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ORIGINAL RESEARCH
*Pediatric Cardiology*

# Pediatric catheter ablation for cardiac arrhythmias with limited fluoroscopy: 1-year single-center experience

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## ABSTRACT

**Objective:** Catheter ablation is a curative treatment with excellent success and minimal complication rates in supraventricular arrhythmias. Recent advances in three-dimensional (3D) electroanatomical-mapping resulted in a significant decrease in fluoroscopy exposure during. The aim of this single-center study is to analyze the results of an electrophysiological study and ablation using an electroanatomical-mapping system.

**Material and Methods:** Between January 2022 and February 2023, patients who underwent electrophysiological study and ablation in SBU Antalya Training and Research Hospital were evaluated retrospectively.

**Results:** Of the 89 patients, 49 were boys. The mean age and weight were 13.8±4.2 years and 48.18±12.37 kg, respectively. Indications for ablation were AVNRT 43 (48.4%), AVRT 38 (42.7%), and FAT 5 (5.6%). In three (3.3%) patients with saddle pre-excitation diagnosed with fasciculoventricular fiber, no ablation was performed. The overall short-term success rate was 95%. The most successful locations were the left lateral AP and typical AVNRT, whereas the most recurrences were observed in posteroseptal AP localization. The left atrium was accessed through transeptal puncture in 14 (15.7%) and through atrial septal defect/patent foramen ovale in 3 patients. The mean procedure duration was 178±64 (130–310) min. There were no complications except 2 patients who developed transient first-degree and Mobitz type 1 AV blocks during cryoablation.

**Conclusion:** Ablation of the supraventricular arrhythmias with 3D electroanatomic mapping-guided transcatheter systems can be curative with excellent patient satisfaction, significantly decreased radiation exposure, and low recurrence and complication rates. Our acute-term success and complication rates are consistent with the literature; however, long-term follow-up with larger series is needed.

**Keywords:** 3D electroanatomic mapping; ablation; arrhythmia.

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# Kardiyak aritmi tanı ve tedavisinde sınırlı floroskopi ile kateter ablasyon; 1 yıllık tek merkez deneyimi


## ÖZET

**Amaç:** Çocukluk çağı supraventriküler aritmilerinde yüksek başarı ve düşük komplikasyon oranlarıyla kateter ablasyon önemli bir yere sahiptir. Günümüzde kullanılan üç boyutlu elektroanatomik haritalama sistemlerinin kullanımı radyasyon maruziyetini önemli ölçüde azaltmaktadır.

**Gereç ve Yöntemler:** Bu çalışmada, Sağlık Bilimleri Üniversitesi Antalya Eğitim ve Araştırma Hastanesi, Çocuk Kardiyolojisi Kliniğinde Ocak 2022-Şubat 2023 tarihleri arasında elektrofizyolojik çalışma ve ablasyon işlemi uygulanan hastalar retrospektif olarak değerlendirildi.

**Bulgular:** Toplam 89 hasta elektrofizyolojik çalışmaya alındı. Hastaların yaş ortalamaları 13,8±4,2 yıl, ağırlık ortalamaları ise 48,18±12,37 kg idi. Ablasyon endikasyonları; atriyoventriküler nodal yeniden girişli taşikardi (AVNRT) 43 (%48,4), atriyoventriküler yeniden girişli taşikardi (AVRT) 38 (%42,7) ve fokal atriyal taşikardi (FAT) 5 (%5,6) idi. Üç hastaya fasikülöventriküler fiber tanısı konuldu ve ablasyon yapılmadı. En başarılı lokasyonlar sol lateral aksesuar yol ve tipik AVNRT iken, en başarısız lokasyon sağ posteroseptal idi. Erken dönem işlem başarı oranımız %95 saptandı. Hastaların 14'üne (%15,7) transseptal ponksiyon yapıldı, üç hastada atriyal septal defekt/patent foramen ovale yolu sol atriyuma geçildi. Ortalama işlem süresi 178±64 (130-310) dakika idi. İki hastada geçici birinci derece ve Mobitz Tip 1 atriyoventriküler blok dışında komplikasyon izlenmedi.

**Tartışma:** Günümüzde çocukluk yaş grubunda ablasyon sınırlı floroskopi ve üç boyutlu görüntüleme sistemleriyle başarı bir şekilde yapılmaktadır. Erken dönem nüks oranlarımız literatürle uyumlu görülmekle birlikte uzun dönem izlem sonuçlarına ihtiyaç vardır.


**Anahtar Kelimeler:** Ablasyon; aritmi; elektrofizyolojik haritalama.

## INTRODUCTION

Catheter ablation is a curative treatment with excellent success, patient satisfaction, and minimum complication rates for patients with supraventricular arrhythmias (SVT) (1). Since radiofrequency (RF) catheter ablation was first introduced in the 1980s, it has become the treatment option for many cardiac arrhythmias in both adult and pediatric populations. However, performing RF ablation in critical areas of the septum (close to the AV node or the bundle of His) remains a challenge and carries a risk of complete heart block, which needs permanent cardiac pacing (2, 3). Cryoablation is used for its safety profile and has been successfully used for the ablation of SVT originating from septal substrates in children since 2001 (4, 5). Although success rates vary depending on the arrhythmia substrate, acute success rates in children have been well-described, ranging from 92 to 98% (6–8). Complications associated with these ablative procedures occur at a low incidence of 2–5% (9, 10). Recently, advances in three-dimensional (3D) electroanatomical-mapping technologies have resulted in a decrease or complete elimination of fluoroscopy exposure during catheter ablation procedures.

The study aimed to analyze retrospectively all the patients who underwent electrophysiological study and catheter ablation using the 3D electroanatomical-mapping system in a single center.

## MATERIAL AND METHODS

### Study Population

Between January 2022 and February 2023, a total of 89 pediatric patients with recurrent symptomatic supraventricular tachycardia or asymptomatic pre-excitation were included in the study. All patients <18 years of age who underwent catheter ablation using a 3D mapping system with minimal or no fluoroscopy at a single institution were retrospectively evaluated. Only one patient had previously undergone electrophysiology study and ablation at another medical center. The initial ablation data were included in this study for patients who underwent second ablation procedures due to recurrent or unsuccessful procedures. Institutional approval was obtained from the local ethics committee.

### Electrophysiological Study

Antiarrhythmic medications were discontinued at least 5 half-lives before the electrophysiological study in all patients. Patients were brought to the electrophysiology laboratory in a fasting state. After informed consent was obtained, procedures were conducted under intravenous conscious sedation or general anesthesia with continuous blood pressure monitoring, oxygen saturation, and body surface electrocardiography. All catheters were advanced from bilateral femoral venous access. In all patients, a 3D, surface electrode-based navigation system (EnSite Velocity system; St. Jude Medical, St. Paul, MN) was used. This system allows navigating and visualizing the electrophysiology catheters, which helps to decrease or eliminate the use of fluoroscopy. Using a 3D mapping system, we placed catheters to the high right atrium, right ventricular apex, and coronary sinus. The right atrial and coronary sinus geometries were reconstructed without fluoroscopy using the EnSite™ system (11). Detailed electrophysiological evaluation was performed using standard pacing protocols to establish the correct diagnosis and identify the appropriate ablation site. Electroanatomical mapping was also helpful in marking the potential target sites in 3D geometry. An anterograde approach via transeptal puncture was routinely used for the left-sided APs if the patient did not have patent foramen ovale (PFO) or atrial septal defect (ASD). Anticoagulation with heparin was administered for all the left-sided cases.

The arrhythmia types included AVNRT (typical and atypical); AVRT, either manifest (WPW) or concealed; atrial tachycardia, and including focal atrial tachycardia (FAT). During the EP study for localizing APs, delta wave mapping, retrograde mapping during SVT, and/or retrograde AP mapping during V pace were used in patients with manifest APs. The last two methods were used in patients with concealed APs. Anteroseptal AP location was defined as the apical third of the triangle of Koch, including the presence of a His bundle potential of 0.1 mV at the successful ablation region (12).

Cryoablation was performed in patients with AVNRT (slow pathway ablation) and septal APs. Cryoablation was performed using a 7F 6 mm–tip (Medtronic, Minneapolis, MN). AV nodal conduction was monitored closely during ablation. Ablation was stopped immediately if AV conduction delay was noted, and the catheter was repositioned to search for a safer spot away from the prominent His potentials. For APs, a 4 mm RF catheter was used. RF energy was applied to either the atrial or ventricular side of the atrioventricular annulus. An ablation was determined to be acutely successful if there was no electrophysiologic evidence of the substrate at the end of the procedure: AVNRT-inability to initiate more than a single AV node echo beat and AH jump without and with isoproterenol challenge; AVRT-the absence of antegrade and/or retrograde AP conduction; and atrial tachycardia-inability to reinitiate the tachycardia. A procedure was determined to be unsuccessful if the electrophysiologic substrate continued to be evident at the end of the procedure. After successful ablation, patients were observed for a 30-min waiting period. The possibility of recurrence was assessed using pacing maneuvers and, in some cases, with isoproterenol and/or adenosine.

### Follow-up

Patients were routinely monitored for 24 h after the procedure. A 12-lead electrocardiogram (ECG) and echocardiography were obtained before discharge. All patients were examined at the outpatient clinic 1 week, 6 weeks, and 6 months after the procedure. Physical examination was performed; patient history and ECG were obtained at each visit. 24-h ambulatory Holter monitoring was performed 6 weeks after the procedure. A patient was considered to have an arrhythmia recurrence if, after an ablation, tachycardia mediated by the same mechanism was documented by any method (ECG or Holter monitoring). Palpitations alone were not considered an arrhythmia recurrence. Time to recurrence was determined from a successful ablation to the first arrhythmia recurrence, as documented in the medical chart. Aspirin was continued 6 weeks after the left-sided procedures.

### Statistical Method

The Statistical Package for the Social Sciences 21.0 for Windows (SPSS, Chicago, IL) was used for data analysis. Descriptive features were represented as percentages and mean±standard deviation or as median according to the distribution of the data determined by the Kolmogorov–Smirnov test. The Z test was used to determine the difference between the two proportions. $p<0.05$ was considered statistically significant.

**Table 1. Demographic and clinical characteristics of patients**

| Characteristics | Total (n=89) |
|---|---|
| Age (years) | 13.8±4.2 |
| Male | 49 (55) |
| Weight (kg) | 48.18±12.37 |
| ECG - (WPW syndrome) | 20 (22) |
| Echocardiogram | |
| No underlying heart disease | 88 (98.8) |
| Tachycardia-induced cardiomyopathy | 1 (1.2) |
| Previous drugs | |
| No medication | 27 |
| Beta-blocker or class 1c antiarrhythmic | 50 |
| Beta-blocker + class 1c/class 3 | 9 |
| Beta-blocker + class 1c + class 3 | 3 |

ECG: Electrocardiography; WPW: Wolff-Parkinson-White syndrome, n (%).

## RESULTS

In 1 year, electrophysiological studies were performed on 89 patients at Antalya Research and Education Hospital. Of the 89 patients enrolled in the study, 49 were boys. The mean age and weight were 13.8±4.2 years and 48.18±12.37 kg, respectively. All the patients had normal echocardiographic findings, whereas FAT with tachycardia-induced cardiomyopathy was found in one patient (EF: 45%). All demographic and clinical characteristics of patients are listed in Table 1.

The indications for ablation were AVNRT 43 (48.4%), AVRT 38 (42.7%), and FAT 5 (5.6%) patients. In three (3.3%) patients with saddle pre-excitation diagnosed with fasciculoventricular fiber, no ablation was performed. A single AP was present in all patients; 20 patients (52.6%) had WPW with manifest pre-excitation, and 18 patients (47.4%) had concealed APs. The left-sided APs were present in 16 (42.1%) patients, and the right-sided APs were present in 22 (57.9%) patients; 18 of them were septal locations (4 parahisian, 5 anteroseptal, and 9 posteroseptal). During the procedure, it was found that 4 of the FAT foci were the right-sided and 1 was the left-sided. The right-sided foci were located around the crista terminalis (n=2, 40%), tricuspid annulus (n=1, 20%), and close to the right atrial appendage (n=1, 20%). Left-sided foci were found around the mitral annulus (n=1, 20%). The left atrium was accessed via transeptal puncture in 14 (15.7%) patients and via ASD/PFO in 3 patients.

After the electrophysiological study, RF ablation was performed in 34 (38.2%) patients (irrigated RF was performed simultaneously in 11 cases that did not respond with RF or when a deep ablation lesion was required), and cryoablation was performed in 54 (61.8%) patients. The mean procedure duration was 178±64 (130–310) min, including a 30-min waiting period. Fluoroscopy was used if transseptal catheterization was required and briefly to confirm the anatomic correlation. No fluoroscopy

**Table 2. Procedural characteristics and results of EPS/ catheter ablation**

| Characteristics | Total (n=89) |
|---|---|
| Diagnosis | |
| AVNRT | 43 (48.4) |
| AVRT (APs) | 38 (42.7) |
| FAT | 5 (5.6) |
| Fasciculoventricular fiber | 3 (3.3) |
| Location of APs | |
| Right-sided | 22 (57.9) |
| Left-sided | 16 (42.1) |
| Ablation methods | |
| Radiofrequency ablation | 34 (38.2) |
| Cryoablation | 54 (61.8) |
| Number of complete cryolesions | 5.1 (3–9) |
| Acute success rate | 85 (95) |
| Recurrence at follow-up | 5 (5.6) |
| Procedure duration (minutes) | 178±64 (130–310) |
| Number of patients using fluoroscopy | 16 (17.9) |
| Fluoroscopy time (minutes) (Mean±SD) | 7.75±2.69 |
| Follow-up duration (months) (Mean±SD) | 14.2±5.7 |
| Complications | 2 (2.2) |

AVNRT: Artriventricular nodal reentry tachycardia; FAT: Focal atrial tachycardia; SD: Standard deviation.

was used in 73 of 89 (84.2%) of the procedures. The mean fluoroscopy time in the remaining procedures was 7.75±2.69 min in patients with transeptal puncture. The mean number of complete cryolesions (defined as lesions lasting for a minimum of 240 s) was 5.1 (range 3–9).

The procedure was considered unsuccessful in 4 patients (4.4%); manifest parahisian AP (n=1), manifest posteroseptal AP (n=1), FAT originating from the crista terminalis (n=1), and concealed left lateral AP unsuccessful with a transeptal puncture (n=1). The patient with manifest posteroseptal AP underwent a second procedure due to symptomatic tachycardia episodes during follow-up, which was successful. One patient, who had undergone previous ablation at another center and had manifested a right free wall AP, was successful in her second procedure with an irrigated RF ablation catheter. A successful left lateral concealed RF ablation was performed in the second ablation performed 4 months later.

The overall short-term success rate was 95%. Success rates for AVNRT were 100%, for AVRT were 92%, and for atrial tachycardia were 80%. No recurrence was observed in AVNRT patients. During the mean follow-up of 14.2±5.7 months, the ablation procedure was successful in 16 of 18 (88.8%) patients with concealed AP and 17 of 20 (85%) patients with manifest AP. There were no significant differences between concealed AP and manifest AP in terms of success rate (p=0.721). All recurrences were right-sided APs; three of them were posteroseptal locations. The second procedure for posteroseptal AP was successful with an irrigated RF ablation catheter. Three recurrences were detected 1 day after the procedure with a pre-discharge ECG. Other recurrences were observed within 6 weeks after the ablation procedure.

There were no complications except for two patients who developed transient first-degree and Mobitz type 1 AV blocks during cryoablation that lasted 25–30 s. A transient catheter-induced mechanical block of the AP was observed in one patient (2.6%), who had manifest pre-excitation. No permanent PR interval prolongation was observed at long-term follow-up in that patient. A significant improvement in the left ventricular function was observed after successful ablation of FAT in patients who developed tachycardia-induced cardiomyopathy. The procedural characteristics of the patients included in this study are listed in Table 2.

## DISCUSSION

In this study, we demonstrated the results of 3D electroanatomic mapping-guided transcatheter catheter ablation procedures in children with cardiac arrhythmias. Catheter ablation of cardiac arrhythmias in children is the recommended treatment strategy in patients with symptomatic tachycardia and also asymptomatic WPW for rapid anterograde AP conduction, exposing patients to an increased risk of sudden cardiac death (13, 14). Our study confirms the safety and efficacy of catheter ablation with high acute success and low complication rates with limited fluoroscopy. Although the acute success rates reported in our study are similar to the results from published reports, we reported higher average patient weights and longer procedure durations because of the learning curve. Furthermore, the outcomes of the procedures were encouraging, with satisfying recurrence rates; the procedures were also performed without any major permanent complications.

During the past decade, several studies have reported successful results for transcatheter ablation using 3D electroanatomic mapping systems in children with SVT. In our study overall, the acute success rate was 95%, which compared well to those studies. The MAP-IT study published results with similar success rates (96% for APs and 98% for AVNRT) (15). The largest cohort of pediatric SVT ablations to date over a 20-year period in children is the study by Walsh, which assessed 7,069 ablations. The study reported that overall ablation success rates were 92% for APs, 97% for AVNRT, and 89% for atrial tachycardia (16).

Although RF catheter ablation is a safe and effective option for treating a wide variety of pediatric cardiac arrhythmias, it has some limitations (17). If the ablation target is located near the His bundle or AV node, inaccurate target localization can lead to an AV block (2, 3). Studies assessing RF ablation of septal APs in children and adults report primary success rates >90% but a risk for AV block between 2 and 10% (18). In septal substrates, close to perinodal structures such as the slow pathway

in AVNRT and septal APs, cryoablation has been suggested as a safe and effective alternative to RF ablation (12, 19). Studies in pediatric and adult patients with anteroseptal and septal APs report similar acute success rates for cryoablation and RF ablation (73–100%) but greater recurrence rates for cryoablation (15–45%). Furthermore, similar acute success rates were reported for cryoablation in AVNRT patients. Despite the concerns regarding a greater recurrence rate, cryoenergy has been recommended for ablation of AV nodes, anteroseptal, and mid-septal APs due to the high-grade AV block risk reported for RF ablation (12, 19, 20). In our study, cryoenergy was used in 54 (61.8%) patients with the diagnosis of AVNRT and septal APs. All the recurrences were right-sided, and the majority of them were posteroseptal APs. The largest pediatric RF ablation series reported lower success rates and higher recurrence rates for septal APs as compared with free-wall APs (21).

FAT is a rare cause of SVT in children, which accounts for 5–10% of supraventricular tachycardia cases in adults, with higher rates seen in children (22). Catheter ablation of FAT is considered the first-line therapy in patients with recurrent symptoms, conditions refractory to medical treatment, or incessant tachycardia or tachycardia-induced cardiomyopathy (23, 24). We reported a short-term success rate of 80% in our study. Elkıran et al. (25) and Sahin et al. (26) reported acute success rates of 87.2% and 95%, respectively. Similar to our data Lee et al. (27), described the most common site of FAT foci is the right atrium (75%), with the most common origin areas being the superior and middle parts of the crista terminalis. The left ventricular functions return to normal or near normal in all patients with tachycardia-induced myopathy during the follow-up. Studies showed that a 3D electroanatomical system provides more precise localization of ectopic foci and successful catheter ablation with limited fluoroscopy (28).

Irrigated RF ablation catheter tips prevent excessive temperatures at the electrode tip–tissue interface and allow continued delivery of the RF current into the surrounding tissue. Irrigated RF catheter was used simultaneously in 11 cases that did not respond with RF or when a deep ablation lesion was required. This ablation system creates deeper and larger ablation lesions and minimizes steam pops and thrombus formation. Triedman et al. (29) reported that the extent of lesion depth limits the clinical success of ablation outcomes, and the use of irrigated ablation may result in improved rates of acute success with ablation. There were no complications observed in the procedures where irrigated RF ablation was used in our study.

Children undergoing conventional RF ablation are believed to be at increased risk of developing malignancy caused by radiation exposure (30). Recently, 3D electroanatomic mapping systems have significantly reduced the need to use fluoroscopy for the guidance of transcatheter ablation in pediatric arrhythmias. Fluoroscopy was used if transseptal catheterization is required and briefly to confirm anatomic correlation. In the recent study, the mean fluoroscopy times (mean 7.75±2.69 min) were significantly reduced with the routine use of modern 3D mapping systems compared to previous studies (31).

**Limitations**

Our study presents the experience of a single tertiary pediatric cardiology center. The study's retrospective nature, small sample size, and relatively short follow-up duration are its main limitations. Another limitation is the inability to use event monitors in patients whose palpitations continue after ablation. The use of event monitors may lead to an increase in recurrence rates.

## CONCLUSION

Ablation of the SVT substrate with 3D electroanatomic mapping-guided transcatheter systems can be curative with excellent patient satisfaction, significantly decreased radiation exposure, and low recurrence and complication rates. Although our acute-term success and complication rates are consistent with the literature, in larger series, long-term follow-up results are needed. In addition, our analysis of the learning curve showed that procedure and fluoroscopy time will drop significantly after the 1st year of experience.

**Ethics Committee Approval:** The Akdeniz Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (date: 22.03.2023, number: 267).

**Informed Consent:** Written informed consent was obtained from the families of the patients who participated in this study.

**Conflict of Interest:** No conflict of interest was declared by the author.

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**Hasta Onamı:** Yazılı hasta onamı bu çalışmaya katılan hastaların ailelerinden alınmıştır.

**Çıkar Çatışması:** Yazar çıkar çatışması bildirmemiştir.

**Mali Destek:** Yazar bu çalışma için mali destek almadığını beyan etmiştir.

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