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REVIEW / *Cardiovascular imaging*

Imaging before and after catheter ablation of atrial fibrillation

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Abstract Catheter ablation of arrhythmogenic triggers has been validated for the treatment of atrial fibrillation that is refractory to anti-arrhythmic medication. Imaging plays an important role in guiding the procedure as well as in planning and follow-up. The goal of pre-procedural imaging is to obtain a detailed anatomical description of the pulmonary veins, to eliminate a thrombus of the left atrium and to define the prognostic factors. MDCT angiography effectively and simply meets nearly all of these needs. Thus, a precise description of the left atrium anatomy before the procedure is a key factor to success and left atrium volume is a reliable prognostic factor of recurrence. Radiologists should be aware of early and late complications, sometimes severe such as pulmonary vein stenosis, cardiac tamponade or atrial-esophageal fistula, whose positive diagnosis is based on imaging.

Since the 1990s and the preliminary study of Haïssaguerre et al. [1], catheter ablation of left atrial arrhythmogenic triggers has become a valid option for the treatment of atrial fibrillation (AF) that is refractory to classic antiarrhythmic medications. Besides peri-procedural guidance, imaging also plays a essential role in planning and follow-up [2].

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The goals of this review are to describe the physiological bases of AF and the methods of catheter ablation, to define imaging acquisition and post-treatment protocols for multidetector computed tomography (MDCT) angiography of the pulmonary veins, to identify the morphological and prognostic information that should be obtained to plan the procedure and to define post-therapeutic follow-up imaging modalities.

Catheter ablation of atrial fibrillation

Physiopathology of atrial fibrillation

AF is the most frequent heart rhythm disorder, affecting 5% of patients over the age of 65 and up to 10% over the age of 80 years [3]. The clinical symptoms of this supraventricular tachycardia characterized by chaotic atrial activity are dyspnea, palpitations, and more rarely loss of consciousness. It may also be revealed by an initial complication (stroke, heart failure). The positive diagnosis is made by electrocardiogram (ECG), which shows an irregular rhythm with no visible P waves, replaced by an irregular baseline wave, which is a sign of chaotic electric atrial activity (Fig. 1).

There are four types of AF depending on the duration of the episode [4,5]. They include:

- paroxysmal AF, which generally lasts less than 48 hours, and always less than seven days;
- persistent AF, which lasts more than seven days or requires pharmacological cardioversion;
- longstanding persistent AF, which lasts more than a year;
- permanent AF, which is accepted by the cardiologist and for which no cardioversion is considered [6].

The physiopathology of AF is complex and requires a trigger as well as a substrate to become chronic [7]. Triggers are arrhythmogenic zones that are mainly found around the ostia of the pulmonary veins (PV), but that may also be found around the superior vena cava or the coronary sinus. AF results in electric and structural endomyocardial remodeling (alterations of the extracellular matrix and myocytes) leading to a myofibroblastic proliferation with fibrosis, causing zones of slow conduction and atrial electric conduction disturbances. This remodeling and fibrosis result in re-entry circuits [8] and chronic AF. The pathophysiology of persistent and permanent AF seems to be even more complex, involving cardiac innervation [9] as well as certain anatomical structures such as the ligament of Marshall [10] or the rotors [11—13], which are electric ''wavelets'' that are propagated in certain atrial regions.

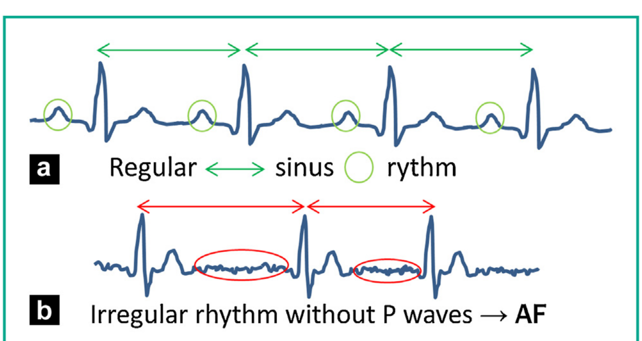

Figure 1. Schematic ECG in a patient with regular sinusoidal rhythm (a) and in a patient with atrial fibrillation (b), with irregular oscillation of the baseline and absence of P waves.

Destruction of these electric or anatomical abnormalities by isolation of the PV and ablation of the left atrial substrate can eliminate arrhythmia and is the basis of curative ablation techniques [14].

Principles of catheter ablation

There are two main indications for technical ablation of AF. One is symptomatic paroxysmal AF that does not respond to optimal anti-arrhythmic medication (grade Ia), or prior to the initiation of an antiarrhythmic drug in voluntary patients (grade IIa). The other is symptomatic persistent AF refractory or intolerant to medical treatment (grade IIa) [4,5,7].

Goals of catheter ablation

The goal of catheter ablation of AF is twofold [7]. First, to obtain circumferential isolation of the PV (ostium and antrum) to electrically isolate the focal triggers initiating the AF. This first step is essential and is often sufficient in paroxysmal AF. Second, to obtain a fragmentation and compartmentalization of the left atrium (LA). This non-standardized step is usually required in persistent AF. Linear defragmentation involves radiofrequency thermoablation of so-called fragmented zones exhibiting Complex Fractionated Atrial Electrograms (CFAE) or rotors [12,13,15]. The creation of linear lesions within the LA (roof, mitral isthmus) resulting in a compartmentalization could help prevent the propagation of these rotors, which participate in the development of chronic AF.

If they are correctly performed, these procedures have an excellent short-term success rate of between 75 and 90% [7,16] with, however, retreatment necessary in more than 25%. The long-term efficacy is still a subject of debate due to possible late recurrence. The best results are obtained in paroxysmal AF [17].

Description of the procedure

The procedure is performed in an interventional cardiology room, under fluoroscopic guidance with optional transesophageal echocardiographic control [18]. The procedure can be performed under general or local anesthesia depending on the usual practices of the medical team. These are complex procedures that last two to five hours.

The first step involves guiding the different catheters with vascular access through the right femoral vein via the inferior vena cava into the right atrium, then into the LA after transseptal puncture. The operator positions the different catheters (lasso and ablation) in the LA as well as a catheter in the coronary sinus. An esophageal temperature probe can be used in sedated patients to mark the position and indicate the temperature.

The second step is the 3D mapping of the LA using the circumferential lasso (Fig. 2a), whose position is determined by the navigation system on real time. Through repetitive contact, it reconstructs the walls of the LA in a 3D model. In the most recent workstations equipped with mapping