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A subvalvular catheter approach for radiofrequency ablation of right-sided accessory pathways

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Abstract

Background Conventional catheter ablation of right-sided accessory pathways (RAPs) can be challenging.

Objective To determine if a subvalvular catheter approach for RAPs targeting the ventricular insertion site, as on the left side, can improve catheter stability and tissue contact and thus increase acute and chronic ablation success rates.

Methods and results We retrospectively compared 22 patients (pts) with conventional catheter ablation of RAPs (group 1) with 9 consecutive pts (group 2) undergoing catheter ablation of a RAP using a subvalvular catheter approach targeting the ventricular site of AP. Ablation failed in 2/22 group 1 vs 0/9 group 2 pts (ns) and recurrences of AP conduction were registered in 4/19 group 1 vs 1/9 group 2 pts (ns) during follow-up. Significant shorter values were found in group 2 pts compared with group 1 for number of RF applications (3.6 ± 1.6 vs 8.2 ± 4.3), AP block time (6.2 ± 2.4 vs 9.2 ± 3.9 min), fluoroscopy time (17.2 ± 6.9 vs 25.6 ± 10.3 min), and procedure time (70.8 ± 23.9 vs 138 ± 44.4 min). There were no procedure related complications.

Conclusion Catheter ablation of RAPs using a subvalvular approach seems as effective and safe compared with conventional ablation but with reduced procedure time and radiation exposure and might be at least considered an alternative after failed conventional catheter ablation of RAPs.

Keywords Catheter ablation · Right-sided accessory pathway · Wolff-Parkinson-White syndrome · Supraventricular tachycardia

1 Introduction

Radiofrequency (RF) catheter ablation has become an effective first-line curative therapy for symptomatic accessory pathway (AP)–mediated tachycardias with an overall success rate exceeding 90% [1, 2].

While high success rates exceeding 95% and low recurrence rates ranging from 2 to 5% were obtained in patients with left-sided APs [1, 3], conventional ablation of right-sided APs (RAPs) remains challenging. Among all AP locations, the success rate of catheter ablation therapy for these APs is the lowest, averaging only about 90%, and after successful elimination of AP conduction, recurrence rates up to 35% have been reported [4–6].

The principal reasons for the primary failure and late recurrence are inaccurate mapping of pathway insertions due to unique anatomical properties such as the absence of a venous structure paralleling the tricuspid annulus (TA), greater circumference than the mitral valve, and the difference in angle with which the valve attaches to the TA. Instability of the catheter resulting in poor tissue contact during ablation and difficulty in placing the catheter at the target site and then maintaining it on the annulus contribute to the reported increased rates of AP recurrences [6, 7].

RF ablation under the mitral valve targeting the ventricular AP site has been established as a curative therapy in patients with left-sided APs through a retrograde transaortic approach, but for RAPs, clinical experience with a subvalvular approach is limited [8, 9].

We hypothesized that a subvalvular catheter approach for RAPs (esp. right free-wall APs) targeting the ventricular insertion site, as on the left side, can improve catheter stability and tissue contact and thus increase acute and chronic ablation success rates. We therefore compared ablation and follow-up results of patients with RAPs undergoing a conventional atrial ablation approach with a series of patients treated by a subvalvular approach. The study was approved by the local ethics committee.

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2 Methods

2.1 Patients

Between 2011 and 2014, 22 consecutive patients with recurrent episodes of supraventricular tachycardia underwent electrophysiology study and catheter ablation of a RAP. Patients with right anteroseptal, posteroseptal APs, or a Mahaim fiber were not part of this group. Patients with the need of targeting a second arrhythmia by catheter ablation within the same session were also excluded from data analysis. Also excluded were patients with a use of 3D mapping technology. These exclusions were made to retrospectively compare these patients with a group of 9 consecutive patients, in whom a different ablation approach targeting the right-sided pathways was employed since June 2015.

2.2 Electrophysiology study

All antiarrhythmic drugs were discontinued for at least 5 half-lives before the procedure. After informed consent was obtained from all patients, an electrophysiology study and a catheter ablation were performed under conscious sedation and local anesthesia. Conventional multipolar catheters were placed in the coronary sinus (CS), the high right atrium position (HRA), and the right ventricle (RV) for pacing and recording. Intracardiac electrograms were recorded using a digital electrophysiology recording system (EP-WorkMate/St. Jude Medical, Inc., St. Paul, MN). Bipolar electrograms were filtered at 30–500 Hz, and unipolar electrograms were filtered at 0.05–500 Hz.

The presence of a RAP was confirmed by conventional electrophysiological criteria, which are described in detail elsewhere [1, 3]. In a first step, multiple sites along the tricuspid annulus were sequentially mapped by a multicurve quadripolar ablation catheter (Marinr™ MCXL, Medtronic, Minneapolis, MN, USA). The ventricular insertion of AP causing pre-excitation was identified as the site of earliest local ventricular activation preceding the delta wave with the shortest local atrioventricular (AV) interval during sinus rhythm or atrial pacing. The atrial insertion of APs (both concealed and those capable of pre-excitation) was identified by the site of earliest atrial activation and the shortest local ventriculo-atrial (VA) interval during ventricular pacing or during orthodromic AV re-entry. To enhance mapping precision, it was possible to insert a Halo catheter into the right atrium along the tricuspid annulus or to map AP conduction epicardially along the right coronary artery (RCA) by a 3.3Fr multipolar catheter (Map-iT, APT, Minnesota, USA).

When tachycardia was induced, classical criteria were used to confirm that the RAP was a critical component of the re-entry circuit.

2.3 Ablation strategies

In group 1 patients ($n = 22$), AP elimination was targeted at the atrial site with the "best" local electrogram obtained around the tricuspid annulus using a Marinr™ MCXL RF ablation catheter. RF ablation was then applied by a temperature-controlled mode with a maximum power of 40 W and a temperature limit of 65 °C. RF energy was continued to a maximum of 90 s, if AP elimination occurred within the initial 15 s. It was the operator's decision to stabilize the mapping/ablation catheter with various long (fixed or steerable) sheaths (SR 1–4, St. Jude Medical, Inc., Agilis, St. Jude Medical, Inc.) if AP localization/elimination could not be achieved conventionally. AP block time was calculated in seconds for final block in AP conduction in each patient, which required appropriate right ventricular pacing in patients with only retrograde AP-conduction. Ablation was considered successful when AP-related tachycardia was terminated, the atrium was either dissociated from the ventricle during ventricular pacing or physiological VA-conduction was observed or when the anterograde pre-excitation pattern disappeared during sinus rhythm/atrial pacing. The endpoint of the procedure was persistent absence of both retrograde and/or anterograde AP conduction 30 min after the last radiofrequency application.

In group 2 patients ($n = 9$) the ablation catheter was always directed below the tricuspid annulus to target the ventricular site of AP. To do this, the ablation catheter was advanced to the right ventricle and then curved back to reach the tricuspid annulus from the ventricular, subannular site. Using a long steerable sheath (Agilis™)—if desired by the operator—and rotating the mapping catheter properly, the different regions of the tricuspid annulus could be reached effortlessly. As on the left side, local subannular electrograms typically showed a small atrial signal and a huge ventricular electrogram (Fig. 1a). In patients with only retrogradely conducting pathways, positioning the ablation catheter at the ventricular site underneath the tricuspid annulus sometimes resulted in very tiny atrial signals superimposed in part by huge ventricular electrograms. For better identification of atrial electrograms in this scenario, retrograde AP block by proper RV stimulation was used to compare local mapping electrograms with those showing intact retrograde AP conduction (Fig. 1b, c). All target sites were further identified by fluoroscopy in 35° right and 45° left oblique positions. RF energy was applied in the same way, as described for group 1 patients.

2.3.1 Follow-up

All successfully ablated patients were discharged home off anti-arrhythmic drugs and followed-up at a regular 3 months interval in the outpatient clinic. Arrhythmia recurrence and/or resumption of anterograde AP conduction were assessed

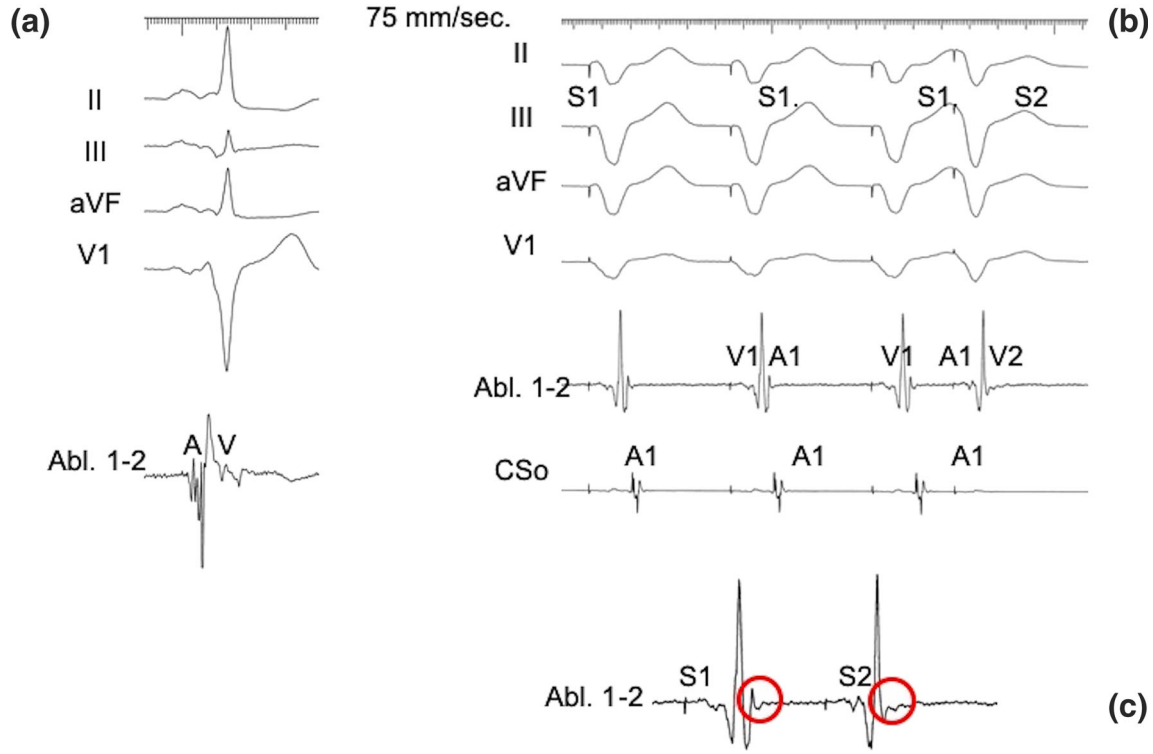

Fig. 1 (**a**) Overt preexcitation in a patient with a right-sided AP. Continuous atrioventricular activation with a small atrial and high amplitude ventricular electrogram at the successful ablation site underneath the tricuspid annulus. Abl. 1–2: distal bipole of ablation catheter. (**b**) Right ventricular pacing in a patient with only retrogradely conducting right-sided AP. There is retrograde 1:1 AP conduction with S1, demonstrated by a discrete and early atrial deflection at the end of the ventricular electrogram in Abl. 1–2. S2 blocks retrogradely in AP and AV nodal His-Purkinje system, producing only a ventricular deflection in Abl.1–2. CSo: catheter bipole at coronary sinus os. (**c**) Augmentation of the local signals from Abl.1–2 comparing electrogram signature after S1 and S2 at the end of ventricular deflections. Red circles with (left) and without (right) atrial component

based on symptoms, 12-lead ECGs recordings, or Holter monitoring.

2.3.2 Statistics

In this retrospective analysis, continuous variables were expressed as mean ± standard deviation and were compared using the Student *t* test. Reported *P* values were calculated using two-tailed tests, and statistical significance was defined as $P < 0.05$. Categorical variables were expressed as numbers and percentages. For comparison of categorical data between both groups, the Chi^2 or Fisher's exact test was used, as appropriate. All analyses were performed using GraphPad Prism software, version 8.

3 Results

3.1 Patient characteristics

Both groups consisted of middle-aged patients (33 ± 13 vs. 39 ± 17 years [16–68], ns.) with male dominance (18/31), suffering from symptomatic recurrent supraventricular tachycardias, refractory to a mean of 1.4 ± 1.2 [0–3] antiarrhythmic drugs. Four group 1 patients (18%) had already undergone a total of five unsuccessful ablation attempts, while four group 2 patients (44%) had undergone a total of seven ablation sessions. Two group 1 patients (pts 1 and 8) underwent a redo ablation with a subvalvular approach (group 2) for tachycardia recurrences.

3.2 Electrophysiology study and catheter ablation

Detailed results of electrophysiology studies and follow-up are presented for both groups in Tables 1, 2 and 3, respectively.

The most common conduction pattern of AP was retrograde only in group 1 (12/22) and bidirectional (6/9) in group 2. Orthodromic tachycardias were the most frequently induced tachycardias in both groups (group 1: 21/24, 88% and group 2: 8/10, 80%). The distribution of the targeted APs around the tricuspid valve is illustrated for both groups in Fig. 2. Elimination of AP conduction was unsuccessful in 2/22 group 1 patients and in none of the

Table 1 Clinical characteristics and mapping results of all patients with conventional atrial ablation approach

Pt. no.	Age	Sex	Prior ablation attempts	AP conduction properties	Tachycardia type	Location of successful ablation	No. of RF	AP block time (sec)	Fluoroscopy time (min)	Procedure time (min)	Follow-up time (months)
1*	26	m	2	Bidirectional	Ortho	Midseptal	8	18	36	234	2
2	44	f	0	Retrograde	Ortho	Anterolateral	10	14	23	154	6
3#	65	m	0	Bidirectional	Ortho	–	12	–	31	135	–
4	23	m	0	Retrograde	Ortho	Posterior	7	9	21	110	12
5	19	f	0	Anterograde	Afib	Lateral	3	7	24	83	26
6	51	m	0	Bidirectional	Ortho	Posterolateral	13	8	29	123	11
7	21	f	0	Retrograde	Ortho	Lateral	8	13	34	144	8
8*	16	m	1	Bidirectional	Ortho	Anterolateral	7	14	25	134	1
9	27	m	0	Retrograde	Ortho	Anterolateral	11	5	28	102	12
10	68	f	0	Retrograde	Ortho, Afib	Lateral	9	10	27	127	18
11	17	m	0	Bidirectional	Ortho, anti	Posterior	3	4	12	100	1
12**	34	f	0	Retrograde	Ortho	Lateral	14	11	39	210	1
13	61	m	0	Retrograde	Ortho	Posterolateral	5	9	12	162	6
14	39	m	0	Bidirectional	Ortho	Midseptal	3	5	16	98	12
15**	29	f	0	Retrograde	Ortho	Anterior	14	13	29	144	3
16	49	m	0	Retrograde	Ortho	Posterolateral	3	4	12	103	–
17	23	f	1	Anterograde	Ortho	Anterior	5	7	18	125	6
18	66	f	0	Retrograde	Ortho	Posterolateral	6	9	19	122	3
19	56	f	0	Retrograde	Ortho	Lateral	8	5	24	134	6
20	70	m	0	Retrograde	Ortho	Lateral	11	12	39	148	12
21#	35	f	1	Bidirectional	Ortho	–	18	–	52	254	–
22	19	m	0	Anterograde	Ortho	Lateral	2	6	14	89	12

pt patient; *AP* accessory pathway; *ortho* orthodromic circus movement tachycardia; *anti* antidromic circus movement tachycardia, AP block time = radiofrequency (RF) time in sec., until final block of AP conduction

*delineates pts. with redo ablation for AP recurrences undergoing both ablation strategies in our clinic (see Table 2)

**delineates pts. with recurrence, but without redo ablation in our institution,

#marks pts. with ineffective catheter ablation: pt. 12 showed early recurrence of orthodromic circus movement tachycardia 2 h after "successful" AP elimination, in pts. 3 and 21 AP elimination could not be achieved during electrophysiology study; Afib = induction of atrial fibrillation by stimulation or catheter manipulation

nine group 2 patients ($p = 0.349$). In two patients (ID 3 and 21), AP elimination could never be obtained, while in one patient (ID 12), orthodromic tachycardia reoccurred spontaneously after removal of all catheters. Significant fewer RF-applications were delivered per patient during electrophysiology study in group 2 (3.6 ± 1.6) compared with group 1 (8.2 ± 4.3), $p = 0.004$. Mean time from the ablation start to final AP conduction block was significantly shorter in group 2 (6.2 ± 2.4 vs 9.2 ± 3.9 s for group 1), $p = 0.049$. As a result, we found significantly shorter procedure and fluoroscopy times for group 2 patients (70.8 ± 23.9 and 17.2 ± 6.9 min), when compared with group 1 patients (138 ± 44.4 and 25.6 ± 10.3 min), both $p < 0.05$ (Table 3). Representative subannular left and right oblique catheter positions of group 2 patients are presented in Fig. 3. In both groups there were no procedure related complications.

Figure 4 shows AP elimination in a group 2 patient with overt pre-excitation: absence of a visible atrial electrogram and early ventricular subannular electrogram preceding onset of delta wave by 30 msec.

3.3 Follow-up results

In both patient groups, there were no complications occurring in the periprocedural period. One group 1 patient refused regular follow-up visits in our department. During a mean follow-up time of 8.3 ± 6.5 months, four of the remaining 19 successfully treated patients in group 1 (21%) had a recurrence of AP conduction, while one of nine group 2 patients had recovery of AP conduction without symptoms shortly after ablation ($p = 0.521$). In this patient, "elimination" of bidirectional AP conduction was achieved with a single RF-application, and no

Table 2 Clinical characteristics and mapping results of all patients with a subvalvular ablation approach

Pt. no.	Age	Sex	Prior ablation attempts	AP conduction properties	Tachycardia type	Location of successful ablation	No. of RF	AP block time (sec)	Fluoroscopy time (min)	Procedure time (min)	Follow-up time (months)
1*	26	m	3	Bidirectional	Ortho	Midseptal	3	8	16	110	6
2**	44	m	1	Bidirectional	Ortho	Posterolateral	1	3	23	56	4
3	53	f	0	Anterograde	Anti	Posterolateral	4	5	21	67	13
4	19	m	0	Retrograde	Ortho	Anterolateral	5	10	12	46	11
5	25	m	1	Bidirectional	Ortho/anti	Posterolateral	2	4	16	98	9
6	44	f	0	Retrograde	Ortho	Lateral	3	6	31	83	21
7	32	f	0	Bidirectional	Ortho	Lateral	5	8	16	46	16
8*	16	m	2	Bidirectional	Ortho	Anterolateral	6	8	11	48	23
9	27	m	0	Bidirectional	Ortho	Posterior	3	4	9	83	15

bonus applications were delivered nearby. Both patients with recurrence of AP conduction after conventional ablation (ID 1 and 8), who underwent successful subvalvular AP elimination, remained symptom-free during follow-up.

4 Discussion

The success rate for conventional RF ablation of RAPs is lower than APs at other locations and the recurrence of conduction after successful ablation may occur in more than 10% of the patients [3, 5, 10].

Possible reasons for an unsuccessful ablation of RAPs are catheter instability resulting in inadequate tissue contact, inaccurate mapping, and anatomic variations such as Ebstein's anomaly. Different techniques have been introduced in the past to overcome these difficulties: long intracardiac sheaths with preshaped or adjustable curves greatly enhance catheter stability. Multipolar Halo catheters, originally used to map activation of atrial flutter along the tricuspid annulus, can be helpful to localize RAPs. [11] Some investigators report successful ablation of RAPs using irrigated ablation catheters or epicardial mapping catheters inside the right coronary artery. [12, 13] In our study, it was the operator's decision to use these techniques in 22 group 1 patients, if necessary. Of note, four of these patients had already undergone an ineffective ablation attempt from the right atrial site. Furthermore, in two of these 22 patients (9.1%) conventional ablation failed and four other patients (20%) had recurrences during follow-up. Using a subvalvular catheter approach in nine patients with RAP, we did not observe significant differences for primary ablation failure and AP recurrences during follow-up, which might be explained by the small sizes of our two groups. Manipulation of the ablation catheter to target the right-ventricular site of APs is generally considered challenging. This ablation approach under the valve is more frequently used for the treatment of left-sided APs through a retrograde aortic approach as an equivalent alternative to a transseptal

Table 3 Detailed results of electrophysiology studies

	Group 1 (conventional)	Group 2 (under-valve)	*P* value
Age (years)	33 ± 13	39 ± 17	0.376
Male/female	12/10	6/3	0.696
No. of prior ablations	0.2 ± 0.5 [0–2]	0.8 ± 1 [0–3]	0.066
No. of RF applications	8.2 ± 4.3	3.6 ± 1.6	*0.004*
AP block time (sec)	9.2 ± 3.9	6.2 ± 2.4	*0.049*
Fluoroscopy time (min)	25.6 ± 10.3	17.2 ± 6.9	*0.032*
Procedure time (min)	138 ± 44.4	70.8 ± 23.9	*< 0.001*
Ablation failure	2/22 (9.1)	0/9 (0)	0.349
Follow-up (months)	8.3 ± 6.5	13.1 ± 6.4	0.078
Recurrences	4/19 (21)	1/9 (11.1)	0.521

Data are mean ± SD and range []

%presented in ()

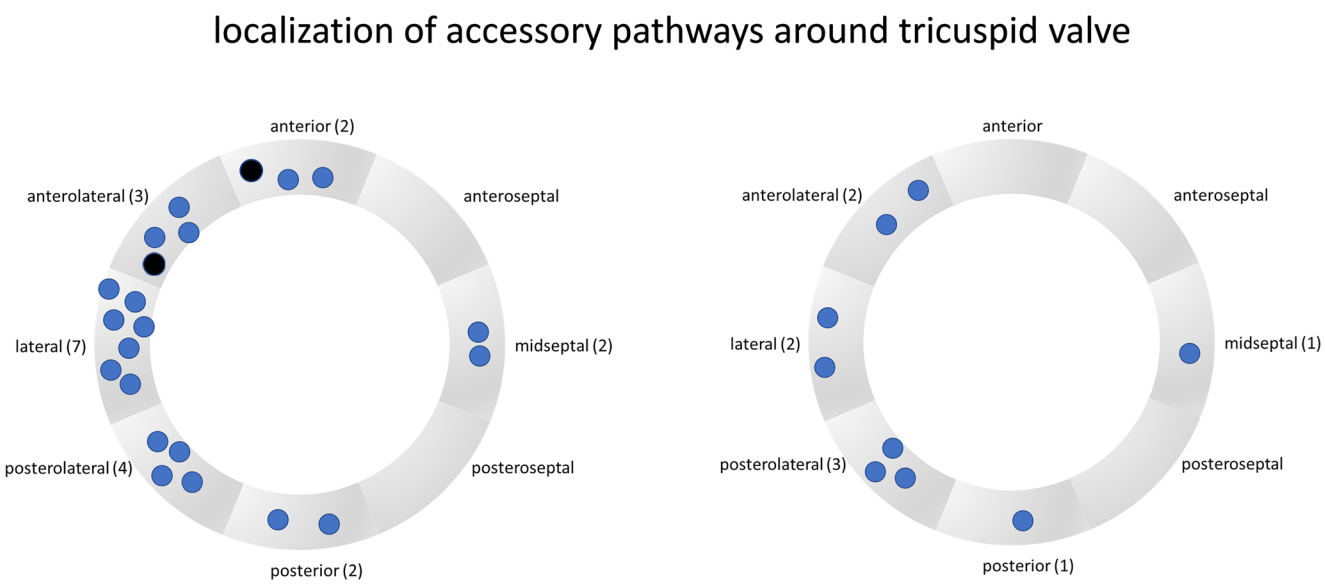

Fig. 2 Localization of targeted accessory pathways around the tricuspid annulus, blue dots, site of successful catheter ablation; black dots, estimated location of accessory pathway, based on best local electrogram, unsuccessful ablation. Left, group 1 and right, group 2.

approach. [14] It is the preferred approach in our institution for many years and all operators in this study were familiar with this technique, probably minimizing the potential learning curve for this approach in right-sided pathways. As a result, we found significantly shorter procedure – and fluoroscopy times with this ablation technique, fewer RF applications for AP elimination and shorter AP block times, when compared with a conventional atrial catheter approach. This can be explained by a more stable catheter position underneath the tricuspid annulus, resulting in a better tissue contact. The lateral deflection offered by the Marinr ablation catheter may have improved mapping precision under the tricuspid valve. Additional use of long intracardiac sheaths further enhanced catheter stability but was not mandatory for successful ablation in all cases. Unlike RF energy delivery at the atrial aspect of the tricuspid annulus, conventional catheter ablation underneath the tricuspid valve is performed in a low-flow area. This might result in inadequate low RF-energy delivery due to a rapid temperature rise, minimizing the efficacy of non-irrigated ablation. In our series of nine consecutive patients, there was no need for additional irrigated RF ablation, since all APs could be successfully eliminated by use of conventional RF catheters. Successful catheter ablation at the ventricular site of an AP in patients with anterograde preexcitation can be achieved by catheter manipulation to the earliest site of ventricular activation. In patients with only retrograde AP

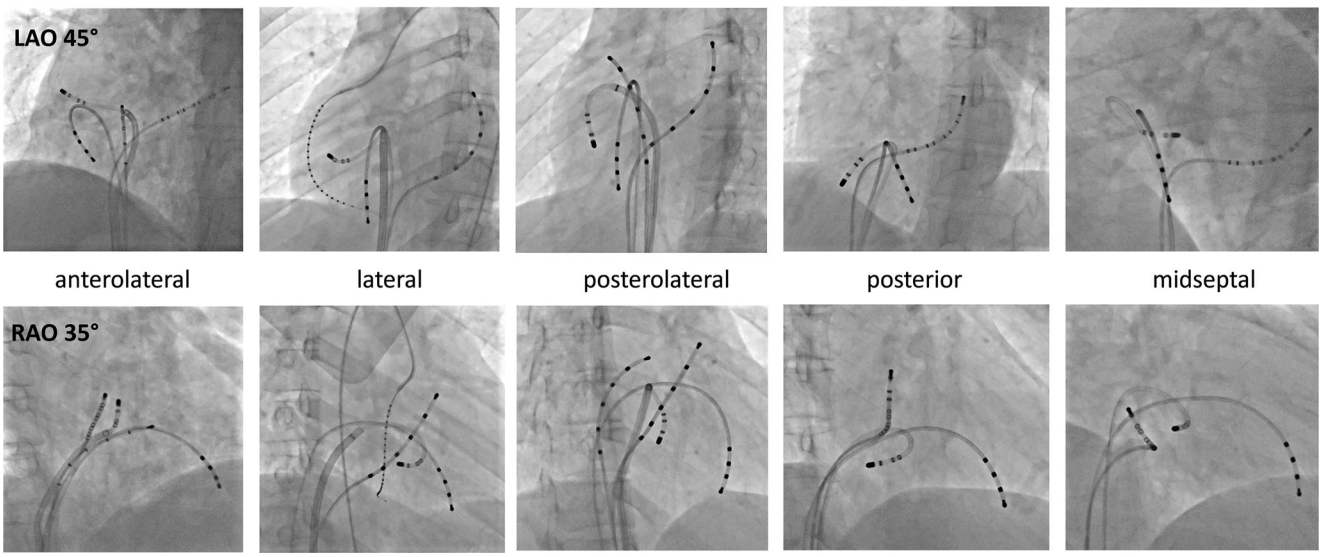

Fig. 3 Representative catheter positions (LAO 45° and RAO 35° views) for subvalvular ablation of right-sided accessory pathways: additional use of long sheaths (anterolateral, lateral, and posterolateral) and epicardial mapping inside right coronary artery (lateral).

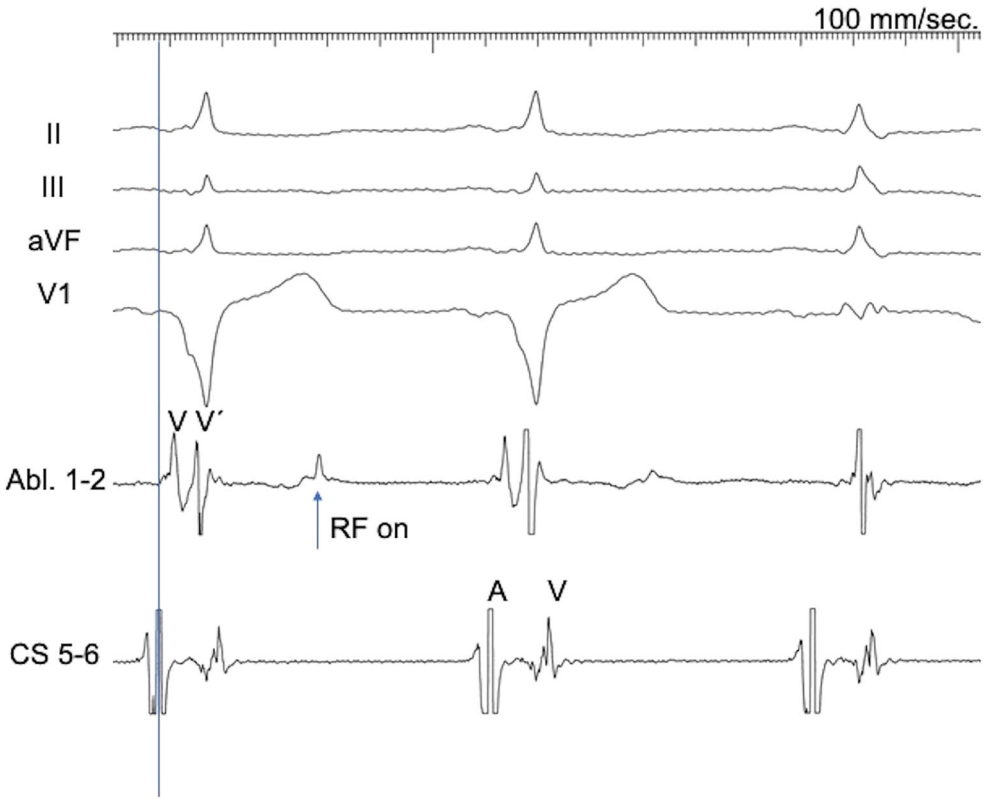

Fig. 4 Elimination of anterograde conduction over a right-sided AP by RF energy. A complex ventricular electrogram is recorded underneath the tricuspid annulus (VV´) from Abl. 1–2, preceding onset of delta wave by 30 msec indicated by blue vertical line. This was the earliest detectable ventricular activation underneath the tricuspid annulus verified by fluoroscopy and RF energy resulted in rapid elimination of anterograde AP conduction (third QRS complex). Of note: Abl.1–2 without detectable atrial signals. CS 5–6: coronary sinus electrogram near CS os.

conduction however, the earliest retrograde atrial activation is more difficult to map, as atrial electrograms are small and the site of earliest retrograde atrial activation does not necessarily correspond anatomically with the ventricular end of the AP. This oblique course of APs might result in anatomically different ventricular and atrial ablation targets along the annulus and is frequently observed with left-sided APs. [7, 15] We did not observe this phenomenon in our small series of patients with RAPs.

At the time, there is only one study analyzing the effect of a subvalvular catheter approach in 12 patients for catheter ablation of RAPs [8]. While the authors did not compare their ablation results with a control group, they report similar results for acute success (100%), follow-up results (no recurrences after 12.5 months). In contrast to our study, they used 3D mapping technology and irrigated ablation catheters, making procedure-related data (e.g., fluoroscopy times) incomparable. Eight out of the 12 patients had already undergone a previously failed ablation, targeting the AP at its atrial insertion site.

4.1 Study limitations

Our study is in part retrospective (group 1 patients) and the number of patients in both groups is too small to demonstrate superiority of any method with a view to acute success or recurrences during follow-up. Use of additional mapping catheters and sheaths in both groups, as requested by the operator, might have affected procedural data and ablation results. “Subvalvular” positions of the ablation catheter were only verified by fluoroscopy and signal interpretation and not by intracardiac echocardiography, reducing the accuracy in defining its position in relation to the tricuspid annulus.

Larger (multicenter) studies and/or results by meta-analysis are needed to qualify a subvalvular catheter approach an alternative or even superior technique for ablation of RAPs.

5 Conclusion

Catheter ablation of RAPs (Kent) using a subvalvular approach seems an effective and safe alternative to conventional right atrial ablation in a small series of patients with reduced procedure time and radiation exposure. It should be at least considered an alternative after failed conventional catheter ablation of RAPs.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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