

Original Article

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Radiofrequency catheter ablation in 246 children with supraventricular tachyarrhythmia

Christine Ilkjaer^{1, 2}, Vibeke E. Hjortdal², Jens Christian Gerdes³, Henrik K. Jensen^{2, 3}, Peter Lukac³, Jesper V. Bjerre⁴, Marianne B. Moller⁵ & Jens Cosedis Nielsen^{2, 3}

1) Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, 2) Department of Clinical Medicine, Aarhus University, 3) Department of Cardiology, Aarhus University Hospital, 4) Department of Paediatrics, Aarhus University Hospital, 5) Intensive Care Unit, Aarhus University Hospital, Denmark

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ABSTRACT

INTRODUCTION: Radiofrequency catheter ablation (RFA) is the treatment of choice for a variety of cardiac arrhythmias in adults. RFA is considered effective and is associated with few complications. We aimed to review the characteristics and outcomes of invasive electrophysiological study (EPS) and RFA in children with supraventricular tachyarrhythmia.

METHODS: Consecutive patients younger than 16 years of age undergoing EPS and possible RFA from January 2009 to September 2018 at Aarhus University Hospital (uptake three million people) were reviewed retrospectively. Procedural and outcome data were collected from patient charts and from the Danish Ablation Database. Numbers (%) or median (range) are reported.

RESULTS: A total of 304 patients (148 girls) underwent EPS (352 procedures). RFA was performed in 246 patients (279 procedures), aged 13 (1-15) years and weighing 46 (6-99) kg. Treatment success was achieved in 195 (79%) of the initial procedures. Using more than one procedure, 227 (92%) patients were free from arrhythmia after 89 (26-143) months of follow-up. The procedure time was 60 (22-222) min. and ablation time 2 (1-23) min. Major complications occurred in two cases. One patient developed transient superior vena cava syndrome and one patient developed an atrioventricular block requiring pacemaker implantation.

CONCLUSIONS: RFA may be performed in children with a high success rate and a low but not negligible risk of complications.

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Catheter ablation has become an increasingly common practice in children suffering from supraventricular arrhythmias. Success rates fall in the 90-98% range and rates of major complications such as atrioventricular (AV) block occur in 0.7-2.9% of young ablated patients [1-3].

Long-term follow-up studies of radiofrequency lesions in the immature myocardium remain few. When to ablate and when to choose medicine/nothing is often the question among patients, parents and physicians. Consequently, a risk-benefit analysis is crucial taking into account age, body size, type of arrhythmia, presence of structural heart disease and expected benefit from three-dimensional non-fluoroscopic mapping.

The aim of the present paper was to disclose the characteristics and outcomes of catheter ablation procedures in children and adolescents in a retrospective population-based study performed at a single specialised tertiary Scandinavian centre.

METHODS

Population

Consecutive patients younger than 16 years of age who underwent electrophysiological study with or without catheter ablation at Aarhus University Hospital (uptake three million people) between January 2009 and September 2018 were reviewed retrospectively. The criteria for intervention were documented or strongly suspected symptomatic supraventricular arrhythmia.

Data were collected from patient charts and from the Danish Ablation Database with approval from the Danish Data Protection Agency. All patients were followed until 5 October 2020 for any later contact to a hospital in the Central Denmark Region.

Data collection

Arrhythmias were classified as Wolff-Parkinson-White syndrome (WPW), AV re-entry tachycardia (AVRT) in patients with exclusively ventriculo-atrial conducting accessory pathway, AV nodal re-entry tachycardia (AVNRT), permanent junctional reciprocating tachycardia, atrial flutter and multifocal or focal atrial tachycardia. For WPW, the presence of Mahaim fibres was noted. The location of accessory pathways was categorised in accordance with the consented nomenclature [4].

Upon concluding the procedure, the electrophysiologist reported whether it was a procedural success (bidirectional block of accessory pathways or flutter-isthmus or non-inducibility of other arrhythmias). Any complications were noted. Treatment success was defined as no documented arrhythmia until end of follow-up for each procedure. Final treatment success was defined as no documented arrhythmia after the latest procedure for each patient.

Procedure characteristics

Antiarrhythmic medication was withheld five half-lives in advance.

The general procedural approaches were as follows: through one or both femoral veins or rarely the subclavian vein, two or three catheters were placed in the right ventricle, at the His bundle region and in the coronary sinus for the electrophysiological study. The ablation catheter (6-7.5F, 3.5-4-mm tip) was introduced either through a venous sheath or for left-sided retrograde procedures through the femoral artery or via trans-oesophagus-guided trans-septal access. For left-sided procedures and patients with congenital heart disease with communication between circulations, unfractionated heparin (100 IU/kg) was administered. Standardised methods were used for mapping and ablation. Ablation was power controlled. The maximal energy delivered was individualised (10-50 W).

For expectedly difficult procedures, non-fluoroscopic electro-anatomical mapping was used.

Statistical analysis

Data were collected and managed using REDCap electronic data capture tools hosted at Aarhus University. Stata/IC 15.1 was used for statistical analyses. Data are presented as numbers (%) or median (range or quartiles). Groups were compared using the χ^2 -test or Mann-Whitney test. $p < 0.05$ was considered significant.

Trial registration: Approval was obtained from the Danish Data Protection Agency (1-16-02-430-13).

Results

Patient characteristics

During the nine and three quarters of a year, a total of 304 patients (148 girls) underwent electrophysiological studies of whom 246 were ablated. A substrate of arrhythmia was identified in 266 patients. Two patients had nodoventricular accessory pathways. The electrophysiologists refrained from ablation in 19 patients due to an estimated high risk, and one patient was inducible for only 6-7 beats in general anaesthesia.

The most common cause of admission was highly symptomatic paroxysmal attacks of tachycardia. Twenty patients had fainted prior to admission. Most procedures (96%) were elective. Ten procedures were scheduled sub-acutely. Five of these patients were initially hospitalised with severely depressed left ventricular ejection fraction of 10-15%. First-line treatment was haemodynamic stabilisation with digoxin and amiodarone aiming at an ejection fraction of at least 30% before performing ablation.

The median age among ablated patients was 13 (1-15) years (Table 1). Eleven patients were younger than five years of age, 61 patients ranged from the age of five to ten years, and 174 patients were 11-15 years of age. The median body weight was 46 (6-99) kg.

TABLE 1 Patients undergoing radiofrequency catheter ablation.

	Diagnosis							
	All	WPW ^a	AVRT ^{b,c}	PJRT	AVNRT	FAT	mFAT	AFLUT
Age, median (range), yrs	13 (1-15)	12 (1-15)	13 (3-15)	9 (4-14)	13 (3-15)	12 (4-14)	13	13 (4-15)
Patients, n (%)	246 (100)	87 (35)	58 (24)	2 (1)	81 (33)	9 (4)	1	8 (3)
Females, n (%)	114 (46)	33 (38)	31 (53)	0	44 (54)	5 (56)	0	1 (13)
Congenital heart disease, n (%)	20 (8)	8 (9)	1 (2)	0	2 (2)	1 (11)	0	8 (100)
Procedural success of initial procedure ^d , n (%)	221 (90)	75 (86)	57 (98)	2 (100)	72 (88)	7 (78)	0	8 (100)
Treatment success of initial procedure ^e , n (%)	195 (79)	69 (79)	54 (93)	0	58 (72)	7 (78)	0	7 (88)
Procedures, n	279	99	60	4	95	12	1	8
Final success ^f , n (%)	227 (92)	82 (94)	56 (97)	1 (50)	72 (89)	9 (100)	0	7 (88)

AFLUT = atrial flutter; AVNRT = atrioventricular nodal re-entry tachycardia; AVRT = atrioventricular re-entry tachycardia; FAT = focal atrial tachycardia; mFAT = multifocal atrial tachycardia; PJRT = permanent junctional reciprocating tachycardia; WPW = Wolf-Parkinson-White syndrome.

a) 3 patients with WPW had 2 accessory pathways each.

b) 3 patients with AVRT had 2 accessory pathways each.

c) 4 patients suffered from AVRT and AVNRT, and they figure among AVRT patients.

d) Procedures reported as successful by the cardiologists after ended procedure.

e) Long-term outcome after the primary procedure.

f) Patients successfully treated for their arrhythmia.

Among patients with a body weight under 20 kg, indications for ablation were side effects to medical treatment (n = 4), arrhythmias refractory to medical treatment (n = 3), sub-acute intervention (n = 2) and one was before a total cavo-pulmonary connection operation.

Ablation procedures

A total of 279 ablation procedures were performed in 246 patients (Table 2). Nine patients had undergone catheter ablation before 2009, three of whom twice.

TABLE 2 Radiofrequency catheter ablation procedure characteristics.

	Diagnosis							
	All	WPW	AVRT	PJRT	AVNRT	FAT	mFAT	AFLUT
Patients, n (%)	246 (100)	87 (35)	58 (24)	2 (1)	81 (33)	9 (4)	1	8 (3)
Procedures, n	279	99	60	4	95	12	1	8
Procedure time ^a , median (range) [IQR], min.	60 (22-222) [46-85]	66 (27-210) [49-103]	54 (23-222) [40-85]	89 (75-160) [79-128]	57 (22-110) [46-70]	100 (65-160) [78-130]	140	54 (23-222) [40-85]
Fluoroscopy time ^b , median (range) [IQR], min.	7 (0.1-50) [5-13]	7 (0.1-50) [5-13]	9 (2-37) [6-19]	5 (1-7) [3-6]	7 (0.9-30) [5-13]	6 (2-10) [4-7]	26	7 (3-24) [5-16]
Radiation dose ^c , median (range) [IQR], Gy × cm ²	1 (0.01-55) [0.82-3]	1 (0.01-55) [0.5-3]	2 (0.2-39) [1-5]	0.15 (0.1-0.2) [0.1-0.2]	1 (0.01-25) [0.8-3]	1 (1-15) [1-2]	-	7 (2-14) [2-14]
Total RF ablation time ^d , median (range) [IQR], min.	2 (1-23) [2-4]	2 (1-23) [2-4]	2 (1-10) [1-4]	3 (1-11) [1-8]	2 (1-12) [1-49]	7 (2-20) [4-11]	16	5 (3-16) [5-7]
RF energy max ^e , median (range) [IQR], W	30 (10-50) [30-40]	40 (20-40) [30-40]	30 (25-50) [30-40]	30 (10-30) [20-30]	30 (20-30) [25-30]	30 (20-35) [25-30]	35	40 (30-40) [30-40]
Retrograde aortic access, n	85	41	43	0	0	0	0	1
Transseptal, n	34	13	17	0	0	3	1	0
Transseptal and retrograde attempt, n	9	2	7	0	0	0	0	0
Irrigated tip catheter, n	52	26	4	2	1	12	1	6
Use of isoprenaline, n	147	19	16	4	91	12	1	4

AFLUT = atrial flutter; AVNRT = atrioventricular nodal re-entry tachycardia; AVRT = atrioventricular re-entry tachycardia; FAT = focal atrial tachycardia; IQR = interquartile range; mFAT = multifocal atrial tachycardia; PJRT = permanent junctional reciprocating tachycardia; RF = radiofrequency catheter; WPW = Wolf-Parkinson-White syndrome.

- a) Missing from 14 procedures.
- b) Missing from 21 procedures.
- c) Missing from 45 procedures.
- d) Missing from 27 procedures.
- e) Missing from 32 procedures.

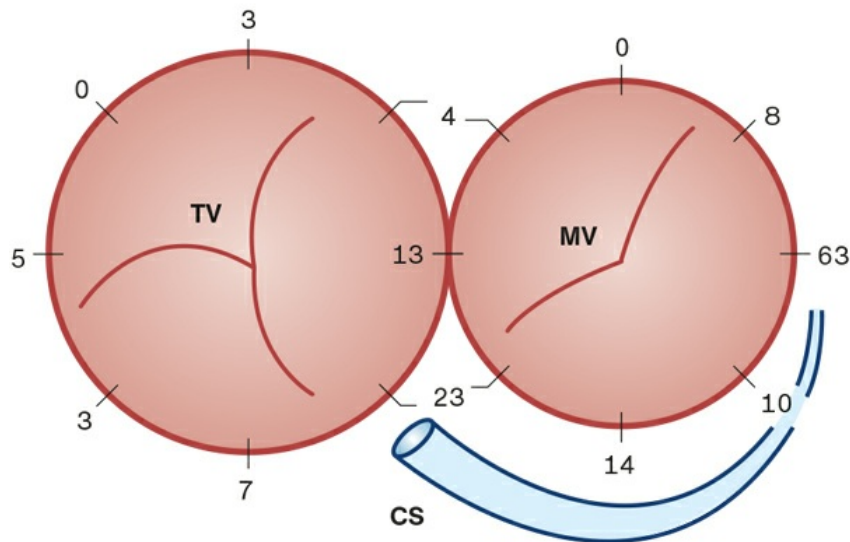
Treatment success was achieved in 195 (79%) of the initial procedures. Following the initial procedure, 34 patients underwent additional ablation: one time (n = 27), two times (n = 3), at another hospital (n = 2) or above the age of 15 (n = 2) years.

Twenty initial procedures were stopped before procedural success due to: a high risk of AV block (n = 14), venous anomaly draining inferiorly to the superior caval vein (n = 1), Mahaim fibre not readily located with rare arrhythmia episodes (n = 1) or long procedure time and oedema (n = 4). One patient with multifocal atrial tachycardia subsequently underwent ablation of the AV node due to tachycardia causing heart failure.

Arrhythmias

Among ablated patients, the most frequent substrate of arrhythmia was an accessory pathway (147 patients, 153 accessory pathways) (Figure 1). Four WPW patients had Mahaim fibres. Four patients had AVRT and AVNRT. The left sided free wall was the most frequent location for accessory pathways (Figure 1). The final treatment success among patients with accessory pathways was 95% (138 patients). Fourteen patients underwent two procedures and one patient underwent three ablation procedures.

FIGURE 1 Localisation of accessory pathways among patients undergoing radiofrequency catheter ablation. Numbers represent the number of accessory pathways in each anatomical position. The atrioventricular valves are seen from a ventricular view.



CS = coronary sinus; MV = mitral valve; TV = tricuspid valve.

A total of 96 patients had documented AVNRT of whom 85 (four patients also had AVRT) underwent catheter ablation. Among the ablated patients only suffering from AVNRT, final treatment success was achieved in 72 (89%) patients either after the first (n = 59), second (n = 12) or third (n = 1) procedure.

Procedure characteristics

The procedure time was 60 (22-222) min. including time of the electrophysiological study (Table 2). The radiation dose was 1 (0.01-55) Gy × cm² and the ablation time was 2 (1-23) min.

Irrigated tip catheters were used in 52 cases, and treatment success with irrigated tip catheters was not different from non-irrigated tip catheter procedures (p = 0.15). Left-sided procedures counted 110 in 106 patients. Electroanatomical mapping was used for 63 procedures in 54 patients, most commonly for WPW (35 procedures) and FAT (11 procedures).

Follow-up

Overall, 227 (92%) patients had final treatment success after 89 (26-143) months of follow-up. During the follow-up period, 71 (31%) of these patients consulted a hospital for symptoms. No arrhythmias were verified by Holter recording (n = 59), exercise test (n = 18) or electrophysiological study (n = 7).

Patients with structural heart disease

Structural heart disease was present in 25 patients of whom 20 were ablated (Table 3). Final treatment success was 90% (n = 18), which is not different from patients with structurally normal hearts (p = 0.69). Three-dimensional electro-anatomical mapping was used in 57% of the procedures compared with 20% in patients without structural heart disease.

TABLE 3 Patients with structural heart disease.

Patient no.	Arrhythmia	Structural heart disease	Surgical correction	Procedure	Non-fluoroscopic electroanatomical mapping	Final treatment success
1	WPW	Univentricular heart Right atrial isomerism	-	RFA	Yes	Yes
2	WPW	Ebstein anomaly	ASD closed	RFA	Yes	Yes
3	WPW	Aortic valve insufficiency	Composite graft	RFA	No	Yes
4	WPW	Ebstein anomaly/ASD	Glenn	RFA	Yes	Yes
5	WPW	Mitral valve insufficiency	-	RFA	No	Medical treatment ^b
6	WPW	CCTGA	-	RFA x 2	No (yes) ^d	Yes
7	WPW	Small ASD	-	RFA	Yes	Yes
8	WPW	Patent ductus arteriosus	-	RFA	No	Yes
9	AVRT	Congenital aortic valve stenosis	Ballon valvuloplasty	RFA	Yes	Yes
10	Atrial tachycardia related to scar	VSD	Closed	RFA	Yes	Yes
11	FAT	Dilated cardiomyopathy	-	RFA	Yes	Yes
12	AFLUT	Marfan syndrome Aortic root dilatation Mitral valve prolapse	-	RFA	No	Yes
13	AFLUT	Right atrial isomerism	TCPC	RFA	Yes	Yes
14	AFLUT	ASD/VSD	Closed	RFA	No	Yes
15	AFLUT	AVSD	2-patch	RFA	No	Yes
16	AFLUT	Tetralogy of Fallot	Repair	RFA	Yes	Yes
17	AFLUT	Transpositio vasorum incompleta RV/ VSD/pulmonary stenosis	Rastelli Pulmonary stent valve	RFA (EPS) ^a	Yes	Medical treatment
18	AFLUT	Tetralogy of Fallot	Pulmonary homograft ICD-PM	RFA	Yes	Yes
19	AVNRT	Aortic valve insufficiency	-	RFA	No	Yes
20	AVNRT	Ebstein anomaly	-	RFA	No	Yes
21	Atrial tachycardia	Univentricular heart	TCPC	EPS	Yes	Medical treatment ^c
22	Non-inducible	VSD	Closed	EPS	No	-
23	Non-inducible	Hypertrophic cardiomyopathy	Myectomy	EPS	No	-
24	Non-inducible	Hypoplasia ventriculi sinistri cordis	TCPC	EPS	No	-
25	Non-inducible	Ebstein anomaly	-	EPS	No	-

AFLUT = atrial flutter; ASD = atrial septal defect; AVNRT = atrioventricular nodal re-entry tachycardia; AVSD = atrioventricular septal defect; CCTGA = congenitally corrected transposition of the great arteries; EPS = electrophysiological study; ICD = implantable cardioverter-defibrillator; PM = previous pacemaker; RFA = radiofrequency catheter ablation; RV = right ventricle; TCPC = total cavo-pulmonary connection; VSD = ventricular septal defect; WPW = Wolff-Parkinson-White syndrome.

a) Had an EPS done at age 16 yrs, and medical treatment was chosen as strategy.

b) Stop of procedure due to abnormal structural venous return from the lower body via azygos vein to superior caval vein and only rare episodes of tachycardia; retrograde access did not offer sufficient signals with precaution to the congenital mitral insufficiency and transseptal access was not possible due to venous abnormalities.

c) Stop due to haemodynamic instability.

d) In the 2nd procedure 3D electroanatomical mapping was used.

Complications

Complications occurred in two patients. One Wolff-Parkinson-White patient with a right-sided infero-paraseptal accessory pathway developed complete AV block requiring a permanent pacemaker. Post-procedural echo disclosed a membranous atrial septum aneurism that had potentially changed the AV node location. Alternatively, the AV node artery may have been damaged.

A 13-year-old boy had FAT with rapid AV conduction and tachy-cardiomyopathy with severely compromised left ventricular ejection fraction and clinical heart failure. He had undergone two previous catheter ablation procedures with high right atrial ablation. Immediately after the procedure, the patient developed superior vena cava syndrome. A computed tomography diagnosed severe stenosis and thrombosis of the superior caval vein.

Symptoms declined on heparinisation, oral anticoagulation and stent implantation. The explanation for the superior caval vein stenosis was likely scarring after the two previous catheter ablation procedures and a small acute endothelial lesion from the ablation or the trans-septal access tool.

DISCUSSION

This study demonstrates that radiofrequency catheter ablation may be used as curative therapy for supraventricular tachyarrhythmia with a high treatment success and a low risk of complications in children and adolescents. After the initial ablation procedure, 195 (79%) of the patients were free from arrhythmia. Using more than one procedure, we successfully treated 227 (92%) patients after 89 (26-143) months of follow-up. Two serious complications occurred. The results are in accordance with other prospective and retrospective multi- and single-centre studies [1-3, 5-7].

The indications for intervention during the study period were documented or strongly suspected symptomatic supraventricular arrhythmia. The youngest ablated patient was one year of age, and the median age was 13 years. Among the ten ablated patients with a body weight below 20 kg, medication was not considered sufficient or caused side effects.

Before embarking for ablation, conducting a risk-benefit analysis is crucial, taking into account an expected life-long antiarrhythmic drug therapy with potential side effects, the possibility of outgrowing the arrhythmia, the threshold for symptoms and the patient's ability to attend activities.

Two serious complications occurred, emphasising that catheter ablation should be offered only to children who are highly symptomatic and only after thorough information to patients and their parents. The reported complication rate was not higher among patients with a body weight below 20 kg or among patients with structural heart disease.

The referral rate for sports active young individuals with a WPW pattern in their electrocardiogram and without any symptoms is rising. The data emphasise that ablation may be considered as a treatment strategy but also underline the importance of an individualised risk-benefit analysis.

A more aggressive ablation strategy might have produced a higher success rate in our cohort. The decision not to ablate was chosen at high-risk positions. We believe that this strategy is reflected in the low complication rate. However, the emerging focus on cryoablation as a substitution for procedures performed close to the AV node might be favourable for a selected group of patients despite a higher reported recurrence rate [8, 9].

We assume that the current report is population based. The Danish healthcare system is a non-pay public system and Aarhus University Hospital had an uptake from the Western part of Denmark (three million people) during the inclusion period. The distribution of arrhythmias and location of accessory pathways reflect what has been reported previously [2, 3, 10]. We found a trend towards a higher success rate for pathways located at the left side of the heart, which is in accordance with other studies [7, 11]. Patients with accessory pathways located at the superoparaseptal or septal positions are considered high-risk patients [4, 10]. In the present study, these patients did not have complications. However, five procedures were stopped due to a high risk of AV block.

All eight patients with atrial flutter had structural heart disease and their arrhythmia was likely caused by post-surgical arrhythmia substrates, as indicated by previous studies [12, 13].

One important aspect of concern when ablating young patients is the exposure to radiation and the subsequent risk of cancer. The procedure time and fluoroscopy time in our study are lower than what was reported in a recent survey by the European Heart Rhythm Association [10].

Recurrent sensing of tachycardia symptoms after ablation is described in 30-60% of patients [14, 15, 16]. True recurrent arrhythmias are expected to occur mainly within the first six months [17], ranging 6-20%, which is in accordance with our findings. In the absence of recurrent arrhythmia, these symptoms are believed to represent a potentially heightened sensitivity to sinus tachycardia and in some cases an increased heart rate after exercise [3] as described in adults [18, 19, 20]. We included any contact to a hospital in the Central Denmark Region from 26 to 143 months of follow-up. Patients who consulted a hospital with subjective sensations of tachycardia with no documentation of tachyarrhythmia accounted for 31% of these complaints. More patients may have seen their general practitioner or a hospital in other regions of Denmark.

Study limitations

The retrospective design of the study has well-known limitations. The moderate number of patients studied from a single centre cannot automatically be considered representative for other centres. Furthermore, only data from patients undergoing electrophysiological evaluation or ablation were included.

CONCLUSIONS

The present results support that catheter-based radiofrequency ablation for highly symptomatic recurrent supraventricular tachycardia has high success rates and low but not negligible complication rates in children and adolescents.

Correspondence *Christine Ilkjaer*. E-mail: c.ilkjaer@clin.au.dk

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Conflicts of interest Potential conflicts of interest have been declared. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

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