COMPLEX CASE STUDY

Reduction in Cryothermal Energy Delivery During Isolation of the Left Persistent Superior Vena Cava: Implications for Safety and Efficacy

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ABSTRACT. Aims: The left superior vena cava (LPSVC) can be a trigger for atrial fibrillation but can be difficult to isolate, which can increase procedure-related risk. Our aim was to demonstrate whether a reduction in cryothermal energy delivery was feasible while still achieving isolation of the LPSVC, potentially improving safety of ablation in this structure. Methods: We present two cases where isolation of the LPSVC was achieved utilizing cryoballoon technology and an inner recording catheter. Preoperative computed tomography imaging was used to appropriately size the balloon to match the diameter of the LPSVC. We utilized an inner recording catheter to provide immediate feedback on electrical isolation of this structure, with the goal of reducing cryothermal energy delivery. Results: Electrical isolation of the LPSVC was achieved after just over 2 min of cryoablation in Case 1 and in 6 min in Case 2, a substantial reduction compared with prior reports. Conclusion: Minimizing energy delivery in the LPSVC with patient-specific balloon sizing and real-time feedback on electrical isolation is feasible and should protect adjacent vital structures. Such techniques may improve safety and durability of ablation in this area.

KEYWORDS. ablation, atrial fibrillation, cryoablation, left persistent superior vena cava.

Introduction

The left persistent superior vena cava (LPSVC) is an uncommon finding in adults that has been shown by other groups to play a role in atrial fibrillation (AF) initiation. The ligament of Marshall, an embryologic remnant of the LPSVC, has also been shown to play a role in AF initiation. Electrical isolation of the LPSVC has been reported by other groups, with both radiofrequency energy and cryothermal energy. In those reports, however, confirmation of isolation was determined after prolonged cryothermal energy applications, increasing the risk for damage to adjacent structures such as the circumflex artery and left phrenic nerve. Given the close proximity of these vital structures to the LPSVC, precise delivery of ablation energy is paramount. Conflicting reports of the safety of ablation in the LPSVC also exist, and the actual complication rate for ablation within the LPSVC is unknown.

A recent advance in cryoablation technology includes the availability of a circular mapping catheter (Achieve®; Medtronic Inc., Minneapolis, MN) that can be used in conjunction with the cryoablation balloon (Arctic Front®, Medtronic Inc.). The Achieve® allows real-time recording of isolation of potentials at a more distal location to the cryothermal ablation site. The time to isolation of pulmonary vein (PV) potential after initiation of cryothermal energy, or “time to effect,” has been shown to significantly correlate with durable isolation of the pulmonary veins and acute procedural success by other groups.

We present two cases demonstrating LPSVC isolation in patients with paroxysmal AF utilizing cryothermal energy via cryoballoon technology. Each patient had continued atrial ectopy or non-sustained atrial tachycardia from the LPSVC/distal coronary sinus after...
pulmonary vein isolation. Each case illustrates a reduction in overall energy delivery compared with prior reports, and may have implications for safety and durability of electrically isolating the LPSVC.

Methods/results

Case 1

A 59-year-old male with a history of paroxysmal AF and LSPVC (Figure 1a) underwent initial pulmonary vein isolation and limited focal ablation within the LPSVC in 2009 without isolation of that structure. The patient had been free of AF for over 2 years until a late recurrence of AF which subsequent drug therapy failed to control.

At repeat procedure, the left superior and right superior pulmonary veins had segmental reconnection and these were reisolated with cryothermal energy. The left and right inferior veins were chronically isolated and were not ablated. We utilized a "freeze–thaw–freeze" strategy to isolate the pulmonary veins, demonstrating occlusion with pulmonary vein venogram and color Doppler flow with intracardiac echocardiography. Despite durable isolation of the pulmonary veins, non-sustained atrial tachycardia from the LPSVC continued. Cryothermal energy application with a 28-mm cryoballoon was utilized along the anterior left superior pulmonary vein and posterior portion of the left atrial appendage (LAA), causing delay in local LPSVC potential (Figure 2) without electrical isolation of the LPSVC. The 28-mm cryoballoon was chosen based upon the measured diameter of the LPSVC (24 mm) at the carina of the left pulmonary veins and the ostial sizes of the PVs from preprocedure computed tomography (CT) scan. The coronary sinus, LPSVC, and LAA were paced for phrenic nerve capture prior to LPSVC ablation, and phrenic nerve capture could not be elicited. We then placed the 28-mm cryoballoon and Achieve™ catheter into the coronary sinus and performed ablation at the mid-LPSVC (Figure 1b). The first application demonstrated rapid isolation of the LPSVC within 6 s, achieving rapid cooling to –65°C, and energy application was halted after 13 s. The LPSVC reconnected and a second more proximal energy application achieved isolation in 4 s, achieving a temperature of –62°C for lesion duration of 120 s (Figure 2). This led to durable isolation of the LPSVC, and no further ectopic beats were seen from this structure.

We monitored ST segments throughout freezing applications, and fluoroscopy revealed normal diaphragm excursion post ablation. The patient experienced mild pericarditis symptoms without electrocardiogram findings which responded to oral non-steroidal anti-inflammatory drug therapy. At short-term follow-up (6 months), the patient was AF free.

Case 2

A 75-year-old male with a history of sick sinus syndrome and prior dual-chamber pacemaker placement (Accent RFT™, St. Jude Medical, St Paul, MN; leads, 2088 TC™, St. Jude Medical) via the LPSVC/coronary sinus presented with highly symptomatic and drug-refractory paroxysmal atrial fibrillation. He was referred for catheter ablation.

During the procedure, PV isolation was achieved with a 23-mm cryoballoon using the technique described in Case 1. Preprocedure CT scan revealed a LPSVC diameter of 21 mm at the level of the carina of the left pulmonary veins and overall smaller pulmonary veins (all <20 mm in diameter). Accordingly, we chose to use the smaller size of balloon. After pulmonary vein isolation, infusion of isoproterenol 3 µg/min induced frequent atrial premature depolarizations with earliest activation at the LPSVC/coronary sinus junction. We again paced LAA and LPSVC, and could not elicit left phrenic nerve capture. Two separate 3-min freezing applications utilizing 23-mm cryoballoon were placed at the LPSVC/coronary sinus junction (Figure 1d), achieving electrical isolation of the mid/distal LPSVC (Figure 3). Temperatures during each of the freezes ranged from –60 to –70°C. Pre- and post-ablation electrograms from the LPSVC demonstrate significant signal reduction and exit block (Figure 3). Pacemaker lead integrity during cryothermal energy application was assessed by pacing just above threshold during ablation. Lead impedance was checked before, during, and after freezing applications (right atrium 440 ohm, range 421–450 ohms; right ventricle 600 ohm, range 600–624 ohms) with stable lead parameters. Normal diaphragm excursion on fluoroscopy.
was seen post procedure. The patient noted no adverse symptoms post ablation. Device interrogation 6 months post procedure revealed no further AF and stable lead parameters.

Discussion

To our knowledge, we have demonstrated the first reported electrical isolation of the LPSVC with cryobal-
Cryothermal energy application immediate to pacemaker leads

We are unaware of data on cold tolerances of pacemaker leads within the human body, and the long-term consequences of cryothermal application in direct apposition to pacemaker leads. Anticipating the need for LPSVC isolation in Case 2, review of device literature in advance of the procedure provided little guidance regarding the safety of ablation near pacemaker leads. We chose to perform ablation targeting isolation of the distal coronary sinus and LPSVC given isoproterenol provoked ectopic beats from this structure despite durable pulmonary vein isolation. During cryothermal applications, we elected to monitor lead integrity with periodic impedance testing during energy application while pacing in DDD mode at near-threshold output. The lead parameters remained stable throughout each freezing application and post-procedure lead parameters remained unchanged in short-term follow-up (6 months). Case 2 presents a unique challenge given the absence of data on this specific situation, but appears to be feasible and safe in the short term. In the absence of long-term data on cold tolerances of pacemaker leads in the human body, however, cryothermal application in direct apposition to pacing leads cannot be routinely recommended and should be avoided in pacemaker-dependent patients.

Reduction in Cryothermal Energy Delivery During Isolation of the Left Persistent SVC

Our experience utilizing cryoballoon technology suggests that the LPSVC isolation is feasible and can be isolated rapidly. As a site of AF initiation due to its embryologic relationship to the ligament of Marshall, techniques to improve LPSVC isolation are integral to long-term AF control. Utilizing real-time electrical recordings provides the operator direct feedback on time of isolation reducing duration of energy delivery. Preoperative CT or magnetic resonance imaging can lead to more appropriate balloon sizing, perhaps achieving a more rapid and durable isolation of this structure. Minimizing energy delivery in the LPSVC with patient-specific balloon sizing and real-time feedback on electrical isolation should protect adjacent vital structures and can improve safety of ablation in this area. Further experience is required to build upon the limited reports in the literature utilizing cryothermal energy to achieve isolation within the LPSVC.

Limitations

Given the rarity of encountering LPSVC during AF procedures, comparison of efficacy and safety between radiofrequency energy and cryothermal energy for LPSVC will be difficult. It is also possible that patient-specific balloon sizing, leading to improved contact and lesion formation, may paradoxically increase risk to adjacent structures despite shorter lesion duration. More compliant or alternative balloon and sheath technology perhaps will allow improved lesions of shorter duration, further improving safety of this strategy. We also acknowledge that variability in the size of the LPSVC may limit the usefulness of patient-specific balloon sizing in an extremely dilated or diminutive LPSVC.

It is difficult to extrapolate our findings from two case reports. However, the published literature includes a paucity of patients with a LPSVC that have undergone AF ablation. Our follow-up of 6 months is short and longer term follow-up on both lead integrity in Case 2...
and clinical arrhythmia recurrences are needed to further support this strategy.

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References