Use of contact force technology for cardiac arrhythmia ablation in children

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BACKGROUND New techniques for cardiac arrhythmia ablation, such as contact force (CF) technology, have emerged recently. These catheters provide information about adequate tissue contact for optimal lesions. In adults, these techniques have shown greater accuracy, reduced arrhythmia recurrence and complications, and higher success rates. However, data on pediatric patients are limited.

OBJECTIVE The purpose of this study was to describe the experience with arrhythmia ablation using CF catheters in the pediatric population.

METHODS A retrospective cross-sectional descriptive study of all patients <18 years old undergoing cardiac 3-dimensional mapping and ablation with CF between March 2016 and June 2022 was performed.

RESULTS A total of 321 patients were included (51.40% male; mean age 12.26 years). The most frequent arrhythmia were supraventricular tachycardia (SVT) mediated by accessory pathways (APs) (atrioventricular reentrant tachycardia in 82.24%, ventricular arrhythmia in 11.21%, atrial tachycardia in 5.92%). Mean procedural time was 2.86 ± 1.2 hours, and average contact used was 14.33*g* ± 6.88*g*. The success rate of ablation was 97.82% with a low risk of complications.

CONCLUSION This is the largest published series of CF technology use in patients <18 years old. 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 APs. Contact with 14*g* is safe and yields an excellent outcome in children. The presence of structural heart anomalies and previous ablation procedures decreased the success rate.

KEYWORDS Accessory pathway; Arrhythmia; Atrial tachycardia; Catheter ablation; Children; Contact force; Supraventricular tachycardia; Ventricular arrhythmia

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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 >90% have been achieved with a very low chance of recurrence.[1,3] Contact force (CF) catheters are among the most recently developed ablation technologies. They are designed to quantify the contact of the catheter tip with myocardial tissue to result in more effective lesions and reduce the risk of complications.[3,4] Result with CF catheters have been very promising, initially in the adult population[5] 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 (APs), atrioventricular nodal reentrant tachycardia (AVNRT), atrial tachycardias (ATs), and ventricular arrhythmias (VAs) with high success rates.[1,3,6–8] However, data in the pediatric population, specifically regarding CF catheter technology, are limited.[5,9] Thus, we aimed to describe the use of CF for cardiac ablation in

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KEY FINDINGS

- Contact force (CF) ablation technology is a safe and accurate alternative for the treatment of arrhythmias in children.
- Atrioventricular reentrant tachycardia is the most frequent indication for cardiac CF ablation.
- The presence of comorbidities and cardiac structural anomalies are a risk factor for unsuccessful ablation.
- Although exact data on the required dose of CF cannot be determined, we can conclude that 14*g* is safe and has a high success rate with no arrhythmic inducibility.

children at the pediatric electrophysiology (EP) laboratory at Fundación Cardioinfantil–La Cardio from 2016 to 2022.

This work was performed in Colombia, South America, where patients in rural areas do not have easy access to specialist doctors or highly complex diagnostic tests. The Fundación Cardioinfantil–LaCardio has a program that sends 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 younger than 18 years undergoing 3 dimensional electroanatomic 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 (Microsoft Corp., Redmond, WA) 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 [AV] canal defects); *right ventricular outflow tract* (RVOT) anomalies (tetralogy of Fallot and pulmonary stenosis); and *extracardiac anomalies* (patent ductus arteriosus, partial anomalous pulmonary venous return, and aortic coarctation). Comorbidities were defined as all other associated pathologies that did 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 1 week or 5 half-lives before the procedure. All procedures were performed with patients under deep sedation or general anesthesia and conducted by our institutional cardiac anesthesia team. Three-dimensional mapping (EnSite/Precision, Abbott Laboratories, Abbott Park, IL; or CARTO 3, Biosense Webster, Diamond Bar, CA) was used for all procedures. The following CF catheters were used: TactiCath Contact Force Ablation Catheter, Sensor Enabled (TactiCath SE, Abbott) or ThermoCool SurroundFlow catheter (SFc, Biosense Webster).

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

The following procedure characteristics were evaluated: procedural time (time from the patient's admission to the EP laboratory until their departure), fluoroscopy time, and number of grams of contact force *(g)* during the ablation (maximum value recorded for a time >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 syndrome, concealed AP, permanent junctional reciprocating tachycardia, and Mahaim fibers), atrial tachycardia, atrial flutter, and VAs (including premature ventricular contractions and ventricular tachycardia). Subsequently, 3-dimensional electroanatomic mapping was performed to localize the origin of the tachycardia or the AP. For ablation, if catheter contact was $<15g$, power delivery was titrated at 35 W; if contact was between 15 and 25*g*, it was titrated at 30 W; and when contact was $>25g$, 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 are given as absolute and relative frequencies. Quantitative variables are given as mean $\pm$ SD or median [interquartile range] depending on the normality of the variable. To describe the success rate in relation to sociodemographic and clinical variables, mean difference (MD) and odds ratio (OR) are presented with their 95%

Table 1 Demographic and clinical variables (N = 321)

Male	165 (51.40)
Age (y)	12.26 ± 3.54
Comorbidities	28 (8.72)
Complications	
Complete AV block	1 (0.31)
Successful ablation	314 (97.82)
Symptom	
Palpitations	231 (72.00)
Chest pain	39 (12.00)
Syncope	32 (10.00)
Other	19 (6.0)
Cardiac anatomy	
Normal	255 (79.44)
SHA	66 (20.56)
TV anomaly	29 (9.0)
Cardiomyopathy	18 (5.61)
ECA	8 (2.49)
Septal defect	7 (2.18)
RVOT anomaly	4 (1.25)
Diagnosis	
AVRT	264 (82.24)
Ventricular arrhythmia	36 (11.21)
Atrial tachycardia	19 (5.92)
Atrial flutter	2 (0.62)
No. of ablation procedures	
1	253 (78.82)
2	58 (18)
3	10 (3.12)
Procedure	
Procedural time (h)	2.92 ± 1.27
Fluoroscopy time (min)	6.44 ± 4.43
Contact force *(g)*	14.37 ± 6.88

Values are given as n (%) or mean ± SD.

AV = atrioventricular; AVRT = atrioventricular reentrant tachycardia; ECA = extracardiac anomaly; RVOT = right ventricular outflow tract; SHA = structural heart anomaly; TV = tricuspid valve.

Table 2 Accessory pathway characteristics (N = 264)

Diagnosis		
WPW syndrome	187	(70.8)
CAP	74	(28.0)
PJRT	2	(0.8)
MF	1	(0.4)
AP localization		
Right	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)
Other	31	(11.73)
No. of APs		
1	224	(84.85)
2	40	(15.15)

Values are given as n (%).

AP = accessory pathway; CAP = concealed accessory pathway; LAL = left anterolateral; LL = left lateral; LP = left posterior; LPL = left posterolateral; MF = Mahaim fiber; PJRT = permanent junctional reciprocating tachycardia; RA = right anterior; RAS = right anteroseptal; RMS = right medioseptal; RP = right posterior; RPS = right posteroseptal; WPW = Wolff-Parkinson-White.

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 followed 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, 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 (mean age 12.26 ± 3.54 years; range 4–18 years). The demographic and clinical characteristics of the cohort are listed 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% of all patients (n = 255) 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 used as the first ablation procedure in 78.82% of the patients (n = 253), 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), Wolff-Parkinson-White syndrome was present in 70.83%, concealed AP in 28.03%, permanent junctional reciprocating tachycardia 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 side in 42.05%, and bilateral in 3.03%. A single AP was found in 84.85% of patients (n = 224), and 2 APs were found in 15.15% (n = 40). AP localizations are listed in Table 2.

The overall success rate of the procedure was 97.82%, and no differences with regard to age, CF, sex, diagnoses, or symptoms were noted. 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 7 patients (2.18%), successful ablation was not achieved due to an inaccessible location or a potentially epicardial focus.

Table 3 Bivariate analysis

Characteristics	Successful procedure		Nonsuccessful procedure		EM	
Demographic characteristics						
Age (y)	12.28	(3.49)	11.6	(5.13)	−0.68	(−3.88; 2.52)
Male	159	(51.13)	6	(60)	1.14	(0.41; 4.69)
Cardiac anatomy						
Normal	251	(80.71)	4	(40)	0.14	(0.05; 0.57)
TV anomaly	27	(8.68)	2	(20)	3.59	(1.03; 25.05)
Cardiomyopathy	16	(5.14)	2	(20)	5.91	(1.67; 42.97)
Septal defect	7	(2.25)	0	(0)	0.00	(0.18; 75.64)
ECA	7	(2.25)	1	(10)	6.28	(1.54; 81.40)
RVOT anomaly	3	(0.96)	1	(10)	12.55	(2.85; 201.11)
Procedural characteristics						
Total procedural time (h)	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 *(g)*	14.33	± 6.88	15.71	± 7.41	1.38	(−4.16; 6.93)
No. of previous ablation 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 arrhythmia	33	(10.61)	3	(30)	2.84	(0.96; 13.41)
Atrial tachycardia	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						
Right	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)
No. of APs						
1	216	(84.71)	6	(85.71)		
2	39	(15.29)	1	(14.28)	0.77	(0.21; 7.71)

Values are given as n (%) or mean ± SD unless otherwise indicated. The effect measure (EM) for continuous variables is the mean difference and the EM for categorical variables is odds ratio.

Abbreviations as in Tables 1 and 2.

The ablation success rate was 98.43% in patients with structurally normal hearts compared to 90.90% in those with SHA (OR 0.13; 95% CI 0.04–0.57). When patients were categorized 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. 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; 95% 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; 95% CI 1.04–48.57).

Overall mean procedural time was 2.86 ± 1.2 hours. In children with structurally normal hearts, mean procedural time was 2.8 ± 1.23 hours vs 3.40 ± 1.31 hours in patients with SHA (MD 0.60; 95% CI 0.96–0.25). Mean procedural time was 3.57 ± 1.66 hours in patients with comorbidities and 2.86 ± 1.21 hours in those without (MD 0.70; 95% CI 0.07–1.34). Mean procedural time was 2.77 ± 1.23 hours for those with AVRT, 3.88 ± 1.21 hours for VA, 3.26 ± 1.04 hours for AT, and 2.5 ± 0.70 hours for flutter. Patients with a single AP had mean procedural time of 2.64 ± 1.18 hours, and those with 2 APs had mean procedural time of 3.52 ± 1.28 hours (MD 0.88; 95% CI 0.45–1.30). Mean procedural time was 2.33 ± 0.82 hours for those with left APs, 3.06 ± 1.36 hours for right APs (MD –0.73; 95% CI –1.00 to –0.45), and 3.87 ±1.64 hours for bilateral APs.

Overall mean fluoroscopy time was 6.22 ± 3.95 minutes. Mean fluoroscopy time was 6.32 ± 4.38 minutes for those with AVRT, 7.69 ± 5.07 minutes for VAs, 6 ± 3.68 minutes for ATs, and 3.5 ± 0.7 minutes for atrial flutter. No differences were noted between diagnoses, sex, comorbidities, SHA, symptoms, or number of previous ablation procedures.

Mean contact force used during the ablation procedures was 14.33*g* ± 6.88*g*, and there was no difference with respect to sex, comorbidities, complications, SHA, symptoms,

success rate, previous ablation procedures, arrhythmia, or number of APs. For left APs, CF of $16.41g \pm 7.56g$ was achieved. For right APs, CF of $12.36g \pm 6.02g$ was attained. For bilateral APs, CF of $10g \pm 1.63g$ (MD 4.05; 95% CI 2.31–5.78) was achieved.

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

Discussion

This study includes the largest published series of pediatric patients undergoing ablation with CF technology. We present a cohort of 321 patients younger than 18 years 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 for all different types of arrhythmias treated. These results demonstrate that CF can be used for most arrhythmic substrates in children. It should be noted this study did not include patients with AVNRT and tachycardias secondary to AP or arrhythmogenic foci close to the cardiac conduction system. 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 of this study are superior to those reported in the literature.[14] In a recent report, Corcia et al[8] described 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 APs (all posteroseptal), which may explain the higher success rate and shorter procedural time found for left APs. The average CF used was $14.3g$ (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 1 patient experienced a complete AV block. This value is lower than those previously reported in other publications,[2,10] thus confirming that CF is a safe technology to use in children.[9]

Study limitations

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 CF with other ablation techniques to determine any potential advantages of using these catheters.

Because this study is descriptive, interpretation of the results 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.

Conclusion

We were able to provide pediatric EP care in remote areas of Colombia through the Fundación Cardioinfantil–LaCardio. By bringing trained electrophysiologists to these patients, we demonstrated that state-of-the-art EP could be performed successfully. This is the largest published series of patients younger than 18 years 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 $14g$ is safe and has an excellent outcome in children. The presence of SHA and previous ablation procedures decreased the success rate.

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