Treatment of Atrial Fibrillation with Radiofrequency Ablation and Simultaneous Multipolar Mapping of the Pulmonary Veins

Almino C. Rocha Neto, Roberto Lima Farias, Angelo A. V. de Paola

São Paulo, SP - Brazil

Objective *- To demonstrate the feasibility and safety of simultaneous catheterization and mapping of the 4 pulmonary veins for ablation of atrial fibrillation.*

Methods *- Ten patients, 8 with paroxysmal atrial fibrillation and 2 with persistent atrial fibrillation, refractory to at least 2 antiarrhythmic drugs and without structural cardiopathy, were consecutively studied. Through the transseptal insertion of 2 long sheaths, 4 pulmonary veins were simultaneously catheterized with octapolar microcatheters. After identification of arrhythmogenic foci radiofrequency was applied under angiographic or ultrasonographic control.*

Results *- During 17 procedures, 40 pulmonary veins were mapped, 16 of which had local ectopic activity, related or not with the triggering of atrial fibrillation paroxysms. At the end of each procedure, suppression of arrhythmias was obtained in 8 patients, and elimination of pulmonary vein potentials was accomplished in 4. During the clinical follow-up of 9.6±3 months, 7 patients remained in sinus rhythm, 5 of whom were using antiarrhythmic drugs that had previously been ineffective. None of the patients had pulmonary hypertension or evidence of stenosis in the pulmonary veins.*

Conclusion *- Selective and simultaneous catheterization of the 4 pulmonary veins with microcatheters for simultaneous recording of their electrical activity is a feasible and safe procedure that may help ablation of atrial fibrillation.*

Key-words: atrial fibrillation, pulmonary veins, radiofrequency catheter ablation

Universidade Federal de São Paulo - UNIFESP
Mailing address: Almino C. Rocha Neto - EPM - Section of Clinical Electrophysiology - Rua Napoleão de Barros, 593 - 04024-002 - São Paulo, SP, Brazil - E-mail: cardiologia.dmed@epm.br

Atrial fibrillation is the most common sustained arrhythmia and may occur in up to 5.9% of the population older than 65 years [1]. Its morbidity is not only related to thromboembolic phenomena but also to the loss of atrioventricular synchronism and maintenance of a high cardiac rate. The available therapeutic options are still limited [2-11], and this arrhythmia is one of the greatest challenges to techniques that use radiofrequency catheter ablation [12-14].

Recent studies developed by Haïssaguerre [15-23] have demonstrated that most atrial fibrillation paroxysms are triggered by premature atrial depolarizations originating inside the pulmonary veins. Its anatomic pathological substrate is striated bundles originating in the left atrium, penetrating into the pulmonary veins with variable course and depth. The correct identification of these foci allows the efficacious utilization of radiofrequency ablation techniques for treating this arrhythmia.

Despite the promising initial results, focal ablation still has a significant relapse rate [24-26] and unknown risk of stenosis in the pulmonary veins [27-33]. One of the limitations of focal ablation is the need for sufficient number of premature atrial depolarization to occur. Often the arrhythmogenic source remains quiescent so that not enough ectapy is present to allow mapping of the pulmonary veins. Another important operational difficulty is the fact that the mapping area encompasses a wide vascular net, with complex ramifications, frequent anatomical variations, and multiple unpredictable triggering capacities [19,34,35].

In an attempt to minimize the difficulties still found in the focal ablation procedures for atrial fibrillation, we accomplished electrophysiological mapping through the simultaneous catheterization of the 4 pulmonary veins, under angiographic control of the sites where radiofrequency was applied. The objective of this study was to report the initial results obtained in our experience using this technique, also emphasizing the unique characteristics of electrograms recorded inside the pulmonary veins in sinus rhythm and in the different types of ectopic activity.

Methods

From October 1998 to December 1999, 10 patients were consecutively studied, 9 men, with an average age of 42±11 years, with paroxysmal (8 patients) or persistent (2 patients) atrial fibrillation. The average time of symptom onset was 7.0±4.9 years and median duration of the last episode of atrial fibrillation was approximately 2 weeks. The initial selection criteria included the presence of symptomatic paroxysmal atrial fibrillation with periodicity of at least 1 weekly episode (present in 6 patients), the number of supraventricular premature atrial depolarization recorded by the Holter above 2000 in 24h, "P on T" pattern, refractoriness to at least 2 antiarrhythmic drugs, absence of structural cardiopathy and atrial thrombosis. All patients had normal left atrium measurement (38±6mm). Four patients, who had a smaller frequency of paroxysms (3/month in 1 patient and 2/month in 3 patients), were later included in the study, because they exhibited frequent periods of short duration atrial tachycardia during sinus rhythm (4 to 8 episodes of 3 to 12 consecutive beats). Seven patients were taking amiodarone.

The antiarrhythmic and oral anticoagulant drugs were suspended 3 days before the procedure, and patients were maintained on low molecular weight heparin. The transesophageal echocardiogram was performed 24h before the examination, in order to exclude eventual thrombus and spontaneous contrast.

Patients underwent an electrophysiological study without sedation. Surface electrocardiogram derivations I, II, avL, and V1 were simultaneously recorded. Polygraphs BARD Electrophysiology LabSystem version 2.56 and Electrophysiologic Measurement System-version 4.0 (Maastricht, Holland) were used and bipolar electrogram recordings with filters of 100 to 500 Hz were obtained.

In the patients with sinus rhythm, the initial step of the procedure consisted of placement of quadripolar electrophysiologic catheters (Daig Co., Minnetonka, MN, USA) in the upper region of the right atrium and in the coronary sinus, which were used for mapping and stimulation. When the number of premature atrial depolarization was insufficient (established by the authors as less than 5/hour), the following provocative maneuvers were performed: Valsalva, massage of the carotid sinus, IV infusion of isoproterenol (2 to 4g/min), adenosine (bolus of 20-80mg), verapamil (10mg), or atrial stimulation (100 to 300 bpm).

The transseptal puncture and catheterization of the pulmonary veins were performed in patients with atrial fibrillation or those with premature atrial depolarization with precocity above 20ms in relation to the reference electrograms, recorded in the catheter previously placed in the right atrium and in the coronary sinus.

After the accomplishment of a transseptal puncture, we proceeded full anticoagulation with sodium heparin IV infusion, administering 5000 IU as a bolus and subsequently 1000 IU /hour.

For transseptal access, a system comprising the Brockenbrough needle and 2 long sheaths (8.5 F, SL1, Daig Co., Minnetonka, MN, USA) were inserted through the fossa ovalis. After placement of the first sheath, a deflectable angiographic catheter (Naviport, Cardima, Fremont, CA, USA) was introduced and selective angiography of the 4 pulmonary veins was accomplished. Following the angiographic study, the interatrial septum was again punctured for placement of the second sheath. The first sheath was then directed to the left pulmonary veins' ostium, from which 2 octapolar microcatheters were introduced (3.3 F, Revelation, Cardima, Fremont, CA, USA) with selective catheterization of the upper and lower pulmonary veins. Similarly, the second sheath directed the other 2 microcatheters to the right pulmonary veins (Fig. 1).

Only after simultaneous catheterization of 4 pulmonary veins, the patients who had atrial fibrillation underwent external electrical cardioversion.

By mapping premature atrial depolarization through microcatheters placed in the 4 pulmonary veins, it was possible to identify the location of ectopic foci. Thus, a pulmonary vein was defined as arrhythmogenic when it gave rise to any type of ectopic activity, initiating or not initiating atrial fibrillation.

Once the origin of an ectopic focal point was located, the diagnostic catheters of the contra-lateral sheath were removed and a 5-mm tip ablation catheter (EP Technologies, San Jose, CA, USA) was directed and radiofrequency was applied during sinus rhythm with a maximum energy limit of 30 watts, temperature of 60°C for a period of 30 to 60s. Except for 2 patients included in the initial phase of the protocol, the applications were made only in the pulmonary veins' ostium, at the points where it was possible to obtain higher ectopic precocity. Caution was taken due to the fact that recent reports demonstrate that the risk of stenosis is directly related to applications on more proximal segments

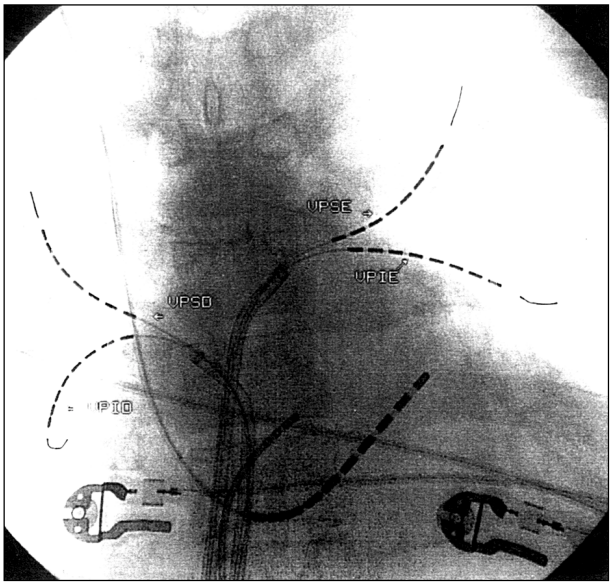

Fig. 1 - Transseptal insertion of 2 long sheaths and selective catheterization with placement of octapolar microcatheters in 4 pulmonary veins. ULPV- upper left pulmonary vein; LLPV- lower left pulmonary vein; URPV- upper right pulmonary vein; LRPV- lower right pulmonary vein.

of the pulmonary veins as well as with the use of higher energy radiofrequency [22,36].

The precise identification of the veno-atrial transition was initially oriented through fluoroscopy, placing the proximal electrodes in the position where microcatheters were separated from the cardiac silhouette on the antero-posterior projection. Subsequently, this position was adjusted by the selective injection of contrast medium in each of the pulmonary veins. The angiographic definition of the ostium was arbitrarily established by the authors as being the intersection point of the first line parallel to the larger axle of the vessel and the second line tangential to the left atrium silhouette on the right and left anterior oblique projections, with an inclination of 30 and 60. In 6 patients, accomplishment of intravascular echocardiography confirmed the placement.

The conclusion of the protocol was established by the absence of ectopic beats and the failure to induce atrial fibrillation, even after the provocative maneuvers described. Considering the possibility of a diagnosis of stenosis soon after application of radiofrequency [22,36], in our protocol we routinely proceeded to control angiography of the ablated pulmonary veins before final removal of the sheaths.

The patients remained hospitalized for at least a period of 72h after each procedure, under full heparinization. After hospital discharge, patients were maintained on oral anticoagulation for at least 3 months.

Results

The recording of activation of the pulmonary veins in sinus rhythm allowed the identification of characteristic atrial electrograms composed of 2 potentials: an initial low frequency one, corresponding to left atrium activation and a terminal spike-shaped fast inscription one, attributed to the passive activation of muscle fibers inside the pulmonary veins, designated as pulmonary vein potentials.

Multipolar longitudinal mapping in sinus rhythm permitted scanning the electrical activation of 32 out of 40 pulmonary veins mapped up to an approximate extension of 38mm from the ostium. At the veno-atrial transition level, the pulmonary vein potential was superimposed on the atrial potential, with a fractional aspect, consisting of several spike potentials. This characteristic morphology was recorded in 15 pulmonary veins (6 left upper pulmonary veins, 6 right upper pulmonary veins, 2 left lower pulmonary veins, and 1 right lower pulmonary vein) and was not related to the presence of local arrhythmogenic activity. However, this unique morphology was absent in all other sites mapped inside the pulmonary veins and left atrium and therefore proved to be a specific marker of the veno-atrial transition region ($p<0.001$).

Farther from the ostium, in the direction of the pulmonary veins' inner side, the pulmonary vein potential was progressively detached from the preceding atrial potential, becoming better visualized (in 32 of the 40 mapped pulmonary veins). Nonetheless, at a variable distance from the ostium, the pulmonary vein potential was no longer recorded, which suggests the presence of a muscular fiber cul-de-sac. In the ostium of the 5 upper left arrhythmogenic pulmonary veins, the potential could not be initially identified because it was completely blended into the atrial potential. In these cases, stimulation of the distal coronary sinus provided a clear separation of the ostium potentials and a better control of the pulmonary vein potential during ablation.

The atrial electrograms were usually followed by electrograms that coincided with the surface QRS complex, referent to the capture of activity far from the ventricles.

An arrhythmogenic pulmonary vein was defined as the one that in any part of its course was capable of producing its own electrical activity, proved by the precocity in relation to the P wave on the surface EEG or reference endocardiac electrogram. This ectopic activity included a spectrum of arrhythmias that might manifest themselves in different ways on the electrocardiogram. The most frequent ectopic forms were the isolated premature atrial depolarizations, bigeminated or coupled. However, in 4 patients, this electrical activity also manifested as short periods of fast repetitive beats, in the form of irregular, unsustained, monomorphic atrial tachycardias.

During the initial electrophysiological study, 7 patients had a small number of premature atrial depolarizations mapped in sinus rhythm, of which 4 responded to maneuvers to induce ectopy as previously described. During the second procedure, 2 patients also had a small number of premature atrial depolarizations, refractory to induction maneuvers.

Characteristically, during ectopy of an arrhythmogenic pulmonary vein, an inversion in order occurred in the atrial electrogram, with the potential of the pulmonary vein preceding the atrial one. Correspondingly, during multipolar mapping, an inversion towards activation occurred, which took the distal to proximal route. The ectopic point of origin (source) was identified as the one with the higher precocity of pulmonary vein potentials and that also had greater detachment from the corresponding atrial potential. The pulmonary vein potential was, then, progressively conducted towards the ostium (exit), where it was easily recognized by the continuity of the morphology of both components, marking the optimum location for application of radiofrequency, where the luminal diameter was larger and, consequently, the risk of stenosis was smaller (Fig. 2).

The premature atrial depolarizations originating in the pulmonary vein had a variable coupling in relation to the preceding sinus beat. The minimum coupling interval observed was 180ms, which remained confined inside the vein, not reaching the atrium, (pulmonary vein blocked potential) with a maximum of 425ms, bestowing on the ectopy a "P on T" electrocardiographic aspect, present in 7 patients. In 3 patients, beats of fusion between the pulmonary veins' sinus and ectopic activities were recorded.

From a total of 40 different pulmonary veins mapped, 16 were shown to be arrhythmogenic: 6 upper right pulmonary veins, 5 upper left pulmonary veins, 3 lower left pulmonary veins, and 2 lower right pulmonary veins. The precoci-

ty of the site of origin in relation to the surface P varied from 40 to 150ms (97±38ms). When it was impossible to identify the P wave, the precocity in relation to the reference catheter in the upper region of the right atrium varied from 56 to 94 ms (83.2±15.40ms). The mean distance of the higher precocity site to the pulmonary veins' ostium was 2.8±1.4mm.

The distinction between arrhythmogenic and nonarrhythmogenic pulmonary veins was defined by the simultaneous catheterization of multiple pulmonary veins, allowing the immediate identification of precocity of the venous ectopy in relation to the reference electrograms, as well as the direction of activation and the order of sequence of the potentials inside each vessel. In this situation, the recorded electrical activity began inside the pulmonary veins and progressively depolarized the ostium, the left atrium, and finally the right atrium.

Identification of a nonarrhythmogenic pulmonary vein mapped during the ectopic activity means passive activation by a distant focos localized in the atrium or in another pulmonary vein, whose activation is similar to that occurring during sinus rhythm, in a proximal to distal direction (Fig. 3).

Although most of the times, they manifested themselves as isolated premature atrial depolarizations, the pulmonary venous foci were also capable of developing repetitive electrical activity. Depending on the frequency cycle, these episodes of sustained discharge may confer different morphological patterns on the surface electrocardiogram.

In 1 patient, the electrical activity of the upper left pulmonary vein replaced the sinus rhythm, and had a regular frequency of approximately 80bpm for a period of 90s exhibiting a low left atrial rhythm morphology on the electroencephalogram. In 2 other patients, repetitive beats originated in a focal point situated at approximately 32mm of the upper right pulmonary vein's ostium, having a frequency cycle of 220 and 350ms and, respectively, conferring a flutter and an atrial tachycardia pattern on the electrocardiogram.

When the frequency of the focal discharge became even more elevated, the electrocardiogram showed a morphological pattern similar to that of an atrial fibrillation, known as focal atrial fibrillation, which was recorded in 2 patients. On the endocardial mapping, these episodes were recorded as a fast and repetitive sequeNCE of spike potentials, many times overshadowing the identification of atrial potentials. The discharge activity moved from inside the vessel to the ostium, had a frequency cycle of up to

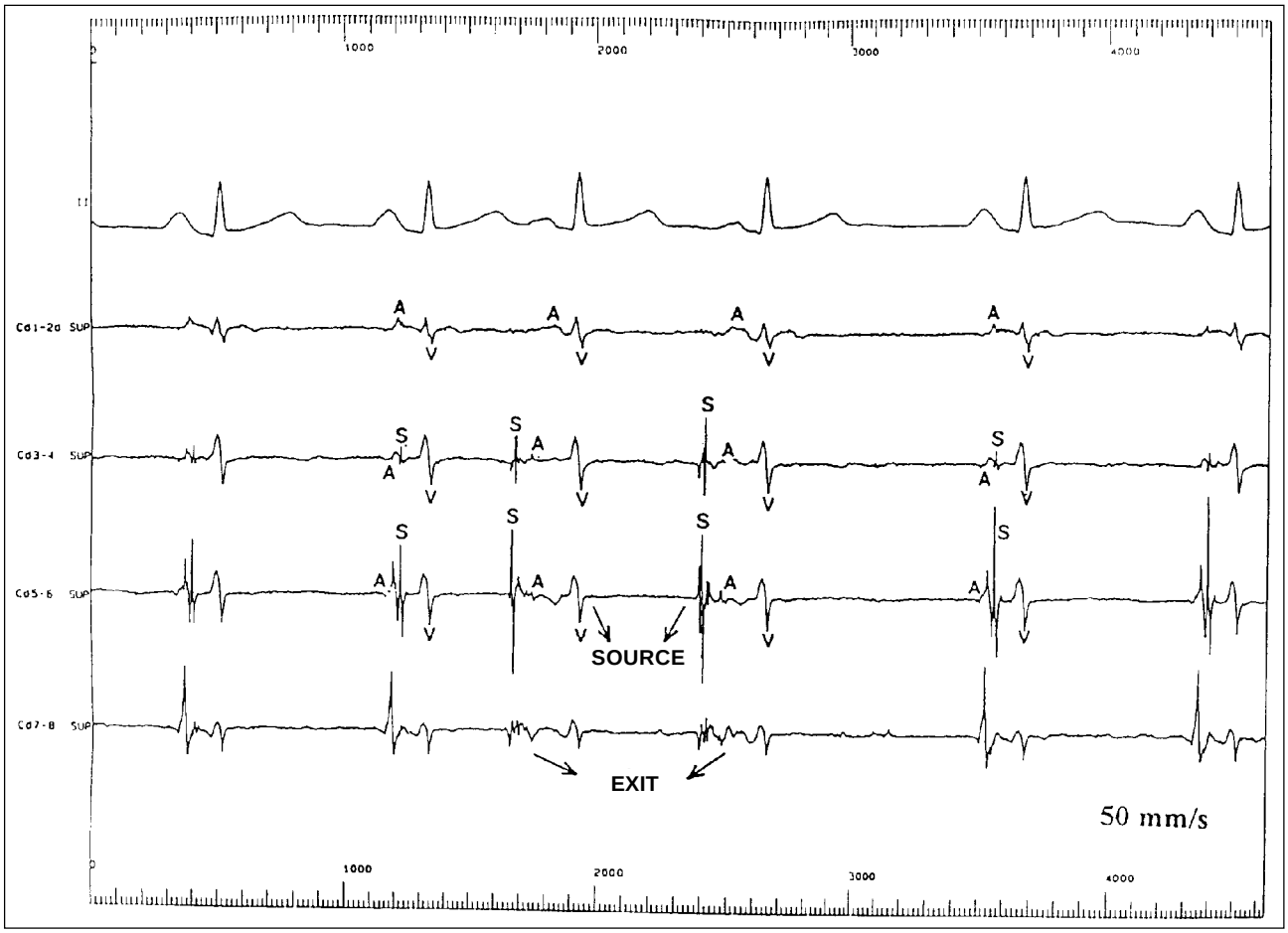

Fig. 2 - Octapolar mapping of the pulmonary vein during coupled premature atrial depolarization (3rd and 4th beats), demonstrating the typical sequential alterations in the order of atrial electrogram components, with the pulmonary vein potential (S), preceding the atrial potential (A). The origin sites (source) and "exit" of ectopia are indicated. The distal dipole (Cd1-2) demonstrates the absence of the pulmonary vein potential, showing the end of the muscle fiber.

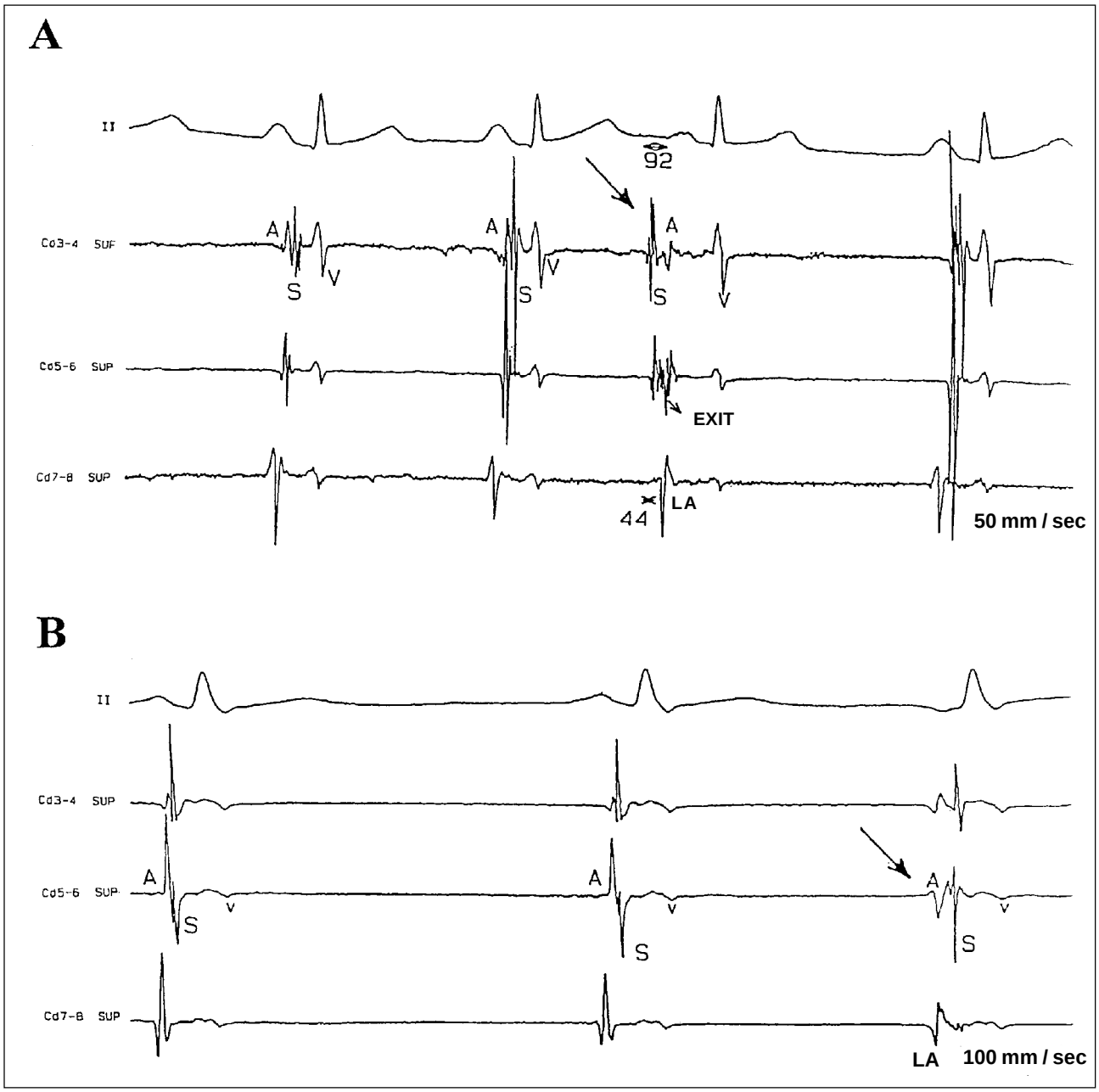

Fig. 3 - Differentiation between arrhythmogenic and nonarrhythmogenic pulmonary vein. A) active depolarization of the pulmonary vein, with the pulmonary vein potential (S) preceding the atrial potential during isolated premature atrial depolarization (arrow), demonstrating that the activation occurs in the direction of the vein to the left atrium (LA). The atrial electrogram recorded in the dipole (Cd 5-6) placed in the veno-atrial transition has the characteristic morphological pattern, with fragmentation and continuity of its components; B) passive depolarization of the pulmonary vein by an premature atrial depolarization of unmapped origin (arrow), with the atrial potential (A) preceding the pulmonary vein potential (S), showing that the activation occurs from the left atrium (LA) to the vein, similar to that during sinus rhythm.

150ms (400bpm), and was superior to the atrial activity, which was relatively organized and unfragmented. In the first case, a tachycardia interruption and prompt reestablishment of sinus rhythm occurred 16 seconds after the onset of radiofrequency application in the upper left pulmonary vein (Fig. 4). In the second, the tachycardia began in the upper right pulmonary vein degenerating to atrial fibrillation before it was possible to apply local radiofrequency. After 3 failed attempts at electrical cardioversion, we opted for ablation of the entire ostium perimeter during atrial fibrillation. After 14 applications, the electrical cardioversion resulted in the stable maintenance of sinus rhythm, although premature atrial depolarizations coming from the same ablated pulmonary vein were present.

The different forms of ectopic manifestations originating in the pulmonary veins were not consistently induced or abolished by the habitual maneuvers of programmed atrial stimulation and were not susceptible to a entrainment, making reentry an unlike arrhythmogenic mechanism.

All the recorded episodes of spontaneous onset of atrial fibrillation occurred soon after the electrical cardiover-

sion. The simultaneous catheterization of multiple pulmonary veins concomitant to the electrical cardioversion permitted the immediate localization of the atrial fibrillation triggering foci, with passive activation of the other pulmonary veins.

Altogether, 7 patients experienced atrial fibrillation during the procedures encompassing 15 electrical cardioversions, no catheters were displaced by cardioversion, thus permitting the mapping of 8 episodes of atrial fibrillation, the onset occurring spontaneously during the first 60s after electrical cardioversion in 5 patients. Five focal points were situated in the upper right pulmonary vein, 1 in the lower right pulmonary vein, and 1 in the lower left pulmonary vein. In 1 episode, it was not possible to exclude the presence of an atrial focal point. Therefore, of the 16 pulmonary venous mapped foci 7 induced atrial fibrillation.

Most of the reinitiation episodes of atrial fibrillation were due to isolated premature atrial depolarization (Fig. 5)

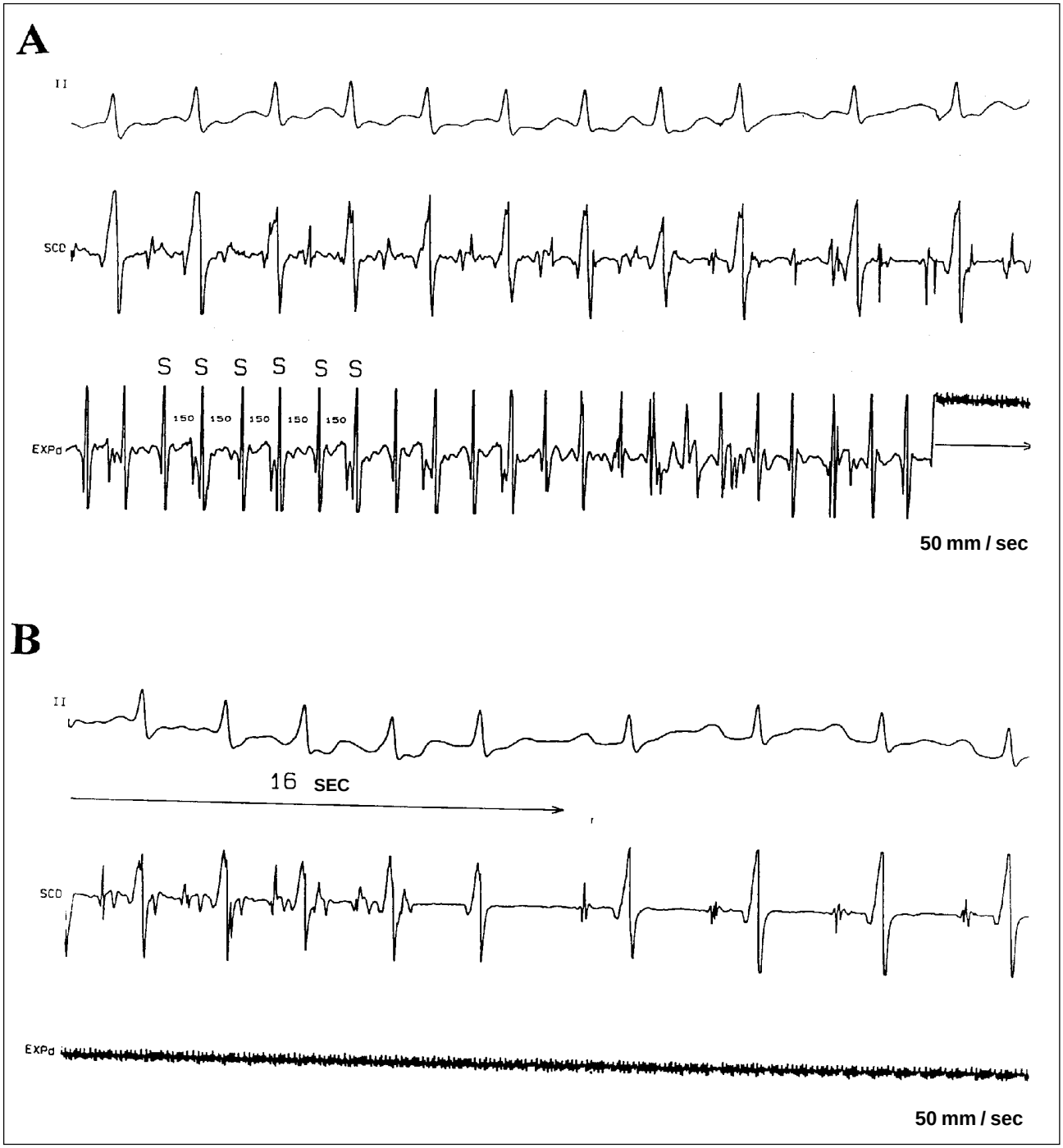

Fig. 4 - A) sustained activity of the upper left pulmonary vein recorded by the exploration catheter (EXP) located inside the vessel revealing the appearance of atrial fibrillation (AF focal) on the surface electrocardiogram. S- pulmonary vein potential; SCD- catheter distal dipole placed inside the coronary sinus; B) reversal of tachycardia and reestablishment of sinus rhythm that occurred 16s after the beginning of local application of radiofrequency.

from the pulmonary veins, originating at an average distance of 2.6cm from the ostium with an average precocity of 90ms in relation to the P wave. In 3 episodes, the triggering was due to fast discharge activity originating inside the pulmonary veins, with a mean frequency cycle of 141ms (425bpm) at a mean distance of 3.8cm from the ostium, associated with the corresponding organized activity in the coronary sinus. It was possible to show that all beats that induced episodes of atrial fibrillation had the same electrocardiographic morphology as that of isolated premature atrial depolarizations originating inside the pulmonary veins, which suggests that the atrial fibrillation and the premature atrial depolarization originated from the same focal point.

Following electrical cardioversion, 3 patients experienced short periods of sinus rhythm followed by atrial ectopia, which quickly reinduced atrial fibrillation. In these cases, radiofrequency was delivered during atrial fibrillation in the entire ostial perimeter. After the applications, the electrical cardioversions produced stable sinus rhythm in all patients.

After radiofrequency application in the target sites, stable sinus rhythm occurred with no premature atrial depolarization.

Seventeen electrophysiological procedures were accomplished: 1 in 4 patients, 2 in 5 patients and 3 in 1 patient. Sixteen arrhythmogenic pulmonary veins were mapped and ablated: 1 in 6 patients, 2 in 2 patients and 3 in 2 patients. During preliminary electrocardiographic monitoring, ectopic density lower than 5 premature atrial depolarization per hour was observed in 5 patients, 2 of which occurred only during the second procedure.

Frequent premature atrial depolarizations occurred in 7 patients during 12 procedures. In these cases, mapping was made by simultaneous catheterization of the 4 pulmonary veins. The local abolition of pulmonary vein potentials associated with premature atrial depolarization suppression was attained in all cases. During the first procedure, 8 pulmonary veins were mapped: 1 in 6 patients and 2 in 1 patient. Recurrence of atrial fibrillation was recorded within a period of 2 to 30 days of ablation in 6 patients who were studied again. Only 1 patient that underwent ablation of the pulmonary vein remained in sinus rhythm.

During the second procedure, recurrent ectopy was verified in 5 pulmonary veins previously approached and 3 new foci. Two of these were mapped in 1 patient who also exhibited relapse of 1 focus previously approached, being possible to identify 3 different ectopic sources during the

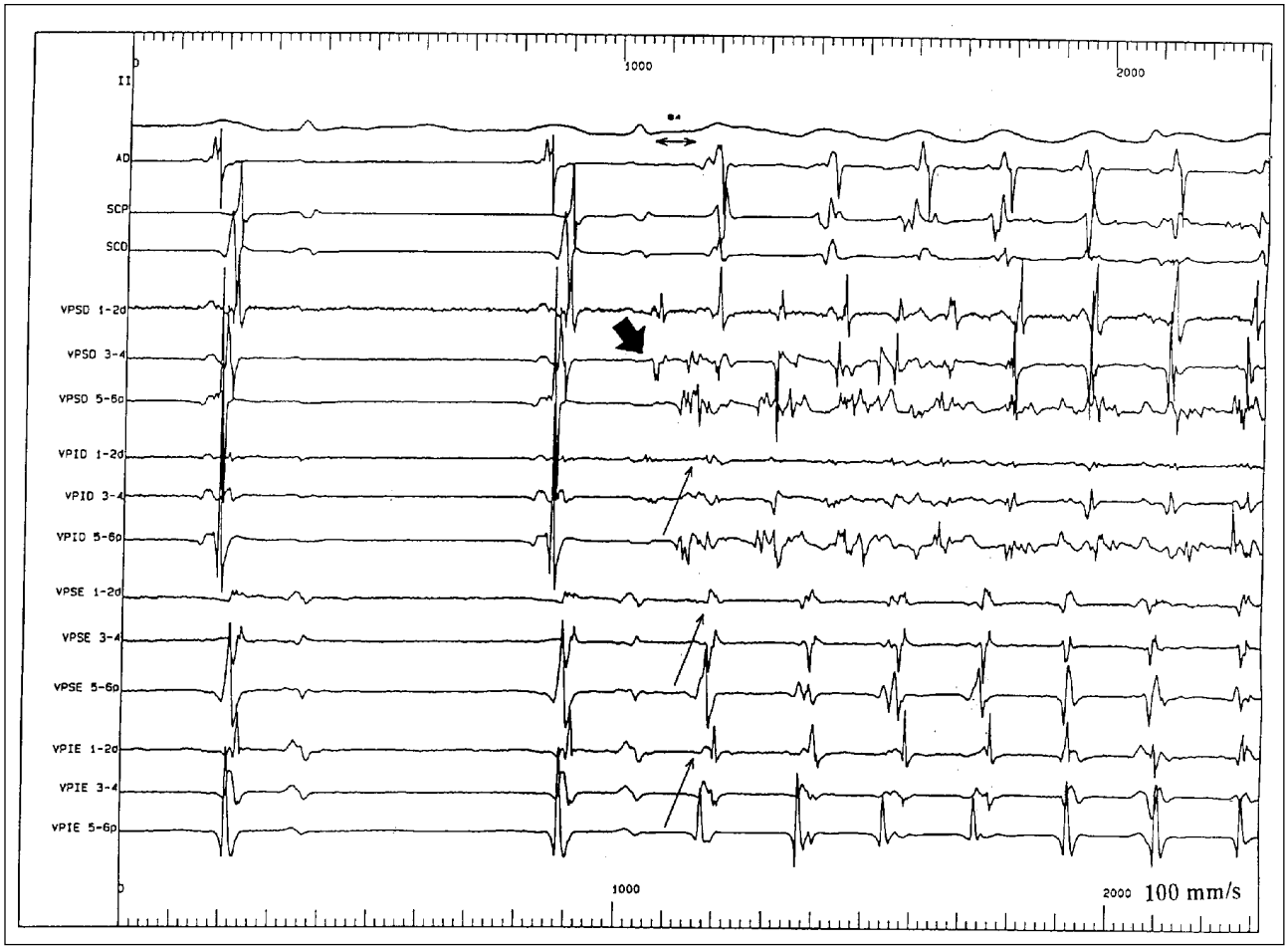

Fig. 5 - Holter of the pulmonary veins: the simultaneous recording of the electrical activity of the 4 pulmonary veins clearly identifies the spontaneous induction of atrial fibrillation from the premature atrial depolarization (dark arrow) of the upper right pulmonary vein (URPV), with passive activation of the other pulmonary veins.

same procedure (upper right, upper left, and lower left pulmonary veins).

During the clinical follow-up, 2 patients experienced frequent supraventricular premature atrial depolarization on the Holter monitor and a period of atrial tachycardia of up to 12 beats associated with palpitations. They remained asymptomatic in sinus rhythm and medicated with amiodarone. Two patients exhibited atrial fibrillation relapse. In 1 of them, atrial fibrillation recurred 48h after the ablation remaining as a paroxysmal form without medication. The last patient had a relapse just 4 months later and underwent a third procedure. During mapping we observed the presence of frequent premature atrial depolarizations with origin in the right atrium, close to the His bundle. This patient did not undergo ablation and remains in sinus rhythm using amiodarone.

During the second procedure, the premature atrial depolarization exhibited the same morphology as that on the previous one in which only 1 arrhythmogenic focus had been identified. After a single transseptal puncture, a vein-to-vein mapping was made by means of an exploration catheter, confirming that the ectopic activity came from the same pulmonary vein approached earlier. In the patients that underwent a single procedure, simultaneous mapping of the 4 pulmonary veins showed the presence of 3 arrhythmogenic focal points in 1 patient and 1 focal point in 2 patients.

Considering the low ectopic density, the criterion for success was not the absence of premature atrial depolarizations, but rather, the abolition of all pulmonary vein potential in the ostium of arrhythmogenic pulmonary veins. This goal was only reached in 2 patients in whom relapse of the arrhythmogenic focal point occurred. They evolved into sinus rhythm without the need for medication. The remaining patients had a relapse of atrial fibrillation in a mean period of 30 days and underwent electrical cardioversion. One of them had persistent atrial fibrillation in 2 arrhythmogenic pulmonary veins and remains in atrial fibrillation refractory to cardioversion. The other 2 patients remain in sinus rhythm and are taking amiodarone.

In the first 2 patients included in the present study, applications were made in the site of origin of the ectopy where the vessel diameter was 6±1.5mm at approximately 30mm of the ostium. In the remaining patients, ablation was performed in the ostium where the vessel diameter was 14±4mm. We performed 16±5mm radiofrequency applications per patient. The mean fluoroscopy time during mapping using simultaneous catheterization of the 4 pulmonary veins was 130±40min.

Different effects of radiofrequency application on the pulmonary vein potentials were verified: it could completely disappear, become intermittent, reduce the amplitude, have a larger retardation in relation to the atrial potential in sinus rhythm, or even not be modified at all. In the 2 patients who evolved to sinus rhythm without medication, after the second procedure the applications were directed solely at 1 segment of the ostium. In these cases, the concomitant multipolar mapping demonstrated the absence of all pulmonary vein potentials previously recorded, and the stimulation performed several points of the vessel was not accompanied by the atrial capture (Fig. 6). In all pulmonary veins previously ablated, relapse of the ectopic activity was associated with the presence of pulmonary vein potentials throughout the extension of the ostium.

Radiofrequency application in the pulmonary veins was well tolerated in most cases. Two patients exhibited pain and 1 patient cough. These symptoms stopped at the end of ablation. Several bradyarrhythmias, described in patients that underwent radiofrequency application in the pulmonary veins were not documented in our experience [37].

The microcatheters remained stable in the pulmonary veins for a variable period of 30 to 90min, inclusive during radiofrequency application and rapid atrial stimulation maneuvers.

During a period of 9.6 months of clinical follow-up, 8 patients remained in sinus rhythm, 5 of whom were using the dosage of amiodarone previously found to be ineffective. One patient remained in paroxysmal atrial fibrillation without medication, and another remained in persistent atrial fibrillation.

In the patients who remained in sinus rhythm, we verified a statistically significant reduction in the number of supraventricular premature atrial depolarization on the 24h Holter from 2.874±7.56 to 9.87±4.95.

Discussion

Simultaneous catheterization of the 4 pulmonary veins adds an exclusive Holter function to the usual mapping techniques, insofar as it allows continuous monitoring of these vessels' electrical activity, selecting only the arrhythmogenic ones for ablation. This method was particularly useful in the situations of early reinitiation of atrial fibrillation after electrical cardioversion, the low number of mapped premature atrial depolarization, and the presence of multiple arrhythmogenic focal points.

Use of octapolar microcatheters allowed the recording of the depolarization of pulmonary veins at a distance of 3.8cm from the ostium. Since arrhythmogenic foci are usually mapped at a depth of 2 to 4cm, [18] this technique makes it possible to scan pulmonary vein potentials throughout the course of the muscle fiber, which allows identification of the most useful mapped surface of the different pulmonary veins and the best sites for ablation.

From the classical work of Nathan and Eliakin [38], it is known that cardiac muscle enter, with varying extensions, into the pulmonary veins forming true sphincters at the venous-atrial transition. This large local confluence of fibers might explain the morphology of electrograms made up of multiple spike potentials, found in the ostium of 15 pulmonary veins.

Despite the preliminary report including a small sample of patients, suggesting that arrhythmogenic pulmonary veins would produce electrograms of higher morphological complexity [39], no sufficient corroboration has yet been

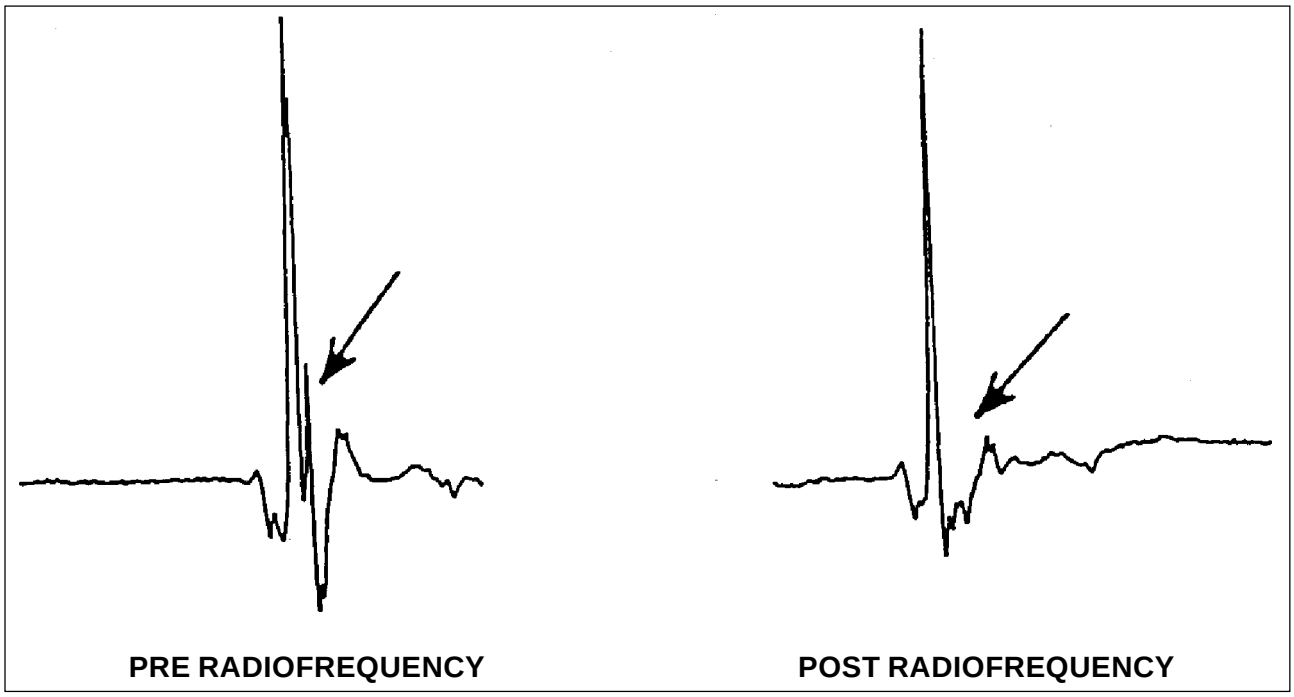

Fig. 6 - Electrograms of the pulmonary veins recorded during sinus rhythm, showing abolition of the pulmonary vein potential (arrow) after application of radiofrequency.

reported in the literature that permits recognition and ablation of a pulmonary vein in the absence of ectopic activity.

Following the concepts defined by Haïssaguerre et al [16,18,23], the component with spiked morphology and the high frequency to pulmonary vein potentials were ranked according to the following evidence: 1) to precede the atrial component during earlier premature atrial depolarization in the catheter positioned inside the pulmonary veins, documented by angiography; 2) higher frequency of the venous tachycardia when compared with the other intracavity electrograms, suggesting exit block; 3) individualization of pulmonary vein potentials through left atrial stimulation maneuvers; 4) disappearance after application of radiofrequency.

We observed that, in patients with atrial fibrillation, the premature atrial depolarization represented the most frequent type of ectopy and almost all of them originated in the pulmonary veins, which was confirmed in 95% of the patients in Haïssaguerre's [22] sample and 88.8% of the patients in Chen's [29] sample. Through a retrospective analysis, we could not distinguish the premature atrial depolarization associated or not with induction of atrial fibrillation, by means of morphology and coupling analysis. This evidence is contradictory to that of Prakash et al [40] who, in a sample of 14 patients with structural cardiopathy, suggest that atrial fibrillation inducing premature atrial depolarization would have a smaller coupling interval when compared with the non-inducing ones.

In the 9 episodes of mapped spontaneous reinitiation of atrial fibrillation, we could not exclude a pulmonary venous origin in only 1 case. In 5 of the 8 episodes, spontaneous reinitiation of atrial fibrillation was caused by isolated premature atrial depolarizations.

Based on the pioneering work of Haïssaguerre, in the present study we proceeded to attempt the ablation of all premature atrial depolarization originating in the pulmonary veins, aiming to eliminate all the patential tuggers of atrial fibrillation. A modification of this strategy was described by Chen et al [29], selecting only the premature atrial depolarization that occurred as bursts or those clearly related to atrial fibrillation for ablation.

The concomitant finding of atrial fibrillation with atrial tachycardia and atrial flutter in 2 patients may reflect the polymorphic capability of the same venous pulmonary focus to manifest itself with distinct frequency cycles. It is important to emphasize that the focal sources of these tachycardias were located at a distance of 3cm from the ostium, a location not usually found in atrial tachycardias originating in the left atrium.

The great difficulty found in mapping ectopic points originating in the pulmonary veins is due to the unpredictability of its manifestation and to the lack of consistent provocative maneuvers. These difficulties may be related, in part, to the lack of a wider understanding of its arrhythmogenic mechanism, which allows its reliable reproducibility. Of the 9 patients who initially had a small number of mapped premature atrial depolarizations, only 4 responded to provocative maneuvers. In the 5 cases that maintained less than 5 premature atrial depolarization per hour, 3 of whom underwent simultaneous mapping of the pulmonary veins, it was possible to identify all the different ectopic origins.

Progressive catheterization of 2 or more pulmonary veins has been shown to be necessary, given the possibility of multiple arrhythmogenic foci. Jaïs et al [28] referred to the presence of more than 1 arrhythmogenic pulmonary

vein in 52% of a sample of 110 patients, with simultaneous catheterization of up to 3 pulmonary veins. Hsieh et al [41] reported the presence of 2 arrhythmogenic pulmonary veins in 46% of 42 patients, all of whom underwent simultaneous catheterization of the 2 pulmonary veins. Schwartzman et al [42] published the results of a study with 9 patients where the multipolar simultaneous mapping of the 4 pulmonary veins was accomplished, in reference to 1 patient in whom 2 pulmonary veins were independently involved in the induction of atrial fibrillation.

In our sample, simultaneous mapping of the pulmonary veins permitted the identification of more than 1 ectopic source during the same procedure in 4 patients. This technique proved particularly useful in 2 of these cases in which it was possible to identify 3 arrhythmogenic pulmonary veins, 1 of them with a small number of premature atrial depolarization. Moreover, new focal points detected in the additional procedures were not manifested during the initial procedure.

Accomplishment of the electrical cardioversion of atrial fibrillation with catheters previously positioned inside the pulmonary veins allowed the identification of the origin of ectopic activities that were occult or suppressed. Recent reports [43-46] demonstrate that external or internal atrial defibrillation is associated with an index of 30% of early reinitiation of atrial fibrillation. Considering that most atrial fibrillation paroxysms are preceded by discharge activity of the pulmonary veins, mapping of these episodes provides an opportunity for identification and ablation of triggering foci. In face of the impossibility of predicting the origin and the exact moment of manifestation of the focal activity, previous catheterization of the 4 pulmonary veins warrants the utilization of all information provided by each reinitiation episode of atrial fibrillation and, consequently, a smaller number of episodes necessary to identify an arrhythmogenic source. This technique has been used during focal ablation of atrial fibrillation by Lau et al [47] and Hsieh et al [41], with early reinduction of atrial fibrillation in, respectively, 36% and 38% of their patients.

Despite the succesful suppression of ectopic activity in the pulmonary veins at the end of most procedures, relapse of atrial fibrillation was a frequent occurrence in our study. This fact may be associated with the inability to completely abolish electrical activity in the pulmonary veins in most of our patients, which would correspond to the need for effecting a total disconnection between electrical activity of the pulmonary veins and the left atrium. Such a hypothesis was confirmed by Haïssaguerre et al [23] in a recent publication in which the authors pointed out that success of focal ablation is more related to total elimination of the pulmonary vein potentials than to the acute suppression of premature atrial depolarizations. Based on circumference mapping of the pulmonary veins, these authors believe it is possible to reach this objective by means of minimal applications directed at preferential sites of the fibers' entry (inputs) from where they are distributed to the rest of the ostial circumference and the vessel's longitudinal extension [48]. Another potentially related factor is the presence of the prolonged length of atrial fibrillation in our patients (median of 2 weeks), possibly reflecting a greater remodeling of the atrial substrate and, consequently, less dependency on the focal triggers. In larger samples, the patients selected had atrial fibrillation paroxysms occurring periodically every 2 to 3 days [18,29].

Although it was not possible to reproduce the high levels of primary cure reported in larger samples, we obtained efficient control of atrial fibrillation with the introduction of antiarrhythmic drugs that had previously been ineffective. These results point to the beneficial role of a hybrid treatment for arrhythmia, by approaching the focal triggers with electrophysiological procedures and the atrial substrate with drugs [49]. Elimination of atrial fibrillation through this combined approach occurred in 13% of the 79 patients reported in Chen et al [29] and in 33% of 110 patients reported in Haïssaguerre et al [28]. According to this point of view, 8 of our 10 patients remained in stable sinus rhythm without potentially related symptoms. In addition, no evidence of lesion of the pulmonary veins or pulmonary hypertension was documented.

In conclusion, most of the arrhythmias detected in our sample originated from foci mapped inside the pulmonary veins. Such foci were the triggers of almost all episodes of atrial fibrillation, which points out the importance of its precise electrophysiological and anatomical catheterization. Simultaneous multiple catheterization of the pulmonary veins proved to be a feasible and safe technique, providing a dynamic monitorization of the electrical activity of these vessels, which helped the identification and ablation of different arrhythmogenic sites. This procedure, however, was associated with a significant occurrence of atrial fibrillation relapse, which appeared to be more closely related to the inability to abolish all pulmonary vein potentials than to the acute suppression of ectopy. Nonetheless, effective clinical control was obtained by the association of drugs that were previously ineffective. This new approach, consisting of elimination of focal triggers with the radiofrequency catheter associated with the modulation of atrial substrate by medication may reveal a new way of treating this arrhythmia.

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