

Morphologic Study of the Pulmonary Veins by Magnetic Resonance Angiography

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Accurate knowledge of the anatomy of the pulmonary veins is important in clinical electrophysiology. In order to evaluate the usefulness of magnetic resonance angiography for this purpose, we studied 17 unselected patients. All the pulmonary veins were visualized in each individual. The diameters of the ostia ranged between 9 mm and 22 mm. The cross-section of the ostium was elliptical in 35% of cases. In 14 patients (82%), the 4 veins each had independent drainage. In 2 patients (12%), there was an additional intermediate right vein and, in 1 patient (6%), both left veins had a common ostium. In 74% of patients, the right pulmonary veins had a short common trunk with early branching. This pattern was seen in only 10% of left veins. Magnetic resonance angiography using a contrast medium is an excellent technique for studying the anatomy of the pulmonary veins and for identifying variants. The resulting information is potentially useful for electrophysiologists.

Key words: *Magnetic resonance imaging. Pulmonary veins. Catheter ablation. Atrial fibrillation.*

Estudio morfológico de las venas pulmonares por angiorresonancia magnética

El desarrollo de la electrofisiología clínica ha potenciado el interés por el conocimiento de la anatomía de las venas pulmonares. Con el objetivo de valorar la utilidad de la angiografía por resonancia magnética para este fin se estudió a 17 pacientes no seleccionados, en los que se visualizó la totalidad de las venas en cada paciente. El diámetro máximo de los *ostium* osciló entre 9 y 22 mm y su morfología era oval en el 35% de casos. En 14 casos (82%) se observó una desembocadura independiente de las 4 venas. En 2 (12%) había una vena media derecha independiente y 1 (6%) presentaba un *ostium* común para las venas izquierdas. Las venas derechas mostraron ramificación precoz en un 74% de los casos, frente a un 10% de las izquierdas. La angiorresonancia magnética con contraste permite estudiar, de manera adecuada, la morfología de las venas pulmonares y sus variantes anatómicas, información potencialmente útil para el electrofisiólogo.

Palabras clave: *Resonancia magnética nuclear. Venas pulmonares. Ablación con catéter. Fibrilación auricular.*

INTRODUCTION

Radiofrequency ablation of ectopic foci located at the junction of the pulmonary veins (PV) in patients with paroxysmal atrial fibrillation has raised interest in imaging techniques capable of offering adequate information on the anatomy of these vessels.¹ The purpose of this study was to determine the usefulness of mag-

netic resonance angiography (MRI angiography) for routine anatomic study of the PVs.

PATIENTS AND METHODS

The study included 17 consecutive patients who were undergoing cardiac magnetic resonance imaging (cardiac MRI) at our hospital and required the administration of paramagnetic contrast material. Three-dimensional MRI angiography sequences (Philips Intera 1.5T, Best, Netherlands) were taken of all patients during the administration of gadoteridol 0.2 mmol/kg (ProHance, Bracco International BV, Amsterdam, Netherlands) at an infusion speed of 3 mL/s. A detailed analysis was performed of the projected images (Figure 1A), solid three-dimensional

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Figure 1. Modalities used for visualization of the pulmonary veins (PV) obtained in a patient with an independent right middle lobe (RML) vein. A: maximum intensity projection (MIP) showing all PVs in a single plane. B: 3D solid image, obtained by post-processing of the original acquisition volume, which highlights the RMLPV independence. C: coronal view oriented on the longitudinal axis of the right superior PV (RSPV). Ostium delimited by the arrows. The line corresponds to programming of the orthogonal slice obtained in D. E: intracardiac image of the left atrium, oriented to the right PV junction, obtained by virtual endoscopy at the post-processing station. Three independent ostia are identified corresponding, from top to bottom, to the RSPV, the RML PV (note the convergence of two branches, which form a clearly oval ostium) and the right inferior PV (RIPV).

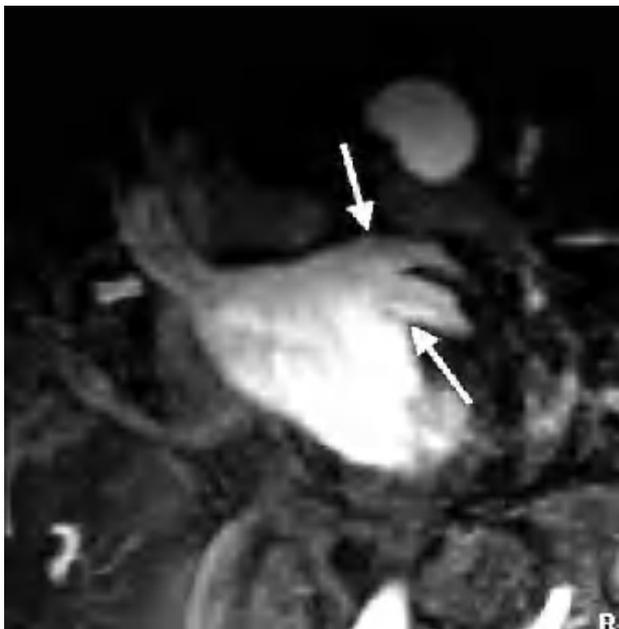
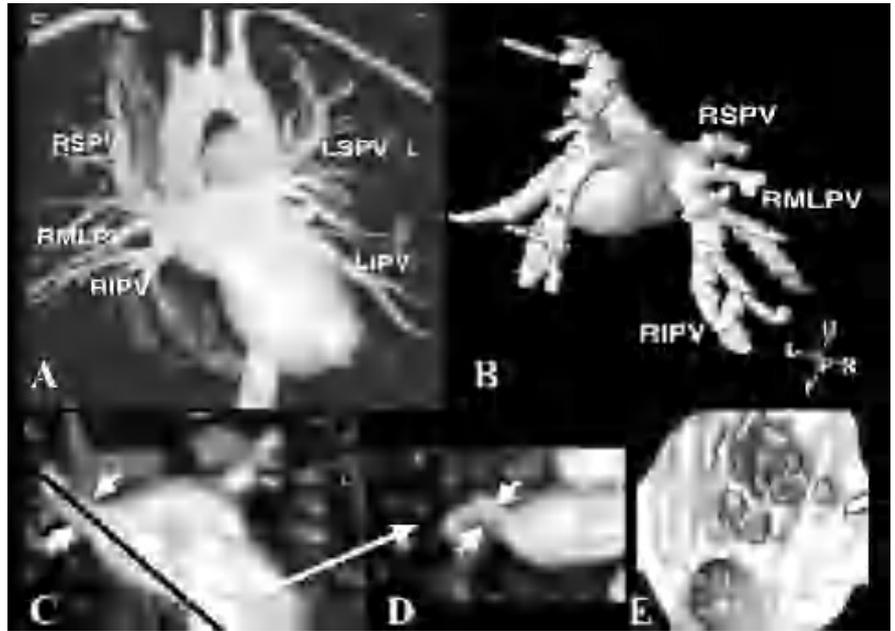


Figure 2. Oblique coronal view showing convergence of the left pulmonary veins, which form a large common ostium in the left atrium.

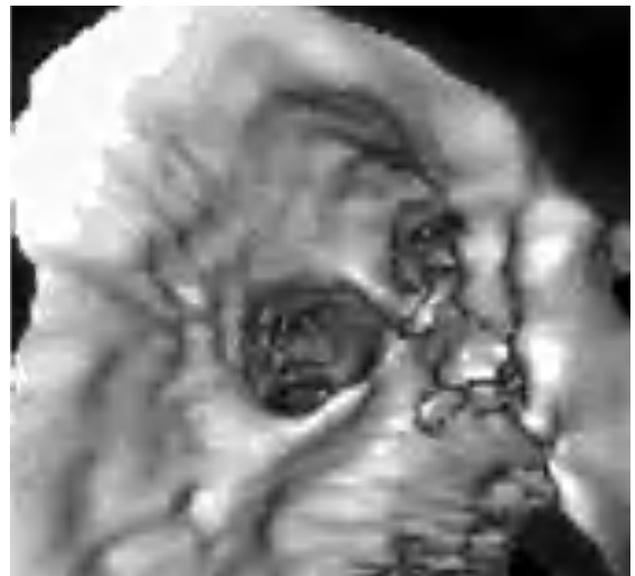


Figure 3. Same case as Figure 2, showing the intracardiac view of the common ostium by endoscopy from the mitral valve.

images (Figure 1B), tomographic images (Figure 1C and 1D), and virtual endoscopy images (Figure 1E), using dedicated software (Easy Vision, Philips Medical Systems, Best, Netherlands and MASS Bonus V 5.0 Medis, Leiden, Netherlands). Because the junction orifice of the pulmonary veins can have an irregular shape, the ostium measurement was systematized by using 2 orthogonal diameters (Figures 1C and 1D) as well as the cross-sectional area, and the

mean value and standard deviation were calculated for each main vein. Student's *t* test was used to compare the means between numerical variables; significance was set at a *P* value <.05.

RESULTS

High-quality images allowing interpretive reading were obtained for all patients. Table contains the characteristics of the group studied and the measures obtained.

TABLE. Patient Characteristics and Ostium Diameters (mm) and Area (mm²) of Each Pulmonary Vein Analyzed*

Patient	Sex	Diagnosis	Right Superior			Right Inferior			Left Superior			Left Inferior		
			Diameter 1	Diameter 2	Area	Diameter 1	Diameter 2	Area	Diameter 1	Diameter 2	Area	Diameter 1	Diameter 2	Area
1	M	PV preablation	14	15	6.6	13	17	6.9	13	14	5.7	12	15	5.6
2	F	Myocarditis	16	13	6.5	17	13	6.9	11	15	5.2	12	16	6.0
3	M	Sudden death	15	18	8.5	14	14	6.1	15	13	6.1	10	10	3.1
4	M	Ischemic heart disease	22	20	13.8	19	17	10.1	21	22	14.5	20	17	10.7
5	M	Dilated cardiomyopathy	17	18	9.6	15	16	7.5	16	16	8.0	17	18	9.6
6	M	Hypertrophic cardiomyopathy	19	15	8.9	17	18	9.6	14	16	7.0	12	15	5.6
7†	M	PV preablation	15	16	7.5	16	16	8.0	12	11	4.1	11	15	5.2
8	F	Hypertrophic cardiomyopathy	14	14	6.1	18	19	10.7	11	12	4.1	11	17	5.9
9	F	PV preablation	11	17	5.9	10	13	4.1	15	15	7.1	13	14	5.7
10	F	Interatrial septum defect	14	15	6.6	14	18	7.9	15	14	6.6	11	14	4.8
11	M	Takayasu disease	15	13	6.1	15	15	7.1	15	16	7.5	12	19	7.2
12†	F	PV preablation	16	14	7.0	14	19	8.3	17	12	6.4	11	17	5.9
13	F	PV preablation	16	18	9.0	16	18	9.0	13	15	6.1	14	14	6.1
14	M	Amyloidosis	20	17	10.7	13	11	4.5	15	13	6.1	11	16	5.5
15‡	M	PV preablation	20	19	11.9	14	17	7.5	17	16	8.5	16	17	8.5
16	M	Dilated cardiomyopathy	13	15	6.1	19	15	8.9	17	15	8.0	9	16	4.5
17	M	Ischemic heart disease	13	13	5.3	12	14	5.3	16	14	7.0	12	14	5.3
Media±SD			15.8±2.9	15.9±2.2	8.0±2.4	15.1±2.5	15.9±2.3	7.6±1.9	14.9±2.5	14.6±2.4	7.0±2.3	12.6±2.8	15.5±2.0	6.2±1.9

*SD indicated standard deviation; PV, pulmonary vein.
 †Patients with independent junction of the right middle pulmonary vein.
 ‡Patients with confluent junction of the 2 left pulmonary veins.

The diameter of the ostium was between 9 and 22 mm. Although the mean value of the diameters of each ostium in any axis was similar in all the vessels studied, the calculated areas were greater in right than in left PVs, with significant differences between the area of the left inferior PV (6.2±1.9 cm²) and that of the right superior (8.0±2.4 cm²; P=.02) or right inferior PV (7.6±1.9 cm²; P=.04), respectively.

In addition, 35% of the ostia had an elliptical shape, defined as a difference ≥3 mm between the 2 orthogonal diameters. This was more evident in the inferior PVs (72% of cases with elliptical ostium) than the superior PVs; the left inferior PV was most frequently found to have an elliptical ostium (61% of all patients).

With regard to the number of ostia, 4 were visualized in 14 patients (82%), 5 in 2 patients (12%), with the supernumerary ostium corresponding to an independent junction of the middle right PV (Figure 2), and 3 in 1 patient (6%) in whom the 2 left PVs had a common junction (Figure 3). These last 3 patients correspond to the preablation cases.

In the case of PV branching, 10 patients (59%) were found to have convergence of the branches of the right PV very near the ostium which resulted in a short common trunk, and 5 patients (29%) had no common trunk, the ostium being formed by direct confluence of the lobar veins (right superior PV, 3 cases; left superior PV, 2 cases; right inferior PV, 1 case). Considered as a whole, the right PVs branched earlier than the left PVs (74% vs 10%).

DISCUSSION

The study results show that MRI angiography is an extremely useful technique for routine anatomic study of the PVs, as reported by other authors.^{2,3} Although a complete description of the anatomical characteristics of the veins can be done in all patients using 2D images, 3D solid reconstruction is extremely useful, as it provides a spatial view, whereas 3D virtual endoscopy offers highly illustrative images of the intracardiac arrangement of the PV ostia. This information is useful for the elec-

trophysiologist and facilitates the planning and performance of PV catheterization. Because the technique is noninvasive and does not emit ionizing radiation, unlimited follow-up studies can be performed to rule out possible complications secondary to ablation.

The morphological findings observed in our series are consistent with those described in the classic anatomical treatises^{4,6}: the superior PVs tend to present larger cross-sectional areas than the inferior veins, just as occurs with the right PVs versus the left PVs, all this in accordance with the size of the pulmonary lobes. Measurement of the ostium diameter on surfaces orthogonal to the longitudinal axis of the vessel made it possible to determine the ostial morphology, which was elliptical in one third of the PVs studied. This justifies the recommendation to use 3D postprocessing techniques.⁷ Postablation follow-up to rule out stenosis in the ablated veins should always be done by comparing with the baseline images obtained prior to ablation.

In our series, the 3 patients with PV junction variants corresponded to preablation cases. Because only few cases were studied, it is risky to relate these anomalies to the presentation of paroxysmal atrial fibrillation. Furthermore, although there are data in the literature that suggest a higher prevalence of morphological variants among patients with this arrhythmia,⁸⁻¹¹ a clear relationship between the 2 phenomena has not been established.

A limitation of the present study is that it was not done in healthy volunteers, but instead with a heterogeneous sample of patients with heart disease, which prevented the measurements obtained in the PV ostium from being considered normal reference values.

CONCLUSIONS

Knowledge of the anatomical positions and morphology of the PVs gained by magnetic resonance angiography is highly useful for the electrophysiologist, as it facilitates catheter positioning during pulmonary vein ablation. The availability of accurate information on the morphology of each PV is an advantage for follow-up studies, which can be unlimited due to the non-

invasive nature and lack of radiation of cardiac magnetic resonance imaging.

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