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Conjoined Inferior Pulmonary Veins during Pulmonary Vein Isolation: Prevalence and Novel Approach for Pulmonary Vein Isolation with Cryoballoon

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Abstract

The number of patients referred for ablation of atrial fibrillation (AF) has been increasing with the advent of cryoenergy use in addition to the preexistent radiofrequency therapy for pulmonary vein isolation. Successful pulmonary vein isolation using cryoballoon is immensely dependent on the atrial and the pulmonary vein anatomy. Presented here are three successfully completed cases out of 351 cryoballoon ablations, performed in two centers from January 2010 to December, 2013 found to have unique pulmonary vein anatomy not previously described in association with cryoballoon. Prior to the procedure, these patients had undergone CT Angiography to determine pulmonary vein anatomy and size. During the procedure, The FlexCath catheter and a circular mapping catheter were used to map the pulmonary veins and for stability of the cryoballoon, after which the standard cryoballoon technique was performed. All three cases where successful cryoablations, despite the variant anatomy. Further improvements to cryoballoon technology will further shed light on these variant anatomies and make cryoablation more amenable in the future.

Introduction

Each patient prior to the cryoballoon ablation underwent a 64-slice multidetector computed tomography (CT) of the heart with contrast to define the pulmonary vein anatomy. On the day of the procedure, the operator reviewed the CT scan for pulmonary veins anatomy and size. The CT scan data was uploaded to the ENSITE NavX® System (Endocardial Solutions Inc., USA) for display during the ablation. The FlexCath catheter (Medtronic, Minneapolis, MN) was used to guide the ArcticFront cryoballoon (Medtronic, Minneapolis MN). A circular mapping catheter (Achieve, Medtronic, Minneapolis MN) was used to map the pulmonary veins and for stability of the cryoballoon. A 28 mm cryoballoon was inflated and positioned at the ostium of each pulmonary vein. The rest of the ablation procedure was carried out in a standard fashion as previously described (1).

Case 1: A 54-year-old man with history of hypertension and paroxysmal AF presented for cryoballoon pulmonary vein isolation. He previously failed treatment with antiarrhythmic medications and radiofrequency ablation. Contrast enhanced CT scan and 3D ESI mapping system showed a posterior bulging trunk rising from the posterior wall. The left and right superior pulmonary veins drained separately into the atrium proper. The left and right inferior veins joined a common infundibulum before draining into the medial wall of the left atrium forming a separate semi-chamber. The width of the infundibulum was 3.1 cm. The coronary sinus extended inferiorly to the semi-chamber. The esophagus coursed behind an early bifurcation of the left inferior pulmonary veins (Figures 1-2).

Cryoballoon ablation was performed with emphasized attention to the phrenic nerve. Diaphragmatic capture was monitored through compound motor action potentials (CMAP) and by manual tactile monitoring of right-sided diaphragmatic stimulation. There were no significant difficulties during the ablation. A total occlusion of the pulmonary veins with the cryoballoon was confirmed with contrast injection. Isolation of each of the pulmonary veins was achieved with one freeze and one bonus freeze. The left inferior pulmonary vein required two freezes for isolation and one bonus freeze. The lowest temperature reached was -60 C at the left superior vein. Left atrial dwell time was 82 minutes. The median left atrial dwell time at that center was 110 minutes. Follow up at 6 months confirmed the absence of recurrent atrial fibrillation.

Case 2: A 64-year-old female with a history of coronary vasospasm presented with persistent atrial fibrillation despite several radiofrequency ablation procedures. She was planned for a hybrid

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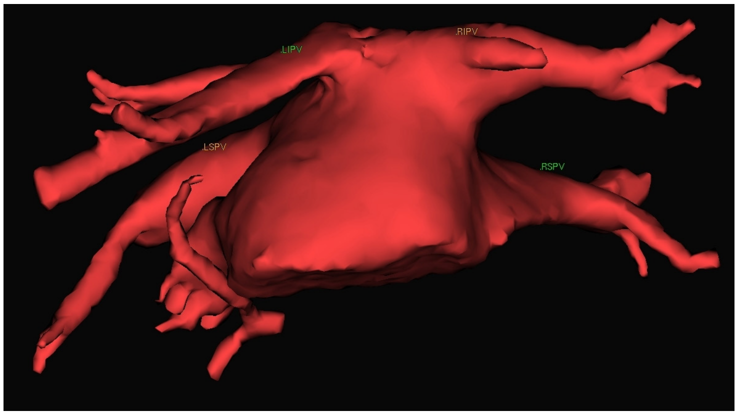


Figure 1: ESI NavX 3D mapping images of the left atrial posterior bulging trunk and originating pulmonary veins. LIPV=Left inferior pulmonary vein. LSPV= left superior pulmonary vein. RIPV= right inferior pulmonary vein. RSPV= right superior Pulmonary vein

ablation procedure with minimally invasive epicardial approach using NContact deviceTM (nContact, Morrisville, NC) and endocardial ablation with 28 mm cryoballoon. Computed tomography of the heart demonstrated conjoined right and left inferior pulmonary veins with common drainage into the left atrium. Figure 3 is an illustration of an elongated carina between the superior and inferior veins. Epicardial ablation of the left atrial posterior wall was performed with the NContact device. Pulmonary vein reconnection was noted at the carina between the right superior and inferior veins as well as the roof/antrum of the superior veins. Cryoballoon ablation isolated each superior vein and cryothermal energy delivery at the complex right carina isolated the right inferior vein. At six months of follow up, the patient had no recurrence of atrial fibrillation (Figure 3).

Case 3: A 62-year-old male with a history of apical hypertrophic cardiomyopathy on amiodarone therapy presented for cryoballoon ablation. Ambulatory cardiac monitoring recorded a high burden of paroxysmal atrial fibrillation. CT scan showed the infundibulum conjoining the right and left inferior veins (Figure 3). The right and left inferior veins were ablated individually. Segmental balloon freezes were additionally applied around the antrum of the conjoined inferior pulmonary vein, isolating this structure. Follow up at one year did not reveal any further complication and cardiac event monitoring did not reveal any recurrence of atrial fibrillation.

Discussion

The abnormal pulmonary anatomy outlined above, though rare, can prove itself to be difficult in the setting of pulmonary vein isolation. Among 351 consecutive atrial fibrillation ablation cases three such abnormalities were reported (<1%). CT scan was available prior to each procedure which allowed the operator to review the anatomical variation and plan the ablation procedure accordingly. The 64-slice multidetector computerized tomography with improved temporal and spatial resolution is one of the most commonly used tests for evaluation of pulmonary veins position, anatomy, geometry, and relation to other intrathoracic organs. MRI is another modality that is widely used also to anticipate unusual anatomy and to determine size and shape of the pulmonary veins orifice prior to cryoballoon ablation.[1]

Contralateral veins joining into an atrial infundibulum have seldom been described.[2-3] More so, the isolation of these structural variations has not been previously described with cryoablation. In all of the above cases, knowing the unique cardiac anatomy prior to each study was imperative to procedure planning. Preprocedural imaging provides the anatomy of left atrium, its dimension and the presence or absence of left atrial thrombus.[4] It also delineates the pulmonary veins with precise measurement of each ostial diameter, the distance to the first branch and allows the identification of accessory or supernumerary PVs. Imaging also allows recognition of major but rare anomalies such as persistent left superior vena cava, vein of Marshall, anomalous pulmonary venous return, a common ostium for veins, and hypoplastic or occluded pulmonary vein.

Common ostia most commonly receive ipsilateral veins but in this series the infundibulum collected blood from two contralateral veins either in a pedunculated or sessile manner.[5] Radiofrequency or cryoballoon ablation techniques can be challenging in the presence of such abnormalities. Ablation of the common pulmonary vein using radiofrequency energy would usually require a large circumference and a continuous line to achieve pulmonary vein isolation. The latter technique is tedious since it relies on point to point ablation to form a continuous block line. Alternatively, a cryoballoon approach can be adopted. The common pulmonary vein would most likely require

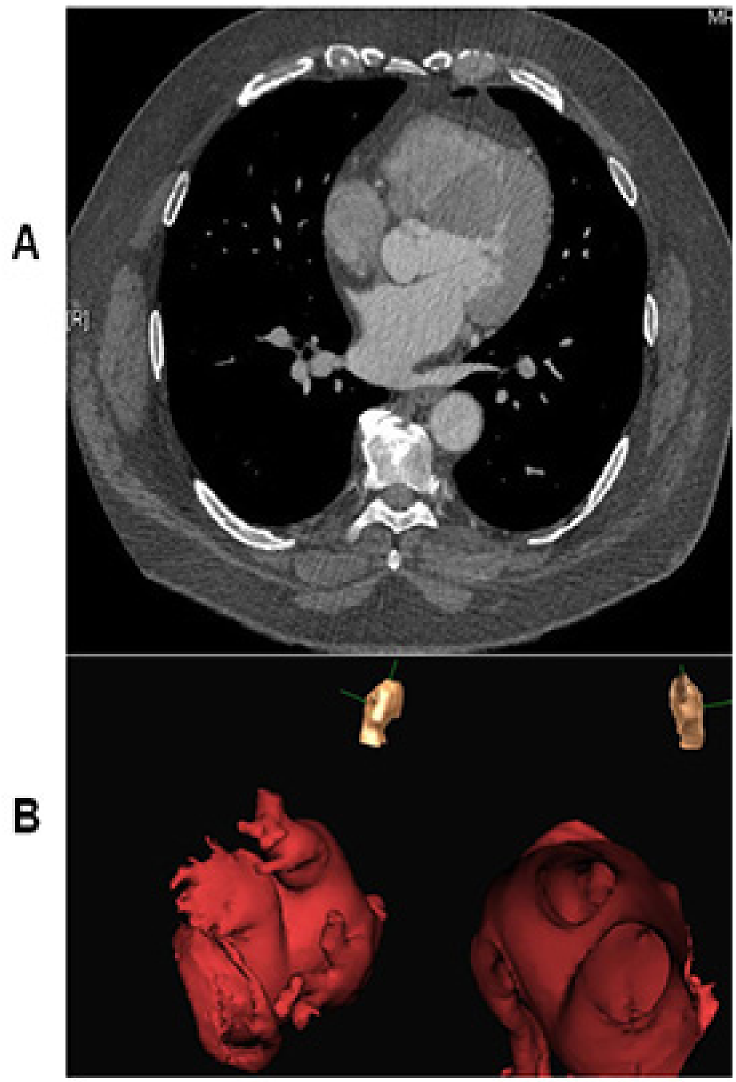
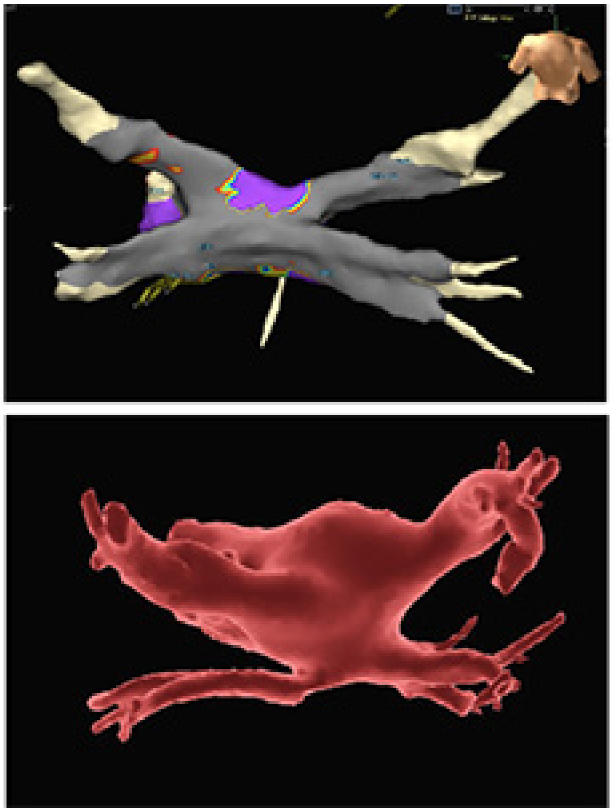


Figure 2: 2A: Axial contrast-enhanced CT angiogram images of the pulmonary veins originating from the posterior left atrial trunk. 2B: ESI Navx 3 D mapping showing conjoined sessile inferior veins and prolonged carina between inferior and superior veins

A



B

Figure 3: A: Case 3.Voltage map post ablation shows the development of low voltage scar areas at the site of freezing at the origins of all four veins. LAA=Left Atrial Appendage; LIPV=Left Inferior Pulmonary Vein; LSPV=Left Superior Pulmonary Vein; RIPV=Right Inferior Pulmonary Vein; RSPV=Right Superior Pulmonary Vein
B: Case 3. ESI 3D NavX system. Image shows the right and left inferior pulmonary veins rising from a common infundibilum from the posterior wall of the left atrium

a segmental ablation using the cryoballoon, if the diameter of the common ostium is larger than the diameter of the cryoballoon. It might also require repetitive freezes if the ostium is oval leading to complete occlusion by the spherical balloon. Nevertheless, cryoballoon might be the preferred method of choice in the presence of confluent veins as it offers a much larger surface of contact and a perfect occlusion if the catheter is correctly manipulated during segmental freezing.[6] Vogt et al. had published that the cumulative freedom from atrial fibrillation after one year of pulmonary vein isolation with cryoballoon was 62%, all shapes and locations of pulmonary veins included.[7]

Adjunctive imaging such as CT is crucial for a safe ablation.[8] Preprocedural imaging is performed to identify pulmonary anatomy and anomalous pulmonary veins. Sorgente et al. had retrospectively studied the inverse relationship between the ovality index (ratio between vertical and horizontal diameter) of the left pulmonary veins and the degree of occlusion at the interface of the cryoballoon and the ostium. An inverse relationship also exists between the orientation of the ostium and the degree of occlusion.[8] Another study by Kubala et al. evaluated pulmonary vein anatomy in 118 patients with either paroxysmal (72%) or persistent (28%) atrial fibrillation.[9] The authors demonstrated that the presence of a normal pulmonary pattern is associated with lower rates of AF recurrence at 13 months of follow up, if compared with patients with left common ostia (67% vs. 50%, P = 0.02). A future malleable cryoballoon may be able to conform to the shape of the pulmonary vein ostium and the atrium, improving upon current technologies.

In our series, two of the three (the third case did not have prior radiofrequency ablation, it was a de novo cryoballoon) cases had failed radiofrequency ablation. Failure might be related to the challenging anatomy of the veins as well as prolonged carina between inferior and superior veins.

The motion of the heart with each heartbeat and with breathing impedes the application of a constant force during radiofrequency ablation. An excessive force could lead to cardiac perforation and a suboptimal contact would result in a partial thickness lesion. A ThermoCool® SmartTouch™ by Biosense Webster is a relatively new technique that allows adjustment of the radiofrequency power according to the contact force sensed by the catheter thus avoiding the occurrence of steam pops, impedance rise and perforation.[10-11] In the absence of such a technique, cryoablation is a successful alternative. Due to its ability to stick on tissue, cryoballoon ablation circumvents the problems created by varying contact force and allows the delivery of an equivalent high contact force to all surfaces of the ablated area.[12] Several phased radiofrequency catheters have been engineered to allow more efficient application and delivering of the energy, including the irrigated multipolar ablation catheter nMARQ[13] and the pulmonary vein ablation catheter. These circular ablators could be of benefit especially when faced with abnormal anatomic pulmonary veins. Nevertheless, no head to head comparison exists between these catheters and the cryoballoon and the safety of these catheters in avoiding subclinical esophageal and cerebral lesions is yet to be determined.[14] A more novel technology termed laser balloon may also be useful in isolating conjoined pulmonary veins as it was shown to be as efficient as cryoballoon ablation for drug resistant paroxysmal atrial fibrillation.[15]

Conclusion

The drainage into the left atrium of two controlateral veins can rarely be conjoint with or without an infundibulum. In all such three cases, cryothermal ablation was able to achieve a good short and long term outcome as bidirectional block was achieved without recurrence of atrial fibrillation at >6months. Our approach suggests an alternative to point by point ablation with radiofrequency energy and suggests that ablation tools that are able to form contiguous lesion sets may offer a preferred approach in this rare structural anatomy.

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