

Cryoballoon ablation of the right atrial appendage to treat tachycardia in a pediatric patient

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ABSTRACT

Catheter ablation to treat atrial tachycardia originating in the atrial appendages can be challenging due to complex anatomy and concerns for myocardial perforation. When conventional endocardial ablation is unsuccessful or patients have recurrent tachycardia, alternative approaches may be entertained, including an epicardial transcatheter approach or surgical isolation or resection of the atrial appendage. Endocardial cryoballoon ablation is commonly used in adults with atrial fibrillation to electrically isolate the pulmonary veins, and has been extended to isolate the left atrial appendage to improve outcomes in these patients. There are limited reports using cryoballoon ablation to treat adults with non-fibrillation tachycardia originating in atrial appendages, and none in children. In this report, we describe our experience using cryoballoon ablation to electrically isolate the right atrial appendage to treat a pediatric patient with recurrent atrial tachycardia following 2 previous catheter ablation procedures.

1. Introduction

Catheter ablation to treat focal atrial tachycardia (FAT) originating in the atrial appendages can be challenging due to complex anatomy, simple catheter manipulation distorting the thin myocardial walls during electrophysiologic mapping, and less aggressive ablation to avoid myocardial perforation [1,2]. When conventional endocardial ablation is unsuccessful or patients have recurrent tachycardia post-ablation, alternative approaches may be entertained, including an epicardial transcatheter approach [3] or surgical isolation or resection of the atrial appendage [4–6].

For adults with atrial fibrillation, cryoballoon ablation (CBA) is a technique frequently employed for pulmonary vein isolation [7]. More recently, catheter-based electrical isolation of the left atrial appendage has been shown to improve outcomes in some of these patients [7,8]. There are limited reports using CBA to specifically treat adult patients presenting with isolated FAT originating in either atrial appendage [4,9], and none in children. Herein we describe our experience using CBA to electrically isolate the right atrial appendage (RAA) to treat a pediatric patient with recurrent FAT following 2 previous catheter ablation procedures.

2. Patient characteristics and methods

The patient was a 14-year old girl presenting with palpitations for several weeks. In clinic, her cardiac exam revealed a persistent heart rate of 178 bpm and jugular venous distention. Her ECG showed narrow QRS tachycardia with 1:1 AV conduction, and echocardiogram showed diminished ventricular systolic performance (EF 35%) with an otherwise structurally normal heart. She was admitted for acute medical management. Inpatient telemetry and 12-L ECG confirmed incessant tachycardia, with variable AV conduction and a single P wave morphology suggesting abnormal automaticity originating in the right atrial appendage. Gently titrated esmolol infusion minimally blunted tachycardia and ventricular response, but resulted in mild-moderate hypotension, prompting referral for urgent catheter ablation.

During initial electrophysiology study (EPS), FAT remained incessant (Fig. 1A). After induction of general anesthesia, esmolol was withheld and dopamine infusion administered to treat hypotension. Three-dimensional EP mapping was performed with the CARTO3 navigation system and a conventional EZ Steer mapping/ablation catheter (Biosense Webster, Diamond Bar, CA); a diagnostic multipolar EP catheter was positioned in the coronary sinus for temporal reference. The initial 3-D activation map was consistent with focal tachycardia originating in the medial base of the RAA. Earliest atrial electrograms were

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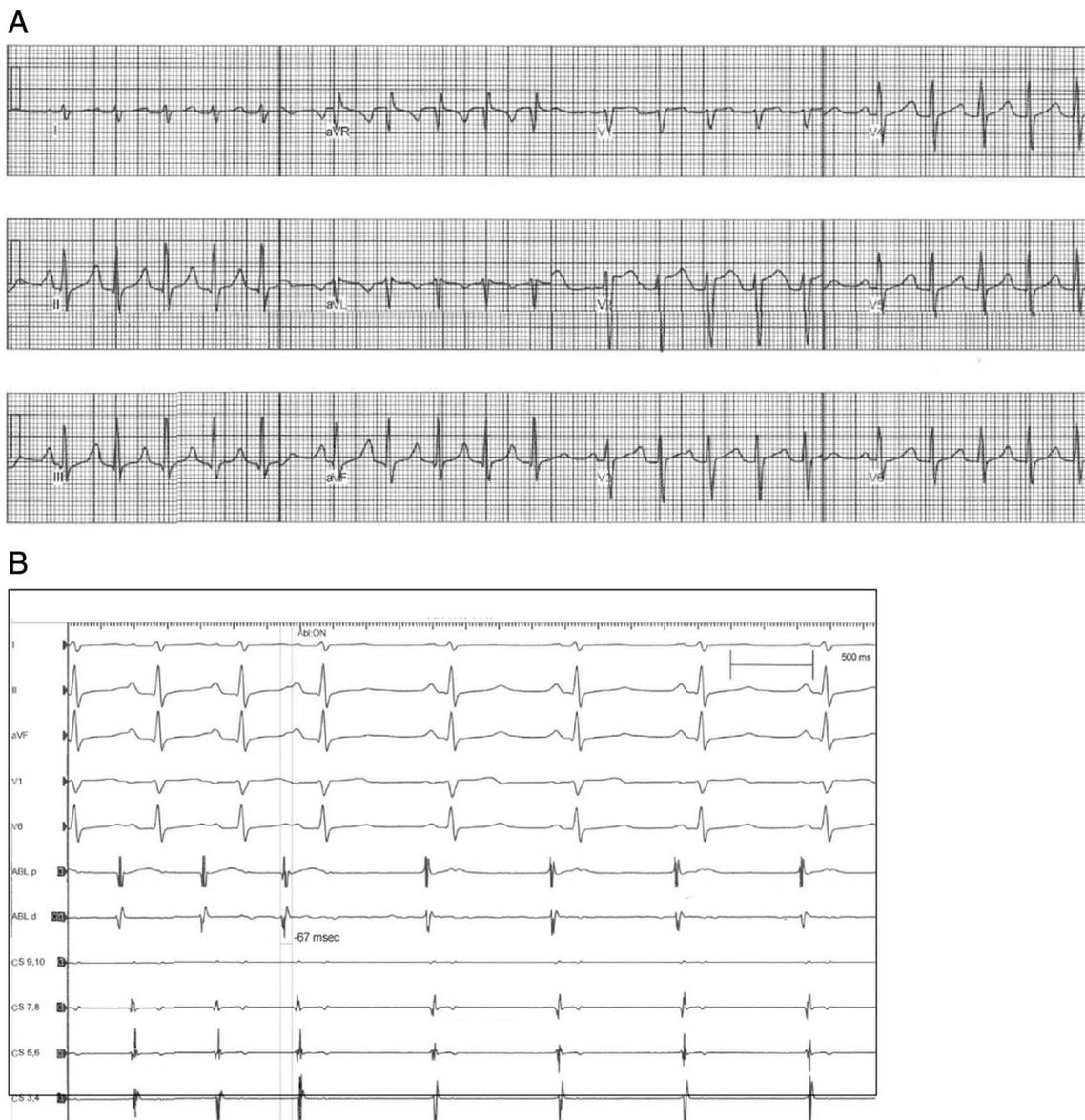


Fig. 1. (A) 12-Lead ECG recorded in a 14 year-old girl with sustained atrial tachycardia and dilated cardiomyopathy. (B) Intracardiac EP recording showing radiofrequency ablation at an early activation site (67 ms prior to onset of surface P wave), abruptly terminating focal atrial tachycardia originating in the right atrial appendage and resulting in sinus rhythm. (C) Repeat ECG showing recurrent atrial tachycardia after initially successful catheter ablation; P wave morphologies are similar to the presenting tachycardia. (D) Final ECG showing sinus rhythm after repeat catheter ablation.

rather diffuse, possibly indicating multiple foci or otherwise complex substrate (Fig. 2A); electrograms otherwise suggested healthy tissue. Simple catheter manipulation in this area transiently bump-suppressed FAT. Targeting the earliest signals with radiofrequency ablation (RFA) terminated FAT (Fig. 1B); a full 60-second application was placed, followed by several consolidation applications. FAT recurred during early post-ABL testing when isoproterenol was added to dopamine, and P wave morphologies on surface ECG were similar to the presenting arrhythmia (Fig. 1C). Repeat EP mapping identified and RFA (20–30 W) eliminated 2 other FATs in the distal RAA, up to 15 mm from the initial focus. RAA angiography to evaluate for atypical anatomy showed a typical broad-based RAA with normal contractility, no evidence of aneurysms, and a small lobe in the superior distal RAA where one of the foci was ablated. Observation over the next 60 min at baseline and during isoproterenol infusion (up to 5 $\mu\text{g}/\text{min}$) showed sinus rhythm only (Fig. 1D), confirmed with 3-D activation mapping. She was awakened and extubated, and dopamine weaned off uneventfully. She did well overnight with no acute complications or tachycardia recurrence

on repeat ECG or telemetry, and was discharged home.

Our patient developed palpitations 1 week later, and ECGs confirmed recurrent FAT with a similar P wave morphology. At this time, atenolol suppressed tachycardia. Repeat echocardiogram 3 months after her original presentation showed ventricular function had normalized. As the patient and family desired coming off medical therapy, a second EP procedure was performed after discontinuing atenolol for 4 days. On entering the EP laboratory, her baseline rhythm alternated between slow FAT with clinical P wave morphologies and sinus rhythm. Isoproterenol (1 $\mu\text{g}/\text{min}$) converted her rhythm to incessant faster FAT, persisting after induction of anesthesia. This procedure was otherwise generally similar to the first, identifying 2 distinct FATs, one likely targeted during the first procedure, and another ~20 mm anterior and inferior to prior sites. Temperature-limited (60 °C) RFA at this new site with an EZ Steer catheter was ineffective, attributed to low power delivery (~10 W); however, tachycardia was eliminated when we switched to an irrigated tip catheter (up to 20 W). Over the next 2 h and during isoproterenol infusion up to 20 $\mu\text{g}/\text{min}$, only sinus rhythm was

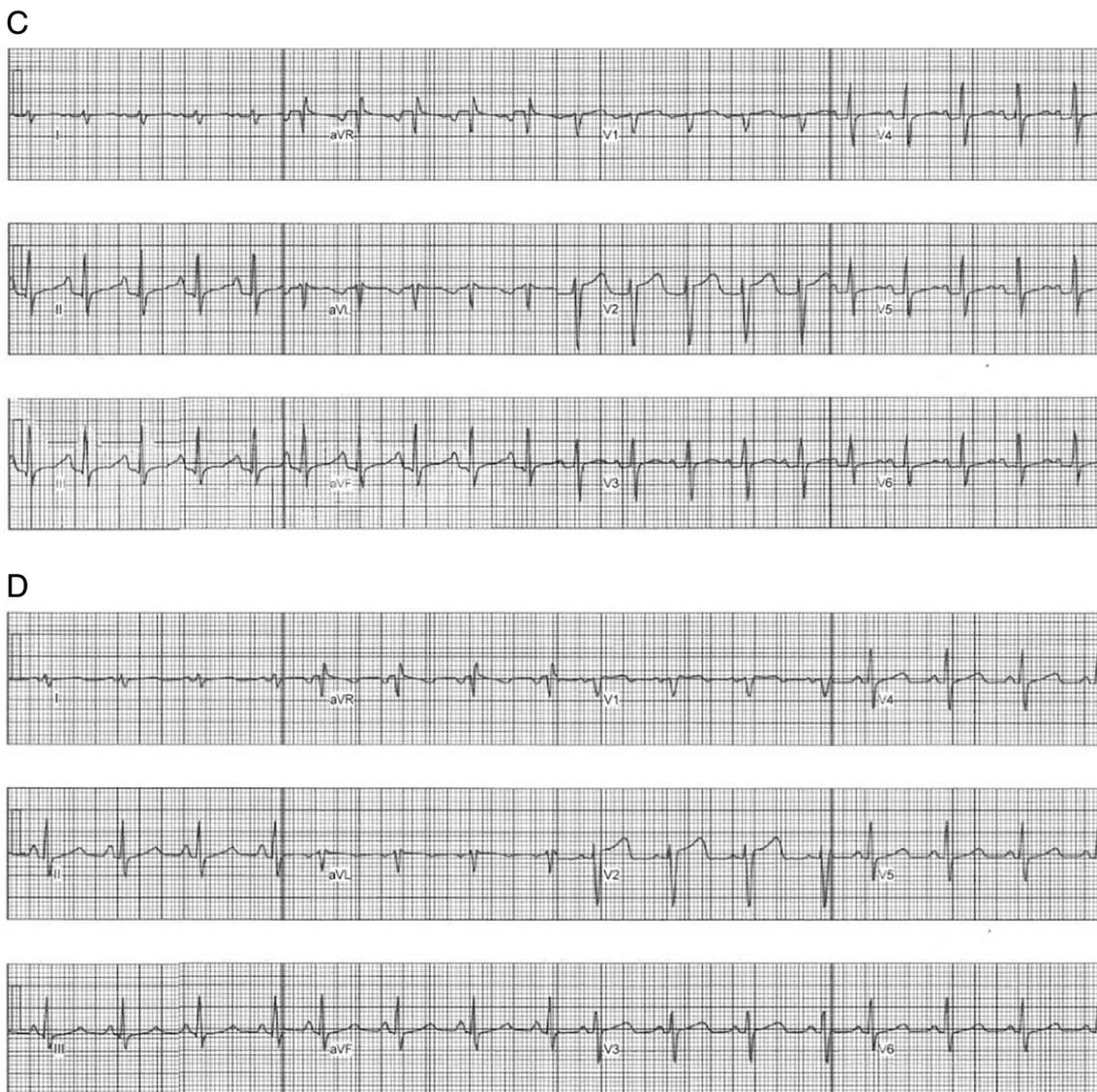


Fig. 1. (continued)

seen, again confirmed with 3-D activation mapping. She did well overnight without atrial ectopy on ECG monitoring, and was discharged home off atenolol the following morning.

Unfortunately, she again developed palpitations 10 days later. ECG confirmed intermittent tachycardia with P wave morphologies similar to prior FATs, and her arrhythmia suppressed with atenolol. Despite no side effects to atenolol, she frequently stopped taking the medication, then developed exertional palpitations confirmed by ambulatory ECG to be FAT. Over ensuing months, the patient and family expressed interest in any intervention that might eliminate her requirement for chronic medications. We discussed options including repeat catheter ablation using an endocardial or epicardial approach, or RAA isolation with surgical or catheter-based techniques. We decided to try cryoballoon ablation for its broad tissue contact to eliminate residual tachycardia foci and/or electrically isolate the RAA.

Although the patient's atenolol was withheld for 7 days prior to this last procedure, in the EP Lab she had minimal atrial ectopy at baseline and despite progressively higher doses of isoproterenol infusion prior to any sedatives. As RAA electrical isolation was a potential goal, we proceeded after she had been placed under anesthesia. We created 3-D geometries of the RA freewall and RAA, and a multipolar EP catheter was positioned in the coronary sinus for temporal reference during activation mapping and to help monitor effectiveness of ablation to

isolate the distal RAA. High-output endocardial pacing confirmed the right phrenic nerve [10] was quite posterior to the region of the RAA to be targeted for CBA. After creating a baseline 3-D activation map of sinus rhythm, a CBA catheter (28 mm Arctic Front, CryoCath Technologies, Inc., Kirkland, Canada) was deployed with a coiled Achieve EP catheter (Medtronic, Inc.; Minneapolis, MN) advanced to the tip via a long steerable sheath (Fig. 3). Combination of fluoroscopy and intracardiac echocardiography facilitated positioning the AF catheter in the RAA, and the Achieve catheter was advanced to the distal RAA to record local electrograms and perform intermittent pacing. Acceptable seating of the AF catheter was confirmed with distal contrast injections showing good circumferential tissue contact. Multiple cryothermal applications (-44 to -51 °C) were delivered as we monitored baseline rhythm and intermittent pacing from the Achieve catheter to assess sinus node function and continuity of conduction between the distal RAA and right atrium/coronary sinus. If discontinuity was not achieved after 180 s or if significant sinus slowing was observed at any time, cryotherapy was discontinued and the CBA/sheath repositioned. Minimal transient sinus bradycardia was observed rarely during cryotherapy. After 7 full applications (240 s), electrical conduction between the distal RAA and the RA/CS positions persisted but was markedly prolonged. A PentaRay multipolar catheter (Biosense-Webster, Diamond Bar, CA) was used to create dense activation and voltage maps,

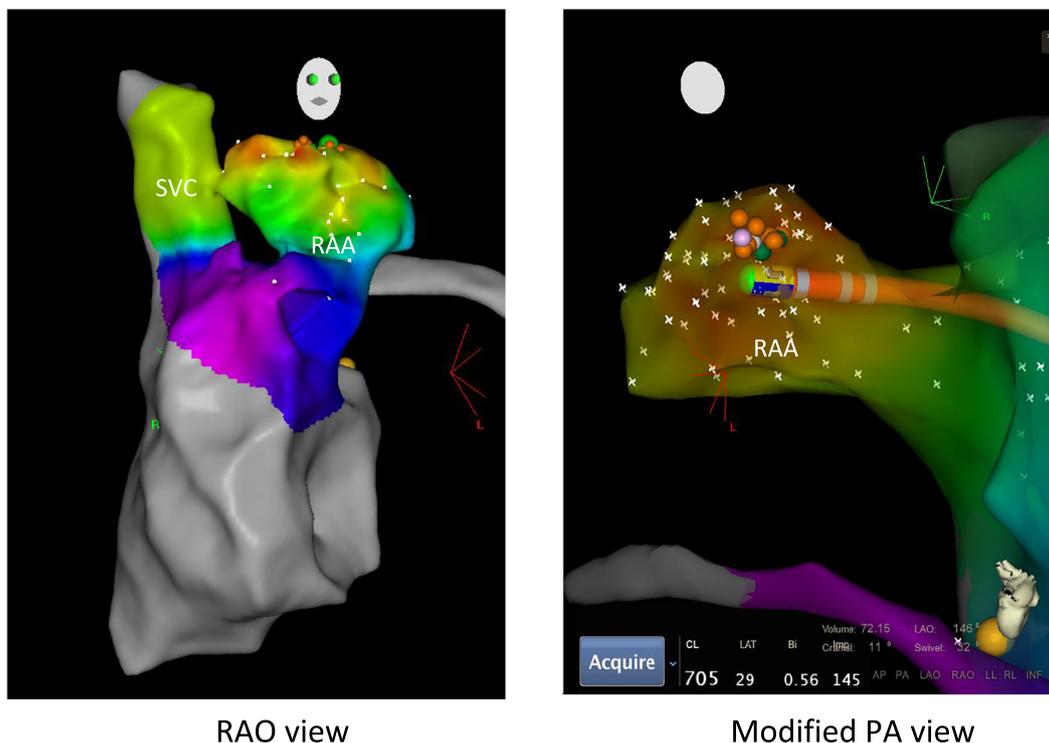


Fig. 2. Two representative 3-D activation maps (CARTO3) from different procedures in a 14 year-old girl with incessant tachycardia showing complex and diffuse areas of early activation from multiple tachycardia foci (red) within the right atrial appendage. Small pink and orange tags represent where ablation terminated tachycardia acutely.

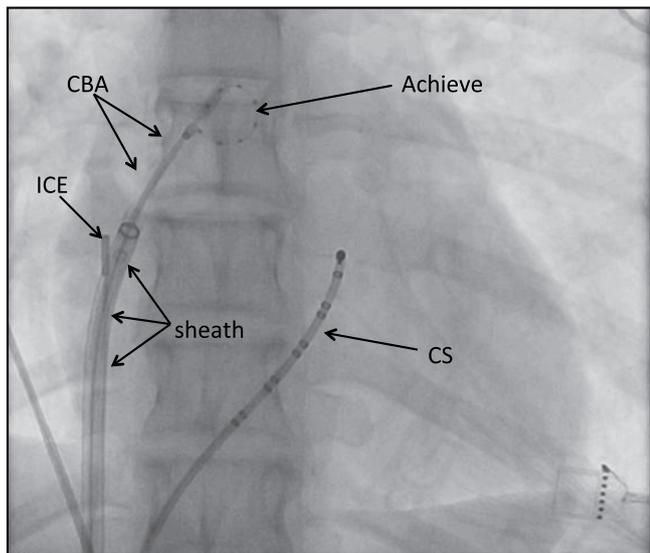


Fig. 3. Fluoroscopic image (AP view) showing position of the cryoballoon catheter deployed via a long stabilizing sheath into the right atrial appendage in a 14 year-old girl with multiple focal tachycardias. Achieve = coiled halo catheter deployed with the CBA catheter, CBA = cryoballoon ablation catheter, CS = multipolar EP catheter in the coronary sinus, and ICE = intracardiac echocardiography catheter.

revealing a few small gaps of residual conduction around the broad ring of effective ablation created by CBA (Fig. 4). These gaps were ablated using a conventional RF or linear cryocatheter (6 mm tip, CryoCath Technologies, Montreal, Canada), at sites where only low RF power was achieved. Ultimately, complete electrical isolation of the distal RAA was achieved at baseline and during infusion of adenosine and isoproterenol. Catheters were removed after RAA isolation had been

confirmed for 60 min. Total fluoroscopy time was 5.4 min, principally for positioning of the AF catheter and contrast venography to ensure tissue contact.

Our patient did well overnight with no atrial ectopy on telemetry and ECG, and was discharged home on low-dose aspirin for 6 weeks. During follow-up over 12 months, she has remained arrhythmia-free on serial ambulatory ECG recordings off medications, and is now actively participating in competitive sports. Non-contrast cardiac MRI obtained 12 months post-CBA showed normal anatomy and contractility of the right atrium and RAA, no cardiac mass or thrombus, and normal blood flow in the RAA on cine imaging.

3. Discussion

This is the first report of cryoballoon ablation used to treat tachycardia originating in the RAA in a pediatric patient. Incessant atrial tachycardia can predispose such patients to developing potentially reversible tachycardia-induced cardiomyopathy [11], as was seen in our patient. Whereas FAT from the right atrium is common, most originate in the crista terminalis, coronary sinus os, tricuspid annulus, perinodal region or interatrial septum, where catheter ablation using standard methods is usually successful [1,11–13]. In one series of pediatric patients, a RAA origin was more common than reported in adults [2].

When focal atrial tachycardias are associated with structural disease (e.g.; atrial aneurysms), surgical resection may be required (CLJ pers. obs., [14]). But catheter ablation of FAT even in a structurally normal RAA presents challenges that limit the chance for acute success and can lead to high recurrence rates [4,5,9]: (1) complex anatomical landscape including dense pectinate muscle bands alternating with thin walled myocardium, (2) simple catheter manipulation displacing the RAA walls, affecting detailed EP mapping and making the optimal site for ablation a moving target, (3) occasional catheter bumping of a tachycardia focus limiting precise 3-D mapping, (4) inability to deliver adequate RF energy in regions of low bloodflow using standard RF ablation catheters, and (5) the desire to avoid myocardial perforation

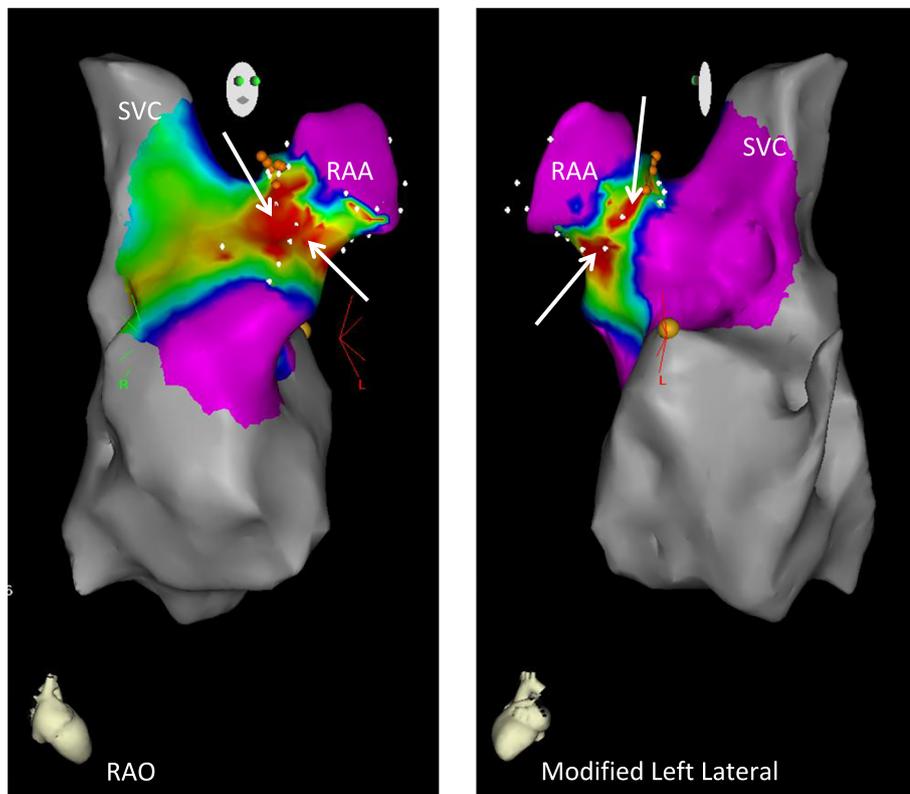


Fig. 4. 3-D voltage map (0.1–0.5 mV) showing bands of effective cryoballoon ablation in the right atrial appendage. The areas in red (arrows) reflect very low voltage/scar post-ablation, and purple indicates healthy tissue with higher voltage. The broad area of green involving the high lateral right atrium and superior vena cava (RAO view) is related to computerized interpolation by the 3-D system, not post-ablation injury.

during ablation. In addition to these challenges, our patient's tachycardia originated from multiple discrete foci within the RAA, distinct sites too far apart to be attributed to simple distortion of the RAA during catheter manipulation. After recurrence following 2 prior 'successful' ablation sessions using standard techniques, CBA helped create complete electrical isolation of the distal RAA where some foci had been mapped, and may have consolidated ablation at more proximal sites. This approach rendered our patient tachycardia-free off medications for over a year follow-up.

Prior to this last procedure, we considered multiple approaches to treat her recurrent tachycardia. Repeat catheter ablation with conventional techniques targeting residual FAT might have been effective, as her arrhythmia burden incrementally improved after each session. After 2 prior procedures failed to be curative, however, the family was understandably reluctant to pursue this strategy. In addition, we were concerned that sedation or anesthesia for peri-procedural anxiolysis and comfort, strongly desired for this patient, might temporarily suppress clinically relevant focal arrhythmia(s) and preclude comprehensive 3-D mapping. Electrical isolation of the RAA either with catheter-based [4] or surgical techniques [5,6] presented a reasonable alternative for this patient. Recognizing inherent challenges for conventional ablation catheters to completely spot-weld the complex anatomy of the RAA, we opted to try cryoballoon ablation.

There is extensive experience using cryoballoon ablation to electrically isolate the pulmonary veins in adults with atrial fibrillation [7]. Recent reports have shown that adding isolation of the left atrial appendage, with or without CBA, improves outcomes in these patients [7,8]. However, this latter approach may increase risk for thromboembolism, prompting recommendations for either chronic anticoagulation or implantation of LAA exclusion device in these patients [7]. CBA has also been used in a dilated coronary sinus to treat atrial fibrillation in an adult with persistent left superior vena cava [15].

There are very few reports of CBA in adults to treat tachycardia originating in the RAA [4,9], and none in children. Chun et al. [4] used CBA to treat an adult with FAT from the RAA. After multiple

unsuccessful endocardial RF applications and epicardial mapping showing less optimal sites, CBA was ultimately successful in isolating the RAA. They found the smaller (23 mm) AF catheter was more effective in providing an adequate seal in their patient than the 28 mm AF catheter. Amasyali and Kilic [9] used the 28 mm AF catheter for its broad contact with the RAA wall to directly ablate otherwise elusive tachycardia in the "delicate" RAA without causing electrical isolation. These authors raised the theoretical concern that electrical isolation of the RAA could precipitate a thromboembolic complication similar to LAA isolation. For our patient, we reasoned that EPS had demonstrated multiple tachycardia foci within the RAA, she had documented tachycardia recurrence after prior ablations, and had minimal atrial ectopy for adequate mapping at the third (hopefully definitive) EP procedure. We further balanced theoretical concerns of RAA thrombosis against her not having atrial level shunting by echocardiogram or during catheter manipulation during several EP procedures. In addition, following CBA, the bulk of her RAA base had not been ablated and therefore should maintain preserved systolic function, and the broad-based shape of the RAA might be less likely to develop distal thrombosis than a more tubular LAA. We treated our patient with low-dose aspirin for 6 weeks after the procedure as prescribed in most of our patients post-ablation. Follow-up cardiac MRI of the RAA one year post-ablation was reassuring.

4. Conclusions

This is the first report demonstrating that CBA to electrically isolate the RAA was effective in eliminating recurrent tachycardia in a pediatric patient who underwent prior catheter ablations using conventional techniques. Electrophysiologists faced with a challenging RAA ablation should consider this approach early on, as it might reduce the chance for post-procedure tachycardia recurrence. Although electrical isolation of the RAA can be challenging due to its broad base, trabeculations and distensible thin walls, CBA safely provided extensive circumferential lines of ablation; additional 'touch-up' ablation was required to achieve

complete isolation. Limited exposure to fluoroscopy and IV contrast were used to perform this procedure. For clinicians considering this approach, evidence of intracardiac shunting or prothrombic state should be evaluated prior to the procedure as that might affect clinical decisions (e.g.; chronic anticoagulation, defect closure, etc.). Delivering broad CBA lesions in the RAA without complete electrical isolation might be preferred in some patients. It is important to avoid excessive pressure when deploying the stiff CBA/sheath and the Achieve catheter in the distal RAA [9]. During CBA in the RAA, frequent monitoring of sinus node function is recommended. Although injury to the phrenic nerve can be a significant concern with CBA in the LAA or right pulmonary veins, that is not expected for the more anterior RAA.

Declarations of interest

None.

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