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REVIEW

Catheter Ablation of Atrial Fibrillation

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ABSTRACT

Catheter ablation of atrial fibrillation (AF) has become a viable therapeutic alternative in symptomatic patients resistant to antiarrhythmic drugs. Since the first report of catheter ablation a decade ago, several techniques have evolved. These techniques reflect principal mechanisms of AF. Besides segmental electrical isolation, circumferential ablation around the pulmonary venous ostia with a support of the 3D electroanatomical mapping system appears to be the most frequently used techniques. Some authors use various combinations of these techniques including guidance with intracardiac echocardiography (ICE). Most recently, ablation within areas of fractionated electrograms during AF has been proposed. The aim of this review is to summarize briefly current techniques, their efficacy and safety.

KEY WORDS: *atrial fibrillation, catheter ablation, electroanatomical mapping, intracardiac echcardiography, pulmonary vein isolation*

Abbreviations

AF = atrial fibrillation
ICE = intracardiac echocardiography
PAF = paroxysmal atrial fibrilaltion

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INTRODUCTION

Catheter ablation of atrial fibrillation (AF) has become a viable therapeutic alternative in symptomatic patients resistant to antiarrhythmic drugs. Since the first report of catheter ablation a decade ago, several techniques have evolved. These techniques reflect principal mechanisms of AF. The aim of this review is to summarize briefly current techniques, their efficacy and safety.

FROM MAZE SURGERY TO SEGMENTAL PULMONARY VENOUS ISOLATION

The multiple wavelet hypothesis suggested by Moe and Abildskov in the late fifties was the most accepted mechanism of AF until recently.[1] It stated that AF occurs due to random movement of multiple wavelets throughout the atria. Experimental support for this mechanism was provided by Allessie et al who discovered that four to six wavelets were important for sustenance of AF.[2] Most importantly, this hypothesis resulted in development of the first curative approach to AF – MAZE surgery.[3] This ingenious technique has been designed to reduce critical mass of the tissue, prevent movement of multiple circuits within the atria and around the caval veins, and to isolate pulmonary veins. The reported success rate reached above 95% with perioperative mortality around 2%. However, its complexity and potential for complications prevented wider use of the MAZE procedure.[4] Not surprisingly, electrophysiologists soon tried to reproduce this scheme of lines using various catheter techniques.[5,6] Early in this stage of development, it has been realized that linear ablation within

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the right atrium is much less successful in abolition of AF as compared with lesions in the left atrium.[7] Reproduction of MAZE-like linear lesions within the left atrium was found technically difficult and again, associated with a high risk of complications. During these early attempts, Haissaguerre et al[8] described the first three cases of focal mechanism of AF. Foci of spontaneous electrical activity that triggered AF were described predominantly within pulmonary veins and became the target for ablative attempts.[9] Subsequent anatomical studies confirmed previous observations about the presence of atrial muscular sleeves around the ostia of the pulmonary veins[10,11] and one of the recent publications revealed the presence of node-like cells in these muscular extensions.[12] All these observations revived the hypothesis of a rapidly firing focus that was described in 1925 by Sir Thomas Lewis.[13] Further experimental support for this mechanism was provided by Scherf et al,[14] who used local application of aconitine to initiate AF and demonstrated that subsequent obliteration of the site of application leads to termination of AF. Other studies have shown that episodic bursts of electrical activity with a distal-to-proximal activation of the pulmonary vein,[15] suggesting their role in AF maintenance. After a period of focal ablations within the pulmonary veins, Haissaguerre et al[16] came with a concept of selective electrical isolation of arrhythmogenic or all pulmonary veins. The concept reflected variable arrangement of muscular fibers around the ostia with some preferential routes of conduction from the vein and vice versa. Using a purpose-constructed circular mapping catheter (Lasso, Biosense-Webster, Diamond Bar, CA, USA), this group was able to map sites of the conduction and destroy them selectively instead of burning the whole circumference of the pulmonary vein ostia. After initial excitement, several limitations of this approach have been revealed. First, it appears to work predominantly in subjects with clear evidence of focus-triggered AF (i.e. subjects with multiple runs of self-terminating AF initiated by frequent premature ectopic beats) and less in patients with persistent or permanent AF. The success rate of this procedure ranges between 60-80%, the best results occurring in patients with paroxysmal AF and without structural heart disease.[17] Second, there is a risk of pulmonary vein stenosis (1-3%) that can be very symptomatic and optimal treatment of which is still unknown. Third, the long-term success is impaired by very frequent recovery of conduction, and many subjects require repeated procedures.[18] This may reflect minimalistic energy delivery in the proximal segments of the pulmonary veins in an attempt to eliminate risk of pulmonary venous stenosis.

CIRCUMFERENTIAL ABLATION AROUND PULMONARY VENOUS OSTIA

Parallel to significant research work of the Bordeaux group, Pappone et al developed their own strategy to treat AF.[19,20] Using a 3D electroanatomical mapping system (CARTO, Biosense Webster, Haifa, Israel), this group started to use circumferential deployment of radiofrequency lesions around the pulmonary venous ostia. The endpoint for ablation was signal amplitude abatement ≤0.1 mV and local activation time difference between points on both sides of a line >30 ms (as confirmed by a remap around ostia). Although a complete electrical isolation of the pulmonary veins is relatively rare with this technique, a substantial modification of the substrate and/or partial denervation of the heart seem to be its main results. It does not refute the concept of focal origin of AF. However, it may also prevent the formation of stable rotors out of the pulmonary veins which could maintain AF. These vortex-like reentry circuits have been described in the posterior left atrium and pulmonary venous ostia by Jalife et al using a high-resolution optical mapping.[21] Rapid electrical impulses originating from these rotors then propagate throughout the atria and sustain fibrillatory conduction. The efficacy of Pappone´s method has been confirmed by its authors as well as by others.[22] The success rate ranges between 75 to 90%. Non-randomized comparison of medical treatment with catheter ablation documented better prognosis of subjects treated interventionally.[23] Comparison of circumferential ablation around the pulmonary venous ostia with segmental isolation within proximal segments of the pulmonary veins showed higher long-term success rate for the former technique.[24] At 6 months, 88% of patients who underwent circumferential ablation and 67% of patients who underwent segmental isolation were free of symptomatic PAF when not taking antiarrhythmic drug therapy. In the same time, the risk of pulmonary venous stenosis is lower when radiofrequency energy is applied around the ostia. However, a new and serious complication of this approach has recently been described – atrio-esophageal fistula.[25]

COMBINED TECHNIQUES

Limited success rate of either of the above techniques has led to development of combined techniques. Mansour et al [26] described a novel method of circumferential extraostial isolation of the pulmonary veins, combining electroanatomical mapping and the use of Lasso catheter. Isolation of the right and left pulmonary veins was achieved by a single encirclement of ipsilateral veins. This approach led to abolition of AF in 75% of patients as compared with 60 % in a group with segmental isolation within the pulmonary venous ostia. There was one thromboembolic complication in each group. Natale et co-workers [27] described another combined technique that uses intracardiac echocardiography (ICE) to visualize pulmonary venous ostia and the Lasso mapping catheter for assessment of local signals and assessment of complete electrical isolation of the veins. The position of the Lasso catheter is controlled by ICE and continuously adjusted to eventually cover the whole circumference of the veno-atrial junction. This allows deployment of the lesions at the level of veno-atrial junction and in the same time, assessment of electrical isolation of the relevant pulmonary vein. Initial experience with this novel approach resulted in a discovery of the phenomenon of "microbubbles" during radiofrequency energy delivery. Appearance of microbubbles reflects tissue overheating and precedes sudden increase of impedance and/or "pop" phenomenon. Monitoring of gradually increasing radiofreqeuency energy delivery seems to prevent complications as well as allows administration of a relatively high energy to the tissue. All the above potential advantages appear to contribute to very high efficacy and safety of this technique, both in patients without and with structural heart disease and in patients with paroxysmal as well as persistent AF. The reported success rate reaches above 90% and 70%, respectively.[27,28]

ABLATION OF AN ELECTROPHYSIOLOGICAL SUBSTRATE

Theory of mother rotors with subsequent fibrillatory conduction and previous experimental data [21] led to attempts to modify electrophysiological substrate for these reentry circuits. One of them was minimally invasive surgical approach in subjects without significant structural heart disease. Simple scheme of linear lesions created by a hand-held radiofrequency probe was designed to interconnect ostia of the pulmonary veins connect them with the mitral annulus in order to destroy periostial anchoring reentrant circuits.[29] Despite the fact that the pulmonary veins were not isolated with this technique, both mid- and long-term success (between 93-97%) were higher than reported for segmental isolation of the pulmonary veins. Further sophistication of the technique that is primarily focused on abolition of rotors was introduced by Nademanee et al[30] who used electroanatomical mapping of both atria to annotate areas with complex and fragmented local electrograms in an anatomical map. These areas were localized predominantly on the posterior left atrial wall and/or in the septal region. Catheter ablation within these areas led to interruption of AF in 115 of 121 patients and prevented the recurrence of arrhythmia at one-year follow-up in 92 of 121 (76%) after the first procedure and in 110 of 121 (91%) after the second procedure. The mechanism by which the ablation within areas of fragmented potentials prevents recurrence of AF is not clear. Rather extensive ablation may eliminate some triggers in the periostial area, eliminate or modify abnormal atrial substrate needed for maintenance of AF and/or modulate cardiac parasympathetic activity.

THE PRAGUE CURRENT APPROACH

At present, most of the centers use circumferential ablation supported by electroanatomical mapping. Following previous experience with segmental isolation and then with circumferential ablation, we started to use ICE in association with electroanatomical mapping system and the Lasso catheter. One of the reasons for this move was observed variability in pulmonary venous ostial arrangement that does not allow accurate location of the pulmonary venous ostia by electroanatomical mapping system.[31] The other reason was to improve efficacy and safety similar to that reported by Manssour et al.[26] So far, we performed 23 procedures in patients with and without structural heart disease, and 12 of them has minimum follow up of 2 months. Eight subjects are without AF, one reported symptomatic improvement and the remaining three continue to have symptoms. Although it is early to analyze efficacy of the above approach, we believe that ICE may provide significant help in catheter ablation of AF regardless the method used. First, it can be used to assist transseptal puncture, especially in difficult anatomy of the septum (e.g. lipomatous hypertrophy etc) (Figure 1). Second, ICE is able to identify intracardiac thrombi that develop during the procedure and thus, has a potential to minimize a risk of thromboembolism.[32] Third, ICE allows visualization of all pulmonary veins, their arrangement and size (Figure 2). It enables precise placement of the lasso catheter at the level of venoatrial junction (Figure 3) and of the ablation catheter proximal to it. Fourth, it may help to create adequate radiofrequency lesions by monitoring of power delivery and creation of microbubbles as a sign of tissue overheating (Figure 4). Fifth, ICE enables assessment of pulmonary venous blood flow before and after ablation and thus, estimation of venous stenosis.

CONCLUSIONS

The last decade has witnessed significant development of catheter ablation strategies to cure AF. Besides segmental electrical isolation, circumferential ablation around the pulmonary venous ostia with a support of the 3D electroanatomical mapping system appears to be the most frequently

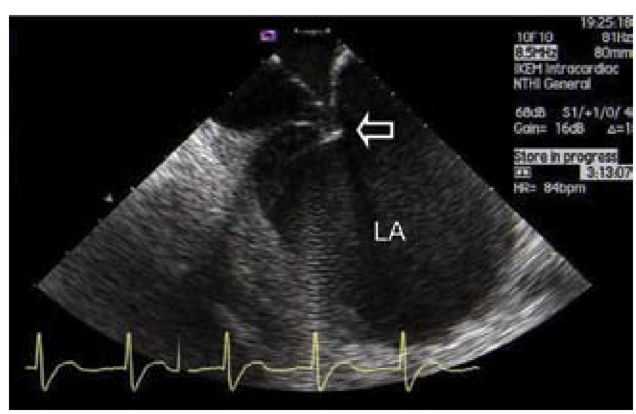

FIGURE 1. Intracardiac echocardiogram of both atria obtained immediately before transseptal puncture. Note tenting of the interatrial septum by transseptal needle (arrow) from the right atrium towards the left atrium (LA).

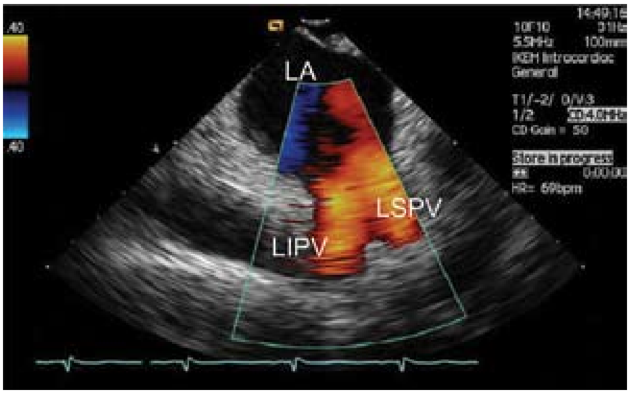

FIGURE 2. An example of intracardiac echocardiogram of the left atrium (LA) and left-sided pulmonary veins (LIPV – left inferior and LSPV – left superior pulmonary vein, respectively) with a common vestibule. Color Doppler documents flow towards the LA.

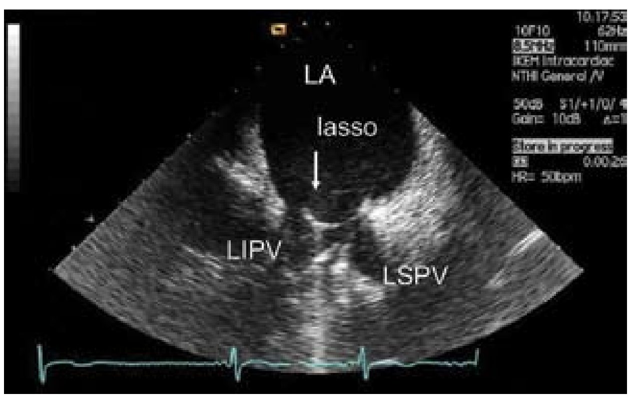

FIGURE 3. Intracardiac echocardiogram of the left atrium (LA) showing the Lasso catheter held in the proximal part of the vestibule. It is apparent that the Lasso is smaller than the diameter of the vestibule of left-sided veins (LIPV – left inferior and LSPV – left superior pulmonary vein, respectively).

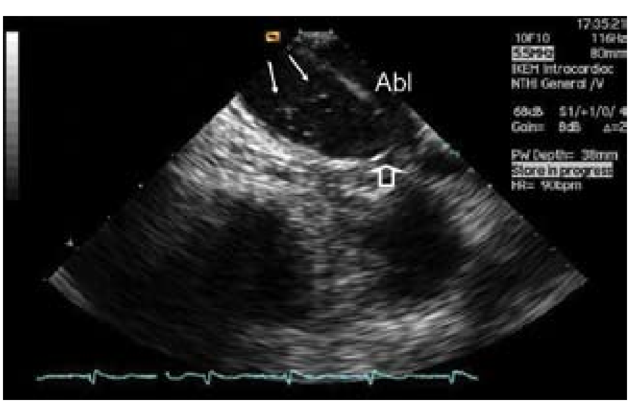

FIGURE 4. Intracardial echocardiography of the left atrium (LA) during radiofrequency (RF) delivery through the tip of the ablation catheter (Abl). Large arrow depicts part of the Lasso catheter, small arrows show scattered microbubbles.

used techniques. Some authors use various combinations of these techniques including guidance with ICE. Most recently, electroanatomical mapping system was used to guide ablation within areas of fractionated electrograms during AF without any attempt for circumferential ablation of the pulmonary veins. Further progress can be achieved only through precise assessment of relative efficacy, safety and ease of these techniques.

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