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ORIGINAL PAPER

Remaining challenges in catheter ablation of accessory pathways: rare entity of coronary sinus diverticulum-associated pathways

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Abstract

Introduction A limited number of case reports of coronary sinus (CS) diverticula complicating catheter ablation have been published.

Methods and results We retrospectively analysed 2245 patients who underwent ablation of an accessory pathway (AP) at our institution between 1/11/1993 and 31/10/2016. Eight patients (0.36%) were found to have a CS diverticulum in venography. APs showed a mean antegrade conduction time of 276 ± 23 ms (range 220–310 ms) and a mean retrograde conduction of 301 ± 45 ms (230–350 ms). Four patients had 1 ($n = 2$), 2 ($n = 1$), or 3 ($n = 1$) previously failed ablation attempts. Pathways could not be ablated with a conventional 4 mm tip catheter in 7 of 8 cases. In seven patients, ablation was successful, in two using an 8-mm ablation catheter, in two using cryoablation, and in the remaining three with an irrigated tip ablation catheter. After failed femoral approach, one 9-year-old female was successfully ablated via the right jugular vein. In one 75-year-old female, ablation was not successful. During a mean follow-up of 8.9 ± 6.4 years, all patients remained free of recurrences.

Conclusion In inferoseptal pathways, especially with previous failed ablation attempts, venographies of the CS should be performed. After successful ablation long-term prognosis is excellent.

Keywords Ablation · Accessory pathway · Coronary sinus · Diverticula · WPW syndrome

Introduction

Since the first reports of ablation of right- [1] and left-sided [2] accessory pathways (AP) have been published, catheter ablation has evolved as a treatment of choice for patients with Wolff–Parkinson–White syndrome. The overall success rate of catheter ablation of accessory pathways is approximately 95% [3]. Pathways located at the posterior mitral annulus are associated with particular high success rates [4], whereas pathways located inferoseptally sometimes remain challenging. The posterior septal space is a complex anatomic region comprised of the mitral and tricuspid valve annuli, the ostium of the coronary sinus (CS), the middle cardiac vein, the atrial and ventricular septa and the epicardial fat pad in the atrioventricular groove [5].

One particularly rare and complex entity of inferoseptal pathways are accessory pathways associated with CS diverticula. CS diverticula (see Fig. 1) represent a congenital anomaly of the CS, consisting of a neck connecting the CS to a venous pouch. It has been proposed that the formation of the diverticulum is due to an incomplete regression of the sinus venosus, a contractile chamber whose right extension during embryogenesis comes to be the cardiac end of the superior vena cava, and whose left extension forms the CS. Myofibral remnants of said sinus venosus in the CS diverticulum are likely to cause atrioventricular (AV) connection [6, 7]. It has also been suggested [8] that inferoseptal pathways are associated with CS diverticula in 10% of cases, but to this date only a few case reports have been reported and long-term follow-up data after ablation therapy is scarce. We therefore aimed at performing a systematic analysis of patients referred to our centre for catheter ablation of accessory pathways associated with CS diverticula.

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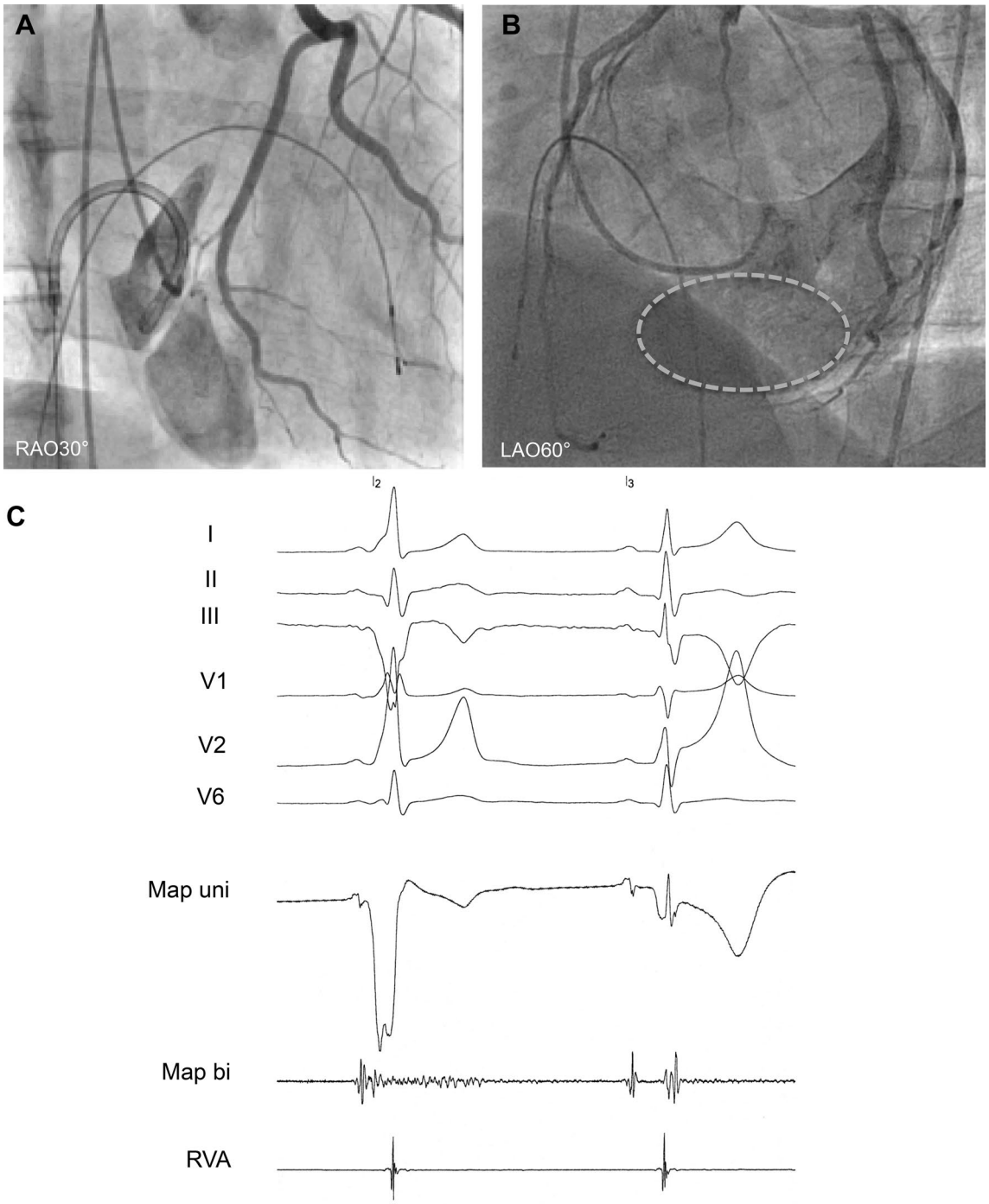

Fig. 1 **a/b** Angiography of CS diverticula of patient 5, including coronary angiography to demonstrate spatial relation. **c** 30 s after Freeze-Onset Block in the AP (Modified from [9])

Methods

Study design

The present study is in accordance with regional and institutional ethics guidelines. Retrospective data collection was approved by the local ethics committee ("Ethik-Kommission der Ärztekammer Westfalen-Lippe und der Westfälischen Wilhelms-Universität"); there are no conflicts of interest to declare. We performed a retrospective analysis of a prospectively designed single centre

database of consecutive patients referred to our centre for catheter ablation. The database comprised 2245 patients who underwent catheter ablation of an accessory pathway between 1/11/1993 and 31/10/2016. In eight of these patients (0.3%), a CS diverticulum was diagnosed by phlebography of the CS. These eight patients were included in this study and analysed with regard to clinical, as well as electrophysiological characteristics and procedure outcome. The mean follow-up was 8.9 ± 6.4 years.

ECG diagnostics

A standard 12-lead ECG was recorded with 25 mm/s as well as 50 mm/s. ECG were recorded 1 day prior to, immediately after the ablation, as well as on discharge and every following visit at our centre. Delta waves were defined as a slurred up or down stroke at the beginning of the QRS. Polarity and AP localization was classified as positive or negative depending on criteria established by Arruda et al. [10].

Ablation procedure

All procedures were performed under conscious sedation using intravenous boli of piritramide, midazolam, and/or propofol. Once venous access was gained through the femoral vein, quadripolar catheters were placed in the right ventricular apex and the bundle of HIS. A steerable decapolar catheter was positioned in the CS. Programmed stimulation was performed before and after administration of orciprenaline to evaluate AV nodal and accessory pathway conduction properties as well as to induce tachycardia.

The tricuspid/mitral annulus was mapped via the right femoral vein during tachycardia, as well as during fixed ventricular pacing. If left atrial mapping was required using an 8-F non-steerable sheath under fluoroscopy guidance with continuous pressure monitoring, a transseptal puncture (TSP) was performed. In this case, ACT-guided anticoagulation using unfractioned heparin was administered. CS phlebographies were performed at the operator discretion and were carried out by injecting approximately 10 ml of non-ionic contrast in posterior–anterior and left-anterior oblique 60° projections using a multi-purpose catheter (MP1SH, Boston Scientific Inc., Natick, MA, USA). Before ablation, weight adjusted bolus of unfractioned heparin was administered intravenously. To prevent damage to the coronary arteries, coronary angiography was performed prior to energy delivery. Ablation was performed using an 8-mm non-irrigated radiofrequency (RF), cryo- (Fig. 2), or an irrigated 4-mm catheter. Energy delivery was initially set at 25 W for radiofrequency ablation. If antegrade and retrograde block was achieved, a waiting period of 30 min was respected in all patients. Transthoracic echocardiography was performed immediately, as well as 24 h after the procedure to exclude pericardial effusion (Fig. 3).

Follow-up

All patients underwent scheduled visits after 3 months in our outpatient clinic for follow-up. Furthermore, patients were instructed to present at our emergency department if tachycardia recurrences occurred. End point of the follow-up was pathway and/or tachycardia recurrences with or without documentation.

Results

Patient collective

In total, 2245 patients were screened for the study, 21% showed posteroseptal pathways. Eight patients, three female, were included in the study (mean age was 40 ± 22 years, range 8–82 years). All patients had a history of documented, symptomatic, and supraventricular tachycardia. No patient suffered from structural heart disease except for one patient with a pre-existing coronary artery disease with normal left ventricular function. Two patients had a history of paroxysmal atrial fibrillation. Three patients had a history of failed flecainide therapy. 12-lead ECG showed a delta wave in six of the eight patients. Positive delta waves were seen for all six patients in leads I, aVL and V1 (see Table 1). The remaining two patients had an only retrogradely conducting pathway. Negative delta waves inferior were seen in all patients [11]. The mean PQ interval was 110 ± 37 ms, mean QRS 122 ± 38 ms and the mean QTc 403 ± 45 ms (Table 2).

Procedural findings

Patients received a mean of 2.1 ± 1 procedures before they were free of symptoms [1 ($n = 2$), 2 ($n = 1$), or 3 ($n = 1$) previously failed ablation attempts]. In one patient, a 75-year-old woman, ablation was unsuccessful after three attempts. She received flecainide after failed ablation and remained free of recurrences thereafter. In one patient, ablation was not possible via a femoral access. In this 9-year-old girl, ablation was finally successful via a jugular vein approach.

Venographies revealed a diverticulum (Fig. 1) defined as a bulging/pouch connected to the CS by a short neck. The mean antegrade conduction time of the accessory pathways was 276 ms ± 23 ms (range 220 ms–310 ms) and the mean retrograde conduction time was 301 ± 45 ms (230–350 ms). Tachycardia was induced prior to ablation in all patients and showed a mean CL of 322 ± 55 ms. Venography was performed either during the first ($n = 2$) or during the second ablation attempt ($n = 6$). In all patients with non-concealed

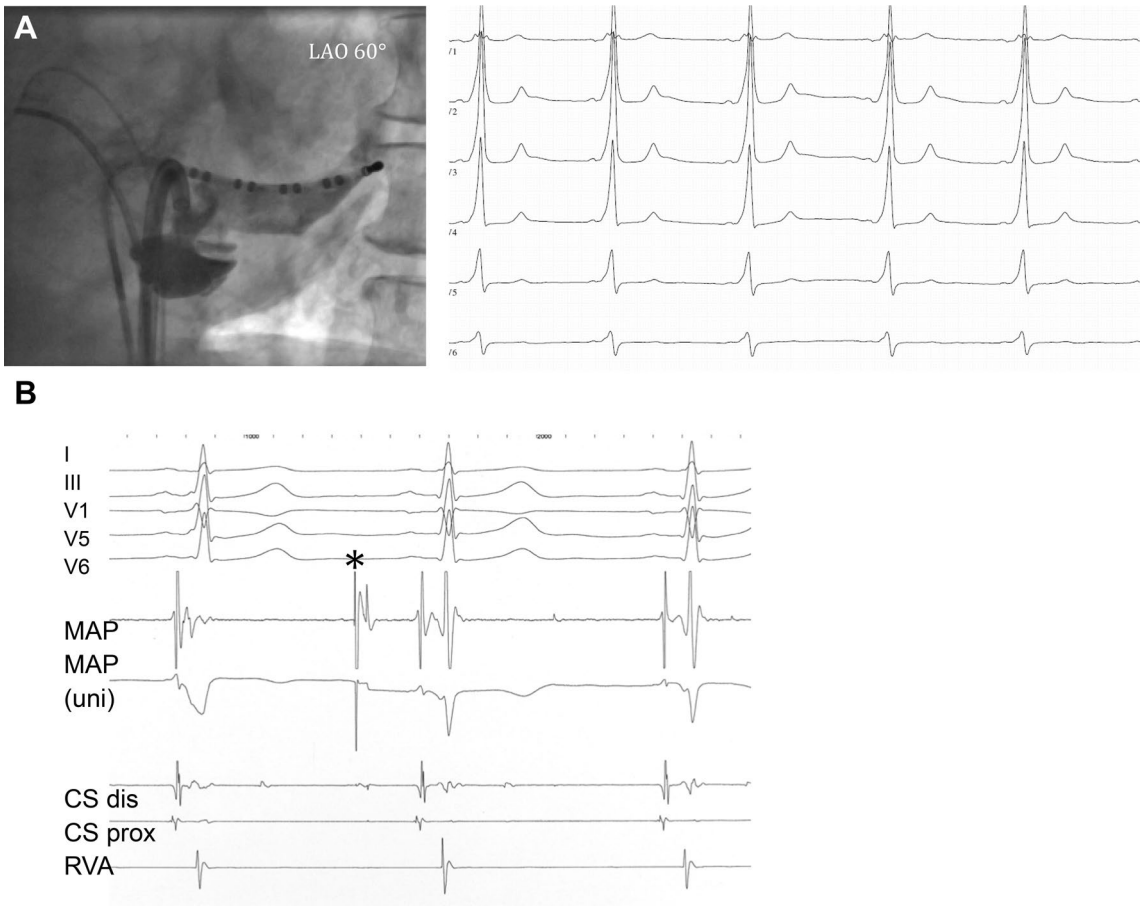

Fig. 2 **a** Angiography of CS diverticulum of patient 8. ECG at rest shows positive delta wave on precordial leads. **b** Block of conduction in the accessory pathway immediately after start of ablation (*)

AP, delta waves (Table 1) were no longer visible on rest ECG after successful ablation. Successful ablation was achieved in most cases in the neck of the diverticulum. During our follow-up of 8.9 ± 6.4 years, seven patients remained free of symptoms. No complications related to the ablation procedures were reported.

Discussion

In the present study, we were able to show that CS diverticulum-associated accessory pathways are a rare phenomenon in patients with an accessory pathway. Our current data adds further prove that ablation inside of an CS diverticulum is safe using conventional RF or cryoablation. Ablation was performed with a success rate of 88% after 2.1 ablations. In the present collective, we saw no complications following ablation and no long-term complications related to the procedure or the diverticulum itself. Furthermore, our follow-up showed a long-term success rate for patients with successfully ablated APs of 100% over a time period of nearly 11 years. In line with previous publications [12, 13], showing that a negative delta wave in lead II hints at an CS associated AP with a sensitivity of ≥ 70%, we saw in all patients with antegrade conducing properties a negative delta wave lead II.

CS diverticula represent a rare congenital malformation. On venography, they impose as an out pouching of the CS [14]. Histological examination showed that the wall of the diverticula is composed of multiple muscular fibres [15, 16]. These fibres connecting atria and ventricles constitute possible APs. In general, CS anomalies are not linked with structural heart disease or known genetic disorders but an association with membranous ventricular septum and subaortic membranes has been described [17, 18]. In the present collective, none of the patients showed congenital heart disease. Two patients were diagnosed with a hemodynamically irrelevant persistent foramen ovale, not known to be associated with CS diverticula.

Of all patients who were referred to our centre for ablation of an AP and screened for this study, 0.36% had an AP associated with a CS anomaly. Given that at our centre,

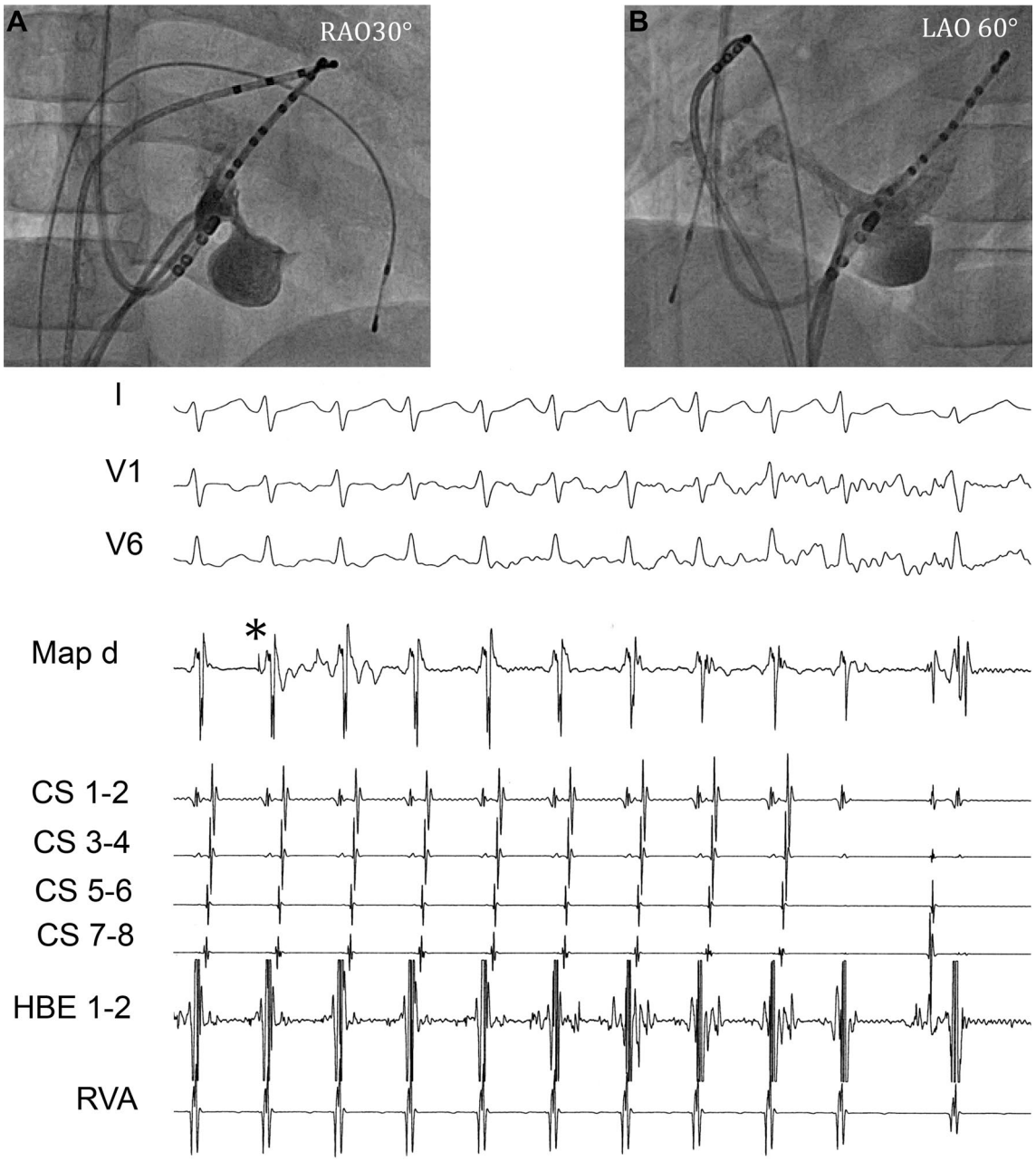

Fig. 3 CS diverticulum in a 9–year-old female (patient 2) with recurrent SVT and a retrogradely conducting accessory pathway. "Asterisk" marks onset of RF energy delivery during SVT. At that site, the pathway blocked a few seconds after starting RF. **a/b** Venogramm in the presence of the ablation catheter via the right jugular vein

Table 1 Deflection of delta in 12-lead ECG at rest for patients with antegrade conduction properties

Patient	I	II	III	aVR	aVL	aVF	V1	V2
3	+	−	+		+	−	+	+
4	+	−	−		+		+	+
5	+	−	−	−	+	−	+	+
6	+	−	−		+	−	+	+
7	+	−	−	−	+	−	−	+
8	+	−	−	−	+	−	+	+

+: Positive deflection; −: negative deflection

Table 2 Electrophysiological properties of the AP

Patient	Age (years)[a]	# of procedures	Success	IAP (ms)	IVP (ms)	CL (ms)	Energy/catheter used
1	73.43	3	N	320	310	310	Cooled RF
2	9.07	2	Y	300	–	240	Cryo
3	82.49	2	Y	–	< 300	425	RF
4	45.89	4	Y	< 270	< 260	340	Cooled RF
5	18.62	1	Y	280	–	280	Cryo
6	29.03	1	Y	280	–	350	Cooled RF
7	26.82	2	Y	270	350	330	RF
8	44.54	2	Y	< 280	< 300	300	RF

[a]Age at first ablation

venographies are not routinely performed, the number of APs associated with anomalies of the CS in the 2245 patients screened may be higher. APs in patients with diagnosed CS diverticula have also been reported to be successfully ablated at sites different from the diverticulum itself. Weiss and colleagues [19] reported a series of nine patients with an inferoseptal AP and a CS diverticulum, block in the AP was obtained at the right atrioventricular annulus.

Prior to ablation, all our patients presented with documented paroxysmal tachycardia accompanied by typical symptoms. Six out of the eight patients (75%) showed preexcitation on routine ECG. In a literature review with regards to cases of congenital malformations of the right atrium and the coronary sinus between the years 1955 and 1998, Binder et al. [14] were able to show that 86% of patients with CS diverticula had a history of supraventricular tachycardia, and 79% of these patients exhibited preexcitation on routine electrocardiogram. Only 7% remained asymptomatic at the time of diagnosis. Surgical removal of these diverticula in patients with symptomatic AVRT has also been reported to be successful [20].

Of note, a series of cases of sudden cardiac death in patients with CS diverticula has been published [6, 16, 21]. It has been reported that APs associated with CS diverticula may exhibit a short antegrade refractory period and hereby harbour the potential risk of pre-excited AF [20]. In our collective, two patients had paroxysmal atrial fibrillation but no history of syncope or survived sudden cardiac death. In the particular case of AP associated with a diverticulum complication rates of ablation may be higher due to the potentially thin walls. Moreover, the coronary sinus is in close proximity to the posterolateral branch of the right coronary artery. Furthermore, due to the spatial relations, impedance during energy delivery is generally higher leading to excessive heat and formation of coagula, to mediate using irrigated catheters or cryoablation was found to be useful. To mediate the harmful effects of ionizing radiation during invasive electrophysiology procedures, recent publications showed the feasibility of zero-fluoroscopic ablation for supraventricular tachycardias, in particular also for APs [22].

In summary, our data fortunately showed that ablation of an AP associated with a malformation of the CS seems is safe and not associated with long-term complications. Furthermore, using non-irrigated catheters as well as cryoablation, proved to be comparably safe and effective in our collective.

Conclusion

Coronary sinus diverticula are rare but seem to be a significant cause of ablation failure in the case of inferoseptal pathways. If suspected a CS venography should be performed during the ablation procedure. Using 8 mm, cryo, or irrigated tip ablation catheters, a high long-term success rate was found.

Compliance with ethical standards

Conflict of interest There are no competing financial and/or non-financial interests in relation to the present paper.

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