Percutaneous ablation of atrial fibrillation: for whom and how?

Atriyal fibrilasyonun perkütan ablasyonu: Kime ve nasıl?

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ABSTRACT

Recent development in our understanding of atrial fibrillation (AF) have focused on the key role of pulmonary vein initiators of multiple wavelet reentry in the atria.

Percutaneous catheter ablation of atrial fibrillation is commonly performed by electrical disconnection of pulmonary vein myocardium from the left atrium. As a result, pulmonary vein foci can no longer drive the atria into fibrillation.

At present, the procedure is offered to patients with paroxysmal atrial fibrillation refractory to multiple antiarrhythmic agents. For patients with persistent atrial fibrillation, supplementary linear lesions in the left atrium may be necessary. Success rates (AF elimination) are 90% without drugs in case of paroxysmal atrial fibrillation and 80% for persistent atrial fibrillation. Complications including pulmonary vein stenosis are uncommon. *(Anadolu Kardiyol Derg 2006; 6: 68-73)*

Key words: Atrial fibrillation, radiofrequency ablation, pulmonary vein ectopy

ÖZET

Atriyal fibrilasyon (AF) anlayışımızda son gelişmeler pulmoner venlerin atriyumlarda çoklu "wavelet reentry"nin tetikleyici anahtar rolünde yoğunlaşmıştır. Atriyal fibrilasyonun perkütan kateter ablasyonu genellikle pulmoner ven miyokardının sol atriyal miyokardından elektriksel bağlantısının kesilmesi ile yapılmaktadır. Sonuçta, pulmoner ven odakları atriyumların fibrilasyona girmelerini sağlamaz. Bugünlerde, bu prosedür çoklu antiaritmik ilaçlara refrakter olan paroksizmal AF'li hastalara önerilmektedir. Persistan AF'li hastalar için ek olarak sol atriyumda lineer lezyonların yaratılmasına ihtiyaç duyulabilir. Başarı oranı (AF eliminasyonu) ilaçsız paroksizmal AF'li olgular icin %90 ve persistan AF için - %80'dir. Pulmoner ven darlığı ile beraber olan komplikasyonlar nadirdir. *(Anadolu Kardiyol Derg 2006; 6: 68-73)*

Anahtar kelimeler: Atriyal fibrilasyon, radyofrekans ablasyonu, pulmoner ven ektopisi

Introduction

The very first results of percutaneous ablation of atrial fibrillation (AF), imitating surgical Maze procedure were inconclusive (1). Electrophysiologic mapping data revealed the importance of atrial myocardial cells within the pulmonary veins (PV) as foci of initiators of atrial fibrillation (2). Percutaneous ablation was therefore developed to neutralize the arrhythmogenicity of the pulmonary veins. Today these techniques are being offered to increasing numbers of patients with atrial fibrillation.

Pulmonary Veins: Anatomy and Physiology

Pulmonary venules at the periphery of lungs join together to form pulmonary veins. The wall of a pulmonary vein consists of a fine layer of endothelium, the media is composed of smooth muscle cells and fibrous tissue, and outermost is a fibrous layer of adventitia.

The endocardium of the left atrium continues within the inner wall of pulmonary vein. A cuff of atrial myocardium also extends into proximal part of the pulmonary vein and interspersed with a layer of smooth muscle fibers of the pulmonary vein. These are extensions of atrial muscles into pulmonary veins, which are present in nearby all pulmonary veins, but are especially important at the level of superior pulmonary veins when compared to inferior pulmonary veins. These extensions become smaller and well separated in the pulmonary vein, as pulmonary veins are segmented into smaller branches.

Arrangement of muscular fibers within the cuff plays an important role in the electrophysiologic property. The myocytes arranged in circular and spiral pattern interconnect each other, but they equally make connections with other fibers in oblique and longitudinal orientation (3).

Imaging of Pulmonary Veins

Anatomy of the PVs differ in different subjects, in addition each PV differs in size, position of the ostium and branching pattern even in the same individual.

Imaging of the pulmonary veins with angiography reveals their anatomy well enough to facilitate performance of an electrophysiologic study or ablation.

Computerised tomography or magnetic resonance imaging can also be utilised with success before and after the procedure. Noninvasive nature and ability of applicability of 3 dimensi-

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onal images makes these tests advantageous in pre-interventional preparation of the patients and also as follow up after the intervention. Magnetic resonance imaging when compared to computerised tomography has an advantage of applicability in hemodynamically compromised patients and in renal insufficiency patients by avoiding contrast agents. But it cannot be used in patients with cardiac pace makers and other metallic implants which are common in patients with heart diseases.

The most important issue in imaging the pulmonary veins is the diameter of PVs, their number and localisation of their ostia. Intracardiac echocardiography can provide these data. Determination of the size of the PV is very important to be able to optimise use of circular mapping catheter. For the operator performing angiography it is very important not to miss any ostia. In fact, while selective angiography can reveal the ostia near the catheter a CT scan or MRI scan can show all the pulmonary vein ostia.

Electrophysiology of the Pulmonary Veins

The myocardial tissue within the pulmonary veins, is electrically active. It is continuous proximally with left atrial myocardium, and distally it continuous for a few centimetres from veno-atrial junction up to first branches of pulmonary veins. As a consequence, in sinus rhythm, activation occurs in "cul-de sac" fashion distally into pulmonary veins, whereas an ectopy from the pulmonary veins results in activation propagating into the adjacent atrial myocardium.

Sharp potentials (high dv/dt, short duration) with a long activation time and proximal preceding distal activation sequence within pulmonary veins are characteristics of myocardial potentials in the pulmonary veins during sinus rhythm (4). Their disappearance after proximal (ostial) ablation constitutes a reliable endpoint of successful PV isolation.

Recently the use of pre-shaped circular mapping catheters showed that specific segments of the PV circumference are activated before other segments, resulting in asymmetric activation in pulmonary veins (5), but mechanism of arrhythmogenecity of the myocardial cells within the pulmonary veins remains to be clarified.

Because of slow and decremental conduction pattern in the pulmonary vein ostia (2,6) , there is a significant heterogenicity in refractory periods. This heterogenicity may cause the veno-atrial junction to serve as a substrate for re-entry. In sinus rhythm, primary activation of a typical ectopic beat follows sinus beat about 100-200 ms later. Activation within the pulmonary veins compatible with re-entry in pulmonary veins may spread to veno-atrial junction and thereafter to the left atrium. In patients with a dilated left atrium, pulmonary veins, other great veins and atrial myocardium may play a role in initiation and continuation of persistent atrial fibrillation.

Recent observations showing termination of paroxysmal AF during PV isolation suggest that peri-PV-ostial reentry may be responsible for maintenance of this type of atrial fibrillation, a mechanism distinct from its initiation.

Veno-Atrial Junction

The pulmonary vein-left atrial junction cannot be distinguished from the surrounding atrial myocardium even anatomically or histologically. Therefore other characteristics have been clinically utilised for its identification.

Maximal change in the diameter of the vein can be used as an indicator: the intersection of tangents drawn from the pulmonary vein and left atrium (LA) is used as a marker (7).

This diameter criterion can be applied to all imaging techniques used for identification of the ostium. Moreover, this method has an advantage of being simple and applicable.

Typically, the extracellular potentials generated by myocardial cells within the pulmonary veins show a sharp dv/dt and a short duration of activation (as compared to atrial myocardium) so that change in these characteristics may be used for identification of pulmonary veno-atrial junction.

The optimal level at which the pulmonary vein should be isolated is not well known, so ablation is often performed as proximally as possible and certainly more proximal than the site of earlier activation during an ectopic beat.

In the absence of arrhythmia or during sustained atrial fibrillation an arbitrary designation of the PV-LA junction is accepted for ablation. In our laboratory, we utilise morphological characteristics, such as a change in the PV diameter and additionally eliminate ostial sharp potentials in the vicinity.

Pulmonary Vein Ablation

In patients with frequent or nonsustained arrhythmias like isolated ectopics and short episodes of paroxysmal atrial fibrillation, it is possible to map and localise the exact site of earlier activation (8). It is clear that focal mapping techniques (like those utilised for atrial tachycardias) are difficult or even impossible in the absence of sufficient arrhythmic beats or during sustained atrial fibrillation, and the risk of creating hemodynamically significant stenosis is higher when ablation is performed inside the PVs (away from the PV-LA junction).

Isolation of the myocardium within pulmonary veins, which are actually or potentially responsible for arrhythmogenicity can be carried out during sinus rhythm.

When electrophysiologically guided ostial ablation is performed, the local activation in pulmonary vein is either retarded or disappears as shown in Figures 1 and 2. Typically, all activity in pulmonary veins distal to the level of ablation is eliminated. Though atrial potentials may persist, voltage of residual activities originating distally is not a reliable criterion of successful isolation (4,9).

In practice, using the above-mentioned technique, isolation of the majority of PVs can be carried out successfully without prolonging the duration of the procedure and without multiple cardioversions even during sustained atrial fibrillation (10). All pulmonary veins are anatomical targets given that most of the (>90%) initiating ectopics arise from any or each of these pulmonary veins though there may be multiple ectopies from different pulmonary veins at the same time.

Complications of Pulmonary Vein Isolation

Thromboemboli and air embolism can be prevented by careful attention to detail and correct technique in isolation of pulmonary veins. Continuous irrigation of the long sheath and ablation catheter as well as appropriate use of heparin further decreases the risk of embolic events.

It is well known from the experimental studies that, the magnitude of radiofrequency energy delivered to the tissues is res-

ponsible for pulmonary vein stenosis (11,12). High radiofrequency energy delivered to tissues, as well as extensive and too distal ablation favours future stenosis. Long-term rates of stenosis are thought to be low (1-2%) so it is unclear whether patients need long term surveillance.

Presence of signs and symptoms of pulmonary vein hypertension, even exertional or rest dyspnea should lead to enough investigation for pulmonary vein stenosis. Balloon dilatation may ameliorate symptoms in significant stenosis but restenosis rates are high.

Pulmonary vein isolation creates zones of scar at the PV ostia, which can serve as central obstacles for a reentrant circuit. As a result nearly 10% of patients may develop macro-reentrant flutter originating in the LA.

Effects of Pulmonary Vein Isolation on Atrial Fibrillation

Recent data shows that results of pulmonary vein isolation for atrial fibrillation are better for paroxysmal than persistent or permanent atrial fibrillation. Eighty five percent or more of patients with paroxysmal atrial fibrillation can be cured with successful isolation of all 4 pulmonary veins. Anatomical encircling ablation of all 4 ostia with the aid of mapping systems may result in similar cure rates in a large cohort of patients with persistent atrial fibrillation (13).

Adjunctive Ablation Techniques

Residual arrhythmia after isolation of 4 veins suggests either the presence of triggers outside of the ablated zone or presence of a substrate for maintenance of sustained atrial fibrillation.

Mapping shows most of the residual localisable triggers (ectopics and non sustained arrhythmias). In most cases, they originate from the posterior left atrial wall in close proximity to pulmonary veins. Certain but not all, may arise from the border of zone ablated.

Too distal ablation of the PVs may spare proximal arrhythmogenic myocardium in the proximal (ostial) pulmonary veins resulting in a recurrence of arrhythmias.

The right atrium, great veins such as superior vena cava (14), and coronary sinus may be regarded as other sites responsible for arrhythmias. Marshall's ligament, which is a remnant of Marshall's vein (the future left common cardinal vein) is atretic in most of the patients, but in some cases it may persist (as the left persistent SVC) and may serve as a trigger for atrial fibrillation (15). Without documented arrhythmogenicity, ablation of the SVC or the vein of Marshall is usually unnecessary.

Ablation of Left Atrium

The electrophysiological rationale for linear ablation still remains unclear because EP data from successful surgical Maze

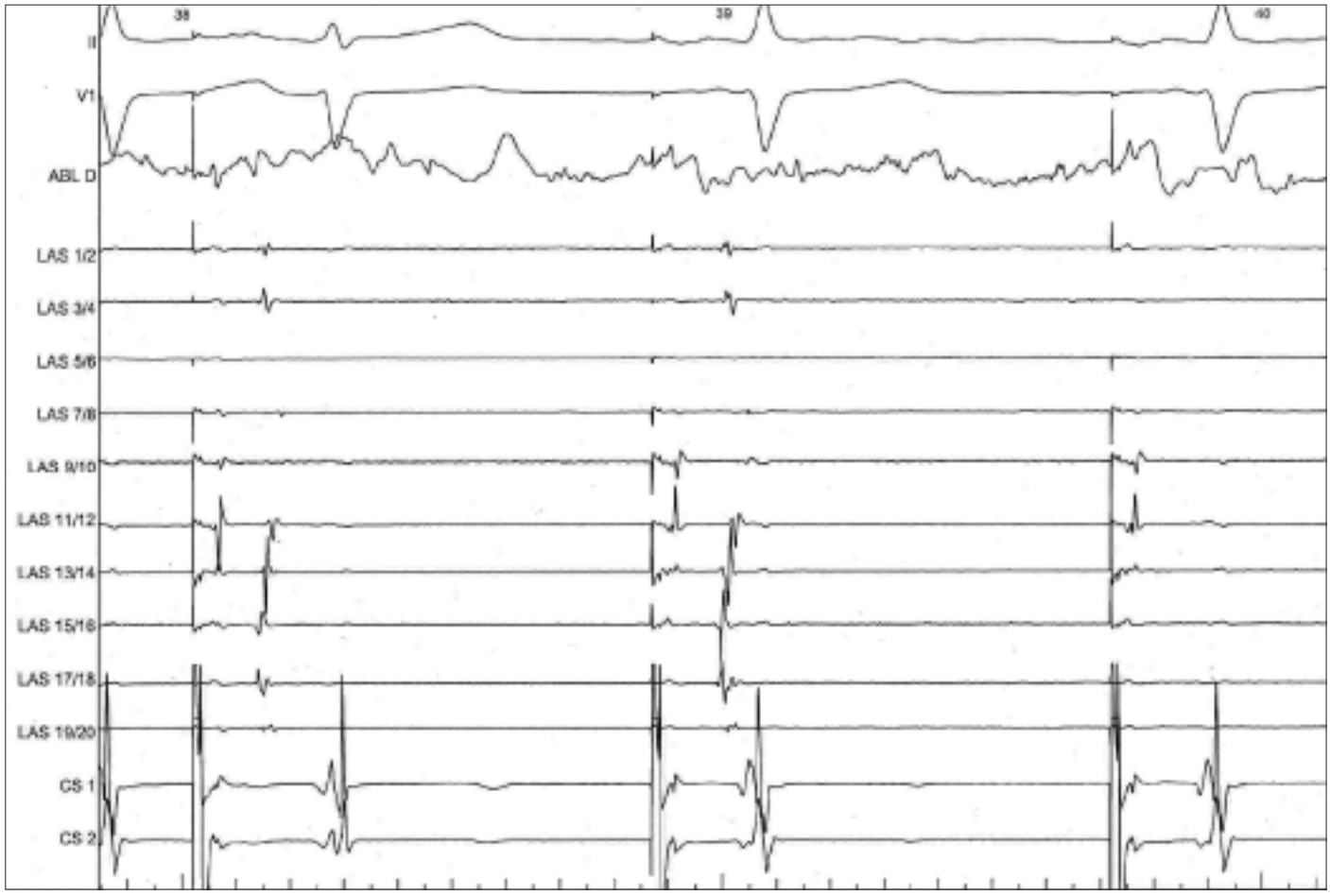

Figure 1. Disappearance of pulmonary vein potentials during radiofrequency ablation in the left superior pulmonary vein

procedures or equivalent catheter techniques using linear ablation are limited. The exact mechanisms responsible for diminishing or eliminating atrial fibrillation with these lesions still unknown. Available data shows that such linear lesions prolong activation times in the atrium and block anatomically defined reentry or reduce "wandering routes". It can even slow conduction velocities eliminate pivot points or widen excitable "gap".

Lesions causing minimal alterations of activation during sinus rhythm and leaving as much functional atrial tissue as behind is preferable.

Most linear lesion based LA ablation strategies have used to advantage the PV ostia as anchor points in the posterior LA. The longer complete linear lesion probably is that extending from the right inferior PV to successively join the ostia of the right superior PV, left superior PV and left inferior PV before reaching the posterior mitral annulus. These lesions producing complete conduction block along their length, can prevent anatomically based reentry around the PV ostia and/or mitral annulus.

Clinical Experience in Ablation of Atrial Fibrillation in Geneva

Between January 2002 and September 2005, percutaneous radiofrequency ablation has been performed on 226 patients. Mean age of patients was 56±9 years and forty six were female. One hundred sixty four patients had paroxysmal AF while the remaining had persistent/permanent AF. In all procedures cooled tip radiofrequency ablation catheters were used with a maximal energy delivered during the procedure being 35-45 Watts. In all patients mapping guided pulmonary vein isolation was routinely performed. In case of accompanying atrial flutter, cavotricuspid isthmus ablation also performed. Left atrial linear ablation (with 3D map validation) was utilised as an adjuvant therapy only for persistent atrial fibrillation or AF recurring despite successful pulmonary vein isolation.

Among 226 patients who are being followed up, 176 reached a follow-up period of ≥6 months (patients ablated before February 2005). The results shown here belong to these patients followed more than 6 months. As shown in Table 1, of 176 patients, 144 (82%) were male. Their mean age was 56±9 years. One hundred twenty seven of the patients (72%) underwent ablation for paroxysmal AF, while 49 (28%) were ablated for persistent AF. All the patients were resistant to one or more antiarrhythmic drugs. Structural heart disease was found to be present in 20 (11%), cerebrovascular emboli - in 9 (5%) and typical atrial flutter - in 67 (38%) patients before ablation. Overall, 219 procedures were performed in all patients (1.2±0.6 procedure/patient). Complications included one reversible ischemic neurological

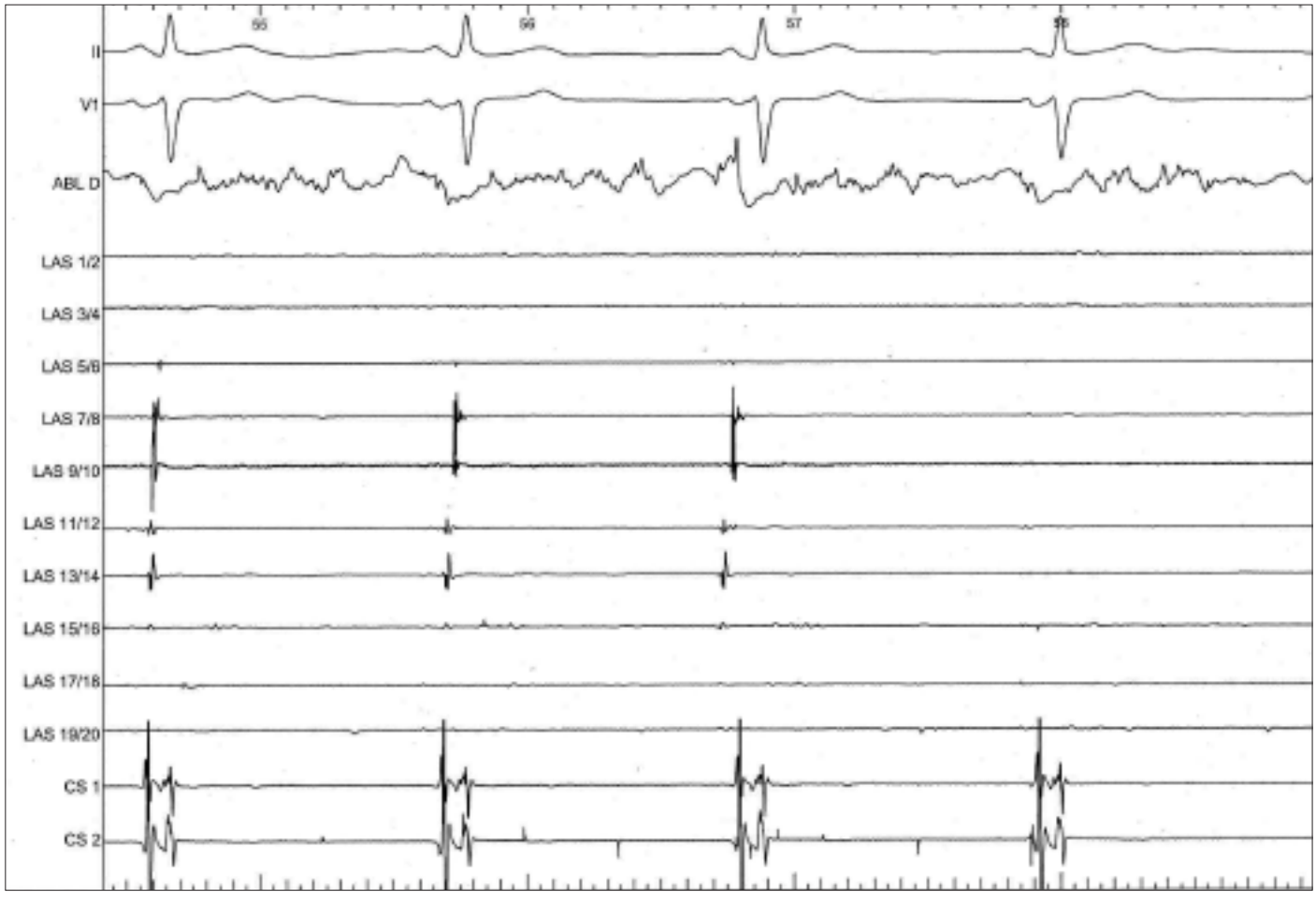

Figure 2. Disappearance of pulmonary vein potentials during radiofrequency ablation in the right superior pulmonary vein

deficit, 3 tamponade (drained percutaneously), 3 asymptomatic pulmonary vein stenosis and gastroparesis in 2 patients.

As shown in Table 2 in paroxysmal AF patients mean left atrium size and volume were 40±6 mm and 62±23 ml, respectively. Median number of procedures performed per patient was 1.2, mean total procedure time was 180±42 minutes, fluoroscopy time- 52±16 minutes and radiofrequency time - 49±17 minutes. In 8 patients (6%) only additional linear left atrial ablation was performed. Cavotricuspid isthmus ablation was performed in 60 (47%) patients. By the end of 18±8 (6-43 months) months of follow-up 109 (86%) of patients with paroxysmal AF were in stable sinus rhythm without antiarrhythmic drugs.

In the forty-nine patients with persistent AF (Table 2), structural heart disease was present in 9 patients (18%). Mean LA diameter and volume were 46±5 mm and 109±24 ml, respectively. Mean 1.3±0.7 procedures were performed per patient with total procedure time of 229±65 minutes. Supplementary linear left atrial ablation was performed in 41 (84%) patients including left pulmonary vein-mitral line in 41 and left pulmonary vein-right pulmonary vein line in 30 patients. Cavotricuspid isthmus ablation was performed in 9 (18%) patients. By the end of 15±6 (6-42) months, 41 (84%) of patients were in stable sinus rhythm without antiarrhythmic drugs.

Table 1. Demographic data of patients underwent ablation for atrial fibrillation in the University Hospital of Geneva between January 2002 and September 2005

Total number of patients, n	226
Mean age, years	56±9
Paroxysmal atrial fibrillation, n/%	164/73
Persistent/permanent atrial fibrillation, n/%	62/27
Follow-up ≥6 months, n	176 patients
Mean age, years	56±9
Male, n/%	144/82
Female, n%	32/18
Paroxysmal atrial fibrillation, n/%	127/72
Persistent atrial fibrillation, n/%	49/18
Structural heart disease, n/%	20/11
Cerebrovascular emboli, n/%	9/5
Typical flutter, n/%	67/38

Conclusion

At present, pulmonary vein isolation represents a routine and effective treatment for eliminating paroxysmal atrial fibrillation. Particularly for patients with persistent/permanent atrial fibrillation, adjuvant strategies including left atrial linear ablation or other forms of substrate alteration will be necessary. The long-term prognostic effect of eliminating atrial fibrillation needs to be clarified.

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Table 2. Differences in the laboratory characteristics of patients with paroxysmal and persistent atrial fibrillation

	Paroxysmal AF	Persistent/Permanent AF
Number of patients, n	127	49
Mean age, years	56±9	58±9
Follow up, months (range)	18±8 (6-43)	15±6 (6-42)
LA diameter, mm	40±6	46±5
LA volume, ml	62±23	109±24
Procedure time, min	180±42	229±65
Fluoroscopy time, min	52±16	65±19
Radiofrequency time, min	49±17	49±24
Linear LA ablation, n/%	8/ 6	41/ 84
Cavotricuspid isthmus ablation, n/%	60/47	9/18
Atypical flutter ablation, n/%	9 /7	17/35
Stable sinus rhythm, n/%	109/86	41/84

Continuous variables are presented as ``mean+standard deviation``
AF - atrial fibrillation, LA- left atrium

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