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Original article

Predictors of Luminal Loss in Pulmonary Veins After Radiofrequency Ablation

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ABSTRACT

Introduction and objectives: The reported incidences of stenosis after radiofrequency ablation of pulmonary veins are highly variable. Moreover, most studies have focused on severe stenosis and have overlooked mild stenosis. Our aims were to study postablation morphological changes in the pulmonary veins and to evaluate preablation magnetic resonance imaging predictors for stenosis.
Methods: Eighty consecutive patients with atrial fibrillation underwent cardiac magnetic resonance imaging before undergoing radiofrequency ablation. Magnetic resonance imaging was repeated a median of 95 days after ablation. Ostium area/ellipticity and atrial volume were blindly assessed. We evaluated the presence of stenosis and classified it as mild (< 50% area reduction), moderate (50%-70%), and severe (> 70%).
Results: Postablation stenosis was identified in 78 of 322 veins (24.2%). The stenosis was mild in 66 (84.6%), moderate in 11 (14.1%), and severe in 1 (1.3%). All of them were asymptomatic. The left inferior pulmonary vein showed the highest frequency of stenosis, which was detected in 26% of them ($P < .001$). A multiple regression analysis revealed that left inferior pulmonary vein (odds ratio = 3.089; $P = .02$) and a greater preablation ostium area (odds ratio = 1.009; $P < .001$) were independent predictors for postablation stenosis. Age (odds ratio = 1.033) showed a strong trend to statistical significance ($P = .06$).
Conclusions: After ablation, vein ostia size is reduced and stenosis is detected in less than one third of patients. Most cases are mild, and severe stenosis is rare. Postablation stenosis is more likely to develop in older patients, those with larger vein ostia, and in the left inferior pulmonary veins.

Predictores de pérdida luminal de venas pulmonares tras ablación por radiofrecuencia

Palabras clave:
Fibrilación auricular
Venas pulmonares
Ablación percutánea
Estenosis
Remodelado
Resonancia magnética

RESUMEN

Introducción y objetivos: La incidencia descrita de estenosis de venas pulmonares tras la ablación por radiofrecuencia es muy variable. Además, la mayoría de los estudios se han centrado en las estenosis graves y han prestado poca atención a las de carácter leve. El objetivo de este trabajo es estudiar los cambios morfológicos de las venas pulmonares después de la ablación y los posibles factores predictivos de estenosis en la resonancia magnética previa a la ablación.
Métodos: Se examinó mediante resonancia magnética cardiaca a un total de 80 pacientes consecutivos con fibrilación auricular antes de practicarles una ablación por radiofrecuencia. Se repitió la resonancia magnética una mediana de 95 días después de la ablación. Entre las variable estudiadas, se midió, utilizando un diseño ciego, el área/elipticidad del *ostium*, así como el volumen auricular. Se evaluó la presencia de estenosis y se clasificó como leve (< 50% de reducción del área), moderada (50-70%) o grave (> 70%).
Resultados: Se identificó estenosis tras la ablación en 78 de 322 venas analizadas (24,2%). La estenosis fue leve en 66 (84,6%) venas, moderada en 11 (14,1%) y grave en 1 (1,3%). Todas estaban asintomáticas. La vena pulmonar inferior izquierda es la que presentó la mayor frecuencia de estenosis: se detectó en un 26% de ellas ($p < 0{,}001$). Un análisis de regresión múltiple reveló que el tipo de vena (vena pulmonar inferior izquierda, *odds ratio* = 3,089; $p = 0{,}02$) y una mayor área del *ostium* antes de la ablación (*odds ratio* = 1,009; $p < 0{,}001$) eran factores independientes predictivos de estenosis tras la ablación. La edad (*odds ratio* = 1,033) mostró una tendencia fuerte hacia la significación estadística ($p = 0{,}06$).

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Conclusiones: Después de la ablación se produce una disminución del tamaño del *ostium* de las venas pulmonares y se detecta algún grado de estenosis en menos de una tercera parte de los pacientes. La mayoría son leves y las estenosis graves son excepcionales. Los pacientes de más edad, aquellos con venas de mayor tamaño y las venas inferiores izquierdas tienen mayor probabilidad de presentar estenosis.

Abbreviations

AF: atrial fibrillation
MRI: magnetic resonance imaging
PV: pulmonary vein

INTRODUCTION

Atrial fibrillation (AF) is the most common arrhythmia. The incidence of AF is likely to rise because of the increasing age of the population.[1] The left atrium and proximal pulmonary veins (PVs) play key roles in the initiation and maintenance of AF.[2] This disorder can be initiated by rapid ectopic beats originating in sleeves of left atrium myocardium extending into the PVs.[3] Over the past decade, PV isolation by means of multiple consecutive radiofrequency energy applications around PV ostia has emerged as an effective and increasingly important therapeutic option for the treatment of AF.[3–6]

Stenosis of the PV has been identified as a complication of this procedure.[7–9] Its risk may be minimized by reducing the radiofrequency energy delivered and by avoiding applications inside the PVs.[6,10,11] Consequently, detailed knowledge of the PV anatomy in each patient may be essential to optimize PV isolation.[12]

Several studies have evaluated the incidence of severe PV stenosis after ablation, reporting percentages ranging widely from 0.0% to 42.4%.[9,13–16] However, little is known about minor degrees of luminal loss after ablation.

The aims of this study were: *a)* to accurately assess PV anatomical remodelling after ablation, and *b)* to look for potential predictors of risk of PV stenosis based on analysis of magnetic resonance imaging (MRI) studies performed before and after radiofrequency ablation of AF.

METHODS

Patients and Ablation Procedure

We studied 80 consecutive patients with symptomatic recurrent AF (either paroxysmal or persistent) refractory to antiarrhythmic drugs who were referred for AF radiofrequency ablation, in whom contrast-enhanced MRI was obtained before and approximately 3 months after the procedure (median of 95 days [interquartile range, 90-104 days]).

The ablation approach was ostial PV isolation using irrigated tip catheters (Navistar and Navistar Thermo-cool; Biosense Webster) and circular decapolar catheters (Lasso; Biosense Webster) with simultaneous use of an electro-anatomical mapping system (CARTO; Biosense-Webster) integrated with 3-dimensional MRI. The end point of ablation was to achieve bidirectional PV conduction block in all PVs.

The study protocol was approved by the local ethics committee and study patients gave written informed consent for the MRI and the ablation procedure.

Image Acquisition

The cardiac MRI was performed with a 1-T (Signa LX; GE Medical Systems) or a 1.5-T system (Sigma Excite; GE Medical Systems). Gadolinium contrast injection timing for the angiographic sequence was performed either with a bolus tracking technique or a previous bolus timing acquisition (2 mL gadolinium contrast at a rate of 2 mL/s followed by a bolus of 20-30 mL of physiological solution at 2 mL/s), followed by a gadolinium-enhanced, breath-hold, 3-dimensional angiography in the coronal plane covering the left atrium and PVs (20 mL of gadopentetate dimeglumine at a rate of 2 mL/s followed by a bolus of 20 mL to 30 mL of physiological solution at 2 mL/s).

Electrocardiography-gated cine imaging was done to measure left atrium volumes using spoiled gradient echo sequences (1-T system) or steady-state free precession sequences (1.5-T system) acquired in adjacent axial planes covering the left atrium and proximal PVs during breath holding.

Pulmonary Vein and Left Atrium Morphometry Measurements

Images from all studies were assessed by a reader who was blinded to whether the study had been performed before or after ablation. As shown in Figure 1, the superoinferior and anteroposterior diameters of each PV were assessed in 8 mm to 10 mm-thick slices of 2 long-axis MIP (maximum intensity projection) PV images (oblique coronal and oblique axial images) based on the long axis of the PV. The PV ostium was defined as the point of inflection between the left atrium wall and the PV wall. The ostium cross-sectional area was estimated by the formula:

$$\text{Ostium cross-sectional areas} = \pi \times \frac{\text{superoinferior diameter}}{2} \times \frac{\text{anteroposterior diameter}}{2}$$

Baseline and postablation PV cross-sectional areas were assessed at the PV ostium, at 3-mm intervals and at the point of maximal narrowing.

The ostium elipticity was calculated as follows:

$$\text{Ostium elipticity} = \frac{(\text{longest diameter} - \text{shortest diameter})}{\text{longest diameter}}$$

This formula results in a value between 0 (circumference) and 1 (straight line). The distance from PV ostium to the first branching and PV angles in reference to the axial and coronal planes of the body were also assessed.

Left atrium diameters (anteroposterior, transversal and longitudinal) and volumes (end-systolic and end-diastolic) were measured.

The MIP and the MPVR (multiprojection volume reconstruction) reformations were performed with the aid of commercial volume-visualization software (Advantage Workstation 4.2; GE Medical Systems).