USE OF CONTACT FORCE TECHNOLOGY FOR CARDIAC ARRHYTHMIA ABLATION IN CHILDREN

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We the authors have no conflicts to disclose for ***"Use of contact force technology for cardiac ablation in children"***

Abstract

Introduction: Recently, new techniques for cardiac arrhythmia ablation, such as contact force (CF) technology, have emerged. These catheters provide information about adequate tissue contact for an optimal lesion. In adults, these techniques have shown greater accuracy, reduced arrhythmia recurrence and complications, and higher success rates. However, data in pediatrics are limited.

Objective: We aimed to describe the experience of arrhythmia ablation in the pediatric population with CF catheters.

Methods: A retrospective cross-sectional descriptive study of all patients younger than 18 years of age undergoing cardiac 3D mapping and ablation with CF between March 2016 and June 2022 was performed.

Results: A total of 321 patients were included (51.40% male with a mean age of 12.26 years). The most frequent arrhythmias included supraventricular tachycardia

(SVT) mediated by accessory pathways (AP) [atrioventricular reentrant tachycardia (AVRT)] in 82.24%, ventricular arrhythmias (VA) in 11.21% and atrial tachycardia (AT) in 5.92%. The mean procedure time was 2.86 hours (sd 1.2), and the average contact used was 14.33 grams (sd 6.88). The success rate of ablation was 97.82% with a low risk of complications.

Conclusion: This is the largest published series of patients under 18 years of age using CF technology. In the pediatric population, CF ablation is a safe procedure with high success rates and can be used for most arrhythmic substrates. The most frequent tachycardia observed in this study was SVT mediated by AP. Contact with 14 grams is safe and yields an excellent outcome in children. The presence of SHA and previous ablation procedures decreased the success rate.

Keywords: Contact force, Catheter, Ablation, Children, Arrhythmia, Supraventricular tachycardia, Accessory pathway, Ventricular arrhythmia, Atrial tachycardia.

Conflict of interest: The authors have no conflicts to disclose.

Introduction

Ablation techniques for cardiac arrhythmias were created as a response to treatment failure and the high probability of arrhythmia recurrence in the general population[1]. Radiofrequency ablation is performed through a catheter that directly transmits energy to the tissue, causing cell death[1,2]. Since the introduction of ablation techniques and further technological improvements, success rates of greater than 90% have been achieved with a very low chance of recurrence[1,3]. Contact force (CF) catheters are among the most recent ablation technologies developed, and these catheters are designed to quantify the contact of the catheter tip with myocardial tissue to cause more effective lesions and reduce the risk of complications[3,4]. CF catheters have been very promising, initially in adults and since approximately 2014 in the pediatric population[1,3].

In children, the most frequent indications for cardiac ablation are supraventricular tachycardia (SVT) mediated by accessory pathways (AP), atrioventricular nodal reentrant tachycardia (AVNRT), atrial tachycardias (AT) and ventricular arrhythmias (VA) with high success rates[1,3,5–7]. However, data are limited in the pediatric population, specifically regarding CF catheter technology. Thus, we aimed to describe the use of CF for cardiac ablation in children at the pediatric electrophysiology (EP) laboratory at Fundación Cardioinfantil-LaCardio from 2016 to 2022.

This work was carried out in Colombia South America (a third world country), where patients in rural areas do not have easy access to specialist doctors or highly complex diagnostic tests, but the Fundación Cardioinfantil-LaCardio has a program that carries out brigades displacing a group of pediatric cardiologists to remote regions of the country, to diagnose heart disease in the pediatric population and patients are treated at the institution.

Materials and methods

Study design

A retrospective cross-sectional descriptive study was performed that included children under 18 years of age undergoing three-dimensional electroanatomic mapping (3D mapping) and ablation with CF between March 2016 and June 2022 at Fundación Cardioinfantil-LaCardio. Data were collected through a standardized form that included all variables, including demographic and clinical variables and those related to the ablation procedure. A database was designed in Microsoft Excel 2013 to store the information of the study population. The principal

investigator oversaw verification of the information to guarantee the quality of the data collected.

For statistical tabulation purposes, a diagnostic grouping of structural heart anomalies (SHAs) was performed as follows: *tricuspid valve anomalies* (Ebstein anomaly and tricuspid valve dysplasia); *cardiomyopathies* (dilated, hypertrophic and noncompaction *cardiomyopathy*); *septal defects* (atrial, ventricular and atrioventricular canal defects); *right ventricular outflow tract* (RVOT) anomalies [tetralogy of Fallot (TOF) and pulmonary stenosis]; and *extracardiac anomalies* [patent ductus arteriosus (PDA), partial anomalous pulmonary venous return and aortic coarctation]. Comorbidities are defined as all other associated pathologies that do not involve the heart or great vessels.

Study population

During the study period, all children younger than 18 years who were admitted to Fundación Cardioinfantil-LaCardio who underwent cardiac ablation with the use of CF were included in the cohort. Patients whose ablation procedure with CF was performed at a different institution and patients who required the use of another type of technology for ablation of their arrhythmia were excluded. Data were collected retrospectively from medical records within the institutional pediatric EP laboratory.

Procedure

Informed consent was obtained, and antiarrhythmic medications were stopped one week or five half-lives before the procedure. All procedures were performed under deep sedation or general anesthesia and conducted by our institutional cardiac anesthesia team. Three-dimensional mapping (EnSite/Precision, Abbott Laboratories or Carto 3, Biosense Webster) was used for all procedures. The following CF catheters were used: TactiCath Contact Force Ablation Catheter, Sensor Enabled [TactiCath SE, Abbott Park, Illinois] or ThermoCool SurroundFlow catheter [SFc, Biosense Webster, Diamond Bar, CA].

The acute success rate was established as the noninducibility of the arrhythmia, and in patients with AP, the absence of conduction (antegrade and retrograde) through the AP after ablation. Significant complications related to the ablation procedure were noted.

The following procedure characteristics were evaluated: procedure time (from the patient's admission into the EP laboratory until their departure), fluoroscopy time, and the number of grams of contact force during the ablation (the maximum value

recorded for a time greater than 15 seconds during the ablation was taken for data analysis).

An initial standard EP study was performed, and the mechanism and type of arrhythmia were identified and grouped as atrioventricular reentrant tachycardia (AVRT) [including patients with SVT secondary to Wolff–Parkinson–White (WPW) syndrome, concealed AP, permanent junctional reciprocating tachycardia (PJRT) and Mahaim fibers], atrial tachycardia, atrial flutter, and ventricular arrhythmias (VA) [including premature ventricular contraction (PVC) and ventricular tachycardia (VT)]. Subsequently, 3D mapping was performed to localize the origin of the tachycardia or the AP. For ablation, if the catheter contact was < 15 gr, the power delivery was titrated at 35 W; if the contact was between 15 and 25 gr, it was titrated at 30 W; and when the contact was > 25 gr, it was titrated at 25 W.

In our institution, irrigated catheters are not used for ablation close to the cardiac conduction system; therefore, patients with AVNRT, AP or arrhythmic foci near the AV node were excluded.

Data analysis

Qualitative variables were described through absolute and relative frequencies. Quantitative variables were defined through means and standard deviations or medians and interquartile ranges depending on the normality of the variable. To describe the success rate in relation to sociodemographic and clinical variables, mean differences and odds ratios (ORs) are presented together with their 95% confidence intervals (CIs). All statistical analyses were performed in R software version 4.0.2.

This study was presented and approved by the institutional ethics committee in agreement with national and international regulations and following the standards of the Declaration of Helsinki and its subsequent amendments (1964). The study was considered low risk given that no interventions were performed in the context of the study nor was there a change in the course of treatment.

Results

During the study period, a total of 334 patients were enrolled. In total, 13 were excluded for not meeting the inclusion criteria, and 321 were included in the analysis. Of the participants, 51.40% were male with a mean age of 12.26 years (sd 3.54 years) and an age range from 4 to 18 years. The results of the demographic and clinical characteristics of the cohort are presented in Table 1.

Palpitations were the principal symptom in 72.0% of patients followed by chest pain (12.20%) and syncope (10.0%). A structurally normal heart was noted in 79.44% (n=255) of all patients and 20.56% of patients with SHAs (n=66). In addition, tricuspid valve anomalies were noted in 9.03% of patients (n=29), cardiomyopathy in 5.61% (n=18), extracardiac anomalies in 2.49% (n=8), septal defects in 2.18% (n=7), and RVOT anomalies in 1.25% (n=4). CF catheters were utilized as the first ablation procedure in 78.82% (n=253) of the patients, the second procedure in 18% (n=58) and the third procedure in 3.12% (n=10).

AVRT was the most frequent arrhythmia in 82.24% of patients, VA in 11.21%, AT in 5.92%, and atrial flutter in 0.62%. Among patients with AVRT (n=264), WPW syndrome was present in 70.83%, concealed AP in 28.03%, PJRT in 0.76% (n=2), and tachycardia secondary to Mahaim fibers in 0.38% (n=1). The AP was located on the right in 54.92% of patients, left in 42.05% and bilateral in 3.03%. A single AP was found in 84.85% (n=224) of patients, and two APs were found in 15.15% (n=40). AP localization is described in Table 2.

The overall success rate of the procedure was 97.82%, and no differences regarding age, OF, sex, diagnoses or symptoms. For AVRT ablation, success was achieved in 97% of patients. Regarding localization, 100% success was noted with left-side APs, 95.80% with right-side APs, and 87.50% for bilateral APs. In patients with AT and flutter, the procedure was 100% successful. In patients with VA, a 91.66% success rate was obtained (Table 3). In seven patients (2.18%), successful ablation was not achieved due to an inaccessible location or a potentially epicardial focus.

The ablation success rate was 98.43% in patients with structurally normal hearts compared to 90.90% in those with SHA (OR 0.13 CI 0.04-0.57). When categorizing patients based on structural pathology, a success rate of 100% was noted in patients with septal defects, 93.10% for tricuspid valve anomalies, 88.88% for cardiomyopathies, 87.50% for extracardiac anomalies and 75% for RVOT anomalies. The comorbidities identified included microcephaly, Down syndrome, seizure disorders, neurodevelopmental delay, renal tubulopathies, depression and type 1 diabetes mellitus. Patients with comorbidities had a success rate of 85.71%, and those without comorbidities had a success rate of 97.95% (OR 6.56 CI 2.28-29.95). The success rate in patients undergoing the first procedure was 98.02% compared to 91.52% in those who had undergone previous procedures (OR 4.10 CI 1.04-48.57).

The overall mean procedure time was 2.86 hours (hrs) (sd 1.2). In children with structurally normal hearts, the mean procedure time was 2.8 hrs (sd 1.23) versus 3.40 hrs (sd 1.31) in patients with SHA (MD 0.60 CI 0.96-0.25). The mean procedure time was 3.57 hrs (sd 1.66) in patients with comorbidities and 2.86 hrs (sd 1.21) in those without (MD 0.70 CI 0.07-1.34). The mean procedure time was 2.77 hrs (sd 1.23) for AVRT, 3.88 hrs (sd 1.21), for VA, 3.26 hrs (sd 1.04) for AT and 2.5 hrs (sd 0.70) for flutter. Patients with a single AP had a mean procedure time of 2.64 hrs (sd 1.18), and those with two APs had a mean procedure time of 3.52 hrs (sd 1.28) (MD 0.88 CI 0.45-1.30). The mean procedure time was 2.33 hrs (sd 0.82) for left APs, 3.06 hrs (sd 1.36) for right APs (MD -0.73 CI -1.00; -0.45) and 3.87 hrs (sd 1.64) for bilateral APs.

The overall mean fluoroscopy time was 6.22 minutes (min) (sd 3.95). The mean fluoroscopy time was 6.32 min (sd 4.38) for AVRT, 7.69 min (sd 5.07) for AV, 6 min (sd 3.68) for TA and 3.5 min (sd 0.7) for flutter. No differences were noted between the diagnoses, sex, comorbidities, SHA, symptoms, or number of previous ablation procedures.

The mean contact force used during the ablation procedures was 14.33 gr (sd 6.88), and there was no difference with respect to sex, comorbidities, complications, SHA, symptoms, success rate, previous ablation procedures, arrhythmia or number of APs. In the left AP, a CF of 16.41 gr (sd 7.56) was achieved. In the right AP, a CF of 12.36 gr (sd 6.02) was attained. For bilateral APs, a CF of 10 gr (sd 1.63) (MD 4.05 IC 2.31; 5.78) was achieved.

Only one patient (0.3%) experienced an intracardiac procedural complication (complete auricular-ventricular block). Vascular access complications occurred in 3 patients (0.93%), including arterial thrombosis (n=1) and venous thrombosis (n=2).

Discussion:

This study includes the largest published series of pediatric patients undergoing ablation with CF technology. We present a cohort of 321 patients under 18 years of age who underwent CF ablation for different types of arrhythmias with a high success rate and low incidence of complications.

AVRT was the most frequent arrhythmia (82.61% of cases) followed by VA, AT and atrial flutter. This finding correlates with the frequency of arrhythmias presented in the pediatric population[10,11].

The overall success rate of the procedure was 97.82%. This value is higher than the rates reported in The Pediatric Radiofrequency Catheter Ablation Registry (92-

95%[12]) with very good outcomes achieved in all different types of arrhythmias treated. These results demonstrate that CF can be used in most arrhythmic substrates in children. It should be noted that patients with AVNRT and tachycardias secondary to AP or arrhythmogenic foci close to the cardiac conduction system were not included in this study. In this study, patients with SHA or comorbidities had a lower success rate, and children with SHA had a success rate of 90.90%. These patients had more complex arrhythmias and substrates, which makes the procedure difficult and decreases the success rate[13.] However, the results shown in this study are superior to those described in the literature[14]. In a recent report, Corcia et al.[7] described the Ebstein anomaly as a risk factor for failed ablation. However, in this study, ablation was achieved in 93% of these patients, so CF catheters represent a possible solution for the treatment of arrhythmias in SHA.

No relationship was noted between the grams of contact and the types of arrhythmia. However, regarding AP location, better contact was achieved in the left AP compared with the right AP and bilateral AP (all posteroseptal), which may explain the higher success rate and shorter procedure time found in the left AP. The average CF used was 14.3 gr. (SD 6.8), and excellent results were obtained, making it a safe and effective dose for pediatric patients.

The frequency of complications related to CF in this cohort was low (0.3%). Specifically, only one patient experienced a complete AV block. This value is lower than values previously described in other publications[2,10], confirming that CF is a safe technology to use in children.

The limitation of this study is that no medium- or long-term follow-up was performed, and only acute success was measured. Therefore, it is necessary to perform more studies, ideally multicenter studies, in which the evolution of children undergoing CF ablation can be evaluated.

It is necessary to perform studies on the use of CF in a larger pediatric population with SHA and compare it with other ablation techniques to determine any potential advantages in using these catheters.

As this study is descriptive, the interpretation of the result of the associations is limited by the small number of patients who experienced a failed procedure. This study was unable to determine whether these associations are representative of the pediatric population.

Patients with AVNRT or foci close to the AV node were excluded; therefore, no conclusions can be drawn on the use of CF in patients with these arrhythmias.

As a strength of our study, this is the first study with a significant sample size in which CF was used as an ablation technique in pediatric patients. We believe that the findings from this study will provide guidance regarding the use of CF ablation in similar centers.

Conclusions:

This is the largest published series of patients under 18 years of age using CF technology. In the pediatric population, CF ablation is a safe procedure with high success rates, and it can be used for most arrhythmic substrates. The most frequent tachycardia in this study was SVT mediated by AP. Contact with 14 grams is safe and has an excellent outcome in children. The presence of SHA and previous ablation procedures decreased the success rate.

This work was carried out in Colombia South America (a third world country), where patients in rural areas do not have easy access to specialist doctors or highly complex diagnostic tests, but the Fundación Cardioinfantil-LaCardio has a program that carries out brigades displacing a group of pediatric cardiologists to remote regions of the country, to diagnose heart disease in the pediatric population and patients are treated at the institution. In addition, state-of-the-art technology has not always been available, but government health policies have made advances in medicine more accessible and with less delay compared to first world countries.

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Abbreviations:

(RF) Radiofrequency

(CF) Contact force

(SVT) Supraventricular tachycardia

(AVNRT) Atrioventricular nodal reentrant tachycardia

(AV) Atrioventricular

(AVRT) Atrioventricular reentrant tachycardia

(TV) Tricuspid valve

(ECA) Extracardiac anomalies

(WPW) Wolff–Parkinson–White

(MF) Mahaim fibers

(RVOT) Right ventricular outflow tract

(TOF) Tetralogy of Fallot

(PJRT) Permanent junctional reciprocating tachycardia

(SHA) Structural heart anomalies

(AP) Accessory pathways

(CAP) Concealed accessory pathways

(MD) Mean difference

(OR) Odds Ratio

(sd) Standard deviation

(CI) Confidence interval

Table 1. Demographic and clinical variables		
Variable	**n=321**	
Sex, male	165	51.40%
Age (years)	12.26	sd 3,54
Comorbidities		
#	28	8.72%
Complications		
Complete AV block	1	0.31%
Successful ablation		
#	314	97.82%
Symptoms		
Palpitations	231	72.00%
Chest pain	39	12.00%
Syncope	32	10.00%
Others	19	6.0%
Cardiac anatomy		
Normal	255	79.44%
SHA	66	20.56%
TV Anomalies	29	9.0%
Cardiomyopathies	18	5.61%
ECA	8	2.49%
SD	7	2.18%
RVOT Anomalies	4	1.25%
Diagnosis		
AVRT	264	82.24%
Ventricular arrhythmia	36	11.21%
Atrial tachycardia	19	5.92%
Atrial flutter	2	0.62%
Number of ablation procedures		
1	253	78.82%
2	58	18%
3	10	3.12%
Procedure		
Procedure time (hrs)	2.92	sd 1,27
Fluoroscopy time (min)	6.44	sd 4,43
Contact force (gr)	14.37	sd 6,88

AV: Atrioventricular; SHA: Structural heart anomalies; TV: Tricuspid valve; ECA: Extracardiac anomalies; SD: Septal defects; ; RVOT: Right ventricular outflow tract; AVRT: Atrioventricular reentrant tachycardia sd: standard deviation

Variable n=264		
Diagnosis	#	%
WPW	187	70.8%
CAP	74	28.0%
PJRT	2	0.8%
MF	1	0.4%
AP localization		
Rigth	145	54.9%
Left	111	42.1%
Bilateral	8	3,03%
RPS	59	22.35%
LAL	36	13.64%
LL	32	12.12%
RA	27	10.23%
LPL	21	7.95%
RP	18	6.82%
LP	18	6.82%
RAS	11	4.17%
RMS	11	4.17%
Others	31	11.73%
AP number		
Single	224	84,85%
Two	40	15,15%

WPW: Wolff-Parkinson-White; CAP: Concealed accessory pathw ay; PJRT: Permanent junctional reciprocating tachycardia.

MF: Mahaim fibers; RPS: Right posteroseptal; LAL: Left anterolateral; LL: Left lateral; RA: Right anterior.

LPL: left posterolateral; RP: Right postterior; LP: Left posterior; RAS: right anteroseptal; RMS: Right medioseptal.

Tabla 3. Bivariate Analysis

	Successful procedure			Non-successful procedure			Effect measure (EM)	
Demographic characteristics, n %								
Age (years)	12.28	3.49		11.6	5.13		-0.68	(-3,88 ;2,52)
Sex (male)	159	51.13	%	6	60	%	1.14	(0,41; 4,69)
Cardiac anatomy, n %								
Normal	251	80.71	%	4	40	%	0.14	(0,05 ; 0,57)
TV anomalies	27	8.68	%	2	20	%	3.59	(1,03 ; 25,05)
Cardiomyopathies	16	5.14	%	2	20	%	5.91	(1,67; 42,97)
Septal Defects	7	2.25	%	0	0	%	0.00	(0,18 ; 75,64)
ECA	7	2.25	%	1	10	%	6.28	(1,54 ; 81,40)
RVOT anomalies	3	0.96	%	1	10	%	12.55	(2,85 ; 201,11)
Procedural characteristics, mean SD								
Total procedure time (hrs)	2.86	1.2		4.9	1.85		2.04	(0,88 ; 3,19)
Fluoroscopy time (min)	6.22	3.95		14.11	10.39		7.89	(1,089; 14,69)
Contact force (gr)	14.33	6.88		15.71	7.41		1.38	(-4,16 ; 6,93)
Ablation pevious procedures								
0	248	79.74	%	5	50	%		
1	54	17.36	%	4	40	%	3.01	(1,04 ; 13,42)
2	9	2.89	%	1	10	%	4.13	(1,05; 48,57)
Diagnosis								
AVRT	257	82.64	%	7	70	%		
Ventricular arrhythmias	33	10.61	%	3	30	%	2.84	(0,96; 13,41)
Atrial tachycardias	19	6.11	%	0	0	%	0.00	(0,05; 15,99)
Flutter	2	0.64	%	0	0	%	0.00	(0,30 ; 155,81)
AP Type								
WPW	180	70.04	%	7	100	%		
CAP	74	28.79	%	0	0	%	0.00	(0,01 ; 2,86)
PJRT	2	0.78	%	0	0	%	0.00	(0,21; 109,33)
MF	1	0.39	%	0	0	%	0.00	(0,30; 213,81)
AP location								
Rigth	137	53.73	%	6	85.71	%	0.15	(0,04; 1,62)
Left	111	43.53	%	0	0	%	0.00	(0,00 ; 0,60)
Bilateral	7	2.75	%	1	14.29	%	2.44	(0,61; 28,90)
AP number								
Single	216	84.71	%	6	85.71	%		
Two	39	15.29	%	1	14.28	%	0.77	(0,21 ;7,71)

TV: Tricuspid valve; ECA: extracardiac anomalies; RVOT: right ventricular outflow tract; sd: standard deviation; AVRT: Atrioventricular reentrant tachycardia; WPW: Wolff-Parkinson-White; CAP concealed accessory pathway; PJRT:Permanent junctional reciprocating tachycardia; MF: Mahaim 1. (EM) The effect measure for continuous variables is a mean difference and the effect measure for categorical variables is Odds Ratio (OR).

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prepared by the authors

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