribed the same AADs as prior to HABL. Changes in AAD

therapy were made carefully once 3-month blanking period expired, with a reduction or discontinuation of AAD therapy over the next 6–12 months as medically indicated. Aspirin (75 mg) was substituted for warfarin at six months post procedure if maintenance of sinus rhythm was confirmed, unless there were other indications for systemic anticoagulation such as $CHADS_2 \geq 2$ [16]. All patients were seen in an outpatient clinic at 6 and 12 months post procedure (patients with implanted REVEAL® XT – were monitored every 3 months post procedure). Five patients had ECG Loop Monitors (Reveal XT) implanted at the time of the epicardial ablation procedure. For the remaining patients, twenty-four hour Holter monitoring was performed at 3 months and seven day Holter monitoring at 6- and 12-month visits. Transthoracic echocardiography (TTE) was performed 6 and 12 months postoperatively.

Monitoring and data collection

All patients were scheduled for visit in an outpatient clinic at 6 and 12 months after the procedure (patients with implanted REVEAL XT were monitored every 3 months after the procedure). Five patients had ECG Loop Monitors (Reveal XT) implanted at the time of the epicardial ablation procedure. For the remaining patients, 24 h Holter monitoring was performed at 3 months and seven-day Holter monitoring at 6- and 12-month visits. Transthoracic echocardiography (TTE) was performed 6 and 12 months postoperatively

Statistical analysis

Continuous variables are expressed as mean ± SD. Continuous parameters were compared with the Student t test. P value ≤0.05 indicate statistical significance.

Results

Procedural aspects

In 37.8% patients lesion pattern A while in 62.2% patients the lesion pattern B were created. Conversion from AF to

SR during the procedure was noted in 19% of patients, while remaining 81% underwent successful electrical cardioversion after all epicardial applications had been completed. In two patients, the left atrial appendage (LAA) was removed, via left thoracoscopic approach. In these cases, LAA was removed first with an endoscopic stapler (GI Ethicon) followed by ablation of LA roof and ligament of Marshall. Surgical procedure took on an average 113 ± 23 min (skin-to-skin) with mean number of applications 28.4 ± 7.4 per patient. Table 2 summarizes the surgical procedure characteristics.

Efficacy outcome analysis

Efficacy outcomes are presented for the 70 consecutive patients who underwent convergent dual-stage HABL from July 2009 to September 2013 and had completed the 12-month post procedure follow-up. Four of the seventy patients who were included in the efficacy analysis have not received the endocardial component of the staged HABL. At 6 months post procedure, 78.3% patients were in SR without any interventions. At 12 months post procedure, 84.1% patients were in SR, 82.6% were in SR without any interventions, and 62.3% were in SR and off class I/III AADs. Only 1% of patients required a repeat ablation for atrial flutter. Table 3 summarizes the efficacy outcomes after 6 and 12 months.

Safety data analysis

Several adverse events were observed during follow up period. The most serious was decease of one of our patients, 27 days after discharge in unclear circumstances. Cause of death was not determined, as a post mortem was not performed due to the patient's religious beliefs.

We observed two episodes of cardiac tamponade. One patient requires emergency treatment 12 h after the endocardial procedure. Percutaneous pericardiocentesis was attempted but failed. Surgical intervention followed: a 2-cm incision was made just below the xyphoid and peritoneal cavity was entered and a 28 F drain was introduced to the pericardium through a previously made fenestration of the diaphragm. The patient remained haemodynamically stable thereafter, but was readmitted 30 days later due to significant fatigue and shortness of breath. Transthoracic echocardiography revealed a considerable amount of fluid in the pericardial sac (4–5 cm anterior to the right ventricle). Again, percutaneous pericardiocentesis was unsuccessfully attempted, and a totally endoscopic fenestration of the pericardium through the right pleural space followed. The patient remained stable throughout the hospital stay and was discharged home seven days later. Data obtained from the REVEAL® monitor showed freedom from AF/atrial flutter throughout the short follow-up. Second incident was noted immediately after the endocardial procedure, treated in the operating room with a placement of a drain in pericardial cavity via subxyphoid incision. Careful "watch-and-wait" strategy was adopted, till patient was hemodynamically stable. Three days later drain was removed, and patient had uneventful recovery.

In one case, we observed the signs of pericardial effusion - patient experienced symptoms of inflammation shortly after the epicardial ablation, possibly due to the

Table 2 – Surgical procedure characteristics	
Surgical procedure characteristics	
Lesion pattern A (%)	37.8
Lesion pattern B (%)	62.2
Conversion to sinus rhythm during procedure (%)	19
Need of electrical cardioversion after procedure (%)	81
Time skin-to-skin (min); average (SD)	113 (23)
Number of applications per patient; mean (SD)	28.4 (7.4)

Table 3 – Efficacy outcomes of the convergent procedure		
Follow-up		
Time	6 months	12 months
Patients in SR (%)	78.3	84.1
Patients in SR, no interventions (%)	78.3	82.6
Patients in SR of AADs (%)	43.5	62.3

extensive ablation of the posterior atrial wall required due to the fibrosis and size of the left atrium. The condition was managed with steroids, as the amount of pericardial fluid did not restrict myocardial wall movement, resolving within 4 weeks. As patient remained in stable SR throughout entire treatment, he subsequently refused to undergo endocardial component of the staged HABL.

One patient required a sternotomy due to bleeding from a laceration of the inferior vena cava, following completion of all posterior lesions. Extracorporeal circulation was initiated and the epicardial lesions were completed on the beating heart without aortic cross-clamping, with the same RF device. The ligament of Marshall was cut and coagulated and both right and left atrial appendages were removed. The patient remains in SR throughout the two-year follow-up. As the procedure was completed via a sternotomy, this patient was excluded from the final data analysis.

Phrenic nerve palsy occurred in a patient with difficult right side anatomy, with an additional pulmonary vein. While unnoticed by the patient, higher position of the right diaphragm on the chest x-ray, and its limited contractility on cine confirmed diagnosis. Changes resolved within 3 months, as the patient was followed-up closely.

Lastly, transient ischemic attack was noted in a patient with history of stroke, two days after epicardial procedure. The event was limited to parietal loss of vision, and occurred during transition from LMWH to Rivaroxaban (Xarelto, Bayer).

Feasibility observations

As mentioned previously, the HABL was performed as a staged procedure to accommodate the local reimbursement challenges, requiring implementation of stable anticoagulation therapy during the interval between the staged procedures. While most of patients tolerated this inconvenience well, one patient despite LMWH, had blood stasis and "spontaneous" echo contrast noted in LAA prior to II stage (endocardial ablation). Such a condition remains associated with an increased risk of LA thrombus formation and embolic complications. The patient was discharged with VKA and the endocardial ablation was delayed. Once LAA proved clear, the patient underwent successful LAA exclusion with the Watchman device, followed by the CARTO guided endocardial ablation completing the HABL protocol. Of noteworthy is, that the procedure was feasible in patients with congenital variations of pulmonary vein anatomy, encountered in 26.7% of the analyzed cohort. These variations (most commonly seen as an additional vein or single ostium), present in nearly 30% of the general population, are known for their arrhythmogenic potential [17]. In only one case could the procedure not be performed as planned – in a patient with history of gastric ulcer perforation and subsequent peritonitis, treated surgically in 2001. An attempt was made to enter the peritoneal cavity with lateral placement of endoscopic ports to avoid the previous incision line. Despite careful manoeuvres aimed at dissection of severe peritoneal adhesions, the procedure was discontinued to avoid risks of dissecting the extensive adhesions. Although our and others experience shows that pericardioscopy can be safely performed in patients with a history of multiple abdominal surgeries, this individual had severe adhesions which prevented safe access to the diaphragm.

Discussion

Aim of this paper was to show our experience in performing dual-stage closed-chest HABL procedure with transabdominal access. We presented our safety, efficacy and feasibility results of HABL treatment in patients with PSAF LSPAF.

In analyzed population successful outcomes were comparable with previously presented data [13]. Moreover, moderate rate of complications and 1% of patients requiring a repeat ablation were noted.

A combination of a linear, comprehensive epicardial lesion pattern with precise, CARTO-guided endocardial applications is being recognized as an efficacious treatment option for patients in whom contemporary therapies have failed [9,15]. The Convergent Procedure described here was introduced in 2009 and with over 3700 patients treated to date constitutes an important treatment option for symptomatic patients with either PSAF or LSPAF [18]. Although surgical option is more invasive, it greatly facilitates percutaneous intervention, as EP procedure is shorter and requires less radiation exposure. Moreover, extensive ablation of the posterior left atrium, impossible to achieve with endocardial approaches, prevents esophageal injury caused by endocardial ablation.

One of the most discussed problem is whether HABL should be performed in one, sequential or two, separate procedures. Both methods have their advantages and potential drawbacks. Single procedure, because of their length, can be a challenge for the operators. Not without significance is the prolongation of the anaesthesia and need of periprocedural heparinization after transseptal puncture which could increase the bleeding risk. Such procedure requires special hybrid operating room to provide procedural environment for both surgeon and electrophysiologist. But probably the most important problem could be the origination of cardiomyocytes oedema because of tissue damage due to ablation. This phenomenon could impede testing of the lesion and ablation in the same area. Postponed catheter ablation may give a possibility to identify the region of early reconnection and make gaps in previously created lines detectable. Despite better detection and subsequent ablation of these gaps, such procedure did not improve the HABL efficacy [19]. The major drawback of hybrid ablation is the cost of the entire procedure. HABL being a new method, it is not yet recognised by the Polish National Insurance System and therefore does not exist on its reimbursement lists. Both surgical and catheter ablations may be compensated for when performed as separate, rather than convergent, procedures. This means it is necessary to stage the procedure. A minimum of 14 days from discharge to re-admission must exist in order to reimburse both procedures. Although better for hospital financing, such a dual stage procedure seems less satisfactory for the patient, as another hospitalisation and repeated transoesophageal echocardiography prior to endocardial ablation are required. All patients are informed about the nature of the

staged procedure, and seem to understand and accept its limitations. However, some patients may remain or return to AF due to incompleteness of the lesion pattern. Conversely, some patients might be reluctant to undergo endocardial ablation because of rhythm restoration and a rapid improvement of quality of life.

While bilateral or unilateral thoracotomy and less invasive thoracoscopy allow for circular electrical isolation of both pairs of pulmonary veins, they require chest incisions and sequential lung deflation [20]. This can be difficult to obtain in patients suffering from chronic pulmonary disease or after lung/lobe resection or inflammation, where pleural adhesions may severely limit endoscopic access. Transabdominal access is independent of lung function and anatomy allowing for unrestricted PV isolation in patients with severe chronic obturatory pulmonary disease (COPD) or other pulmonary disease. Our experience shows that successful AF ablation is possible even in patients with a history of total lung resection due to massive chest trauma. Single incision allows to spare intercostal muscle cut and in consequence reduce the postoperative pain. Importantly, both strategies allow for direct visualization of pulmonary veins irrespective of anatomy.

LAA is considered to be the origin for more than 90 % of emboli in nonvalvular AF [21]. LAA can be also a source of triggers for AF origination [22]. Thus, LAA ligation or exclusion represents a valuable asset of thoracoscopic approach, but as shown here, it can also be combined safely with transabdominal access in a selected population.

The open issue remains the possibility and optimal time of discontinuation of antiarrhythmic and anticoagulation therapy. The disparity between rates at one year post procedure, between sinus rhythm of 84.1% and freedom from arrhythmia and AAD of 62.3%, reflects our philosophy of cautious AADs withdrawal, which in many cases of LSPAF is performed over 18–24 months rather than 1 year. Similar strategy is applied to anticoagulation regime, as we tend not to discontinue VKA in patients with CHA_2DS_2-VASc equal or greater than 2 despite no AF episodes during 7-day Holter monitoring. Since loop monitors remain non-reimbursable, we have limited their use to patients with CHA_2DS_2-VASc = 1 in whom VKA/RIVA could be safely abandoned when SR was confirmed.

While this material contributes to growing evidence on safety and efficacy of both surgical and hybrid ablation of AF there is an urgent need for prospective randomized, multicentre clinical trial (RCT) to independently assess its role in AF treatment. With thousands of patients successfully treated worldwide, surgical standalone or hybrid ablation is still considered a Class IIb indication in both European AF treatment guidelines [4,5] limiting its use to either "highly symptomatic" or in whom percutaneous procedure (or procedures) have failed. Just by assessing our material it is not difficult to notice, that with mean EHRA score of 2.6 "symptomatic", rather than "highly symptomatic" patients are treated. Analogous condition applies to patients who failed percutaneous treatment – barely 20% of the reported cohort. Interesting observation is the changing of patients profile with time. Our initial experience focused on patients with a long history of AF disqualified from any percutaneous interventions. This EPs scepticism slowly, but progressively, ceased as concise entrance-and-exit block

was confirmed during CARTO mapping in consecutive patients. Once long-term benefits have been observed [10], rapid referral of PSAF rather than LSPAF was noted, often as the first line of invasive treatment, as in majority of LSPAF and PSAF with long history of disease, predicted efficacy of percutaneous treatment is low. More importantly comparable patient profile is encountered in nearly all papers on surgical and/or hybrid ablation, questioning applicability of published treatment guidelines. Yet, until there is solid data from RCTs, HABL, despite their high efficacy and excellent safety profile, will primarily be utilized as a last-resort for patients who have failed multiple treatment modalities including percutaneous catheter ablation, or are deemed not to benefit from such treatment by the experienced Heart Team.

Limitations of the study

This was an observational, non-randomized, single centre study in limited number of patients. To compare the dual stage with the convergent procedure, further randomized studies are needed. Only several patients received Reveal XT implantable loop recorders. Standarization of procedure efffectiveness monitoring could rise the credibility of the data. Patients with PSAF and LSPAF were analazyed together which made the comparision of this two groups dificult. In several patients LAA was excluded which could affect the safety and efficacy of the procedure in those subjects.

Conclusion

Data from this registry proves that the HABL utilizing transabdominal approach is an effective treatment option for patients diagnosed with PSAF and LSPAF with acceptable risk of complications. The procedure efficacy was demonstrated by restoration and maintenance of sinus rhythm in 84% of patients at one-year follow-up. Importantly, surgical or hybrid techniques must not be looked upon as competitive, but rather complementary, patient-tailored approaches.

Ethical statement
The appropriate Institutional Review Board (IRB) and Ethics Committee approvals were obtained for the study prior to initiating patient enrolment.

Informed consent
The authors declare that informed consent was obtained from the patient participating in this study.

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