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Walsh EP.
Ablation within the coronary venous system in young patients: A focus on safety.

Zusammenfassung des wissenschaftlichen Inhalts

(Dr. med. Matthias Müller)

In dieser Studie wurden die Ergebnisse der Katheterablation der bislang weltweit größten Gruppe von jungen Patienten mit epikardial lokalisierten Leitungsbahnen vorgestellt. Alle Patienten wurden anhand eines einheitlichen Studienprotokolls untersucht. Trotz aller Vorsichtsmaßnahmen trat bei 2 der 22 behandelten Patienten eine Verletzung einer Koronararterie auf. Bei einem beträchtlichen Teil der Patienten kam es zudem zu einem Tachykardierezidiv.
Aufgrund dieser Ergebnisse sollte die Katheterablation von epikardialen akzessorischen Leitungsbahnen bei Kindern und Jugendlichen nur bei hochsymptomatischen Patienten unter strenger Abwägung von Nutzen und Risiko erfolgen.

Die Publikation wurde durch einen Kommentar durch einen der weltweit führenden Kinder-Elektrophysiologen, Herrn Prof. Edward P. Walsh, vom Boston Children´s Hospital, Boston MA, ergänzt. Der Kommentar ist den Gö-VIP-Bewerbungsunterlagen beigefügt.

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Foto des Autors

Catheter ablation of coronary sinus accessory pathways in the young

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BACKGROUND Accessory atrioventricular pathways (APs) are the most common tachycardia substrate for supraventricular tachycardia (SVT) in the young. Endocardial catheter ablation of AP may be unsuccessful in up to 5% of patients because of a coronary sinus location.

OBJECTIVE The purpose of this study was to obtain data on ablation of accessory pathways within the coronary venous system (CVS) in the young.

METHODS Analysis of feasibility, outcome, and safety in patients ≤18 years with coronary sinus accessory pathways (CS-APs) and catheter ablation via CVS in a tertiary pediatric electrophysiological referral center (May 2003 to December 2021) was performed. The control group adjusted for age, weight, and pathway location was established from patients of the prospective European Multicenter Pediatric Ablation Registry who all had undergone endocardial AP ablation.

RESULTS Twenty-four individuals underwent mapping and intended AP ablation within the CVS (age 2.7–17.3 years; body weight 15.0–72.0 kg). Because of proximity to the coronary artery, ablation was withheld in 2 of the patients. Overall procedural success was achieved in 20 of 22 study patients (90.9%) and in 46 of 48 controls (95.8%). Coronary artery injury after radiofrequency ablation was noted in 2 of 22 study patients (9%) and in 1 of 48 controls (2%). In CVS patients, repeat SVT occurred in 5 of 22 patients (23%) during median follow-up of 8.5 years, and 4 of the 5 underwent reablation, resulting in 94.4% overall success. Controls were free from SVT during follow-up of 12 months as defined by the registry protocol.

CONCLUSION Success of CS-AP ablation in the young was comparable to that of endocardial AP ablation. Substantial risk of coronary artery injury should be considered when CS-AP ablation is performed in the young.

KEYWORDS Cardiac veins; Children; Coronary sinus accessory pathway ablation; Cryoablation; Radiofrequency current; Supraventricular tachycardia; Accessory atrioventricular pathway

(Heart Rhythm 2023;20:891–899)

Introduction

Atrioventricular reentrant tachycardia (AVRT) due to an accessory atrioventricular pathway (AP) is the most common supraventricular tachycardia (SVT) in children and adolescents. AP localization is most frequent in the left lateral (30%), posteroseptal (25%), and left posterior (11%) areas.[1] Catheter ablation of AP using radiofrequency (RF) or cryoenergy application is the standard treatment of symptomatic patients and those with high risk of sudden cardiac death. Overall procedural success in children and adolescents with or without congenital heart disease is 94%, and the complication rate requiring additional diagnostic or therapeutic measures beyond standard of care is well below 1%.[1] Nevertheless, because of the anatomic location of the AP, endocardial ablation of posteroseptal and left posterior APs is not successful in approximately 5% of cases.[1,2] These pathways need to be approached from the coronary venous system (CVS) and are termed coronary sinus accessory pathways (CS-APs).[3] CS-APs are formed by myocardial cords or sleeves that extend around the coronary sinus (CS) and the middle cardiac vein serving as a connection between the ventricle and the CVS, preventing successful catheter ablation from the endocardial surface.[3] CVS-APs have been reported in 36% of adult patients referred for ablation of a posteroseptal or left posterior AP, and 58% of these patients had previously unsuccessful catheter or surgical ablation. Abnormalities of the CVS, such as diverticulum of the CS, were reported in 21% of the patients, and fusiform or bulbous enlargement of the small cardiac vein, middle cardiac vein, or CS was present in 9%.[3] RF ablation in the CVS was associated with an increased risk of coronary artery (CA) injury because of close proximity to the coronary

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arteries, particularly in children.[4,5] In contrast, cryoablation in the CVS was safe, and no significant complications related to the CA or CVS have been reported.[6–8] However, the success of cryoablation (71%) was inferior[6] to that of RF ablation in adult patients.[4]

To date, data on RF and cryoablation of CS-AP within the CVS in children are sparse. To improve our knowledge, we analyzed the feasibility, outcome, and safety in all patients ≤18 years of age who had undergone catheter ablation of an CS-AP in our tertiary pediatric electrophysiological (EP) referral center. Results were compared with contemporary data from patients who had undergone endocardial ablation of a posteroseptal and left posterior AP in the European Multicenter Pediatric Ablation Registry "EUROPA."[1]

Patients and methods

Data on all patients ≤18 years of age who had undergone CS-AP ablation at our center between May 2003 and December 2021 were enrolled. The study was approved by the ethical committee of the University of Goettingen under file no. 9/7/20 (date: July 13, 2020). Research reported in this paper adhered to the Declaration of Helsinki. During the study period, a total of 24 individuals (12 female [50%]) underwent intended ablation for an CS-AP. Median age was 12.4 (range 2.7–17.3) years, and median body weight was 43.8 (range 15.0–72.0) kg. Twenty-two of the 24 patients (91.7%) had a structurally normal heart. Of the remaining 2 patients, 1 girl was status post repair of common atrium and pulmonary valve stenosis, and the other girl had native mild subaortic stenosis. Palpitations were the indication for AP ablation in most patients (91.7% [22/24]); 1 adolescent (4.2% [1/24]) had been resuscitated from cardiac arrest, and another patient (4.2% [1/24]) had asymptomatic preexcitation.

The control group was generated adjusted for age, body weight, and pathway location from the 683 patients included into the EUROPA registry.[1] The control group included 48 individuals (27 female [56.3%]) who all had undergone endocardial AP ablation. None of these patients had undergone ablation in the CVS. Patients in the control group had a median age of 11.4 (range 0.1–17.8) years and median body weight of 50 (range 6.2–78.6) kg. Three of the 48 control subjects (6.3%) had a congenital heart defect (type not specified). There was no significant difference between the study population and control group with regard to gender, age, body weight, congenital heart disease, and number of APs. Patient characteristics are detailed in Table 1.

Early and late ablation eras

Electroanatomic 3-dimensional (3D) mapping systems were used for mapping and ablation in all patients. Considering progress of nonfluoroscopic 3D mapping systems during the last 20 years, analysis of results was separated into an early era ranging from May 01, 2003, to December 31, 2012, when the LocaLisa® (Medtronic, Inc., Minneapolis, MN) system was used in 14 of 24 patients undergoing CS-AP ablation. Starting from January 01, 2013, the EnSite NavX® (St. Jude Medical, St. Paul, MN) system was used in 42% (10/24) of patients who had undergone CS-AP ablation. A 3D mapping system had been used in all control patients.

EP study and catheter ablation

At the discretion of the operator, general anesthesia or intravenous sedation was used. Vascular access was accomplished via the femoral vessels and/or the antecubital vein or the right internal jugular vein. To reduce the use of fluoroscopy and to facilitate catheter guidance, nonfluoroscopic catheter navigation systems were used in all cases. At the beginning of the procedure, as institutional standard, before ablation all patients in the CS-AP group underwent selective coronary angiography, which included delineation of the venous phase (Figure 1A). EP study and endocardial mapping were performed as described previously.[1,9] Initial endocardial mapping of the AP was conducted along the tricuspid valve and mitral valve annuli as well as at the mouth of the CS, where appropriate. If detailed mapping failed to support a conducting accessory pathway in these areas, retrograde CS venous angiography was performed using a 5F left Amplatz® catheter (Cordis Corporation, Miami Lakes, FL) to delineate the particular anatomy of the CS and to visualize a suspected CS diverticulum (Figures 1B and 2A).

If a stable position of the ablation catheter could not be achieved, a long steerable vascular sheath (Agilis™ NxT, 8.5F, 91 cm, St. Jude Medical) was used for support (Figure 2A).

Depending on operator choice and patient size, a variety of RF and cryoablation catheters were used. RF was used as the initial energy source. As described previously by our center,[9] in patients weighing ≤25 kg, a 5F RF ablation

Table 1 Patient characteristics

	CS-AP (n = 24)	Controls (n = 48)	*P* value
Female	12 (50)	27 (56.3)	.62
Age (y)	12.4 [2.7–17.3]	11.4 [0.1–17.8]	.55
Body weight (kg)	43.8 [15.0–72.0]	50.0 [6.2–78.6]	.34
Congenital heart defect	2 (8.3)	3 (6.3)	.326
Preexcitation	13 (54.2)	37 (77.1)	**.048**
Single AP	19 (79.2)	42 (87.5)	.358

Values are given as n (%) or median [range] unless otherwise indicated. Bold indicates statistical significance set at $P < .05$.

AP = accessory atrioventricular pathway; CS-AP = coronary sinus accessory pathway.

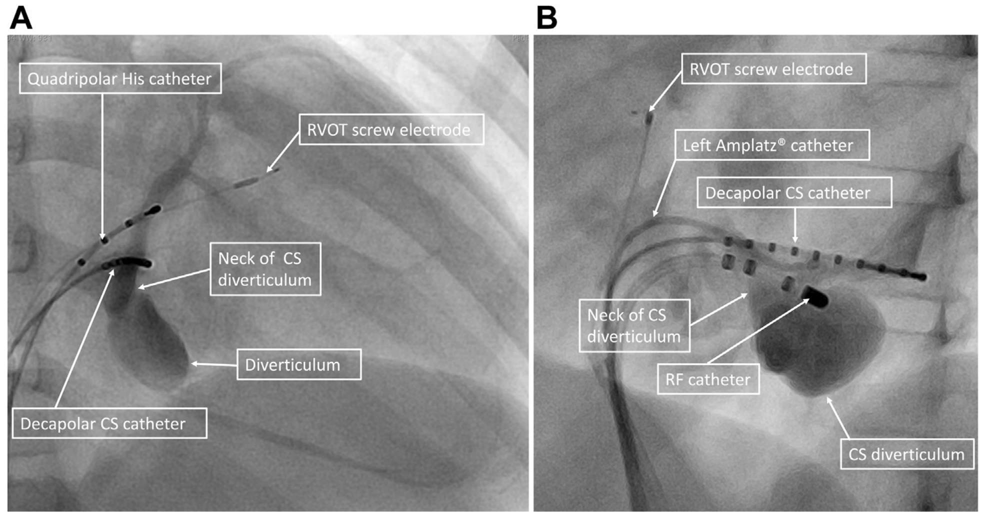

Figure 1 Angiographic workup of a 10-year-old boy (32 kg) with recurrent supraventricular tachycardia. **A:** Venous phase after selective contrast injection into the left coronary artery exhibiting a large coronary sinus (CS) diverticulum (30° right anterior oblique projection). A decapolar electrode catheter has been introduced into the CS. A quadripolar catheter marks the His-bundle region. A 2F screw electrode has been placed in the right ventricular outflow tract (RVOT) as stable reference for the LocaLisa® system. **B:** Selective retrograde CS angiography via a 5F left Amplatz® catheter delineates anatomy of the large (19.4 × 15.4 mm) CS diverticulum for mapping of the accessory atrioventricular pathway before radiofrequency (RF) ablation (60° left anterior oblique projection). A 7F RF catheter has been introduced into the neck of the CS diverticulum, and the decapolar catheter has been placed in the CS.

catheter was used; in patients weighing ≥25 kg, 7F or 8F RF ablation catheters were applied. RF ablation was performed in a temperature-controlled mode with a generator setting of 30 W in patients ≤25 kg and 50 W in patients ≥25 kg at a target temperature of 65°C. RF energy pulses were applied for a maximum of 30 seconds.

If elimination of accessory atrioventricular pathway conduction was deemed to be at increased risk by RF due to

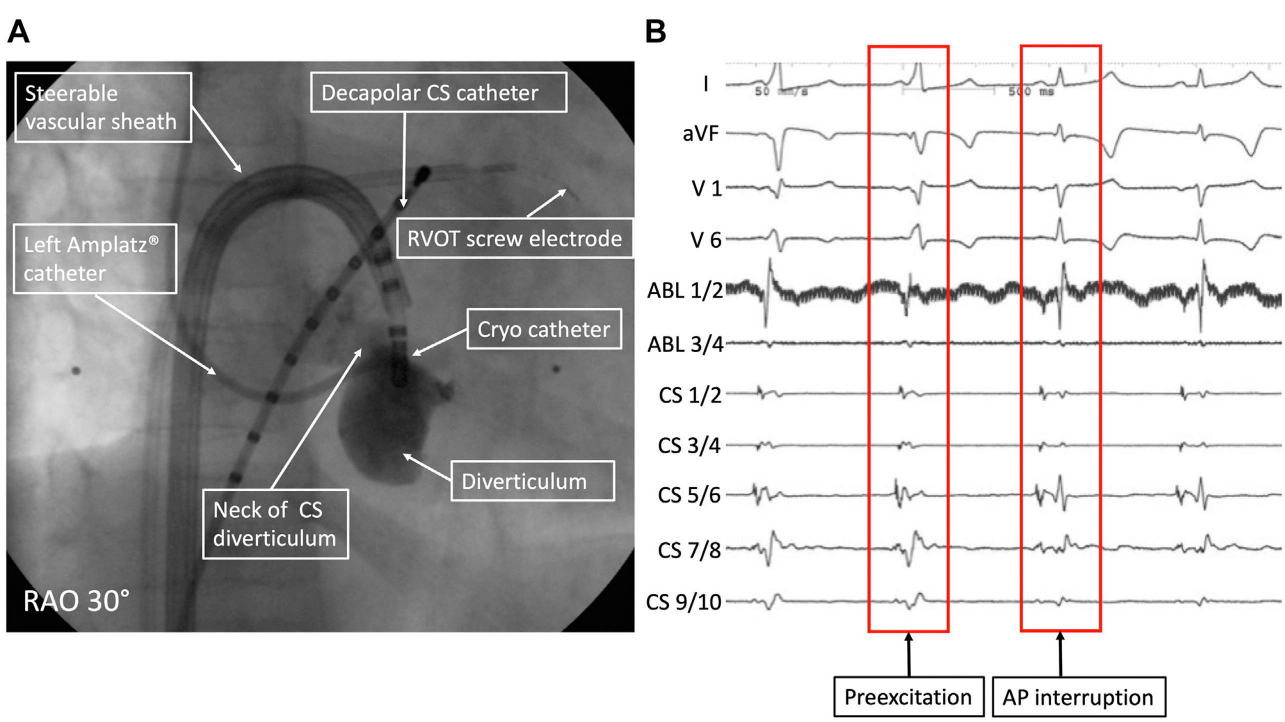

Figure 2 Combined superior and inferior approach to a coronary sinus (CS) diverticulum in a 9-year-old boy (30 kg). **A:** Selective retrograde venography into the CS diverticulum (20.7 × 16.4 mm) was performed via a 5F left Amplatz® catheter, which was introduced from the right internal jugular vein. The 7F cryocatheter was introduced into the neck of the diverticulum supported by a steerable sheath (Agilis^{TM} NxT, 8.5 F, 91 cm, St. Jude Medical). A decapolar electrode catheter is in place in the CS, and a 2F screw electrode has been placed in the right ventricular outflow tract (RVOT) as stable reference for the LocaLisa® system. **B:** Surface ECG and intracardiac electrograms during cryoablation with interruption of anterograde accessory atrioventricular pathway (AP) conduction as evidenced by loss of preexcitation. ABL = ablation catheter; Cryo = cryoenergy; RAO = right anterior oblique.

potential damage of a CA, cryoablation was performed at –70°C for 4 minutes since June 2003 (Figures 2A and 2B).[9]

In selected patients of the CS-AP group, selective CA angiography was repeated to assess the proximity of the target area to the nearby CA. In the control patients, CA damage was reported as a major complication.

To avoid CA injury during CS-AP ablation, recommendations as stated for adults with CS-AP were followed.[3] Specifically, for RF ablation a distance between the intended ablation spot and the nearby CA branch vessel >5 mm was considered safe. The final decision to proceed with RF or to switch to cryoenergy was at the discretion of the individual operator.

Success and safety

Successful ablation of concealed or manifest accessory pathway targets was defined as complete interruption of anterograde (when applicable) and retrograde pathway conduction after a waiting period of at least 30 minutes as assessed by repeat atrial and ventricular extrastimulus and adenosine testing.

Complications

Every procedure-related incident requiring additional diagnostic or therapeutic procedures beyond standard of care was defined as a complication.

Statistical analysis

Statistical analysis was performed using IBM SPSS® Statistics 27.0 software (IBM, Armonk, NY). The Shapiro-Wilk test was used to test data for normal distribution. Differences between numerical data were calculated using the Levene test and the parametric t test in normal distributed datasets and the Mann-Whitney U test if normal distribution was not given. Numerical data are presented as median [range] unless otherwise stated. Differences in categorical variables were calculated by the χ^2 test or Fisher exact test. $P < .05$ was considered significant.

Results

Of the 24 patients with CS-AP ablation, 13 (54.2%) had preexcitation pattern on ECG compared to 37 of 48 (77.1%) in the control group (P = .048.). In 19 of 24 patients (79.2%), evidence of a single AP was given, whereas 5 children (21%) had multiple pathways compared to 42 of 48 control subjects (87.5%) who had a single AP and 12.5% (6/48) who had multiple AP (P = NS) (Table 1). Of the 24 patients who underwent CS-AP ablation, 2 presented with permanent junctional reciprocating tachycardia (PJRT).

Within the CS-AP group, most APs (33% [8/24]) were localized in the proximal CS, followed by a location in the middle cardiac vein (25% [6/24]) and in the mid CS (25% [6/24]). CS-AP were only occasionally observed in the great cardiac vein (8% [2/24]) and in the distal CS (8% [2/24]) (Figure 3). A CS diverticulum was present in 6 of 24 patients (25%). The most common AP localization in the control group was posteroseptal (66.7% [32/48]), followed by the left posterior space in 33.3% (16/48) (P = NS). None of the control patients had evidence of a CS diverticulum.

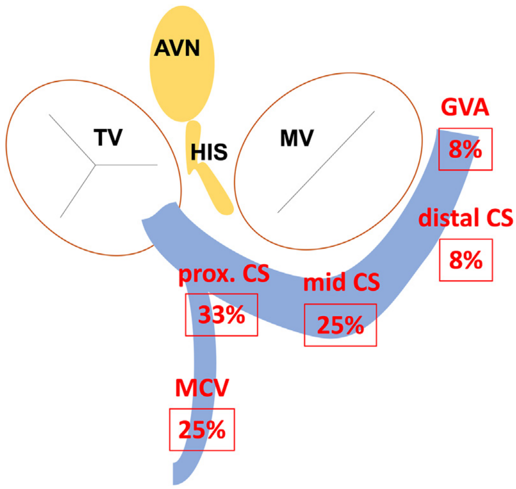

Figure 3 Location of coronary sinus accessory atrioventricular pathways in the coronary venous system of the study patients. AVN = atrioventricular node; CS = coronary sinus; GVA = great cardiac vein; HIS = bundle of His; MCV = middle cardiac vein; MV = mitral valve; prox. = proximal; TV = tricuspid valve.

Overall success

In 2 of 24 CS-AP patients, catheter ablation was not performed because of immediate proximity to a CA. One patient was a 3-year-old girl (15 kg) with PJRT in whom the intended ablation spot in the proximal CS was almost immediate to the branches of the right coronary artery (RCA). RF ablation was deferred because the stiff cryoablation catheter was thought to be inappropriate in this little child. The second patient was a 17-year-old boy (72 kg) with a left posterior CS-AP. In this patient, mapping within the CS demonstrated a distance of 1.16 mm to the underlying left circumflex CA (Figure 4A). RF was abandoned, and cryoenergy was not intended. Subsequently, pericardial puncture in this 17-year-old boy via a subxiphoid approach was performed as previously described.[10] After introduction of an 8F sheath into the pericardium, a 7F mapping and ablation catheter was advanced to the intended ablation spot (Figure 4B). Distance to the left circumflex branch was measured as 3.7 mm. Accordingly, RF energy was not applied, and cryoenergy was not used at the discretion of the operator.

For the whole CS-AP group, acute success was achieved in 20 of 22 individuals (90.9%); success was 84.6% (11/13) during the early era and 100% (9/9) during the late era (Figure 5). All 6 patients (5 early, 1 late) who exhibited a CS diverticulum had successful AP ablation. In the control group, success of AP ablation was 95.8% (46/48) (Table 2).

Ablation of a CS-AP ultimately was unsuccessful in 2 patients. In 1 patient (age 15.8 years; weight 61.6 kg) during detailed mapping within the CVS, the ablation catheter dislodged into the right atrium. Subsequently, access to the CS could not be achieved despite intensive efforts. In the other patient (age 16.6 years; weight 58.5 kg) interruption

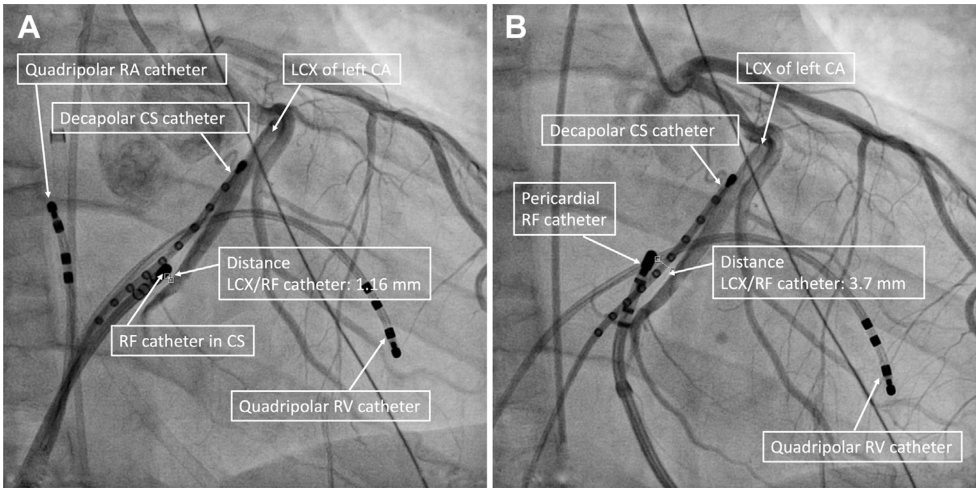

Figure 4 Selective coronary angiography (30° right anterior oblique projection) of the left coronary artery during mapping of a left posterior accessory atrioventricular pathway (AP) in a 17-year-old boy (65 kg). **A:** The radiofrequency (RF) catheter is placed in the proximal coronary sinus (CS). Distance of the tip of the ablation catheter from the intended ablation site to the left circumflex branch (LCX) is measured at 1.16 mm. Quadripolar catheters are positioned in the right atrium (RA) and the right ventricle (RV), and a decapolar catheter is placed in the CS. Contrast injection has been accomplished via a 5F left Judkins® catheter. **B:** Epicardial mapping of the left posterior AP after percutaneous subxiphoid access to the intrapericardial space has been established. As before, the tip of the mapping and ablation is placed at the intended ablation spot. A distance of 3.7 mm between the tip of the RF catheter and the intended ablation site becomes evident. A quadripolar catheter is in place in the RV and a decapolar catheter in the CS. The left coronary artery (CA) was visualized using a 5F left Judkins® catheter.

of the AP by RF and cryoablation was unsuccessful despite promising local electrograms. In this patient, irrigated RF application was not performed because of proximity (<5 mm) between the target and the circumflex CA.

Energy source

RF was the most common energy source in the CS-AP group, used in 18 of 22 patients (81.8%). Seventeen of the 22 patients (77.3%) had nonirrigated RF and 1 of 22 (4.5%) had irrigated RF application. Cryoablation was performed in 4 of 22 patients (18.2%). In the 6 patients with a CS diverticulum, 3 (50%) had cryoablation as the primary energy source. The remaining 3 patients were treated with nonirrigated RF energy. In none of these patients was a problem with energy delivery in the neck of the diverticulum noted. In 1 patient with CS-AP, the energy mode was switched from RF to cryoenergy because of proximity to a CA. In the control group, all patients had nonirrigated RF application.

Procedural data

For the 24 study patients, median procedural duration was 215 [122–418] minutes, median fluoroscopy time was 14.3

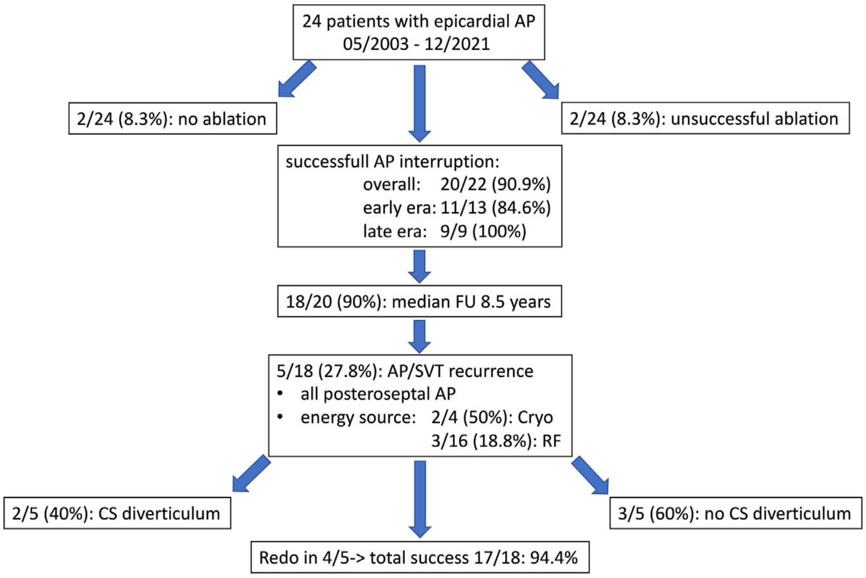

Figure 5 Short- and long-term outcomes of patients after coronary sinus accessory pathway ablation. AP = accessory atrioventricular pathway; CS = coronary sinus; Cryo = cryoenergy application; FU = follow-up; RF = radiofrequency; SVT = supraventricular tachycardia.

Table 2 Procedural data during early and late eras for epicardial ablation and in control patients

	Early era (n = 14/24) (May 2003 to December 2012)	Late era (n = 10/24) (January 2013 to December 2021)	*P* value for comparison of early vs late era	Controls (n = 48)	*P* value for comparison of early era vs controls	Late era vs controls
Procedural duration (min)	263 [139–392]	194 [122–418]	.1	163.0 [76–425]	**.006**	.271
Fluoroscopy time (min)	26.1 [12.5–71.0]	1.5 [0.5–25.5]	<**.001**	6.0 [0.1–31.3]	<**.001**	.195
Median X-ray dosage (cGycm^2)	10,543 [1650–207,450]	1029 [38.0–3860.0]	<**.001**	1002.5 [0.4–4459.0]	<**.001**	.887
Diverticulum	5 (35.7)	1 (10.0)	—	NA	—	
Initial success [n/N (%)]	11/13 (84.6)	9/9 (100)	.217	46/48 (95.8)	.147	.533
Complications	Temporary coronary artery injury (n = 1)	Permanent coronary artery injury (n = 1)	—	Coronary artery injury (n = 1)	—	

Values are given as median [range] or n (%) unless otherwise indicated. Bold indicates statistical significance set at *P* <.05.
NA = not available.

[0.5–71.0] minutes, and median X-ray dosage was 3040 [38.0–207,450] cGycm[2].

During the early era until December 2012 (14/24 patients, CVS diverticulum in 5 patients), median procedural duration was 263 [139–392] minutes, median fluoroscopy time was 26.1 [12.5–71.0] minutes, and median X-ray dosage was 10,543 [1650–207,450] cGycm[2]. During the late era from January 2013 (10/24 patients, CVS diverticulum in 1 patient), total procedural duration had not significantly changed ($P = .1$), whereas fluoroscopy time ($P < .001$) and X-ray dosage ($P < .001$) was significantly decreased compared to the early era (Table 2). The main reason for fluoroscopy during the late era was CA angiography and transseptal puncture.

All patients in the control group underwent EP study and ablation between November 2013 and April 2016. In comparison to the early CVS ablation era, procedural duration ($P = .006$) and fluoroscopy time ($P < .001$) were significantly shorter and X-ray dosage was lower ($P < .001$). For the control group compared to the late CVS ablation era, procedural duration ($P = .271$), fluoroscopy time ($P = .195$), and X-ray dosage ($P = 0.887$) were not significantly different (Table 2).

Complications

A total of 2 major complications occurred (2/22 [9.1%]) during the study period. Both individuals had evidence of CA injury after RF application. The first patient was a 3-year-old boy (16.4 kg) with PJRT who had developed tachycardia-induced cardiomyopathy. RF energy delivered with 30 W at a target temperature of 65°C in the proximal CS resulted in immediate pathway elimination. Selective angiography of the RCA at the end of the procedure revealed a short-distance stenosis of the distal RCA (Figures 6A–6D). Intracoronary application of 0.05 mg nitroglycerin had no effect. Because of the small vessel size, percutaneous transluminal coronary angioplasty and stent implantation were deemed not reasonable. Repeat coronary angiography 4 days and 8 weeks later showed that the RCA stenosis had slightly regressed but was still present. Cardiac magnetic resonance during rest 8 weeks after catheter ablation showed undisturbed perfusion in the posteroseptal space; however, after adenosine stress test, local ischemia became evident (Figures 6E and 6F).

The second patient, a 16-year-old girl (52.6 kg), had successful RF ablation (50 W, target temperature 65°C) in the proximal CS for a right posteroseptal AP. Final coronary angiography revealed a 50% stenosis of the left circumflex artery adjacent to the ablation site. After intracoronary application of 0.05 mg nitroglycerin, findings improved. Repeat coronary angiography 6 weeks later documented complete disappearance of CA narrowing.

In the control group, RF application of a posteroseptal AP in a 16-year-old girl (1/48 [2.1%]; 52 kg) was complicated by

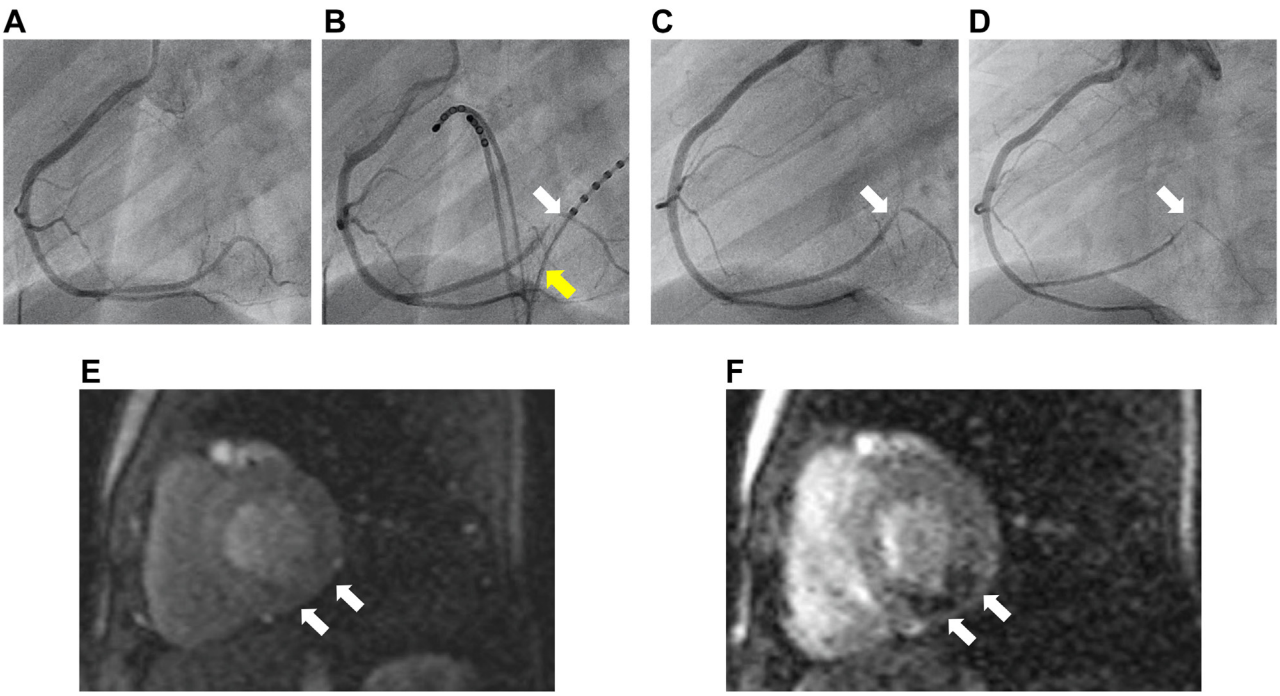

Figure 6 **A–D:** Selective angiography of right coronary artery fluoroscopy in the left anterior oblique (60°) projection of a 3-year-old boy (16.2 kg) with permanent junctional reciprocating tachycardia and coronary sinus posteroseptal accessory pathway ablation. **A:** Normal right coronary artery (RCA) before radiofrequency ablation. **B:** Short distance narrowing *(white arrow)* of the distal RCA 30 minutes after RF ablation of the accessory atrioventricular pathway in the proximal coronary sinus (30 W, target temperature 65°C, 30 seconds). A decapolar catheter is positioned in the coronary sinus *(yellow arrow).* Quadripolar catheters are placed at the His-bundle region and in the right ventricle. **C:** Slightly regressed RCA obstruction *(white arrow)* 4 days after RF ablation. **D:** Unaltered RCA injury *(white arrow)* 8 weeks after ablation. **E, F:** Cardiac magnetic resonance imaging of the same patient as in **A–D** 8 weeks after RF ablation. **E:** Unimpaired myocardial perfusion was present during rest *(white arrows).* **F:** Diminished perfusion in the posteroseptal region *(white arrows)* after adenosine stress test.

coronary injury. RF settings had been at a temperature of 65°C at 50 W. Additional information on the site of CA injury and the course after CA injury was not available.

Follow-up after CS-AP ablation

Data on the mid-term success of AP ablation were obtained from 18 of 20 patients (90%); 2 patients with initial successful ablation were lost to follow-up. During median follow-up of 8.5 [0.1–17.2] years, 5 patients (3 RF, 2 cryoablation) had AP or SVT recurrence after CS-AP ablation. In the 3 patients after RF ablation, recurrence occurred within 24 hours (n = 1), after 2 weeks (n = 1) and after 10.2 years (n = 1), respectively. In the 2 patients after cryoablation, SVT recurred after 3.3 and 12.4 years, respectively. All patients with AP or SVT recurrences had a posteroseptal AP. A CS diverticulum had been present in 2 of 5 patients. After RF application, recurrence rate was 18.8% (3/16) compared to 50% after cryoablation (2/4) (Figure 5). Age ($P = .961$) and body weight ($P = .622$) were not predictive of recurrences. During follow-up, 4 of 5 patients had successful repeat ablation of the CS-AP, and 1 patient denied a repeat procedure. Thus, procedural success including reablation was 94.4% (Figure 5).

Per protocol, control patients underwent follow-up of 12 months, during which no recurrence was reported.

Discussion

This retrospective clinical trial analyzed outcome, mid-term success, and complications in patients ≤18 years of age who had CS-AP ablation in a tertiary pediatric EP center. Results were compared to a matched control group for pathway location, age, and body weight as generated from the EUROPA registry.[1]

Findings are of significance, as all patients with CS-AP ablation had pre- and postablation coronary angiography and median follow-up of 8.5 years, thus allowing meaningful conclusions. In contrast, control patients underwent only 12 months of follow-up. Some recurrences in the CS-AP patients occurred very late (3, 10, and 12 years). Therefore, data may underestimate the number of recurrences in the control group.

As reported before in adults, in the present study most CS-AP were localized in the proximal CS and in the middle cardiac vein.[10–13] Anomalies within the CVS, such as a diverticulum, or enlargement of the cardiac veins may render the ablation procedure more complex. In adult patients, Sun et al[3] described a CVS diverticulum in 21% and fusiform or bulbous enlargement of the small cardiac vein, middle cardiac vein, or CS in 9% of patients with CS-AP. In the present study, a CVS diverticulum was evident in 25% of patients (6/24). Catheter manipulation for detailed mapping within these diverticula in young patients required enhanced vigilance and use of fluoroscopy. Five of 6 patients with a CVS diverticulum were studied during the early era with support of the LocaLisa system, which does not allow reconstruction of detailed anatomy as may be accomplished with the EnSite NavX system.[14] This extraordinary setting may at least in part explain longer procedural time as well as higher fluoroscopy time and X-ray dose during the early era. Apart from these complex ablations, significantly reduced fluoroscopy time and X-ray dose in the late ablation era reflect improvement of 3D mapping systems over time. Procedural data from the late era were not different from data obtained from endocardial mapping and ablation in the control patients who all had mapping supported by a 3D mapping system.

As reported before in adults, RF application within the CVS in immediate proximity to a CA carries an increased risk of CA injury, as was evident in 2 of 22 of our patients. A distance ≤2 mm has been reported to be associated with a 50% risk of CA injury using RF, whereas risk was 0% after cryoablation.[4] The distance from the proximal CS to the adjacent CA may vary between 2.5 mm in young children to 11 mm in adolescents.[5] These findings may explain the increased risk of CA injury in children after RF ablation in the CS.[15]

In the 3-year-old boy with PJRT who had damage of the RCA (Figures 6A–6E), it became evident that the distance from the ablation spot to the vessel had been misinterpreted by the operator. The second patient with transient CA narrowing distance to the coronary vessel was measured as 6 mm.

In the present study, despite focusing on individual CA anatomy, after CS-AP RF ablation, risk of CA injury was increased by almost 5 times (9.1% vs 2.1%) compared to endocardial RF ablation in the control patients. As reported previously, cryoablation was safe, with no evidence of CA injury seen in these patients[7]; however, recurrences were frequent. Although catheter ablation now can be performed without use of any X-ray technology,[16] the present data highlight the importance of fluoroscopy for coronary angiography in young patients when CS-AP ablation is considered.

Overall initial success during the early and late eras of RF and cryoablation of CS-AP in the young was 90.9% and slightly less compared to the control group (95.8%), but the difference did not reach statistical significance. Late AP-CS era patients and controls were all studied with a 3D mapping system. Results now show even a higher initial success rate (100%) for the late CS-AP era than in controls (95.8%). As before, this difference did not reach statistical significance. Findings underline the impact of the 3D mapping systems when complex ablations within the CVS are performed.

There was a substantial risk of CA damage in small patients with CS-AP and RF ablation in the CVS. Nevertheless, even using an intrapericardial access, special attention must be paid to the coronary arteries to avoid CA injury due to ablation therapy.

Study limitations

Given the experience of our center covering >800 ablation procedures for AP since October 2002, CS-AP ablation of AP was rare, resulting in a small patient sample size. Therefore, the statistical power in this work is limited. However, data should be taken into account when CS-AP ablation is performed in the young.

Conclusion

In summary, mapping and ablation of CS-AP in the young required an individual approach depending on AP location and patient size. Selective angiographic delineation of the anatomy of the CVS and CA supply was mandatory for success and safety. Substantial risk of CA injury should be considered when CS-AP ablation is performed in the young.

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EDITORIAL COMMENTARY

Ablation within the coronary venous system in young patients: A focus on safety

Check for updates

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Despite decades of experience, catheter ablation of an accessory atrioventricular pathway (AP) in the posteroseptal region can still be challenging owing to complex anatomy and the proximity to coronary arteries. This is especially true for APs involving the musculature around the proximal coronary sinus (CS), the middle cardiac vein, or a diverticulum off the CS.[1] The coronary venous system (CVS) can be navigated with high precision guided by a contrast injection in the CS, and the mapping data tend to be relatively unambiguous within these structures, usually displaying a clear AP potential. But even when AP localization is firm, the delivery of safe and effective ablation energy is not straightforward. Two obstacles can frustrate ablation efforts. The first is altered thermodynamics for conventional radiofrequency (RF) energy in a semi-enclosed space with reduced blood flow, causing high temperatures and low power delivery. The second relates to the risk of injury to adjacent coronary arterial branches. Unfortunately, efforts to overcome the former with irrigated RF ablation only increases the risk of the latter. The operator is often forced to accept cautious low power RF applications or else resort to cryoablation with a higher-than-average likelihood of AP recurrence.[2,3] Another option may be to consider pericardial access for epicardial ablation,[4] but there is no advance guarantee that an epicardial target will be any safer than a CVS target with respect to coronary vessels and, on occasion, may actually be more hazardous.

The coronary arterial branches at highest risk during these procedures include the posterior descending (when ablating in the middle cardiac vein or certain diverticula) and the posterolateral extension of the distal right coronary supplying the medial aspect of the left ventricular base (when ablating inside the CS proper or certain diverticula). For the occasional patient with left dominant coronary circulation or when ablation is performed much beyond the proximal segment of the CS, the circumflex artery could also be at some risk. It should be emphasized that coronary injury can be subtle in this setting and does not necessarily generate noticeable changes on the surface electrocardiogram during the procedure, even when the damage is angiographically unmistakable. Furthermore, the long-term consequences of even minor coronary injury from ablation are still not completely understood.[5]

Many centers, including our own, insist on coronary arteriography before RF energy is delivered within the CVS. Measurement of the distance between the putative target site and the neighboring coronary arterial branches should then be used to determine the amount of energy and type of energy used for ablation. Stavrakis et al[6] provided valuable and practical safety guidelines for nonirrigated RF ablation in the CVS on the basis of experience with 169 adult patients. Their data suggested that a separation >5 mm is safe, 3–5 mm is borderline, and <3 mm is ill-advised. Cryoablation was recommended for cases where the safety factor was unacceptably low. These recommendations have been widely adopted for both the adult and pediatric populations undergoing ablation for an AP within the CVS, although no pediatric-specific data have been published to date. Given the reduced cardiac size and the uncertain long-term effects of ablation near a coronary vessel in a child's developing heart, more information would be welcome.

In this issue of *Heart Rhythm Journal*, Müller et al[7] provide some much needed data on AP ablation within the CVS in a group of young patients (mean age 12.4 years). These investigators are well-suited to address the issue. Their institution has a long-standing interest in the effects of RF lesions on coronary arteries at all locations in the heart in both children and various animal models and has adopted a rigid policy of performing selective coronary angiography before any ablation within the CVS. Although their study group was relatively small (only 24 cases over 18 years), the challenges of CVS ablation were nonetheless apparent. Despite all reasonable precautions, 2 of their patients still had detectable coronary injury after RF ablation (1 permanent and 1 seemingly transient). In 2 other cases, ablation had to be deferred entirely, and in 4 cases, cryoablation had to be used. They also described 1 teenager in whom pericardial access

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was obtained for epicardial ablation after the best site in the CVS was found immediately adjacent to a coronary branch, although the separation between the epicardial target and the coronary was still too close to justify RF energy delivery, and the procedure had to be aborted. Consequently, outcomes after a first procedure for their study group were inferior to matched controls with non-CVS pathways, and the recurrence rate (23%) was dramatically higher than that in controls.

This experience will ring true with all pediatric electrophysiologists performing ablation procedures at high-volume centers. Müller et al could not offer any new solutions to the challenge of ablation in the CVS, but their data clearly emphasize the need for caution. The fact that coronary injury can still occur at a center of excellence that is so acutely focused on the potential for coronary harm[8] suggests that this is not a trivial concern. Choosing when and how to ablate such APs requires clear-headed judgment that balances the risk of the AP against the risk of ablation. For instance, when managing an ill patient with tachycardia-induced myopathy from the permanent form of junctional reciprocating tachycardia (which frequently maps to the CVS) or a patient with rapidly conducted preexcited atrial fibrillation and cardiac arrest, one would naturally choose to be aggressive and strive for permanent ablation success even if it required accepting some risks. On the contrary, it would be entirely inappropriate to proceed in a similar manner for a conventional concealed AP in the CVS causing occasional self-limited tachycardia events that might be managed perfectly well with vagal maneuvers or a relatively benign medication. None of us want to accept failure when we bring a patient to the laboratory for ablation, nor are we content to tolerate a high incidence of recurrence. However, AP ablation in the CVS should never become a grudge match, and a healthy respect for unintended collateral damage must remain foremost in the clinician's mind whenever such procedures are performed.

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