



Catheter ablation in ASymptomatic PEDIatric patients with ventricular preexcitation: results from the multicenter “CASPED” study

Marta Telishevska¹ · J. Hebe² · T. Paul³ · J. H. Nürnberg² · U. Krause³ · R. Gebauer⁴ · M. Gass⁵ · C. Balmer⁶ · F. Berger⁶ · S. Molatta⁷ · M. Emmel⁸ · W. Lawrenz⁹ · T. Kriebel¹⁰ · G. Hessling¹

Received: 5 September 2018 / Accepted: 26 November 2018 / Published online: 5 December 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract

Background As there are limited data about the clinical practice of catheter ablation in asymptomatic children and adolescents with ventricular preexcitation on ECG, we performed the multicenter “CASPED” (Catheter ablation in ASymptomatic PEDIatric patients with Ventricular Preexcitation) study.

Methods and results In 182 consecutive children and adolescents aged between 8 and 18 years (mean age 12.9 ± 2.6 years; 65% male) with asymptomatic ventricular preexcitation, a total of 196 accessory pathways (APs) were targeted. APs were right sided (62%) or left sided (38%). The most common right-sided AP location was the posteroseptal region (38%). Ablation was performed using radiofrequency (RF) energy (93%), cryoablation (4%) or both (3%). Mean procedure time was 137.6 ± 62.0 min with a mean fluoroscopy time of 15.6 ± 13.8 min. A 3D mapping or catheter localization system was used in 32% of patients. Catheter ablation was acutely successful in 166/182 patients (91.2%). Mortality was 0% and there were no major periprocedural complications. AP recurrence was observed in 14/166 patients (8.4%) during a mean follow-up time of 19.7 ± 8.5 months. A second ablation attempt was performed in 20 patients and was successful in 16/20 patients (80%). Overall, long-term success rate was 92.3%.

Conclusion In this retrospective multicenter study, the outcome of catheter ablation for asymptomatic preexcitation in children and adolescents irrespective of antegrade AP conduction properties is summarized. The complication rate was low and success rate was high, the latter mainly depending on pathway location. The promising results of the study may have future impact on the ongoing risk–benefit discussion regarding catheter ablation in the setting of asymptomatic preexcitation in children and adolescents.

Keywords Accessory pathways · Ventricular preexcitation · Catheter ablation

✉ Marta Telishevska
martat77@gmail.com

¹ Department of Electrophysiology, German Heart Center Munich, Munich, Germany

² Center f. Electrophysiology Bremen, Bremen, Germany

³ Pediatric Cardiology and Intensive Care Medicine, Georg August University Goettingen, Goettingen, Germany

⁴ Pediatric Cardiology, Heart Center, University of Leipzig, Leipzig, Germany

⁵ Electrophysiology, Lake Constance Heart Center, Constance, Germany

⁶ Pediatric Cardiology, University Children’s Hospital Zurich, Zurich, Switzerland

⁷ Clinic for Cardiology, Herz-und Diabeteszentrum NRW, Ruhr-University Bochum, Bad Oeynhausen, Germany

⁸ Pediatric Cardiology, Heart Center, University Hospital of Cologne, Cologne, Germany

⁹ Clinic for Pediatric Cardiology, Heart Center Duisburg, Duisburg, Germany

¹⁰ Pediatric Cardiology, Westpfalz-Klinikum, Kaiserslautern, Germany

Introduction

Catheter ablation of the accessory pathway is the treatment of choice in children > 15 kg and adolescents with Wolff–Parkinson–White (WPW) syndrome and symptomatic atrioventricular reentrant tachycardia [1]. In contrast, the indication and timing of catheter ablation in asymptomatic patients with ventricular preexcitation on the ECG (often referred to as “asymptomatic WPW”) is still a matter of debate [1, 2]. It is recommended as Class I indication only for patients after cardiac arrest or syncope in high-risk patients [3].

Although asymptomatic WPW patients are supposed to have a benign prognosis, sudden cardiac death (SCD) as the first clinical manifestation has been described [4, 5]. The question of risk and benefit, therefore, commonly arises when talking to a young patient and the family about catheter ablation in this setting. The PACES/HRS statement from 2012 suggests to base the decision for catheter ablation on the shortest preexcited R–R interval (SPERRI) during atrial fibrillation (AF). Young patients (8–21 years) with a SPERRI \leq 250 ms in AF are considered at increased risk for SCD and, therefore, catheter ablation is considered as reasonable (Class IIA, Levels of evidence B/C). In contrast, young patients with a SPERRI > 250 ms in AF are considered at low risk for SCD and it is reasonable to defer ablation (Class IIA, Levels of evidence C). However, ablation may be considered (Class IIB, Levels of evidence C) in low-risk patients if the location of the pathway and/or patient characteristics do not suggest that ablation may pose an increased risk of AV block or coronary artery injury [6].

As large data about current clinical practice of catheter ablation in the setting of asymptomatic WPW in young patients are scarce, we performed the multicenter “Catheter ablation in ASymptomatic PEDiatric patients with ventricular preexcitation” (CASPED) study among ten pediatric electrophysiologic centers.

Methods

Data collection

The CASPED study was performed by nine German centers and one Swiss center from the Pediatric Electrophysiology Working Group of the German Society of Pediatric Cardiology. A detailed questionnaire and available institutional clinical records with completely anonymous data presentation were used for retrospective data analysis. All consecutive patients aged from 8 to 18 years without

structural heart disease and asymptomatic ventricular preexcitation who underwent catheter ablation at the centers between 2004 and 2014 were included in the study. All patients were asymptomatic without any clinical history of arrhythmias before catheter ablation. Therefore, no patient was on antiarrhythmic medication. Non-invasive testing (exercise test) with documentation of persistent ventricular preexcitation on the ECG had been performed before ablation in each patient. In 17/199 patients (8.5%), the decision not to perform catheter ablation because of close proximity of the AP to the AV node had been made during the electrophysiological (EP) study. These patients were excluded from analysis. The study protocol was approved by the institutional review boards and all centers obtained approval of their local Ethics Committee.

Patient characteristics

Catheter ablation of the accessory pathway was performed in 182 patients without structural heart disease with asymptomatic ventricular preexcitation. Patients were 65% male and aged from 8 to 18 years (mean age 12.9 ± 2.6 years, median age 13.0 years). Patients’ baseline characteristics are shown in Table 1.

Electrophysiological study and catheter ablation

Electrophysiological studies were performed after written informed consent. The procedure was performed under general anesthesia ($n = 41$; 23%) or conscious sedation ($n = 141$; 77%). Procedural data are shown in Table 2. Diagnostic

Table 1 Baseline characteristics of 182 patients

Variables	
Age (years), mean \pm SD	12.9 \pm 2.6
Gender (% male)	120 (65%)
Weight (kg), mean \pm SD	52.1 \pm 15.7
Height (cm), mean \pm SD	159.7 \pm 15.7
BSA (m ²), mean \pm SD	1.9 \pm 7.3
General anesthesia, n (%)	41 (23)
Conscious sedation, n (%)	141 (77)
Multiple (> 1) APs, n (%)	13 (7)
Retrograde conduction, n (%)	109 (56)
APERP (ms), mean \pm SD	285 \pm 65
APERP < 240 ms, n (%)	31 (16)
AVRT, n (%)	31 (17)
ORT, n (%)	27 (14)
ART, n (%)	4 (2)
Atrial fibrillation, n (%)	8 (4)
SPERRI < 250 ms, n (%)	6 (3)
3D system, n (%)	58 (31)

Table 2 Procedural data

RF ablation, <i>n</i> (%)	170 (93)
Cryoablation, <i>n</i> (%)	7 (4)
Both (RF + cryo), <i>n</i> (%)	5 (3)
Procedure time (min), mean ± SD	137.6 ± 62.0
RF time (min), mean ± SD	4.5 ± 4.5
Cryo-time (min), mean ± SD	7.7 ± 9.3
Fluoro time (min), mean ± SD	15.6 ± 13.8
Fluoro dosage (cGycm ²), mean ± SD	611.0 ± 961.8

catheters were inserted percutaneously via a transfemoral access and positioned in the coronary sinus, His bundle area and right ventricle. Invasive EP testing included evaluation of antegrade (APERP) and retrograde AP and AV nodes characteristics by programmed atrial and ventricular stimulation. In 6/9 centers, programmed atrial or ventricular stimulation was performed to induce AV reciprocating tachycardia. Isoproterenol for the characterization of AP properties was routinely used only in 1/9 centers. Routine induction of atrial fibrillation for SPERRI measurement was performed in none of the centers.

If a left-sided AP was detected, a retrograde aortic (*n* = 46) or transeptal (*n* = 30) approach was performed. AP characteristics are shown in Fig. 1. Radiofrequency current, cryothermal energy or both energy forms were delivered at sites where the established localization criteria for accessory pathways were fulfilled [8].

In 58 patients, a 3-D system (*EnsiteVelocity*TM, St Jude Medical; *Carto*[®] 3, Biosense Webster) or catheter localization system (*LocaLisa*[®], Medtronic) was used for

reconstruction of an anatomical and activation map of the right or left atrium and the tricuspid or mitral annulus. Acute success was defined as elimination of conduction over the AP without recurrent conduction during a waiting period of 30 min.

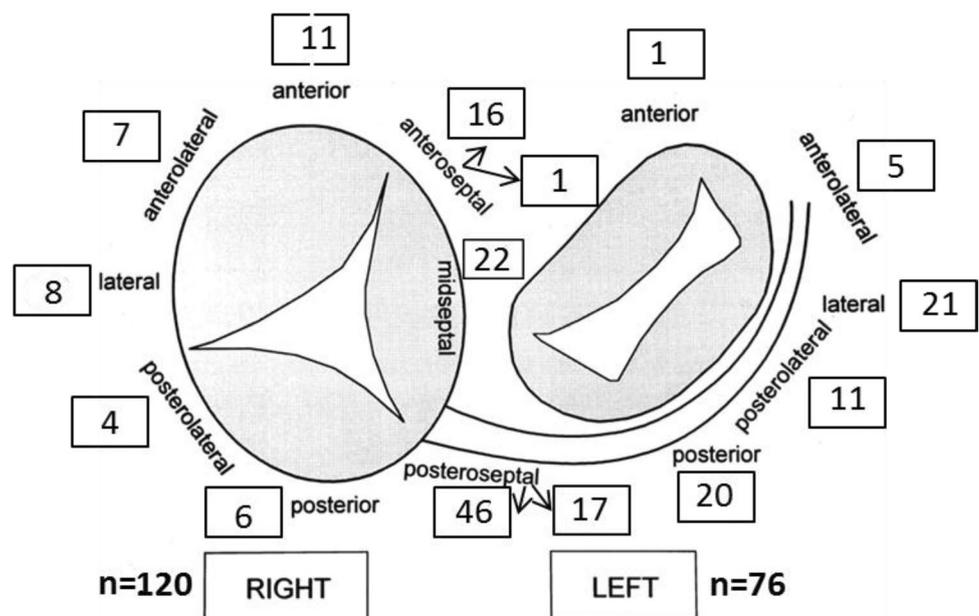
Follow-up

In all patients, a transthoracic echocardiogram was performed at the end of procedure and before discharge to exclude pericardial effusion. A clinical evaluation of patients’ femoral vessels was performed on the day following ablation. In case of abnormalities, an ultrasound evaluation of the femoral vessels was performed. A 12-lead ECG was obtained on the evening of the ablation day and 1 day after the ablation. Another 12-lead ECG was obtained 4–6 weeks, 3 months and 12 months after ablation at the outpatient department of the respective center or at the referring pediatric cardiologist. Recurrence of AP conduction was defined as recurrent ventricular preexcitation on the ECG.

Statistical analysis

Baseline characteristics between groups were compared using the Student’s *t* test and χ^2 test for continuous and categorical variables, respectively. Statistical analyses were performed using SPSS statistical software (version 15.0; SPSS Inc., Chicago, USA).

Fig. 1 Accessory pathway characteristics (*n* = 196 APs)



Results

Anatomical AP characteristics

Overall, 196 APs were found. In 169/182 patients (93%), a single accessory pathway was detected, whereas multiple APs were found in 13/182 patients (7%). Additional diagnoses were AV nodal reentrant tachycardia in one patient (who underwent additional slow pathway modification with RF) and focal atrial tachycardia in two patients (not ablated). The most prevalent AP location in right-sided APs was in the posteroseptal region (46/120, 38%). The most prevalent AP location in left-sided APs was the lateral (21/76, 28%) and posterior (20/76, 26%) mitral valve annulus. All anatomic AP locations are shown in Fig. 1. Pathway location was age dependent. In children < 12 years, 74% of APs (62/84) were located on the right side in contrast to adolescents > 12 years with only 55% right-sided APs (62/112) ($p < 0.01$).

Electrophysiological AP characteristics

The mean anterograde APERP was $285 \text{ ms} \pm 65.1 \text{ ms}$ with an APERP of < 240 ms in 31/196 APs (16%). The most prevalent AP location with an APERP of < 240 ms was found along the mitral valve annulus (21/31, 68%). During ventricular stimulation, retrograde AP conduction was present in 109/196 APs (56%). Retrograde conduction was found in 61/120 (51%) right-sided APs and 48/76 (63%) left-sided APs ($p > 0.05$). Orthodromic reciprocating tachycardia was induced in 27/182 patients (14%), especially in patients with right-sided APs (17/27; 63%). Antidromic reciprocating tachycardia was induced during programmed stimulation in four patients (2%; left AP, $n = 2$ and right AP, $n = 2$). Atrial fibrillation occurred spontaneously or after programmed stimulation in 8/182 patients (4%; left AP $n = 2$; right AP $n = 6$) with a SPERRI of < 250 ms in 6/8 cases (left AP $n = 2$, right AP $n = 4$).

Catheter ablation

In the 76 left-sided APs, a retrograde trans-aortic approach for ablation was chosen in 46 APs (60%) and a transseptal approach in 30 APs (40%). For ablation, RF energy was used in 170 patients (93%), cryoablation in 7 patients (4%), and both methods were used in 5 patients (3%). Cryoablation was mainly performed if the AP was near the AV node (midseptal in three patients and right anteroseptal in four patients). Both methods were used in five patients (four right anteroseptal APs, one midseptal AP). A 3D mapping or intracardiac localization system was utilized in 58 patients (32%) including the *Ensite Velocity™* System (St Jude Medical) in

29 patients (50%), the Carto[®]3 System (Biosense Webster) in 4 patients (7%) or the LocaLisa system (Medtronic) in 25 patients (43%).

Procedure/ablation times and fluoroscopy time/dose

Mean procedure time was $137.6 \pm 62.0 \text{ min}$ (40–375 min) with a mean fluoroscopy time of $15.6 \pm 13.8 \text{ min}$ (range 0.1–75 min) and a mean fluoroscopy dose of $611.0 \pm 961.8 \text{ cGycm}^2$ (range 8–2990). In the patients ($n = 58$) in whom a 3D mapping system was used, mean procedure time was $159.9 \pm 75.7 \text{ min}$ compared to the conventional approach with $126.9 \pm 51.6 \text{ min}$ ($p = 0.01$). Mean fluoroscopy time was shortened by the use of a 3D mapping system to $12.7 \pm 8.6 \text{ min}$ compared to $16.3 \pm 14.7 \text{ min}$ with the conventional approach ($p = 0.19$). Mean RF time was 4.5 min (range 0.1–29 min) and mean cryothermal energy time was 7.7 min (range 1–35 min) ($p = 0.33$).

Procedural and ablation data are shown in Table 2.

Acute success rate

The acute procedural success rate was 91.8% (180/196 APs) in 166/182 patients (91.2%). Procedural success was dependent on pathway location. It was higher for left-sided APs (97.3%; 74/76) compared to right-sided APs (91.7%; 110/120), ($p > 0.05$). Ablation was successful in 158/170 (92.9%) patients undergoing RF ablation, 2/7 (28.5%) patients undergoing cryoablation and in 2/5 patients (40%) in whom both methods were used.

Ablation failures

Ablation failed in the first procedure in 16/196 APs (8%), 14 right-sided APs (13/14 septal APs) and 2 left-sided APs. This is shown in detail in Table 3. The main reported reasons for unsuccessful ablation were lack of catheter stability

Table 3 Ablation failure in regard to anatomic location

AP location	Ablation failure number APs	Ablation failure (%)
All APs	16/196	8.1
Right sided	14/120	11.6
Anteroseptal	5/16	31.3
Posterolateral	1/4	25.0
Posteroseptal	3/46	6.5
Midseptal	5/22	22.7
Left sided	2/76	2.6
Anterolateral	1/5	20
Posterior	1/20	5

($n=3$), epicardial AP course ($n=3$), multiple APs ($n=1$), proximity to the AV node in right anteroseptal APs ($n=5$) or other ($n=2$).

Safety

Overall mortality was 0%. There were no major complications related to the procedure. Minor complications were observed in seven patients (3.8%). These included intraprocedural transient (less than 90 s) second-degree atrioventricular block ($n=4$) or right bundle branch block ($n=2$) and a minor vascular complication at the puncture site (femoral artery pseudoaneurysm with spontaneous thrombosis; $n=1$). All minor complications were reversible. Post-procedural ECGs did not reveal any evidence for coronary artery damage. Transthoracic echocardiography at discharge documented normal ventricular function without signs of dyskinesia, thrombi or pericardial effusion in all patients.

Recurrences

Over a mean observation time of 19.7 ± 8.5 months (3–132 months), AP recurrence after an initially successful ablation was observed in 14/166 patients (8.4%). AP recurrence was depending on pathway location. This is shown in Table 4. Whereas left-sided APs recurred in only 1.3% (1/74), right-sided APs had an overall recurrence rate of 12.3% (13/106) ($p=0.008$). The recurrence rate in right-sided APs was observed only in septal APs with highest recurrence in right anteroseptal (36%; 4/11) and midseptal (29%; 5/17) APs (Table 4). Most recurrences (61%) were observed within 48 h following ablation and before patients were discharged.

Follow-up/repeat ablations

In summary, ventricular preexcitation was still present after the first ablation in 30/182 patients (16%) including 16 patients with a failed first ablation attempt and 14 patients with AP recurrence. A second ablation attempt was

performed in 20 of these 30 patients (67%). Of these, 14 patients had right septal (anteroseptal $n=4$, midseptal $n=5$, posteroseptal $n=5$) APs. In 16/20 patients (80%), the second ablation attempt was successful. Ablation failure in three patients was due to proximity of the AP to the AV node (anteroseptal $n=2$, midseptal $n=1$). The overall success rate was 92.3%.

Discussion

To our knowledge, this is the largest study dealing with current clinical practice of catheter ablation in asymptomatic children and adolescents with ventricular preexcitation. It reflects the experience of nine German and one Swiss center over a time period of 10 years. The main results of the study are that catheter ablation in the setting of asymptomatic pediatric and adolescent ventricular preexcitation is widely performed regardless of antegrade electrophysiological AP properties with very few complications. It shows a high-acute and long-term success rate which is mainly dependent on anatomical pathway location.

AP characteristics

Pathway location

In our study, right-sided APs were more prevalent with 62% with the majority of APs located in the right posteroseptal region. Our results are in line with the findings from a smaller study [7], where anatomic AP location differed between symptomatic and asymptomatic WPW patients. In 51 symptomatic patients, the AP was left sided in 52.9%, whereas in 73 asymptomatic patients, only 28.8% of patients had left-sided APs.

The finding of different AP location between symptomatic and asymptomatic patients was also reported in the large study from van Hare et al. [8] with 379 symptomatic young patients with only 38% right-sided APs. Another study with 103 symptomatic children and young adults [9] again reported right-sided APs in only 35% patients. In contrast is the study of Ceresnak et al. [10] who found that in 651 predominantly symptomatic (asymptomatic, $n=107$) pediatric WPW patients, the majority of the APs (61%) were located on the right side. Chen et al. [11] reported that in 217 symptomatic pediatric patients, AP location was significantly different between children and adolescents, being mostly right sided in patients <12 years (61.3%) and left-sided in patients >12 years (61.5%). We also observed a significant difference in our study with right-sided APs in 74% of children <12 years, but only in 55% of adolescents >12 years. Interestingly, 56% of APs in our study had the capacity of retrograde conduction but this was not

Table 4 AP recurrence in regard to anatomic location

AP location	Recurrence number APs	Recurrence (%)
All APs	14/180	7.8
Right sided	13/106	12.3
Anteroseptal	4/11	36.4
Posteroseptal	4/43	9.3
Midseptal	5/17	29.4
Left sided	1/74	1.3
Lateral	1/21	4.8

significantly different between right- and left-sided APs. The reason for the overall predominance of right-sided pathways in our study remains speculative. In younger patients, the shorter antegrade refractory of the AV node might prevent antegrade conduction over a left-sided AP and so asymptomatic patients might be missed on the ECG. Patients with right-sided APs and retrograde conduction might be asymptomatic because of electrophysiological properties of the AP and the AV node with a smaller window of induction of AV reentrant tachycardia.

AP conduction properties

An antegrade APERP of <250 ms under baseline condition was found in only 16% of patients. However, only one of the centers routinely uses isoproterenol for EP testing. None of the centers routinely tries to induce atrial fibrillation to measure SPERRI in AF and spontaneous AF was seen in only 4% of patients. The current recommendations for risk stratification [6] were, therefore, not applied in a large cohort of our patients. The reasons not to apply the suggested criteria are probably based on two main considerations: a suspicion that measured SPERRI during AF or APERP under baseline conditions might not reflect “real-life” scenario and most important, the assurance that ablation can be performed safely and successfully in most anatomical locations. There is not much literature corresponding to this notion. There are anecdotal reports about young patients who presented with aborted sudden cardiac death and at EP study had an accessory pathway with an APERP or SPERRI that would not fulfil the criteria of “high-risk” pathways. In the recent review of Brugada on the subject [12], the conclusion includes the statement that an ablation procedure should be considered when accepted high-risk factors are present or whenever the risk of complications judged by localization is low.

Acute success

Our study reported an acute ablation success rate of 91.8% and provides additional evidence of the efficacy of catheter ablation in the setting of pediatric and adolescent asymptomatic WPW. Not unexpectedly, success was dependent on pathway location. The highest success rates were found in left-sided APs with 97.3%, whereas success rate was lower in right-sided APs with 88.7% although this did not reach statistical significance. Our results are in line with a smaller study with 41 asymptomatic patients [13] where acute ablation success was 92.3%. Acute success was higher (95.7%) in the large cohort of symptomatic pediatric WPW patients published by van Hare et al. [8] but with predominantly left-sided APs. Also in our study, success rates were higher for left sided and particularly left free-wall APs. Similar results

were published more recently [14] in a combined pediatric and adult publication of 508 patients, where acute success rate was 94.9% in all locations (highest for left free wall). In the study of Wong [9] with 103 symptomatic children and young adults, APs were successfully ablated in 92% of patients with a significantly higher success rate in left-sided accessory pathways (97.3%) compared to right-sided APs (82.1%). In summary, the slightly lower overall acute success rate in our cohort is probably due to the fact that 63% of APs were right sided and often located septally.

Safety

Catheter ablation showed to be very safe in our patient cohort. No patient died from the procedure in our study. No major complications related to the procedure were observed. No evidence of coronary artery injury was found clinically and on repeated ECGs. Minor complications occurred in 3.8% of patients including transient second-degree atrioventricular block (interestingly also observed in two patients undergoing cryoablation), right bundle branch block and femoral artery pseudoaneurysm with spontaneous thrombosis. All minor complications were reversible. Our findings are comparable with other studies. The study of Di Mambro [15] with 73 asymptomatic children showed no complications related to the procedure and suggests that in children and adolescents with asymptomatic preexcitation, catheter ablation is the only effective treatment and should be performed in case of favorable AP location. A small-scale randomized trial by Pappone [16] involving 47 children with asymptomatic preexcitation showed that prophylactic ablation was very safe. The AV block and vascular complication rate is also comparable to other large studies. The most common complications in the large pediatric study with symptomatic WPW patients of van Hare [17] were hematoma at catheter entry (1.4%) and AV block (2.9%) in septal APs.

The study shows that in the hands of experienced operators the procedure is safe and that catheter ablation itself did not add to the procedural risk of the electrophysiological procedure. The decision to perform ablation was not based on electrophysiological properties of the AP, but rather on anatomic AP location. This included the decision not to perform ablation in 17 patients (8.5%) of the initial screening cohort because the operator felt that the AP was too close to the AV node. This fact has to be taken into consideration in the risk–benefit discussion if the asymptomatic WPW patient shows an (antero-)septal AP pattern on the surface ECG.

Recurrence

AP recurrence after an initially successful ablation occurred in 8.4% of patients. As expected, most

recurrences were detected early within 48 h following the ablation procedure. Recurrence rates were significantly higher only for septal right-sided APs, especially when located at antero- or midseptal tricuspid annulus. This is comparable to asymptomatic patients in the study of Di Mambro [7] with a 15.1% recurrence rate and the study of Van Hare [17], where the overall recurrence rate for manifest APs at 1-year follow-up was 11.3%. Recurrence rate varied by substrate location with the lowest recurrence rate for left-sided (mainly lateral and posterior) APs and the highest recurrence rate for right lateral and septal APs. In line with our findings is also the study of Pappone [16] with the highest reintervention rate in septal APs and the lowest in left-sided APs. In summary, success rate including reablations was high with 92.3% which is comparable to large studies in symptomatic patients [8, 9, 13].

Limitations

The main limitation is the retrospective character of the study with data collection over a longer time period which might include a possible variation in patient management between the centers and over time. A further limitation is the fact that the aim of the study was not to assess the indication for catheter ablation which may vary between the centers. Patients that did not undergo EP study or catheter ablation for asymptomatic WPW for any reason were not included in the study.

Conclusions

In this multicenter study, which reflects current clinical practice of nine German and one Swiss centers, catheter ablation in asymptomatic children and adolescents with ventricular preexcitation is a highly effective treatment strategy with a very low complication rate. Right septal accessory pathways presented the greatest challenge with highest acute ablation failure and recurrence rates. In the majority of patients, catheter ablation was performed irrespective of the antegrade electrophysiological AP properties. These promising results may have future impact on the perseverative risk–benefit discussion regarding indication for catheter ablation in asymptomatic pediatric and adolescent patients with ventricular preexcitation.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest.

References

- Obeyesekere MN, Leong-Sit P, Massel D, Manlucu J, Modi S, Krahn AD, Skanes AC, Yee R, Gula LJ, Klein GJ (2012) Risk of arrhythmia and sudden death in patients with asymptomatic preexcitation: a meta-analysis. *Circulation* 125(19):2308–2315
- Chevalier P, Cadi F, Scridon A, Girerd N, Bejan-Angoulvan T, Morel E, Hot JJ, Di Filippo S, Ganne C, Colin C (2013) Prophylactic radiofrequency ablation in asymptomatic patients with Wolff–Parkinson–White is not yet a good strategy: a decision analysis. *Circ Arrhythm Electrophysiol* 6(1):185–190
- Saul JP, Kanter RJ (2016) PACES/HRS expert consensus statement on the use of catheter ablation in children and patients with congenital heart disease. *Heart Rhythm* 13:258–259
- Pappone C, Vicedomini G, Manguso F, Saviano M, Baldi M, Pappone A, Ciaccio C, Giannelli L, Ionescu B, Petretta A, Vitale R, Cuko A (2014) Wolff–Parkinson–White syndrome in the era of catheter ablation: insights from a registry study of 2169 patients. *Circulation* 130(10):811–819
- Sarubbi B, D’Alto M, Vergara P, Calvanese R, Mercurio B, Russo MG, Calabrò R (2005) Electrophysiological evaluation of asymptomatic ventricular pre-excitation in children and adolescents. *Int J Cardiol* 15(2):207–214
- Cohen MI (2012) PACES/HRS Expert consensus statement on the management of the asymptomatic young patient with a Wolff–Parkinson–White (WPW, ventricular preexcitation) electrocardiographic pattern. *Heart Rhythm* 9:1006–1024
- Di Mambro C, Russo MS, Righi D, Placidi S, Palmieri R, Silveti MS, Gimigliano F, Prospero M, Drago F (2015) Ventricular preexcitation: symptomatic and asymptomatic children have the same potential risk of sudden cardiac death. *Europace* 17(4):617–621
- Van Hare GF, Javitz H, Carmelli D, Saul JP, Tanel RE, Fischbach PS, Kanter RJ, Schaffer M, Dunnigan A, Colan S, Serwer G (2014) Pediatric Electrophysiology Society. Prospective assessment after pediatric cardiac ablation: demographics, medical profiles, and initial outcomes. *J Cardiovasc Electrophysiol* 15(7):759–770
- Wong KT, Yung TC, Lun KS, Fan KYY, Chau AKT (2005) Ten-year experience of radiofrequency catheter ablation of accessory pathways in children and young adults. *HK J Paediatr* 10:257–264
- Ceresnak SR, Dubin AM, Kim JJ, Valdes SO, Fishberger SB, Shetty I, Zimmerman F, Tanel RE, Epstein MR, Motonaga KS, Capone CA, Nappo L (2015) Success rates in pediatric WPW ablation are improved with 3-dimensional mapping systems compared with fluoroscopy alone: a multicenter study. *J Cardiovasc Electrophysiol* 26(4):412–416
- Chen TH, Tsai ML, Chang PC, Wo HT, Chou CC, Wen MS, Wang CC, Yeh SJ, Wu D (2013) Risk factors of recurrence and complication in radiofrequency catheter ablation of atrioventricular re-entrant tachycardia in children and adolescents. *Cardiol Young* 23:682–691
- Brugada J, Keegan R (2018) Asymptomatic ventricular preexcitation: between sudden cardiac death and catheter ablation. *Arrhythm Electrophysiol Rev* 7(1):32–38
- Kubuš P, Vít P, Gebauer RA, Materna O, Janousek J (2014) Electrophysiologic profile and results of invasive risk stratification in asymptomatic children and adolescents with the Wolff–Parkinson–White electrocardiographic pattern. *Circ Arrhythm Electrophysiol* 7(2):218–223
- Belhassen B, Rogowski O, Glick A, Viskin S, Ilan M, Rosso R, Eldar M (2007) Radiofrequency ablation of accessory pathways: a 14 year experience at the Tel Aviv Medical Center in 508 patients. *Isr Med Assoc J* 9(4):265–270
- Di Mambro C, Drago F, Milioni M, Russo MS, Righi D, Placidi S, Remoli R, Palmieri R, Gimigliano F, Santucci LM, Silveti

- MS, Prosperi M (2016) Sports eligibility after risk assessment and treatment in children with asymptomatic ventricular pre-excitation. *Sports Med* 46(8):1183–1190
16. Pappone C, Manguso F, Vicedomini G, Sala S, Paglino G (2004) Radiofrequency ablation in children with asymptomatic Wolff–Parkinson–White syndrome. *N Engl J Med* 351:1197–1205
 17. Van Hare GF, Javit H, Carmelli D, Saul JP, Tanel RE, Fischbach PS, Kanter RJ, Schaffer M, Dunningan A, Colan S, Serwer G (2004) Prospective assessment after pediatric cardiac ablation: recurrence at 1 year after initially successful ablation of supraventricular tachycardia. *Heart Rhythm* 1(2):188–196