

# Catheter Ablation of Atrial Fibrillation. Techniques and Results

Mauricio Scanavacca e Eduardo Sosa

Instituto do Coração do Hospital das Clínicas – FMUSP - São Paulo, SP - Brazil

## INTRODUCTION

Over the last years, major advances have been made in catheter ablation of atrial fibrillation (AF). Early attempts to reproduce the catheter maze procedure, although barely effective, led to the observation that ectopic foci often originating in the pulmonary veins triggered paroxysmal atrial fibrillation. This, in turn, has heralded the development of focal ablation and, later on, pulmonary vein isolation techniques. Limitations found in patients with persistent and permanent atrial fibrillation led to the development of more effective techniques to modify the substrate for AF maintenance. Thus, the strategy of reproducing catheter maze surgery was resumed, and now this procedure is performed using a computerized mapping system that provides three-dimensional reconstruction of atrial chambers and ablation with radiofrequency (RF) equipment capable of producing deeper and transmural lesions. Larger lesions at the pulmonary vein antra cause changes in the substrate for AF maintenance, as well as autonomic denervation of the left atrium, and seem to result in better control of atrial fibrillation. These findings have been stimulating the development of new techniques to identify more specific areas associated to the initiation and maintenance of atrial fibrillation. The use of different methods by different investigators has been confusing for physicians who are not familiar with the new techniques to treat atrial fibrillation. The purpose of this update, therefore, is to review the key techniques used today, as well as the expected results and involved risks.

## TECHNICAL ASPECTS

### Radiofrequency ablation

Radiofrequency (RF) is the most common form of energy currently used for catheter ablation of atrial fibrillation, due to its safety and efficacy<sup>1</sup>. It consists of alternating current that is delivered in high frequency cycles by the distal electrode of the ablation catheter and that propagates to an indifferent electrode of large surface

area applied to the skin of the patient's shoulder or back. Radiofrequency energy is delivered for 15 to 60 seconds, and the power of RF pulses is controlled by the catheter tip temperature and system impedance. The high current density at the active electrode surface causes an increase in temperature and produces a tissue lesion with depth and size proportional to the power and surface area of the electrode (4 to 8 mm). Depending on the characteristics of the distal electrode of the ablation catheter and also on the size and depth of the tissue to be ablated, the maximal temperature at the electrode-tissue interface is limited to between 45 and 60 °C, and the maximal energy (power) delivered is set between 20 and 60 watts. Catheters with a 4-mm distal electrode may create, on average, lesions from 4 to 6 mm in diameter and 2 to 3 mm in depth<sup>2</sup>. Larger electrodes or irrigation systems to cool the active electrode allow higher power to be delivered and produce deeper lesions<sup>3,4</sup>. The characteristics of RF pulses applied inside the pulmonary veins (PVs) ostia differ from those applied at the atrial tissue. Pulmonary vein blood flow cools the electrode tip, and to reach the predetermined temperature the system automatically raises the energy delivered, thus increasing both the endovascular lesion and the risk of stenosis. Therefore, applications inside the pulmonary veins are avoided and, whenever necessary, should be reduced in number and applied at temperatures between 45 and 50 °C and maximal energy between 20 and 30 W. Conversely, RF applications at the atrial wall are not significantly cooled and show rapid rise in temperature at low energy input, limiting both the size and depth of lesion. Accordingly, when transmural atrial lesions are intended, catheters with a larger (8 mm) or internally saline-irritated distal electrode that allows greater RF energy input are necessary to create deeper lesions.

The acute lesion produced by RF application consists of a central zone of coagulation necrosis surrounded by a mild zone of inflammation<sup>5</sup>. Chronic lesions are characterized by homogeneous scars with well-defined borders. Stable electrode contact with target tissue is essential to produce definitive lesions. Unstable catheter positioning and insufficient energy power are the primary causes of recurrence after initially successful ablation procedures.

The continuous monitoring of temperature, power, and system impedance to prevent clot formation and myocardial wall perforation during RF delivery ensures safe procedure. Radiofrequency generators currently available automatically stop energy delivery if resistance to the current flow (impedance) increases more than expected, thereby indicating excessive elevation of temperature and fibrin build-up on the electrode surface. Intracardiac echocardiography monitoring of microbubbles formation is considered a good method to adjust energy power during RF ablation. Excess power reflects in an increased number of microbubbles around the catheter, which constitutes an indication to stop application and readjust RF power<sup>6</sup>.

## Mapping and navigation systems

Electrophysiological mapping of the atrium has been traditionally performed using the simultaneous recording of bipolar electrograms obtained by multipolar electrode catheters advanced through the femoral veins to preestablished areas of both atria. The characteristics of the electrograms obtained and the atrial activation sequence in sinus rhythm and tachyarrhythmia are related to the spatial location of the electrode catheters. Data analysis enables the mental picturing of an atrial activation map, its correlation with atrial anatomic structures and functional characteristics of the atrial tissue assessed. Positioning of mapping catheters and navigation of the ablation catheter through the atria are performed under fluoroscopy in several angles (PA, RAO, LAO). Conventional electrophysiological mapping techniques have been used for mapping and ablation of focal atrial fibrillation, in addition to isolation of pulmonary veins ostia<sup>7-10</sup>.

Electroanatomic mapping is a new computerized system for electrophysiological mapping that integrates the characteristics of electrograms obtained by a single catheter in different sites of the left atrium with the real-time, three-dimensional image created when the catheter touches the wall of this chamber<sup>11</sup>. Local electrical patterns and atrial activation time are transformed into colors and visualized on static or dynamic images. Therefore, the functional characteristics of the atrial tissue and propagation of atrial electrical activity can be reproduced and visualized by the whole team. Catheter placement is accomplished under fluoroscopy, but navigation of the exploring catheter inside the chamber during mapping and ablation is guided by the real-time, three-dimensional image created by the system, minimizing x-ray use. Carto, the most widely used mapping equipment, was popularized by Paponne et al<sup>10-13</sup>, who used it to perform circumferential ablation of pulmonary vein ostia and create lines of block when performing the catheter maze procedure. Other systems for electroanatomic mapping using different techniques, yet

with similar purposes, have been also employed (*Nav X, RPM and EnSite*), as well as the non-fluoroscopic navigation system (*Localisa*). The most interesting aspect about these new technologies is the integration of nuclear magnetic resonance or computed tomography images of the left atrium with electroanatomic mapping systems, allowing the electrical activity obtained during mapping to be incorporated to the patient's actual anatomy (*Carto Merge*).

Intracardiac echocardiography has proved to be a useful tool for catheter ablation of atrial fibrillation. This technique was popularized by the Cleveland Clinic team<sup>6,14</sup>, which underscores its usefulness to perform safer transeptal punctures, appropriate circular catheter positioning at PVs ostia, identification of early clot formation in the left atrium, plus monitoring and adjustment of RF energy delivery. Images are generated by a transducer inserted through the left femoral vein and advanced to the right atrium. These authors believe that, by using this system, they have obtained a higher success rate with lower risk of complications.

## Ablation strategies

### Emination of Atrial Fibrillation Firing Foci

**Focal Ablation** - Focal AF ablation, developed by Haissaguere and coworkers at the Hôpital Cardiologique du Haut-Lévêque, in Pessac, France, was the first catheter ablation technique proven effective<sup>7,8</sup>. It is intended for a restricted group of patients in whom the focal mechanisms that trigger AF episodes can be clearly located. Typical cases are patients with frequent atrial extrasystoles and recurrent atrial tachycardia originating in the pulmonary veins (90%), thoracic vessels (5%) [superior vena cava (SVC), left superior vena cava (LSVC), Marshall ligament], *crista terminalis* (5%), or coronary sinus (2%), that, once identified and eliminated, cease to induce atrial fibrillation<sup>10</sup>. The main limitation of this technique is the absence or sparse occurrence of ectopic foci during the procedure, which limits their accurate location. Therefore, techniques were developed to induce ectopic foci, such as vagal maneuver, adenosine infusion, isoproterenol or AF induction with rapid stimulation followed by electrical cardioversion (ECV). However, recurrence rate was high due to foci of a different origin not reproduced in the initial procedure. The current trend in patients with seemingly focal atrial fibrillation is the electrical isolation of all four pulmonary veins. The most relevant complication arising from ablation of ectopic foci inside the pulmonary veins was the induction of PVs stenosis and, eventually, their occlusion, resulting in pulmonary hypertension<sup>15</sup>. Some degree of stenosis was observed in up to 40% of the evaluated veins of the first series with risk of severe stenosis >70% in 3 to 5% of the approached veins<sup>16</sup>. These findings led to the modification of the technique.

## PULMONARY VEIN ISOLATION

### Segmental ablation of pulmonary vein ostia

Partly because of the limitations found in the location of ectopic foci, partly because of the risk of PVs stenosis, two techniques were developed to empirically isolate the ostium of all pulmonary veins. Originally called segmental PV isolation, the technique developed by Haissaguerre et al<sup>17</sup> aims at identifying the muscle sleeves of atrial tissue that penetrate inside the pulmonary veins and performing the specific ablation of the PV ostia quadrants where they are located, avoiding the circumferential ablation associated with high risk of stenosis. For this purpose, a circular catheter is inserted inside each PV to locate the atriovenous (AV) junctions. Ablation is performed using a 4-mm-tip catheter and low energy RF pulses (50 °C and 30W) (figure A1). This technique achieved the clinical control of 70% of the patients, with a low risk of pulmonary vein stenosis. However, reconnection of the isolated pulmonary veins poses a problem, requiring either a new intervention in 20% to 50% of the patients or maintenance of anti-arrhythmic drugs in about half of the cases<sup>17-19</sup>.

### Evolution of the technique

In a recent review, Hocini et al<sup>20</sup> present the technical modifications the group made in pulmonary vein isolation. Ablation now has been performed using an irrigated distal electrode (4 mm) catheter, lesions are created at about 1 cm from the PV ostium and in most part are circumferential (nearly 100%). Additionally, all regions of pulmonary vein antrum with electrograms with two or more components are also ablated. Evaluation of 368 consecutive patients who underwent this technique showed that 69% remained free of atrial fibrillation without anti-arrhythmic drugs in a mean follow-up of 10±5 months. For patients with persistent or permanent AF, the authors suggest that two lines of block be created at the left atrium, in addition to isolation of the pulmonary veins. One line connects the left inferior pulmonary vein to the mitral annulus and the other, both superior pulmonary veins (figure A2). A comparative study also suggests that this approach is useful in patients with paroxysmal AF when sustained AF is induced following the pulmonary veins isolation<sup>21</sup>. By using this strategy, 87% of the patients with paroxysmal AF and 70% of the patients with persistent AF became free of atrial tachyarrhythmia without anti-arrhythmic drugs in a mean follow-up of one year. Evaluating 2,000 patients who underwent AF ablation in its many phases, these authors found that only four patients had severe PV stenosis (>70%), and five others had right phrenic nerve palsy, four of whom experienced a complete recovery<sup>20</sup>. Hemopericardium was also found in 2% of the patients who underwent PV isolation techniques, and in 5% of the patients who underwent linear lesions<sup>22</sup>.

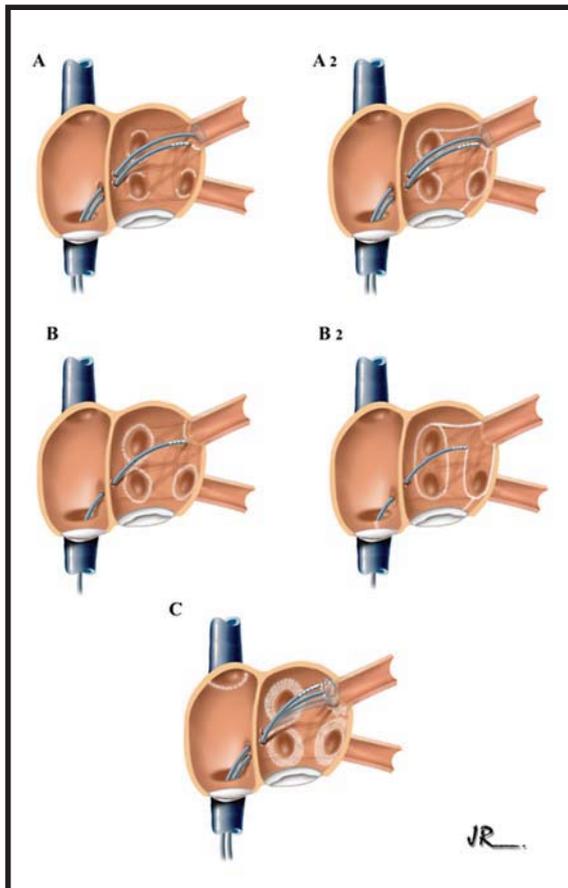
### Circumferential ablation of pulmonary vein ostia

Pulmonary vein circumferential ablation was developed by Pappone et al, at Hospital San Raffaele, in Milan, Italy<sup>12</sup>. At first, the strategy focused on the isolation of each PV ostium by circumferential RF energy delivery at least 5 mm from the ostia to prevent stenosis (fig. B1). To perform this technique, they used an electroanatomic mapping system that generates three-dimensional reconstructions of the left atrium and displays the spatial locations of the pulmonary veins, besides enabling the documentation of the electrical activity in these structures. For the ablation, 4-mm-tip catheters were used at first, with maximal energy of 50W and temperature up to 60 °C. The authors reported that AF was controlled in 80% of the patients with paroxysmal atrial fibrillation, and that no pulmonary vein stenosis was found during a mean one-year follow-up.

### Evolution of the technique

To achieve better results, particularly in patients with persistent AF and associated heart diseases, these same authors enlarged the isolation area of the periostial tissue, expanding the lines of block around the pulmonary veins and isolating them two at a time<sup>13</sup>. They added a posterior block line connecting the two isolated areas and another one from the left pulmonary veins to the mitral valve annulus, similar to the surgical techniques (catheter maze procedure) (fig. B2). Radiofrequency ablation of the cavotricuspid isthmus was also systematically introduced. For this purpose, they used catheters with 8-mm-tip electrodes and 100w RF power to produce transmural atrial lesions. In a prospective, randomized study, Oral et al<sup>23</sup> compared the segmental PV isolation technique with the circumferential ablation technique. These authors found that approximately 100% of the patients who underwent circular catheter-guided isolation achieved electrical isolation, compared to 60% of the patients who underwent electroanatomic-guided circumferential ablation. Despite this, after six months 67% of the patients from the first group and 88% from the second group were free of atrial fibrillation without anti-arrhythmic drugs. During circumferential ablation of the pulmonary vein antra, Pappone et al. noted that 30% of the patients experienced vagal reaction, suggestive of left atrium autonomic ganglia stimulation, which disappeared as the ablation went on. Clinical follow-up of these patients showed that 99% were free of AF without anti-arrhythmic drugs.<sup>13</sup> These data suggest that even the partial ablation of ganglia and fibers of the left atrium autonomic nervous system is important to control AF episodes.

Although more effective, extra-ostial PV circumferential ablation showed severe limitation, namely, high energy RF pulse delivery in close proximity to the esophagus. The first cases of fistula between the left atrium and the esophagus were found recently, a severe and potentially fatal complication<sup>24,25</sup>. Carlo Papponi, in a personal



**Fig. 1** - Most widely used strategies for catheter ablation of atrial fibrillation. **A1** - Segmental pulmonary vein ablation - the technique first proposed by the Hospital Haut-Lévêque group, in Pessac, France, for electrical isolation of the four pulmonary veins. **A2** - Evolution of the technique performed by these authors. Ablation is extended to the extra-ostial tissue of the pulmonary veins, and lines of block are created to connect the ostium of the pulmonary veins to the mitral annulus. **B1** - Reproduction of the early technique of circumferential pulmonary vein ablation, proposed by the Hospital San Raffaele's group in Milan, Italy, performed using the electroanatomic mapping system. **B2** - Evolution of the circumferential ablation technique. The ipsilateral pulmonary veins are simultaneously isolated, aided by the electroanatomic system, and lines of block are created to connect the isolated areas to the mitral annulus. The cavotricuspid isthmus is consistently blocked. **C** - Isolation of pulmonary vein antra, technique proposed by the Cleveland Clinic group, USA. After the isolation of each pulmonary vein, guided by a circular catheter, the lesions are circumferentially extended to the extra-ostial atrial tissue. Positioning of the circular catheter and RF delivery are performed using intracardiac echocardiogram.

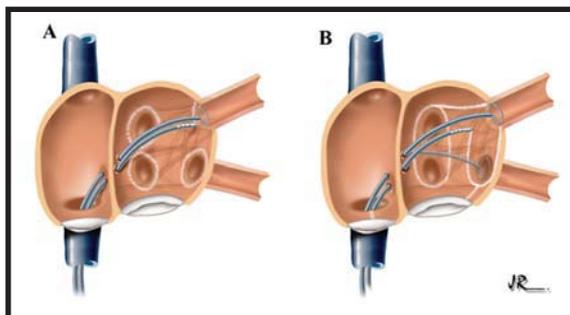
communication, reported a new technical modification after this complication. A 3.5-mm irrigated-tip catheter replaced the ablation catheter with 8-mm distal electrode. The same enlarged circumferential ablation strategy was maintained, except for the moving of the posterior line to the roof of the left atrium to prevent the posterior wall from touching the esophagus.

In a review of 3,980 patients, these authors reported the following complications: hemopericardium: 0.2%; stroke: 0.23%; atrial-esophageal fistula: 0.03%; PV stenosis: 0%, and incisional atrial tachycardias: 6%<sup>26</sup>.

## Pulmonary vein antrum circumferential ablation guided by intracardiac echocardiogram

Pulmonary vein ostia circumferential ablation was developed by Natale et al, in the Cleveland Clinic, Ohio, USA, after several attempts were made using different equipment and technology for AF ablation<sup>27</sup>. The rationale for the procedure is that pulmonary vein electrical isolation is imperative in atrial fibrillation management, but the fibers that originate in the posterior wall of the left atrium and penetrate these vessels are also potentially arrhythmogenic foci and, therefore, should be ablated. In this technique, the PV electrical isolation guided by a circular catheter is an essential step. Ablation is performed using an 8-mm-tip catheter, but the energy delivered is adjusted according microbubbles formation, observed by intracardiac echo. After isolation of each PV, the circular catheter is moved circumferentially around the PV ostium and progressively away, and the identified atrial potentials are ablated. This way, the atrial lesion is extended from the ostia to the posterior, superior, and inferior part of all pulmonary veins, and also to the anterior part (septum) of the right pulmonary veins (fig. C). Lines of block are not performed, but the superior vena cava is consistently isolated. According to an assessment performed two months after the intervention, this technique has an 80% success rate with first procedure, without anti-arrhythmic drugs. These authors are among the first to formulate the concept of blank period, according to which early occurrence of atrial fibrillation does not necessarily means late failure. Repeat procedure, if necessary, is performed after this period, with success rate exceeding 90%. Success rate is higher in young patients with paroxysmal AF, lower in patients with ventricular dysfunction (73%) or prior heart surgery (73%), and worse in patients with scars in the left atrium (<50%). In the last 400 patients submitted to this procedure by Natale and coworkers, 0.25% of the patients had moderate PV stenosis, 0.8% had embolic stroke, and 0.5% had cardiac tamponade. No atrial-esophageal fistula was found<sup>14</sup>.

At InCor, 420 patients underwent AF ablation between 1998 and 2004. Three distinct phases can be highlighted during this period: 1 – focal ablation phase (1998-2000), involving only patients with structurally normal heart and paroxysmal AF; 2 – PVs ostial isolation phase, guided by 15-mm circular catheter and 4-mm ablation catheter with maximum energy of 30J and temperature of 50 °C (2000-2002), involving patients with paroxysmal (90%) and persistent (10%) AF and structurally normal heart; 3 – extra-ostial PVs isolation phase guided by 20- or 25-mm circular catheter and 8-mm ablation catheter with maximum energy of 60W and 55 °C (2002-2004) in patients with paroxysmal (70%), persistent (20%), and permanent (10%) AF, involving patients with structural heart disease (30%) (figure 2 A e B). At focal phase, only 40% of the patients became free of AF recurrence



**Fig. 2** - Techniques used at InCor-HC-FMUSP for catheter ablation of atrial fibrillation. **A** - Circumferential and extra-ostial isolation of pulmonary vein ostia guided by a circular catheter - technique used in patients with paroxysmal AF and normal heart. **B** - Variation of the technique to enlarge the area of atrial isolation. This technique is reserved for patients with persistent or permanent AF, dilated left atria, or structural heart disease.

(50% with AA); at ostial phase, 71% became free (50% with AA); and at extra-ostial phase, 75% became free (25% with AA) after a single procedure and at a mean follow-up of one year. The major complications observed in these periods were: four PV stenoses comprising phases 1 and 2 (one asymptomatic requiring angioplasty); three systemic embolic events (one in the spleen in phase 1, one coronary (angioplasty) in phase 2, and one transient ischemic attack in phase 3); two patients had right diaphragm paralysis in phase 2, with complete recovery at follow-up; eight patients had hemopericardium, resolved by percutaneous drainage over the three periods. The most severe complication leading to death was atrial-esophageal fistula in phase 3, when this complication had not yet been reported in percutaneous procedures (December 2003). After this, some modifications have been made in the technique, such as monitoring of the esophagus position during the intervention by esophagogram or by introduction of an orogastric tube with contrast. If the area to be ablated was close to the esophagus, energy delivery was reduced to a maximum power between 20W and 30W. More recently, we have used an esophageal thermometer to monitor the esophagus temperature, manipulated in such way as to be as close as possible to the ablation catheter during RF delivery. Either rapid elevation of esophageal temperature at the beginning of the application or local temperature of 38°C is used empirically as the criterion to discontinue application in this site. After these measures were implemented, no other case of fistula was detected in 2004.

## NEW STRATEGIES

An interesting aspect in the analysis of results of circumferential ablation of pulmonary vein ostia described by Pappone was that recurrence incidence was lower than in ostial isolation, despite the lower rate of PV isolation. It was hypothesized that a great part of the substrate for maintenance of AF would be at the PV antrum, associated with the arrangement of atrial fibers in this site or with the autonomic innervation of the heart also distributed in

these areas. Extensive ablation of these sites would modify the mechanisms of AF maintenance. Accordingly, three new techniques have been suggested: the first one aims at the ablation of low-amplitude and fragmented electrograms detected during atrial fibrillation, regarded as markers of the rotor areas that maintain the atrial fibrillation<sup>28</sup>. The second technique aims at identifying the areas of AF maintenance in sinus rhythm, based on the spectral analysis of atrial electrograms by Fourier transform; polyphasic electrograms, regarded as possible markers of ANS nerve fibers entering the atrial tissue, are the targets of the intervention<sup>29</sup>. The third technique consists in locating the autonomic ganglia of the heart by neurophysiological stimulation and its specific ablation<sup>30</sup>. In these techniques, ablation of atrial fibers located in the interatrial septum and the roof of the left atrium has gained importance; PV isolation would not be essential for the success of these procedures.

## RESULT REPRODUCIBILITY

As we have seen, although Haissaguerre, Pappone, and Natale groups - which together total at least 8,000 patients who underwent AF ablation - had applied seemingly different strategies, over time all of them started to perform the central intervention in a very similar way (PV antrum ablation, albeit using different mapping and navigation systems), and today they perform these procedures with slight technical variations. Although clinical results reported by these authors are quite satisfactory and involve acceptable risks, an important aspect to its widespread use is its reproducibility in distinct environments. Regarding this aspect, a global survey of AF ablation current status is mandatory. Cappato et al<sup>31</sup> gathered information from 90 centers throughout Europe, USA, Asia and South America involving about 8,745 patients who underwent AF ablation between 1995 and 2002, with a mean follow-up of  $11.6 \pm 7$  months. It must be emphasized that most part of these results reflect the use of PVs isolation strategy, two thirds of which were guided by circular catheter. Control rate was higher among more experienced groups, and total mean was 50% AF control without the use of anti-arrhythmic drugs and 73% with clinical treatment. These findings are consistent with the results obtained by our group using the PV empirical isolation technique, the data of which have been included in this survey. Five hundred and twelve complications (6%) plus four deaths were reported (0.05%). Two patients died from massive stroke; one patient, from hemothorax; and another, from unknown cause. The main complications included: PVs stenosis: 1.63%, cardiac tamponade; 1.22%; stroke: 0.94%; femoral artery pseudoaneurysm: 0.53%; arteriovenous fistula: 0.42%; hemothorax: 0.16%, and diaphragmatic paralysis: 0.11%.

## INDICATIONS

The Brazilian Society of Cardiology recommends AF ablation in patients with symptomatic, paroxysmal AF that is difficult to control with drug therapy, normal left atrium and no metabolic conditions potentially correlated to arrhythmia (Recommendation B2, Level 3); and in patients with structural heart disease and frequent AF paroxysm difficult to control with drug therapy (Recommendation B2, Level 4)<sup>32</sup>.

At the Hôpital Cardiologique Haut-Lévêque in Pessac, France, appropriate candidates are patients with symptomatic AF, with frequent episodes of over one-month duration resistant to two or more anti-arrhythmic drugs. No specific criterion is used. Exclusion criteria are based on AF duration, whether paroxysmal, persistent, or permanent; presence of structural disease; ventricular dysfunction; size of left atrium; prior cerebral embolism; or age<sup>20</sup>.

At the Hospital San Raffaele, in Milan, Italy, patients considered for ablation are those with at least one episode of persistent and symptomatic AF per month, at least one episode of paroxysmal AF per week, or permanent AF, having unsuccessfully used at least an anti-arrhythmic drug. Exclusion criteria include: patients with CHF functional class IV, age over 80, contraindication for anticoagulants, presence of atrial thrombus, size of left atrium >65 mm showed by echo, life expectancy less than one year, and thyroid dysfunction<sup>26</sup>.

At the Cleveland Clinic, only symptomatic patients who failed to respond to at least one anti-arrhythmic drug are candidates for AF ablation, regardless of whether they have paroxysmal, persistent, or permanent AF, but with no restrictions as to age, size of left atrium, or ejection fraction. Patients with thrombus in the left atrium on transesophageal echo, but not spontaneous contrast, are excluded<sup>14</sup>.

At InCor, indications for AF ablation have been changing over the last years with the experience

accumulated by the group. Current candidates are patients with symptomatic paroxysmal or persistent AF for a minimum of six months, refractory to at least two anti-arrhythmic drugs, after potentially triggering conditions, such as hyperthyroidism and excessive alcohol consumption, have been ruled out. AF ablation is avoided in patients with restrictions to oral anticoagulant therapy. Patient's overall clinical condition is an indication determinant, but not age, underlying heart disease, left atrium size, ventricular dysfunction, or previous stroke. Patients with paroxysmal AF and risk factors for thromboembolism, as well as patients with persistent AF, undergo anticoagulation therapy for at least four weeks, INR being maintained between two and three. All patients undergo transesophageal echocardiography prior to the procedure, and those with existent or suspected atrial thrombus are excluded. These patients are maintained on oral anticoagulation for four to six weeks, and transesophageal echo is repeated before intervention. Permanent AF ablation has been considered for young patients with the left atrium <55 mm, especially those with poorly controlled ventricular response or progressive LV dilation and/or LV ejection fraction decrease.

## CONCLUSIONS

Radiofrequency atrial fibrillation ablation aims, basically, at enhancing the patient's quality of life. The primary purpose of the several AF ablation techniques currently used is the curative treatment of the patient; however, in some situations only a partial control is achieved. In such cases, the combination of anti-arrhythmic drugs affords a quite satisfactory clinical condition for the majority of the patients. AF catheter ablation is a safe procedure if performed within the recommended patterns. Its complications vary according to the technique used and the experience of the interventional group. Its benefits depend on the clinical characteristics of the patients.

## REFERÊNCIAS

- Nath S, Haines DE. Biophysics and pathology of catheter energy delivery systems. *Prog Cardiovasc Dis* 1995;37:185-204.
- Grubman E, Pavri BB, Lyle S et al. Histopathologic effects of radiofrequency catheter ablation in previously infarcted human myocardium. *J Cardiovasc Electrophysiol* 1999;10:336-42.
- Nakagawa H, Yamanashi W, Itha JV et al. Comparison of in vivo tissue temperature profile and lesion geometry for radiofrequency ablation with saline-irrigated electrode versus temperature control in a canine thigh muscle preparati. *Circulation* 1995;91:2264-73.
- Bunch TJ, Bruce GK, Johnson SB et al. Analysis of Catheter-tip (8-mm) and actual tissue temperatures achieved during radiofrequency ablation at the orifice of the pulmonary vein. *Circulation* 2004;110:2988-95.
- Nath S, Redick JA, Whayne JG, Haines DE. Ultrastructural observations in the myocardium beyond the region of acute coagulation necrosis following radiofrequency catheter ablation. *J Cardiovasc Electrophysiol* 1994;5:838-45.
- Marrouche NF, Martin DO, Wazni O et al. Phased-array intracardiac echocardiography monitoring during pulmonary vein isolation in patients with atrial fibrillation: impact on outcome and complications. *Circulation* 2003;107:2710-6.
- Jais P, Haissaguerre M, Shah DC et al. A focal source of atrial fibrillation treated by discrete radiofrequency ablation. *Circulation* 1997; 95:572-6.
- Haissaguerre M, Jais P, Shah DC, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. *N Engl J Med* 1998;339:659-66.
- Chen SA, Hsieh MH, Tai CT et al. Initiation of atrial fibrillation by ectopic beats originating from the pulmonary veins: electrophysiological characteristics, pharmacological responses, and effects of radiofrequency ablation. *Circulation* 1999;100(18):1879-86.
- Lin Ws, Tai CT, Hsieh MH et al. Catheter ablation of paroxysmal atrial fibrillation initiated by non-pulmonary vein ectopy. *Circulation* 2003;107:3176-83.



11. Pappone C, Oreto G, Lamberti F et al. Catheter ablation of paroxysmal atrial fibrillation using a 3-D mapping system. *Circulation* 1999;14:1203-8.
12. Pappone C, Rosanio S, Oreto G et al. Circumferential radiofrequency ablation of pulmonary vein ostia: a new anatomic approach for curing atrial fibrillation. *Circulation* 2000;102:2619-28. Pappone 2002
13. Pappone C, Santinelli V, Manguso F et al. Pulmonary vein denervation enhances long-term benefit after circumferential ablation for paroxysmal atrial fibrillation. *Circulation* 2004;109:327-34.
14. Verma A, Marrouche NF, Natale A. Pulmonary vein antrum isolation: intracardiac echocardiography-guided technique. *J Cardiovasc Electrophysiol* 2004;15:1335-40.
15. Scanavacca MI, Kajita LJ, Vieira M, Sosa EA. Pulmonary vein stenosis complicating catheter ablation of focal atrial fibrillation. *J Cardiovasc Electrophysiol* 2000;11(6):677-81.
16. Saad EB, Marrouche NF, Saad CP et al. Pulmonary vein stenosis after catheter ablation of atrial fibrillation: Emergence of a new clinical syndrome. *Ann Intern Med* 2003;138-634-638.
17. Haissaguerre M, Jais P, Shah DC et al. Electrophysiological end point for catheter ablation of atrial fibrillation initiated from multiple pulmonary venous foci. *Circulation* 2000;101:1409-17.
18. Scanavacca M, Sartini R, Tondato F et al. Pulmonary veins isolation to treat patients with refractory paroxysmal atrial fibrillation: clinical results after a single procedure. *Arq Bras Cardiol* 2004;82(2):160-4, 155-9.
19. Macle L, Jais P, Weerasooriyav R et al. Irrigated-tip catheter ablation of pulmonary veins for treatment of atrial fibrillation. *J Cardiovasc Electrophysiol* 2002;13:1067-73.
20. Hocini M, Sanders P, Jais P et al. Techniques for curative treatment of atrial fibrillation. *J Cardiovasc Electrophysiol* 2005;15:1467-71.
21. Jais P, Hocini M, Hsu LF et al. Technique and results of linear ablation at the mitral isthmus. *Circulation* 2004;110:2996-3002.
22. Hsu LF, Jais P, Hocini et al. Incidence and prevention of cardiac tamponade complicating ablation for atrial fibrillation. *Pacing Clin Electrophysiol* 2005;28:S106-9.
23. Oral H, Scharf C, Chugh A et al. Catheter ablation for paroxysmal atrial fibrillation: segmental pulmonary vein ostial ablation versus left atrial ablation. *Circulation* 2003;108(19): 2355-60.
24. Pappone C, Oral H, Santinelli V. Atrio-esophageal fistula as a complication of percutaneous transcatheter ablation of atrial fibrillation. *Circulation* 2004;109(22):2724-6.
25. Scanavacca MI, D'Avila A, Parga J, Sosa E. Left atrial-esophageal fistula following radiofrequency catheter ablation of atrial fibrillation. *J Cardiovasc Electrophysiol* 2004;15(8):960-2.
26. Pappone C, Santinelli V. The who, What, Why, and How – To Guide for Circumferential Pulmonary Vein Ablation. *J Cardiovasc Electrophysiol* 2004;1226-30.
27. Marrouche NF, Dresing T, Cole C et al. Circular mapping and ablation of the pulmonary vein for treatment of atrial fibrillation: impact of different catheter technologies. *J Am Coll Cardiol* 2002;40(3):464-74.
28. Nademanee K, McKenzie J, Kosar E et al. A new approach for catheter ablation of atrial fibrillation: mapping of the electrophysiologic substrate. *J Am Coll Cardiol* 2004 Jun 2;43(11):2044-53.
29. Pachón M JC, Pachón M EI, Pachón M JC. A new treatment for atrial fibrillation based on spectral analysis to guide the catheter RF-ablation. *Europace* 2004;6(6):590-601.
30. Nakagawa JA, Scherlag BJ, Wu R et al. Addition of selective ablation of autonomic ganglia to pulmonary vein antrum isolation for treatment of paroxysmal and persistent atrial fibrillation. *Circulation* 2004;110:17(III-543) 2531.
31. Cappato R, Calkins H, Chen SA et al. Worldwide survey on the methods, efficacy, and safety of catheter ablation for human atrial fibrillation. *Circulation* 2005;111:1100-5.
32. Diretrizes para avaliação e tratamento de pacientes com arritmias cardíacas. DAEC-SBC. *Arq Bras Cardiol* 2002;79:1-50.