Cardiology in the Young

cambridge.org/cty

Mid-term outcomes after catheter ablation in patients with congenital heart disease

Diogo Faim[1], Pedro A. Sousa[2], Carolina Saleiro[2], Andreia Palma[1], Andreia Francisco[1], Natália António[2,3], João Cristóvão[2], Luís Elvas[2], Lino Gonçalves[2,3] and António Pires[1,3]

[1]Paediatric Cardiology Department, Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal; [2]Cardiology Department, Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal and [3]Faculty of Medicine, ICBR, University of Coimbra, Coimbra, Portugal

Original Article

Cite this article: Faim D, Sousa PA, Saleiro C, Palma A, Francisco A, António N, Cristóvão J, Elvas L, Gonçalves L, and Pires A (2024) Mid-term outcomes after catheter ablation in patients with congenital heart disease. *Cardiology in the Young* **34**: 782–787. doi: 10.1017/S1047951123003372

Received: 25 March 2023
Revised: 29 June 2023
Accepted: 24 August 2023
First published online: 13 October 2023

Keywords:
Catheter ablation; congenital heart disease; arrhythmias; long-term outcome

Corresponding author:
D. Faim; Email: diogofaim92@gmail.com

Abstract

Introduction: Cardiac arrhythmias are a major concern in patients with CHD. The purpose of this study was to evaluate the long-term outcomes in patients with CHD submitted to catheter ablation. *Materials and Methods:* Observational retrospective study of patients with CHD referred for catheter ablation from January 2016 to December 2021 in a tertiary referral centre. Acute procedural endpoints and long-term outcomes were assessed. *Results:* A total of 44 ablation procedures were performed in 36 CHD patients (55% male, mean age 43 ±3 years). Fifty-four arrhythmias were ablated: 23 cavotricuspid isthmus atrial flutters, 10 atrial re-entrant tachycardias, eight focal atrial tachycardias, eight atrial fibrillations, three atrioventricular re-entrant tachycardias, and two ventricular tachycardias. During a median follow-up time of 37 months (interquartile range 12–51), freedom from arrhythmia recurrence was achieved in 93%, with 1.2 procedures per patient (18% with anti-arrhythmic drugs). There were no adverse events related to catheter ablation. No predictors of recurrence were identified. *Conclusion:* In patients with CHD, catheter ablation presents a high mid-term efficacy while maintaining a safe profile.

The average incidence of CHD is thought to be 8 per 1000 births, with a live birth prevalence of 7.2 per 1000 births.[1] Advances in paediatric cardiology, as well as improvements in cardiac surgical techniques, have led to an increasing prevalence of adults with CHD, which currently exceeds that of their paediatric-age peers.

Atrial arrhythmias are three times more prevalent in adults with CHD than in the general population.[2] Patients with CHD are prone to cardiac arrhythmias, whether due to abnormal haemodynamic loading, sinus node dysfunction, propensity to congenital accessory pathways, or due to incisional scars, distortion of chamber anatomy, and heterologous or artificial material.[3] In addition, the increasing age reached by these patients led them to face arrhythmias related to age, such as atrial fibrillation, which surpassed intra-atrial re-entrant tachycardia in people with CHD over 50 years.[4] Arrhythmias are the most frequent cause of hospitalisation in patients with CHD and significantly increase their mortality and morbidity.[5]

Anti-arrhythmic drugs are an important strategy in these patients. However, their long-term adverse effects combined with low efficacy led to the development of interventional procedures to address rhythm disturbances. Catheter ablation can be particularly challenging in CHD with distorted anatomy, extra cardiac conduits, or intra-atrial baffles.[6–8] There is a lack of national (Portuguese) data concerning the outcomes of catheter ablation in patients with CHD.

The aim of this study was to assess the impact of catheter ablation on the mid-term outcome of patients with CHD.

Materials and methods

Observational retrospective study of consecutive patients with CHD referred for catheter ablation from 01 January, 2016 to 31 December, 2021 in a tertiary referral centre. Procedural endpoints and mid-term outcomes were assessed.

Data required for cohort characterisation was collected from the patient's clinical records. Arrhythmias were divided into the following groups: cavotricuspid isthmus-dependent atrial flutter, intra-atrial re-entrant tachycardia, focal atrial tachycardia, atrioventricular re-entrant tachycardia, atrial fibrillation, and ventricular tachycardia. The CHD complexity was divided into simple, moderate, and severe as defined by the 2014 Paediatric and Congenital Electrophysiology Society/Heart Rhythm Society expert consensus statement.[9]

All patients provided written informed consent and the study complied with the Declaration of Helsinki and was approved by the local institutional ethics committee.

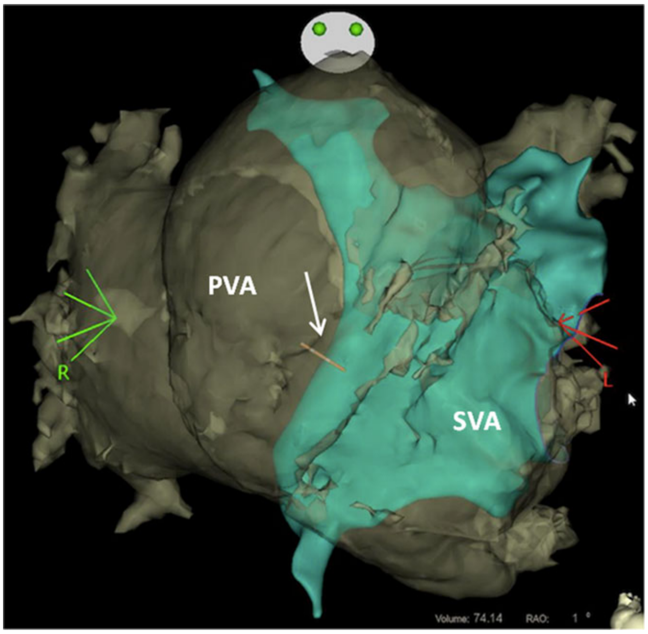

Figure 1. Dextro-transposition of great arteries, after senning procedure. CT scan images were merged with real-time 3D electroanatomical mapping (CARTO 3, biosense webster, inc) allowing the reconstruction of the the systemic (SVA) and pulmonary venous atria (PVA) and the visualisation of the needle tip during transbaffle puncture. Posterior view, the senning baffle is highlighted in blue. The white arrow indicates the transbaffle puncture. PVA = pulmonary venous atrium, SVA = systemic venous atrium.

Patients were eligible for inclusion in the study if they presented any CHD according to the International Paediatric and Congenital Cardiac Code and the Eleventh Iteration of the International Classification of Diseases 11,[10] and were submitted to catheter ablation.

Exclusion criteria were less than 6 months of follow up and patients that only performed a diagnostic electrophysiological study without ablation.

In patients under vitamin K antagonists, the medication was continued in the periprocedural period with an international normalised ratio within 2.0–3.0 range. In patients taking non-vitamin K antagonists, the last drug dose was omitted. Patients interrupted anti-arrhythmic drugs at least 5 half-lives before the procedure, except for amiodarone, which was suspended 1 month prior to the procedure. Whenever necessary, the procedures were performed under general anaesthesia. The use of transesophageal or intracardiac echocardiographies was left to the physician's discretion.

In the setting of left atrial arrhythmias, unfractionated heparin was administered immediately after transseptal puncture and adjusted to achieve a target-activated clotting time above 300 s. In dextro-transposition of the great arteries corrected with Senning procedure, access to the pulmonary venous atrium was achieved by transbaffle puncture (Fig. 1).[11]

Anatomical mapping data was collected using a 3D mapping system (CARTO3®, Biosense Webster) and integrated with a CT imaging reconstruction, when available. Ablation was performed with point-by-point radiofrequency energy with a Thermocool SmartTouch® irrigated tip contact force-sensing catheter, in a power-controlled mode with temperature limited to 43°C. Power settings varied according to the targeted region.

Whenever the patient was in tachycardia at the beginning of the procedure (clinical tachycardia), the first objective was to identify the electrophysiological mechanism and perform ablation to interrupt that circuit. If there was a doubt concerning the interpretation of the activation map, entrainment manoeuvre was performed to confirm the suspected tachycardia mechanism. An additional activation map was carried out to confirm bidirectional block along any de novo linear lesion, followed by attempts to induce other tachycardias, which were mapped accordingly. The goal was to terminate all induced tachycardias and to achieve absence of inducibility at the end of the procedure.

If the patient was in sinus rhythm at the beginning of the case, pacing manoeuvers and isoprenaline were used for tachycardia induction. If induced, the procedure would continue as described above. If an arrhythmia was inducible but not maintained despite several attempts, an ablation guided by substrate was performed. A bipolar voltage mapping was obtained (criteria for healthy and scarred tissue were > 0.5mV and < 0.2mV, respectively). If no arrhythmia was inducible and no ablation was performed, the case was excluded from the study.

If the patient was in atrial fibrillation at the start of the case, and as the goal was to treat other tachycardia, electrical cardioversion was performed. Once in sinus rhythm, we followed the steps above mentioned. However, if our goal was to perform atrial fibrillation ablation, after reconstruction of the left atrium, wide pulmonary vein isolation was performed. If patients maintained atrial fibrillation, an electric cardioversion was performed. A bipolar voltage mapping was subsequently performed and low-voltage areas were ablated to achieve tissue homogenisation. If necessary, lines were performed connecting these scarred areas. Bidirectional block was confirmed after these lines were performed. If atrial fibrillation persisted or was still inducible at the end of the procedure, an electric cardioversion was performed.

The primary endpoint focused on the mid-term arrhythmia recurrence rate in patients with CHD referred for catheter ablation. Recurrence was defined by documenting at least 30 sec of arrhythmia during follow up, irrespective of symptoms.[9]

The secondary endpoints were acute success and safety. Acute success was defined as disappearance of the arrhythmia immediately after catheter ablation, despite induction manoeuvres. Safety was defined as any of the following events occurring within the first month after the index ablation: death, major bleeding as defined by the International Society on Thrombosis and Hemostasis,[12] occurrence of a thromboembolic event, atrio-oesophageal fistula, phrenic nerve palsy, pulmonary valve stenosis, pericarditis, and vascular access complications.

We also evaluated predictors for arrhythmia recurrence during follow up.

Patients were evaluated before discharge, as well as at 3, 6, and 12 months after the procedure and thereafter yearly. Transthoracic echocardiography and 24-hour Holter monitoring were performed before discharge. Information collected during follow up included a 12-lead electrocardiogram and a 24-hour Holter in each appointment. A 7-day Holter monitoring was performed at least once yearly. At discharge, anti-arrhythmic drugs were prescribed according to patient characteristics and operators' decision. The first three months post-procedure were considered as a blanking period. Anti-coagulation strategy was based on the CHA2DS2Vasc Score.

Statistical analysis was performed using IBM SPSS Statistics version 25 (IBM, Chicago). Categorical variables are expressed in frequencies and percentages and continuous variables are expressed as mean ± standard deviation or median and interquartile range for variables with or without normal distribution, respectively. The X^2 test was used to assess differences between categorical variables

https://doi.org/10.1017/S1047951123003372 Published online by Cambridge University Press

Table 1. Population characteristics (n = 36).

Characteristic	Value	Previous surgery/percutaneous procedure (n)
Age (years – Mean ± SD)	45 ± 3	-
Male (n / %)	20 / 55	-
Height (cm – Median (IQR))	163 (158–170)	-
Weight (kg – Median (IQR))	71 (60–80)	-
LVEF (% - Median (IQR))	57 (52–60)	-
Medication		
β-blocker (n / %)	16 / 45%	-
Amiodarone + β-blocker (n / %)	7 / 19%	-
Amiodarone (n / %)	5 / 14%	-
Flecainide + β-blocker (n / %)	1 / 3%	-
Amiodarone + flecainide + B-blocker (n / %)	1 / 3%	-
Sotalol (n / %)	1 / 3%	-
None (n / %)	5 / 13%	-
CHD		
Atrial septal defect* (n / %)	10 / 28%	Corrective surgery (9); Percutaneous closure (1)
Atrioventricular septal defect** (n / %)	4 / 11%	Corrective surgery (4)
Partial anomalus pulmonary venous return** (n / %)	5 / 13%	Corrective surgery (4)
Ventricular septal defect* (n / %)	1 / 3%	Corrective surgery (1)
Dextro-transposition of great arteries*** (n / %)	2 / 5%	Senning procedure (2)
Congenital corrected transposition of great arteries with pulmonary atresia*** (n / %)	1 / 3%	Fontan procedure (1)
Congenital corrected transposition of great arteries*** (n / %)	1 / 3%	-
Ebstein anomaly** (n / %)	1 / 3%	-
Pulmonary atresia with intact ventricular septum*** (n / %)	1 / 3%	Pulmonay valvotomy + PPVI (1)
Tetralogy of Fallot** (n / %)	1 / 3%	Corrective surgery with transannular patch (1)
Tricuspid atresia*** (n / %)	1 / 3%	Bjork procedure (1)
Double outlet right ventricle + pulmonary stenosis + malposed great vessels*** (n / %)	2 / 5%	Rastelli procedure (2) + mechanic aortic valve (1)
Coarctation of the aorta** (n / %)	3 / 8%	End to end anastomosis (2); Percutaneous stent (1)
Left persistent superior vena cava* (n / %)	1 / 3%	-
Interruption of inferior vena cava* (n / %)	1 / 3%	-
Dextrocardia* (n / %)	1 / 3%	-

*simple complexity.
**moderate complexity.
***severe complexity.

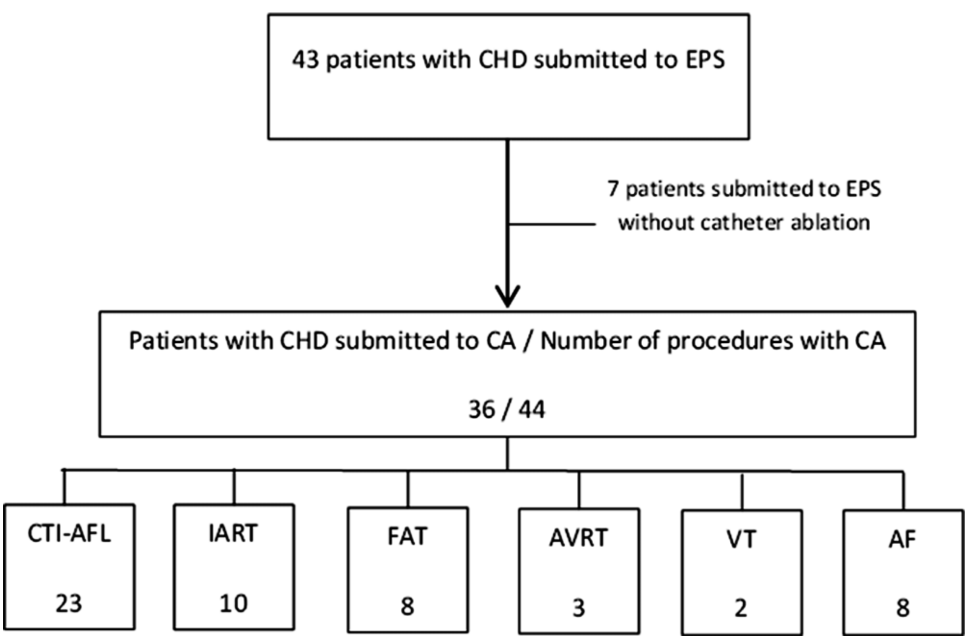

Figure 2. Sample selection and arrhythmias submitted to catheter ablation. AVRT=atrio-ventricular re-entrant tachycardia; CA=catheter ablation; EPS=electrophysiological study; FAT=focal atrial tachycardia; IART=intra-atrial re-entrant tachycardia; IDAF=isthmus-dependent atrial flutter; VT=ventricular tachycardia.

and the Student *t*-test or the Wilcoxon test was used to compare continuous variables with or without normal distribution, respectively. The Kolmogorov-Smirnov test was used to test for normality of distribution of continuous variables. Kaplan-Meier curve was performed to illustrate freedom from atrial arrhythmia recurrence during follow up. Cox regression was used to identify predictors of atrial arrhythmia during follow up. Statistical significance was accepted for p values<0.05.

https://doi.org/10.1017/S1047951123003372 Published online by Cambridge University Press

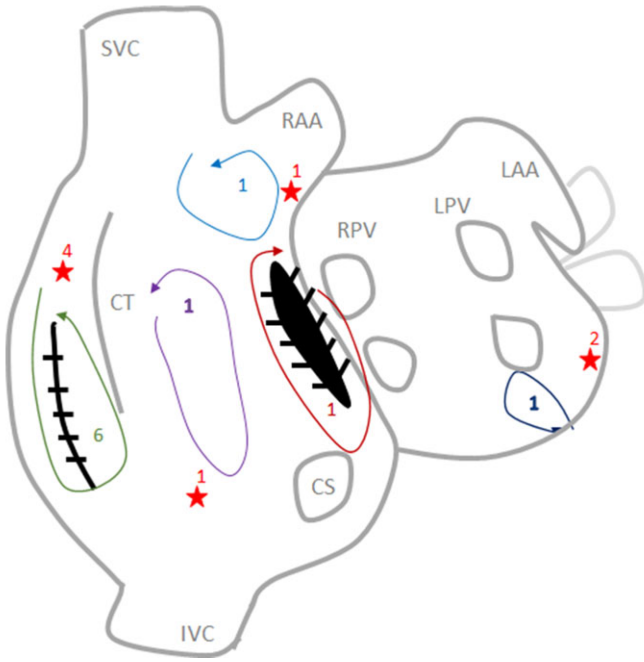

Figure 3. Diagram presenting anatomic distribution of atrial tachycardias. Intra-atrial re-entrant tachycardias are shown as loops with different directions depending on if it is anticlockwise or clockwise. Red stars represent focal atrial tachycardias location. An atriotomy suture line and an atrial septal defect patch are shown in black. CT=crista terminalis; CS=coronary sinus ostium; IVC=inferior vena cava; LAA=left atrial appendage; LPV=left pulmonary veins; RPV=right pulmonary veins; RAA=right atrial appendage; SVC=superior vena cava.

Results

A total of 36 patients (55% male, mean age 43 ± 3 years) fulfilled our inclusion criteria (Fig. 2). During the enrolment period, 44 procedures were performed. A total of 54 arrhythmias were found and ablated (1.2 per procedure, 1.5 per patient): cavotricuspid isthmus-dependent atrial flutter (n = 23), followed by intra-atrial re-entrant tachycardia (n = 10), focal atrial tachycardia (n = 8), atrial fibrillation (n = 8), atrioventricular re-entrant tachycardia (n = 3), and ventricular tachycardia (n = 2). The main baseline characteristics are detailed in Table 1. Accordingly, we had 14 simple, 14 moderate, and 8 severe CHDs in our sample. The diagram of the intra-atrial re-entrant tachycardia circuits and focal atrial tachycardia locations is depicted in Figure 3. The two cases of ventricular tachycardia occurred in a patient with Tetralogy of Fallot, completely corrected with transanular patch and in a second patient with complete atrioventricular septal defect with corrective surgery. The median left ventricular ejection fraction was 57% (interquartile range 52–60). Of note, 36% of the patients were on amiodarone prior to the procedure.

The procedure details are presented in Table 2.

Acute success with just one procedure was achieved in 89%. The ablation of five arrhythmias was unsuccessful, namely in two atrial fibrillation, one atrioventricular re-entrant tachycardia, and two right atrium intra-atrial re-entrant tachycardia.

Median follow up was 37 months (interquartile range 12–52). After one procedure, arrhythmia recurred in four patients – one with atrial fibrillation, one with cavotricuspid isthmus-dependent atrial flutter, one with ventricular tachycardia (ablation guided by substrate), and one with left focal atrial tachycardia. Combining acute failure and recurrence, freedom from recurrence occurred in 80% (36 out of 45 arrhythmias) with just one procedure.

Table 2. Details of the ablations (procedures $n = 44$; total arrhythmias $n = 54$).

Characteristic	Value
Procedures under general anaesthesia (n / %)	39 / 89
Patients in atrial fibrillation prior the procedure (n / %)	8 / 18
Ablations guided by activation mapping (n / %)	51 / 94
Ablations guided by substrate (n / %)	3 / 6
Multiple inducible tachycardia (n / %)	10 / 23
Duration of the procedure (min - mean ± SD)	134 ± 14
Cycle length of tachyarrhythmia (ms – median + IQR)*	330 (290–400)
Fluoroscopy time (min - Mean ± SD)	13 ± 4
Fluoroscopy dose (mGy/cm^2 - Mean ± SD))	550 ± 160
Radiofrequency time (min - Mean ± SD))	12.4 ± 4
Acute success after one procedure	89%
Long term success after one procedure	80%
Long term success after 1.2 procedures	93%
Complications (n)	0

cm = centimetres; IQR=interquartile range; mGy=milligray; min=minutes; ms=milliseconds; n=absolute value; SD=standard deviation.
*Atrial fibrillation excluded.

After 1.2 procedures per patient, overall freedom from arrhythmia was 93% (18% under anti-arrhythmic drug) as depicted in the Kaplan-Meier curve (Fig. 4). Recurrence occurred in four atrial fibrillation cases.

Substrate-guided ablation [Hazar ratio (HR) (95% Confidence interval (CI)) 11.32 (1.59–80.94), p = 0.02] and anti-arrhythmic drug medication after the procedure [HR (95% CI) 15.04 (1.53–147.5), p = 0.02] were related to arrhythmia recurrence during follow up. However, after adjusting for other confounders, these variables lost significance on multiple linear regression (Table 3).

There were no acute or mid-term complications derived from the procedures. A definitive pacemaker was implanted in three patients, which was already planned before the procedure due to sinus node dysfunction.

Discussion

To our knowledge, this was the first Portuguese study assessing the outcomes of catheter ablation in patients with CHD. The main findings of this study are: i) catheter ablation was an effective treatment, with an overall mid-term success of 93% with 1.2 procedures per patient; ii) even in this complex subset of patients, catheter ablation presents a safe profile.

Arrhythmias are a major source of morbidity and mortality in patients with CHD. It is estimated that patients with history of atrial arrhythmia have a two-fold increased risk of stroke or heart failure, and, ultimately, they have a 50% increase in mortality, when compared to those without arrhythmias.[4] Therefore, there is a need to achieve a highly effective treatment in these patients. Catheter ablation has proven to be efficient in this aspect, not only due to the experience acquired by electrophysiologists in this area, but also due to the improvement of mapping systems and ablation catheter design. Our study reinforces that evidence, with a 93% freedom from arrhythmia recurrence with 1.2 procedures per patient. Our results are in line with those reported in other studies,[13-15] although our study also included patients with atrial fibrillation, which are known to have worst results.[16,17] Due to the complexity of these patients, they required more than one procedure to obtain this high effectiveness at long-term follow up, allowing a threefold decrease in the use of anti-arrhythmic drug therapy, known to be associated with several side effects.[18]

https://doi.org/10.1017/S1047951123003372 Published online by Cambridge University Press

Table 3. Univariate and multivariate predictors of arrhythmia's recurrence.

	Univariate model		Multivariate model	
Predictors	Hazard ratio (95% CI)	p-value	Hazard ratio (95% CI)	p-value
Age	4.60 (0.47–-44.99)	0.19		
Gender	0.22 (0.02–2.14)	0.19		
Congenital Heart Disease complexity	1.01 (0.27–0.99)	0.99		
Type of arrhythmia (Re-entry versus others)	0.25 (0.04–1.79)	0.17		
Ablation guided by substrate	11.32 (1.59–80.94)	0.02	3.52 (0.38–32.58)	0.27
Pre medication AAD class I and/or III	5.76 (0.58–56.37)	0.13		
Post medication AAD class I and/or III	15.04 (1.53–147.5)	0.02	8.67 (0.66–113.36)	0.10

AAD = anti-arrhythmic drug; CI = confidence interval; SVT = supraventricular tachycardia.
Re-entry: cavotricuspid isthmus-dependent atrial flutter, intra-atrial re-entrant tachycardia, atrioventricular re-entrant tachycardia, re-entrant ventricular tachycardia. Others: focal atrial tachycardia, atrial fibrillation and non re-entrant ventricular tachycardia.

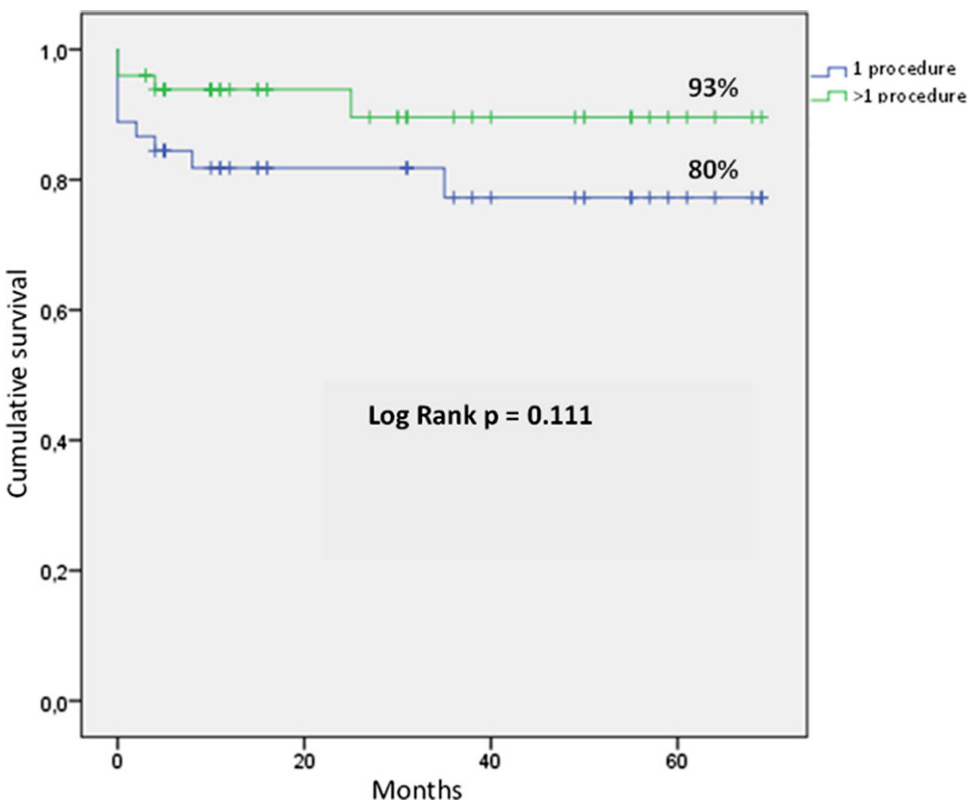

Figure 4. Kaplan-Meier survival curves after one procedure or more than one procedure.

Importantly, despite the challenging complex anatomy in these patients, catheter ablation was safely performed, without any complications observed. This goes in line with reports obtained in other studies,[13-15] despite challenges in vascular access or need for transseptal or transbaffle punctures in distorted anatomies. The low complication rate observed in this study is possibly explained by the use of pre-procedural multimodality imaging,[11,19,20] the improvement in the mapping systems, and also by the performance of these ablations in a high-volume tertiary centre. Importantly, CHD patients are prone to have sick sinus syndrome requiring pacing, resulting either from the condition itself or associated with the cardiac surgery.[21] In our study, our three pacemaker implantations were already planned prior to catheter ablation, as the patients already had severe sick sinus node disease.

This study provides the first national data concerning outcomes following catheter ablation in patients with CHD. It reinforces the high efficacy and the safe profile of catheter ablation at mid-term follow up even in this complex subset of patients.

We acknowledge some limitations in our work. First, this was a retrospective study performed in a tertiary referral centre and therefore our results cannot be extrapolated to other centres. However, our goal was to provide national data concerning mid-term outcomes following catheter ablation in patients with CHD. Second, the number of patients included in this study was not large enough to provide definite conclusions regarding sub-group analysis, arrhythmia predictors, or safety, even though the sample study size was similar to other studies.[22] Further research is required to assess arrhythmia predictors. Third, systematic monitoring using implantable loop recorder could have documented a higher rate of asymptomatic arrhythmia recurrence. However, to minimise that, patients performed a 7-day Holter monitoring once per year. Fourth, we recognise that patients who

https://doi.org/10.1017/S1047951123003372 Published online by Cambridge University Press

implanted a pacemaker might not have recurrence due to the pacemaker effects rather than ablation itself.

Conclusion

In patients with CHD, catheter ablation led to a high freedom of arrhythmia recurrence during mid-term follow up, while presenting a low rate of adverse events.

Acknowledgements. The authors would like to thank all the staff at the electrophysiology laboratory at the Centro Hospitalar e Universitário de Coimbra for their contribution to this manuscript.

Competing interests. P.A.S has received consulting speaker fees from Abbott, Biosense Webster, Boston Scientific, and Medtronic. NA has received consulting speaker fees from Microport and Abbott. All other authors declare that there are no proprietary, financial, professional, or other personal interests of any nature or kind in any product, service, and/or company that could be construed as influencing the content of the manuscript.

Ethical standard. All patients provided written informed consent, the study complied with the Declaration of Helsinki, no patient-identifying data or images are present in the manuscript, and the manuscript was approved by the local institutional ethics committee.

References

1. Dolk H, Loane M, Garne E. Congenital heart defects in Europe: prevalence and perinatal mortality, 2000 to 2005. Circulation 2011; 123: 841–849.
2. Bouchardy J, Therrien J, Pilote L, et al. Atrial arrhythmias in adults with congenital heart disease. Circulation 2009; 120: 1679–1686.
3. Abrams DJ. Invasive electrophysiology in paediatric and congenital heart disease. Heart 2007; 93: 383–391.
4. de Miguel IM, Ávila P. Atrial fibrillation in congenital heart disease. Eur Cardiol 2021; 16: e06.
5. Karbassi A, Nair K, Harris L, et al. Atrial tachyarrhythmia in adult congenital heart disease. World J Cardiol 2017; 9: 496.
6. Bradley EA, Zaidi AN, Morrison J, et al. Effectiveness of early invasive therapy for atrial tachycardia in adult atrial-baffle survivors. Texas Hear Inst J 2017; 44: 16–21.
7. Gallotti RG, Madnawat H, Shannon KM, et al. Mechanisms and predictors of recurrent tachycardia after catheter ablation for d-transposition of the great arteries after the mustard or senning operation. Hear Rhythm 2017; 14: 350–356.
8. Moore JP, Shannon KM, Fish FA, et al. Catheter ablation of supraventricular tachyarrhythmia after extracardiac Fontan surgery. Hear Rhythm 2016; 13: 1891–1897.
9. Khairy P, van Hare GF, Balaji S, et al. PACES/HRS expert consensus statement on the recognition and management of arrhythmias in adult congenital heart disease. Can J Cardiol 2014; 30: e1–63.
10. Franklin RCG, Béland MJ, Colan SD, et al. Nomenclature for congenital and paediatric cardiac disease: the international paediatric and congenital cardiac code (IPCCC) and the eleventh iteration of the international classification of diseases (ICD-11). Cardiol Young 2017; 27: 1872–1938.
11. Palma A, Sousa PA, Silva P, etal V. Transbaffle puncture using multimodality imaging and 3-d mapping with ct image integration in a patient with atrial flutter post-senning procedure. Arq Bras Cardiol 2021; 117: 153–156.
12. Schulman S, Kearon C. Subcommittee on control of anticoagulation of the scientific and standardization committee of the international society on thrombosis and Haemostasis. Definition of major bleeding in clinical investigations of antihemostatic medicinal products in nonsurgical patients. J Thromb Haemost 2005; 3: 692–694.
13. Hebe J, Hansen P, Ouyang F, et al. Radiofrequency catheter ablation of tachycardia in patients with congenital heart disease. Pediatr Cardiol 2000; 21: 557–575.
14. Lukac P, Pedersen AK, Mortensen PT, et al. Ablation of atrial tachycardia after surgery for congenital and acquired heart disease using an electroanatomic mapping system : which circuits to expect in which substrate? Heart Rhythm 2005; 2: 64–72.
15. Jiang H, Li XM, Zhang Y, et al. Electrophysiological characteristics and outcomes of radiofrequency catheter ablation of atrial flutter in children with or without congenital heart disease. Pediatr Cardiol 2020; 41: 1509–1514.
16. Liang JJ, Frankel DS, Parikh V, et al. Safety and outcomes of catheter ablation for atrial fibrillation in adults with congenital heart disease: a multicenter registry study. Hear Rhythm 2019; 16: 846–852.
17. Philip F, Muhammad KI, Agarwal S, et al. Pulmonary vein isolation for the treatment of drug-refractory atrial fibrillation in adults with congenital heart disease. Congenit Heart Dis 2012; 7: 392–399.
18. Wasmer K, Eckardt L, Baumgartner H, et al. Therapy of supraventricular and ventricular arrhythmias in adults with congenital heart disease—narrative review. Cardiovasc Diagn Ther 2021; 11: 550–562.
19. Amaral MA, Sousa PA, António N, et al. Atrial tachycardia ablation in surgically treated congenital heart disease. Rev Port Cardiol 2018; 37: 271–275.
20. Waldmann V, Bessière F, Raimondo C, et al. Atrial flutter catheter ablation in adult congenital heart diseases. Indian Pacing Electrophysiol J 2021; 21: 291–302.
21. Greenwood RD, Rosenthal A, Sloss l, et al. Sick sinus syndrome after surgery for congenital heart disease. Circulation 1975; 52: 208–213. DOI: 10.1161/01.cir.52.2.208.
22. Sherwin ED, Triedman JK, Walsh EP. Update on interventional electrophysiology in congenital heart disease evolving solutions for complex hearts. Circ Arrhythmia Electrophysiol 2013; 6: 1032–1040.