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Pulsed-Field-Ablation for the Treatment of Atrial Fibrillation in

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Patients with Congenital Anomalies of Cardiac Veins

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Short Title

PFA in cardiac vein anomalies

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Conflicts of interest

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Abstract

Introduction

Anomalous cardiac veins are not rare and pulmonary vein (PV) isolation for atrial fibrillation (AF) treatment should include these veins. Pulsed-field ablation (PFA) is a novel technology for AF ablation with excellent efficacy and safety profile.

In this case series, we describe our first experience of isolation of anomalous cardiac veins using PFA in patients with AF.

Methods

We report a series of patients with congenital anomalies of the cardiac veins and AF, treated with PFA. All patients underwent cardiac computed tomography for procedural planning.

Results

We included five patients (4 males). Anomalous cardiac veins included a connection of a left common ostium to the coronary sinus, a partial and a complete drainage of the right superior PV into the superior vena cava (SVC) with and without additional atrial septal defect, a persistent left SVC and an anomalous posterior PV. All anomalous PVs were isolated using PFA. No phrenic nerve palsy or other complications occurred. PFA of an abnormal right superior PV draining into the distal SVC was possible without affecting the sinus node. After a median of four months, four patients were free of recurrence. One patient had recurrent AF and perimitral reentry tachycardia, probably facilitated by PFA in the mitral isthmus region during isolation of an anomalous connection of the left common ostium to the coronary sinus.

Conclusions

Using systematic pre-procedural imaging and 3D-electroanatomic mapping, the currently available PFA system seems well suited, efficient and versatile for the treatment of AF in patients with anomalous cardiac veins.

Key words

Pulsed-field ablation; atrial fibrillation; anomalous cardiac veins; persistent left superior vena cava; unroofed coronary sinus.

Abbreviations and acronyms

AF: atrial fibrillation

LAAO: left atrial appendage occlusion

MRI: magnetic resonance imaging

PFA: pulsed field ablation

PLSVC: persistent left superior vena cava

SVC: superior vena cava

Introduction

Atrial fibrillation (AF) is the most frequent arrhythmia and pulmonary vein isolation is the treatment of choice in patients with symptomatic AF, if antiarrhythmic drugs are ineffective or undesirable.[1] Pulmonary venous anatomy can show various variants, including anomalous drainage into other cavities than the left atrium. Partial anomalous pulmonary venous return has an estimated prevalence of 0.4-0.7% in the general population.[2] Other cardiac veins may also show anomalies. Most notably, there may be a persistent left superior vena cava (PLSVC). In fact, PLSCV is detected in 0.3% of the general population, and in 4.3% of adult congenital heart disease patients[2]. These anomalous veins may play an important role in the pathogenesis of AF and hence AF ablation should include electrical isolation of these veins.[3] However, anomalous cardiac veins may be difficult to isolate because they are less accessible, and such procedures may require advanced operator skills and additional technologies.[4] Isolation of anomalous cardiac veins may also increase the risk of procedural complications like phrenic nerve palsy, tamponade or esophageal damage.

Pulsed-field ablation (PFA) is a novel technology in which microsecond-scale electrical pulses are applied to the tissue. If the electrical field is strong enough, PFA creates irreversible pores in the cell membrane and leads to cell death. The threshold for irreversible electroporation is tissue-specific. Myocardial cells have a very low threshold, which allows for tissue specific ablation.[5] Thus, PFA is ideally suited for catheter ablation of arrhythmias, because it specifically ablates cardiomyocytes, but limits the risk of collateral damage, e.g. to the esophagus or the phrenic nerve. Since February 2021, a first PFA catheter (Farawave, Boston Scientific, Marlborough, MA) is available for clinical use. The design of this PFA catheter is optimized for isolation of the pulmonary veins. It can take any form between a spherical “basket” shape to a fully-deployed “flower” configuration, thereby allowing PFA of both the ostium and antral part of the pulmonary veins. Its design, versatility, and safety profile make it also an ideal tool for electrical isolation of anomalous cardiac veins. In this case series, we report our initial experience with PFA of patients with AF and anomalous cardiac veins.

Methods

Patients selection and ethical approval

The case series includes patients with symptomatic AF and congenital, uncorrected, anomalous cardiac veins (Table 1). Before ablation, all patients underwent multimodality imaging with cardiac computed tomography angiography to reconstruct the cardiac anatomy for procedural planning, and transesophageal echocardiography to rule out intracardiac thrombi. The local ethics committees approved the study and all patients gave written, informed consent.

Ablation procedure

We used propofol, fentanyl and midazolam for deep sedation in three cases[6] and general anesthesia in two. After obtaining femoral venous access and placing a decapolar catheter in the coronary sinus, we accessed the left atrium by fluoroscopy-guided transseptal puncture or via a patent foramen ovale. Unfractionated heparin was administered to achieve a target activated clotting time >350 seconds. We used a multispline catheter (Pentaray, Biosense Webster, Diamond Bar, CA) to generated 3D electroanatomic maps (CARTO 3, Biosense Webster, Diamond Bar, CA) of both the left and right atria and pulmonary and anomalous cardiac veins, as necessary. For pulmonary vein and anomalous cardiac vein isolation by PFA we used the FARAWAVE™ catheter (Farawave, Boston Scientific) with a diameter of 31 mm in all cases. We prefer the 31 mm to the 35 mm catheter in complex anatomies like anomalous cardiac veins, because of its greater maneuverability and versatility. This catheter has five splines which can be deployed in either a basket or a flower configuration and with four electrodes mounted on each spline. For PFA, trains of high-voltage pulses were delivered from all electrodes with a generator output of 2000 V.[5] The PFA catheter was used to treat each pulmonary vein and, as feasible, any anomalous veins. The catheter was first positioned in the ostial part of the vein in a basket configuration to deliver four PFA pulses, rotating the catheter by 30° after the first two pulses, for an additional two pulses. Next, to isolate the antral part of the veins, the catheter was reconfigured into a flower shape and used to deliver another set of four PFA pulses at the entrance of the veins, again rotating the catheter by 30° after the first two pulses. After PFA, we used the Pentaray catheter to create another 3D voltage map to assess the effectiveness of the ablation. If necessary, we performed additional PFA applications until the 3D voltage map showed complete isolation of all targeted veins. All patients were routinely followed-up by continuous 7-day Holter ECG, which we typically perform 3, 6 and 12 months after the ablation procedure.

Results

Case 1

A 54-year-old male patient presented with paroxysmal atrial fibrillation. He was symptomatic with exertional dizziness, which limited his recreational sport activity. Echocardiography showed dilation of the right atrium and right ventricle. Subsequent cardiac magnetic resonance imaging (MRI) indicated a sinus venosus atrial septal defect (ASD) with left-to-right shunt and anomalous drainage of the right superior pulmonary vein into the superior vena cava and ASD region. The patient was admitted for AF ablation. After mapping of the right atrium and the right superior pulmonary vein, which partially drained into the superior vena cava (SVC) and mainly into the region of the ASD (Figure 1), the catheter was advanced into the left atrium through the ASD. However, the superior location of the ASD impaired left atrial catheter handling. A standard transseptal puncture was therefore performed and all pulmonary veins, including a right middle pulmonary vein as well as a part of the anomalous right superior pulmonary vein were ablated by PFA via this transseptal access. The right superior pulmonary vein was additionally targeted by PFA directly from the right atrium. Overall, 64 PFA applications were delivered, including 12 applications in both basket and flower configuration for isolation of the anomalous right superior pulmonary vein. Because of the severely dilated right atrium, additional ablation of the cavotricuspid isthmus was performed with radiofrequency energy (Thermocool ST/SF-catheter, Biosense Webster, Diamond Bar, CA). The patient remained free from AF recurrence 10 months after ablation.

Case 2

A 58-year-old male complained of episodes of dizziness, chest discomfort and palpitations, attributable to drug-refractory, paroxysmal atrial fibrillation. A cardiac MRI evidenced an anomalous drainage of the RSPV and RMPV into the SVC (Figure 2). The right-sided cardiac cavities were of normal volume and function. He was admitted for catheter ablation of atrial fibrillation. Transesophageal echocardiography revealed a large patent foramen ovale, which was used to gain LA access. The pulmonary veins were isolated by PFA with four applications in basket and four in flower configuration for each vein, including the right middle pulmonary vein. Eight additional applications were delivered for a superior branch of the right inferior pulmonary vein. A 3D voltage and a sinus activation map of the right atrium and SVC including the anomalous right superior pulmonary vein were generated. Six PFA applications in basket configuration were delivered in the SVC, distal to the sinus node region, to isolate the anomalous right superior pulmonary vein draining into the SVC. The remap showed complete isolation of the distal SVC, including the anomalous right superior pulmonary vein. Sinus node function remained unaffected. The patient remains free from AF recurrence 4 months after ablation.

Case 3

A 63-year-old male with paroxysmal atrial fibrillation and atrial flutter had undergone cavotricuspid isthmus ablation and repeat pulmonary vein isolation on three occasions, with additional isolation of the SVC during the last procedure. Additionally, his ascending aorta and hemiarch had been replaced, combined with coronary artery bypass grafting some years ago. The patient also presented a PLSVC, which drained into a dilated great cardiac vein. He still had frequent, recurrent, paroxysmal, symptomatic atrial fibrillation and therefore was re-scheduled for ablation, combined with left atrial appendage occlusion (LAAO) because of intolerance of oral anticoagulants. For the latter reason, the procedure was performed in general anesthesia and with transesophageal echocardiography for visualization of transseptal puncture and LAAO. The 3D voltage map at the beginning of the procedure showed isolated pulmonary veins and an isolated SVC. The posterior wall of the left atrium was isolated with 20 PFA applications in flower configuration. Mapping of the PLSVC revealed a large vessel, with electrical activation that extended distal to the ostium of the adjacent left superior pulmonary vein and roof region of the left atrium (Figure 3). The PLSVC was engaged with the steerable sheath and the PFA catheter was placed over the wire in the PLSVC. Repeat PFA applications in both the basket and flower configuration of the PLSVC led to complete isolation of the vein at the level of the junction with the great cardiac vein. LAAO was performed with implantation of a 24 mm Watchman® FLX (Boston Scientific, Marlborough, MA). Five months after ablation, the patient remains in sinus rhythm without additional episodes of atrial fibrillation.

Case 4

A 79-year-old woman was referred for ablation of symptomatic, paroxysmal AF. A 2-chamber pacemaker had been implanted eight years ago because of a tachycardia-bradycardia syndrome. Cardiac computed tomography scan showed a partially anomalous pulmonary vein connection: the left pulmonary veins conveyed into a single ostium, which drained into both the great cardiac vein and the left atrium, with left-to-right shunt and dilation of the right cardiac cavities (Figure 4). The case was discussed in the heart team, which decided against surgical correction but opted for standard pulmonary vein isolation for the treatment of AF.

A 3D electroanatomic map of the left atrium, the pulmonary veins, and the great cardiac vein with the connection to the left common ostium was generated (Figure 4). PFA of the right pulmonary veins and the left common ostium was performed from within the left atrium with the catheter in both basket and flower configuration. Additionally, the PFA catheter was placed over the wire in the dilated coronary sinus and advanced into the left common ostium. PFA was performed with the catheter in basket configuration at the level of the connection of the great cardiac vein with the left common ostium. Overall, 48 PFA applications were delivered to isolate all pulmonary veins, including the left common ostium and its connection to the coronary sinus. The pacemaker showed normal function at the end of the procedure. Because of symptomatic, atypical atrial flutter, the patient was re-scheduled for a second ablation procedure seven months later. For this procedure, we used radiofrequency ablation (Thermocool ST/SF-catheter, Biosense Webster, Diamond Bar, CA). A 3D electrocanatomic map of the tachycardia was generated, which revealed a micro-reentry tachycardia including the region of the left common ostium. Radiofrequency ablation of the ridge terminated the tachycardia into a perimitral tachycardia. An anterior line was ablated from the right superior pulmonary vein to the anterior mitral annulus because this region showed extensive scar area. The right inferior pulmonary vein had to be reisolated as well. Several months later, the patient again suffered from atypical atrial flutter. It was then decided to change to a pace & ablate strategy and the patient was scheduled for ablation of the atrioventricular node.

Case 5

A 55-year-old man with symptomatic, persistent AF and recurrent heart failure had thyroidectomy because of amiodarone-induced thyrotoxicosis. He was then referred for pulmonary vein isolation. Cardiac computed tomography scan revealed an anomalous, posterior pulmonary vein (Figure 5). A 3D electroanatomic map of the left atrium, pulmonary veins and anomalous posterior pulmonary vein was created. PFA of all pulmonary veins, including the anomalous posterior vein (4 applications in basket and 8 applications in flower configuration) was performed. This only left a small band of viable myocardium on the posterior wall. To avoid the occurrence of roof-dependent macro-reentry tachycardia, the posterior wall was ablated with 22 additional PFA applications in flower configuration. 3D voltage map confirmed complete ablation of the posterior wall. Two months after the procedure, the patient remained in sinus rhythm.

Discussion

In our case series, we present five patients with anomalous cardiac veins and symptomatic AF. All five patients were treated with PFA to isolate the anomalous cardiac veins and, as necessary, the pulmonary veins and posterior wall as well. PFA proved both efficient and safe for isolation of all anomalous cardiac veins. In fact, the PFA catheter used in all cases is specifically designed and optimized for the isolation of pulmonary veins. Its configuration can change from a basket pose to a flower pose, to isolate the ostial and the antral part of the pulmonary veins, respectively.[7] The catheter is also very well suited for isolation of any other cardiac vein, as long as the vein can be reached with the catheter. Because of the over the wire design and the accompanying steerable sheath, the catheter can easily be placed e.g. in a PLSVC. Our fourth case demonstrates that even the most complex venous malformations can be treated successfully with the system.

In addition to the larger lesion size, the tissue selectivity of PFA represents the most interesting feature of the technology. As of current knowledge, the risk of energy-dependent side effects is minimal or even nonexistent.[8] Most importantly, persistent phrenic nerve palsy or esophageal damage should not occur with PFA.[9,10] PFA is particularly effective and safe for the isolation of right-sided, anomalous pulmonary veins and for isolation of a PLSVC, which may otherwise carry the risk of phrenic nerve palsy. [11,12] In general, PFA seems to be very well suited for any anomalous cardiac vein with presumed close relation to the esophagus, such as in patients with a common inferior pulmonary vein ostium or for the ablation of the posterior wall itself.[13]

In 2 patients, we used PFA in the region of the lateral mitral isthmus to isolate a PLSVC, and to isolate an anomalous connection of the coronary sinus to the left common ostium. However, it’s important to be cautious when using PFA near a coronary artery, as it has been reported by Reddy et al. to cause coronary spasm[14] Another case report also described coronary spasm during PFA of the mitral isthmus line.[15] In our cases, we did not observe any ST elevation or other clinical signs of coronary spasm, but we did not perform coronary angiography during or after PFA and can therefore not rule out its occurrence. Tohoku et al. also used PFA for isolation of a PLSVC without observing any signs of coronary spasms. They neither noticed any signs of coronary spasm, but they also did not perform coronary angiography.[16] Until more data regarding the risk of coronary spasm is available, it is important to stay vigilant when using PFA in proximity to a coronary artery or to avoid it, and to administer nitroglycerine in case of coronary spasm.

PFA of anomalous cardiac veins in the region of the mitral isthmus leads to scar in this region and may increase the risk of subsequent perimitral reentry tachycardia if the mitral isthmus region is only partially ablated.[17] This was observed in our fourth case and in such cases, it may be sensible to generously ablate the mitral isthmus line as well, with additional endocardial ablation (by either PFA or radiofrequency ablation) and with the goal to achieve bidirectional block across the mitral isthmus line.[18]

Anomalous right-sided pulmonary veins often drain into the SVC. Although animal studies have shown that the SVC can be isolated with PFA without change in sinus node function,[19] we currently refrain from isolation of the SVC with PFA, because we fear isolation of the complete sinus node region and subsequent sinus arrest. In our cases of anomalous right-sided pulmonary veins that drained into the SVC, we first defined the region of the sinus node in detail by generating a sinus rhythm activation map. Once the sinus node region was delineated, we avoided application of PFA in close proximity to the sinus node region with the help of visualization of the PFA catheter position in the 3D electroanatomical map. Sinus node function was not affected after ablation.

One of our patients had a pacemaker implanted. We interrogate any device both before and after PFA, but performe PFA irrespective of the presence of a pacemaker or an ICD. Because PFA energy is delivered for only 2.2 seconds, we generally do not see any relevant interaction of a device with PFA. However, only limited reports have been published regarding PFA in patients with a cardiac implantable electronic device.[20]

Pre-procedural imaging with computed tomography proved very helpful in all our cases. Because we were already aware of the anomalous cardiac veins before the procedure, we were able to plan the procedure accordingly and choose the most suitable ablation technology for such situations: PFA.

Study Limitations

This is a single centre study reporting the procedural safety and the short-term outcomes of PFA for AF: no conclusion can be drawn regarding long-term efficacy. Although the acquisition of post-ablation voltage maps indicated a procedural success, no pharmacological provocative testing was performed to prove the electrical isolation of the pulmonary veins. Ultimately, the limited sample number and case mix does not allow a translation of the safety and efficacy profile on the whole population of adults with congenital heart defects.

Conclusions

With the currently available PFA system, anomalous cardiac veins can efficiently be isolated. In particular, phrenic nerve palsy or esophageal damage are no concern due to the ablation modality being non-thermal. The versatility of the catheter makes it well suited for isolating anomalous cardiac veins, even in uncommon anatomic situations.

Clinical Perspectives

PFA may represent the ablation method of choice in the close future, allowing extensive ablations with a lower risk profile in comparison to conventional ablation technologies, such as radiofrequency and cryoablation, thanks to its tissue-discriminating principle. PFA could simplify the ablation of unusually located venous structures, thus increasing the success rate in the AF ablation in patients affected by congenital heart diseases. Large-scale randomized trials are warranted to compare the outcomes of ablation procedures performed with PFA versus conventional technologies.

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Figure legends

Figure 1 (Central Illustration): Anatomical and Electroanatomical Imaging of the Left Atrium in Patient 1

A) Computed tomography scan reconstruction of the right and left atrium showing the relation of the right superior pulmonary vein (RSPV) with the superior vena cava (SVC) and the left atrium (LA) in two horizontal planes (A^1 and A^2). The red stars indicate the region of the atrial septal defect. B) and C): 3D electroanatomic reconstruction of the left (coloured) and right atrium (green, translucent) showing the voltage map before (B) and after (C) PFA with isolation of the pulmonary veins, including the anomalous RSPV. RMPV: right middle pulmonary vein; LSPV: left superior pulmonary vein; LIPV: left inferior pulmonary vein. D): 3D electroanatomic reconstruction and voltage map of the right atrium including the SVC and RSPV. RAA: right atrial appendage.

Figure 2: Anatomical and Electroanatomical Imaging of the Left Atrium in Patient 2

A) and B) Computed tomography scan reconstruction of the heart showing the anomalous right superior pulmonary vein (RSPV) draining into the superior vena cava (SVC). C) 3D electroanatomic voltage map of the right atrium, SVC, and RSPV. D) 3D electroanatomic map showing the sinus node region and activation of the right atrium (RA) and SVC in sinus rhythm. The PFA catheter was visualized before energy delivery and two exemplary application locations are displayed as brown circles in D) and E). It was ascertained, that the catheter was well above the sinus node region before energy delivery to avoid sinus node dysfunction. E) Voltage map of the region of the SVC and anomalous RSPV after PFA. F) Voltage map of the left atrium (posterior view) after PFA with isolation of the left superior and inferior (LSPV and LIPV) as well as right inferior and middle pulmonary veins (RIPV and RMPV).

Figure 3: Anatomical and Electroanatomical Imaging of the Left Atrium in Patient 3

A) and B) Computed tomography scan (after ablation) showing the relation of the persistent, left superior vena cava (PLSVC) with the left inferior and superior pulmonary veins (LIPV and LSPV) and left atrium (LA). Also shown is the left atrial appendage occluder (LAAO) just anterior of the PLSVC. C) 3D electroanatomical voltage map of the right atrium, superior vena cava (SVC), coronary sinus (CS), and PLSVC showing isolation of the SVC but electrical activation of the PLSVC distal to the ostium of the LSPV. D) 3D electroanatomical voltage map showing complete isolation of the PLSVC at the level of its connection to the CS after additional ablation. E) 3D electroanatomical voltage map of the LA (posterior view) showing persistent isolation of the pulmonary veins. F) Same view as E) after ablation of the complete left atrial posterior wall.

Figure 4: Anatomical and Electroanatomical Imaging of the Left Atrium in Patient 4

A) Computed tomography scan reconstruction showing the common ostium of the left superior and inferior pulmonary veins (LSPV and LIPV) draining both into the coronary sinus (CS) as well as into the left atrium (LA). B) 3D electroanatomic voltage map of the LA and the right superior and inferior pulmonary veins (RSPV and RIPV) and – in "glass view" – the CS, LSPV, LIPV and left CO. C) and D) 3D electroanatomic voltage map of the LA, all pulmonary veins, left atrial appendage

(LAA) and CS in LAO view (C) and posterior view (D). E) AP view of the PFA catheter in flower position at the ostium of the left CO with the wire in a branch of the LSPV. Both the multispline and decapolar catheter are placed in different branches of the LSPV and LIPV via the CS and its communication to the left CO. F) and G) LAO (F) and RAO (G) view of the PFA catheter in basket configuration located in the CS at the level of the connection to the left CO and with the wire in one of the branches of a left pulmonary vein. H) 3D electroanatomic voltage map after PFA showing isolation of the communication of the left CO to the CS. I) 3D electroanatomic voltage map (posterior view) showing ablation of the posterior wall and isolation of all pulmonary veins. Example positions of the PFA catheter during posterior wall ablation are displayed on the 3D map.

Figure 5: Anatomical and Electroanatomical Imaging of the Left Atrium in Patient 5

A) Computed tomography scan reconstruction showing the anomalous posterior pulmonary vein (APPV). B) 3D electroanatomic map of the left atrium, of all four regular pulmonary veins as well as the APPV. C) 3D electroanatomic voltage map after isolation of all pulmonary veins including the APPV as well as ablation of the complete posterior wall. LIPV: left inferior pulmonary vein; LSPV: left superior pulmonary vein; RIPV: right inferior pulmonary vein; RSPV: right superior pulmonary vein.

Figures

Figure 1 (Central Illustration)

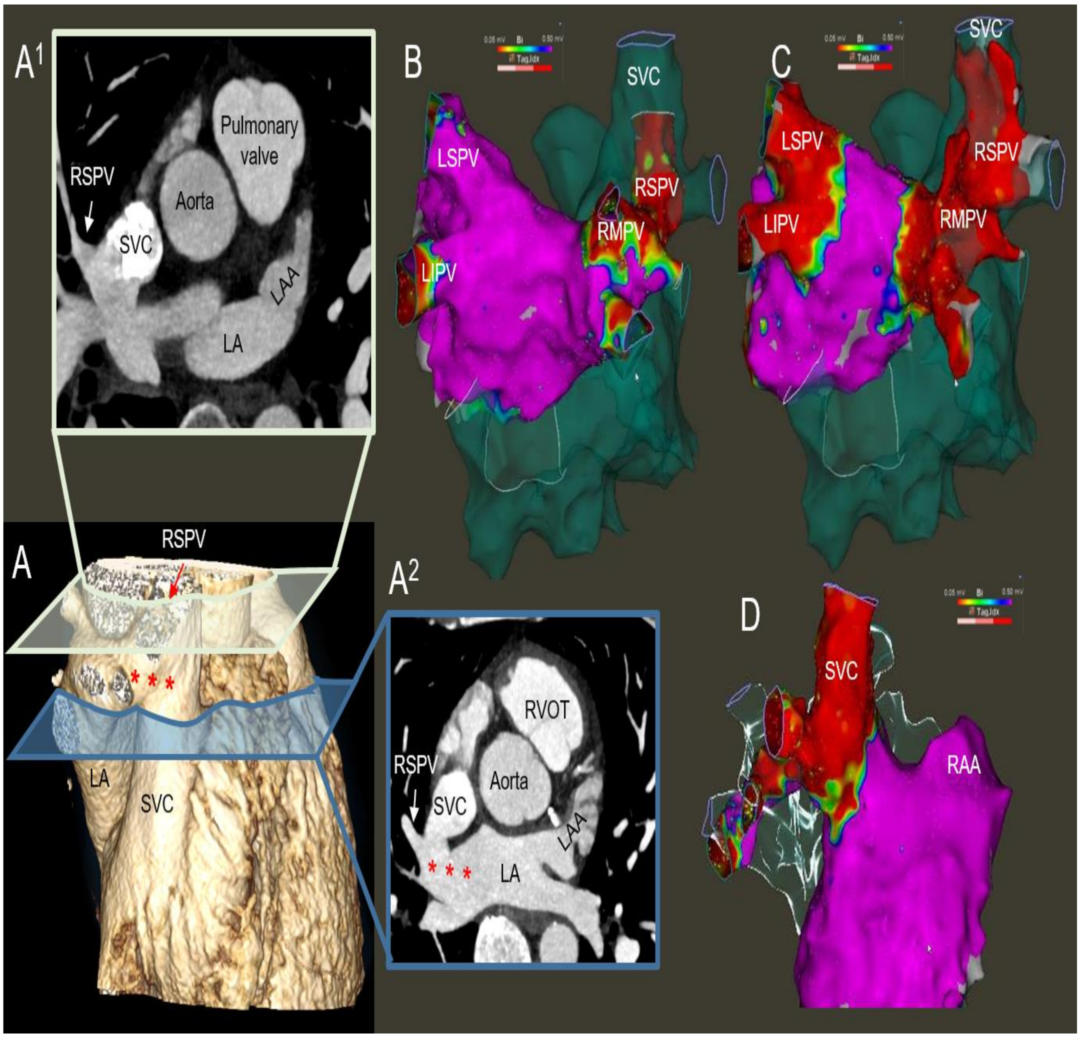
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Figure 2

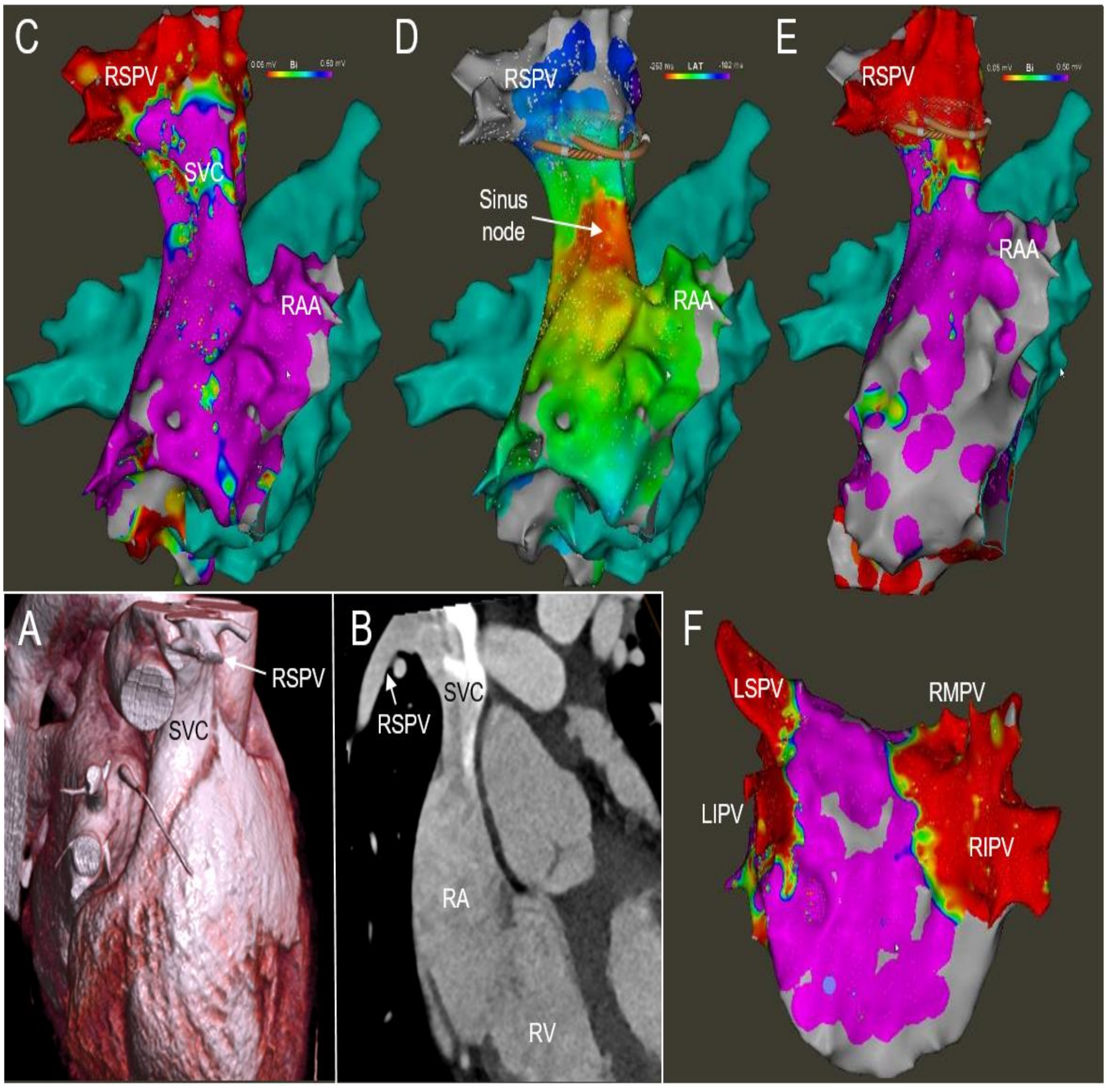
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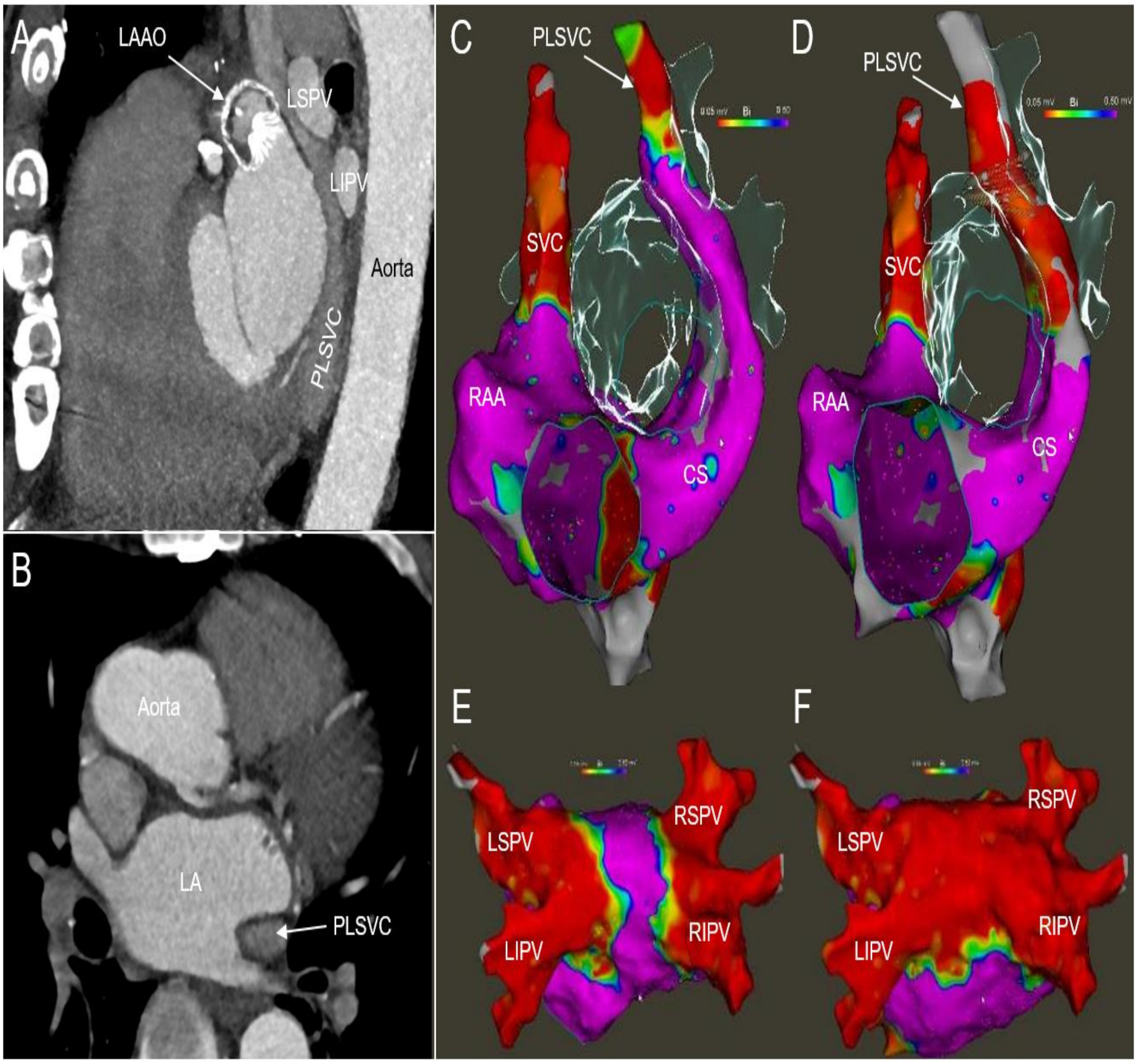
Figure 3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RIPV

Figure 4

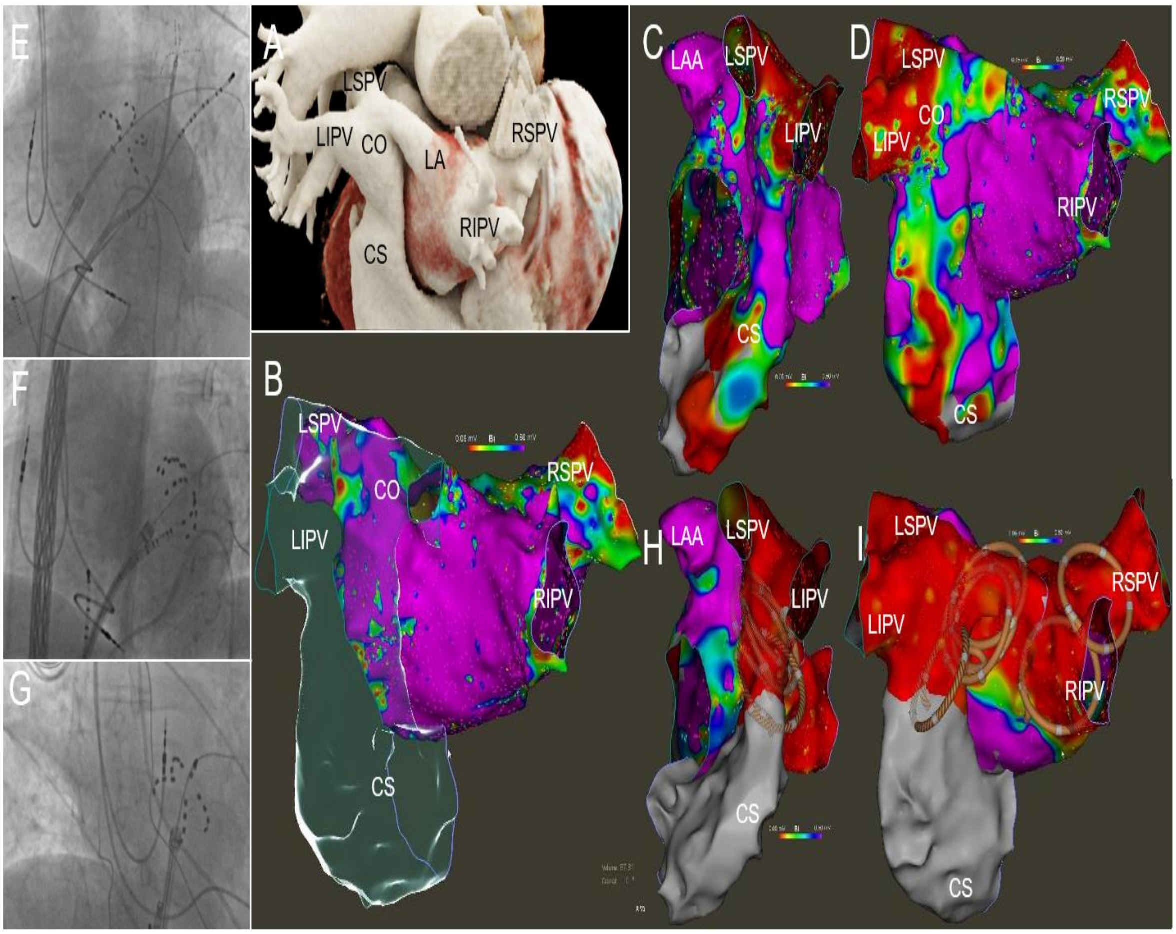
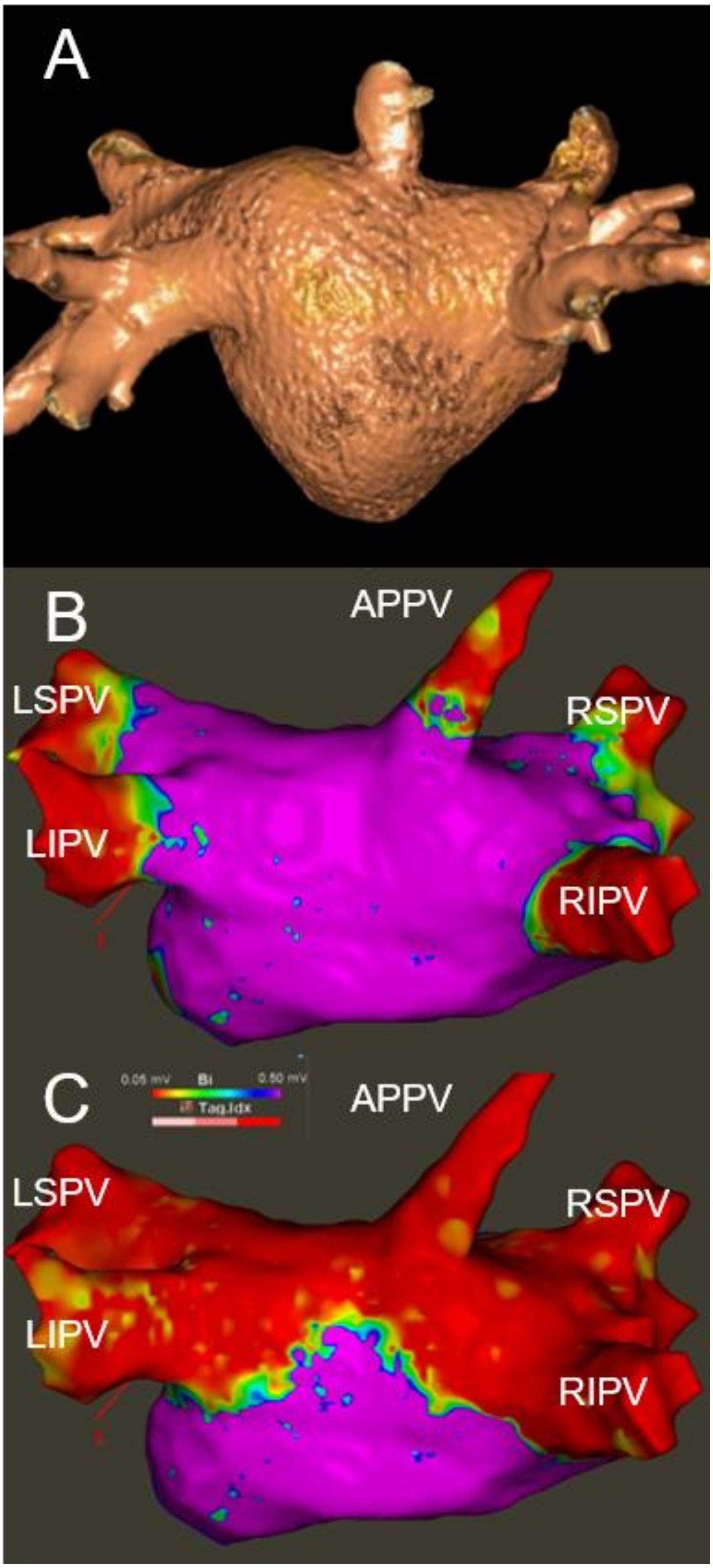

E
F
G
A
LSPV
LIPV
CO
LA
RSPV
RIPV
CS
B
LSPV
CO
LIPV
RSPV
RIPV
CS
C
LAA
LSPV
LIPV
CS
D
LSPV
CO
LIPV
RSPV
RIPV
CS
H
LAA
LSPV
LIPV
CS
I
LSPV
LIPV
RSPV
RIPV
CS

Figure 5


A
B
APPV
LSPV
RSPV
LIPV
RIPV
C
0.05 mV
Bi
0.50 mV
Tag.Idx
APPV
LSPV
RSPV
LIPV
RIPV

Tables

Table 1. Patient characteristics.

Case	Age	Sex	Symptoms	Type of AF	Other Arrhythmias	Type of thoracic vein anomaly	Other cardiac malformations
#1	53y	m	Dizziness and palpitations, EHRA IIb	Paroxysmal	None	Anomalous drainage of the RSPV into the SVC	Sinus venosus atrial septal defect
#2	58y	m	Dizziness, palpitations, thoracic discomfort, EHRA III	Paroxysmal	None	Anomalous drainage of the RSPV and RMPV into the SVC	Patent foramen ovale grade 3
#3	63y	m	Palpitations, EHRA IIb	Paroxysmal	Typical atrial flutter	Persistent left superior vena cava	-
#4	79y	f	Palpitations, EHRA IIb	Paroxysmal	Tachycardia-bradycardia syndrome	Anomalous drainage of the LSPV and LIPV in the CS	Unroofed coronary sinus
#5	55y	M	Heart failure, EHRA III	Persistent	None	Anomalous posterior pulmonary vein	-

AF: atrial fibrillation; CS: coronary sinus; EHRA: European heart rhythm association score (a score to classify symptoms associated with atrial fibrillation with a range from I [no symptoms] to IV [disabling symptoms]); LIPV: left inferior pulmonary vein; LSPV: left superior pulmonary vein; RMPV: right middle pulmonary vein; RSPV: right superior pulmonary vein; SVC: superior vena cava.

Table 2. Procedural characteristics

Case	Procedure	PFA applications	Procedure duration (min)	Fluoroscopy time (min)	Radiation dose (cGy.cm^2)	Periprocedural complications	Previous ablations
#1	PVI + CTI (RF)	64	225	42	853	None	none
#2	PVI + distal SVC	46	145	26	119	None	None
#3	PWA + PLSVC + LAAO	32	124	21	1447	None	2003 CTI 2005, 2018, 2021 PVI
#4	PVI + CS	48	200	44	2081	None	None
#5	PVs + PWA	54	97	21	2018	None	None

CS: coronary sinus; CTI: cavotricuspid isthmus; PLSVC: persistent, left superior vena cava; PFA: pulsed field ablation; PV: pulmonary vein; PVI: pulmonary vein isolation; PWA: posterior wall ablation; RF: radiofrequency ablation; SVC: superior vena cava.