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Electroanatomic mapping-guided catheter ablation of atrial tachycardia in children with limited/zero fluoroscopy

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Abstract

Introduction: Atrial tachycardia (AT) is an uncommon cause of supraventricular tachycardia in children and it is often resistant to medical therapy. Catheter ablation can be curative in children with AT. However, experience of ablation of pediatric AT is still very limited. The aim of this study, which is the largest series from a single center, was to assess the efficacy and safety of ablation of AT using an electroanatomical-mapping system.

Methods: It was a retrospective review of 39 children with AT who underwent catheter ablation procedure using the EnSite Velocity system (St. Jude Medical, St. Paul, MN, USA) between July 2012 and April 2017.

Results: The mean patient age was 13.32 ± 6.82 years. The location of AT was right sided in 25 and left sided in 13, and both sides in one patient. The mean procedure time was 184.23 ± 60.19 min. Fluoroscopy was not used in 25 of 39 patients. The mean fluoroscopy time in the remaining patients was 5.53 ± 5.22 min. Radiofrequency (RF) ablation was used in 22, cryoablation was used in 10, and both RF and cryoablation were used in seven. Acute success was achieved in 34 patients (87.2%). During a mean follow-up of 51.35 ± 12.62 months, AT recurred in five patients. These patients underwent second ablation procedures and four of them were successful. Final success was achieved in 33 out of 39 patients (84.6%). There were no complications except for one patient who had an uneventful pericardial needle injury during transseptal puncture without effusion.

Conclusions: Catheter ablation of AT in children can be performed safely and effectively with a limited fluoroscopy using electroanatomical mapping systems.

KEYWORDS

atrial tachycardia, catheter ablation, children, limited/zero fluoroscopy

1 | INTRODUCTION

Atrial tachycardia (AT) is an uncommon cause of supraventricular tachycardia (SVT) in children and accounts for up to 10-15% of SVT in patients <30 years.[1–3] Although generally benign, if it is incessant, it may result in tachycardia-mediated cardiomyopathy, which is reversible with control of the arrhythmia.[4,5] AT is generally poorly responsive to medication and control with medical therapy alone is difficult. Therefore, catheter ablation should be considered early in patients with recurrent symptoms or those with incessant tachycardia or a tachycardia-mediated cardiomyopathy.[6,7] However, mapping with traditional two-dimensional (2D) fluoroscopic systems to locate ectopic sites is often difficult and involves long procedure and fluoroscopy times.[8] Three-dimensional (3D) electroanatomical-mapping system allows for more precise localization of ectopic foci and successful catheter ablation with limited floroscopy.[9,10] Although several reports showed that this system can significantly decrease or even eliminate fluoroscopy exposure during catheter ablation of SVT substrates,[11–13] there are only few on ablation of AT in children.[8,14,15] The aim of the study, which is the largest series from a single center, was to assess the efficacy and safety of ablation of AT using an electroanatomical-mapping system and limited fluoroscopy.

2 | METHODS

2.1 | Patient characteristics

This retrospective single-institution study evaluated all patients who underwent ablation of AT substrates using 3D mapping (The EnSite system, St. Jude Medical, St. Paul, MN, USA) with minimal or no

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fluoroscopy guidance between July 2012 and April 2017. The study was approved by the ethical committee of our institution. The diagnosis of AT was based on electrocardiogram (ECG), 24-h ambulatory ECG, or event recorder data consistent with electrophysiological criteria previously described.[1,16]

A total of 39 consecutive patients, who were admitted to our institution with symptomatic AT refractory to antiarrhythmic therapy, were included. Seven patients (20.5%) had previously undergone electrophysiology studies and/or ablation at our or other medical centers.

2.2 | Electrophysiological study

The electrophysiology study and catheter ablation procedure was explained to all patients and written informed consent was obtained. Depending on age, electrophysiological study (EPS) was performed either under local anesthesia with mild sedation or under general anesthesia without intubation. For left-sided foci, access to the left atrium was achieved via patent foramen ovale (PFO) or transseptal puncture. Antiarrhythmic medications were discontinued for at least five half-lives before the EPS in all patients. Three dimensional, surface electrode-based navigation system (EnSite Velocity system) was used in all patients. This system allows to visualize and navigate the electrophysiology catheters, including the cryoablation catheter, which helps to decrease or even eliminate the use of fluoroscopy.

The procedures were begun without using fluoroscopy by inserting a 7-Fr sheath into the right femoral vein and two 5- or 6-Fr sheaths into the left femoral veins. A steerable quadripolar 5F catheter was inserted via the right femoral venous access. The catheter was moved up into the right atrium gently using anteroposterior and lateral views of NavX system (St. Jude Medical). When the right atrial signals were noted, the catheter was pulled back and when the signals were lost, this location was marked as inferior vena cava. The catheter was then further advanced into the right atrium untill the loss of electrogram, where it was labelled as the junction of right atrium and superior vena cava. The Bundle of His signals was also marked on the right atrial chamber. Following electroanatomical reconstruction of cardiac geometry, a steerable decapolar 5F catheter was deployed into the coronary sinus for a positional reference. Following that, a quadripolar 5F catheter was inserted in the right ventricle. In children, where there was difficulty in navigation of a catheter into the heart, one of the other catheters already present in the heart was pulled back to that area of the inferior vena cava or iliac vein. Using that catheter path as a reference, the other catheter was also navigated into the heart safely.

If the adequate spontaneous atrial activity was not present at the beginning of the procedure, standard atrial and ventricular pacing maneuvers, and if necessary, orciprenaline bolus were administered to stimulate atrial ectopy. Location of the potential targets was determined by prematurity of local atrial activation compared with the stable reference. In addition, a pure negative deflection (QS pattern) of unipolar atrial electrogram was investigated. Color-coded electroanatomical mapping was also helpful in marking the potential target sites in 3D geometry.

2.3 | Ablation procedures

2.3.1 | Radiofrequency ablation

Radiofrequency (RF) energy application was applied in the majority of patients. A steerable RF catheter was used for mapping and energy delivery. RF ablation applications were performed during continuous temperature and impedance monitoring. Selection of irrigated or nonirrigated-tip catheter was based on the physician's preference or the property of ectopic foci. RF energy was delivered with a target temperature of 60°C in cases ablated with nonirrigated catheter and 41°C in cases ablated with irrigated catheter and a power of 30-50 W for maximum 60 s.

2.3.2 | Cryoablation

Cryoablation was performed using 7F 6-mm-tip or 9F 8-mm-tip catheters (Medtronic, Minneapolis, MN, USA) in patients with foci close to the atrioventricular (AV) node. Because cryoablation catheter distal electrode spacing is wide due to the 6- or 8-mm ablation segment (which slightly displaces the geometric center point of the measuring bipole), and because cryoablation catheters have limited maneuverability, especially in younger children, mapping was performed using a steerable quadripolar 6F electrophysiology catheter with 5-mm distal electrode spacing to determine the precise location. When a target was identified, its location was marked as a point on the 3-D map obtained using the EnSite Velocity system. The mapping catheter was then exchanged for a cryoablation catheter. If a 6-mm-tip catheter was used, cryomapping was performed at −30°C at the previously marked location after further fine mapping and was discontinued if no effect was seen within 30-45 s. If an 8-mm-tip catheter was used, short cryoablation applications lasting ≤30 s were performed and terminated if no effect was seen.

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 orciprenaline.

2.4 | Follow-up

All patients underwent continuous telemetry monitoring, 12-lead ECG, and 24-h ambulatory ECG before they were discharged. The follow-up visits were arranged at 2 weeks, 3 months, and 6 months after the procedure, and then every 12 months thereafter. At each visit physical examination, ECG, and 24-h ambulatory ECG monitoring were performed or event recorders were placed. Recurrence was defined as the return of clinical symptoms consistent with episodes before ablation, documented AT with an ECG, a 24-h ambulatory ECG, or an event recorder.

2.5 | Ethical standards

The parents of all the participating children were informed about the study, and their informed consent was received. In accordance with the Helsinki Declaration of 1975, as revised in 2008, the Ethics Committee of the institute approved the study before it began.

TABLE 1 Demographic and clinical characteristics of patients

Characteristics	*n* = 39
Age (years)	13.32 ± 6.82
Gender (M/F)	19/20
Weight	44.36 ± 17.24
Congenital heart disease	
No congenital heart disease	32
ASD	4
Ebstein's anomaly	1
TOF	1
Fontan operation	1
The location of ectopic foci	
Right-sided	25
Left-sided	13
Both sided	1

Data presented as mean ± standard deviation.
ASD = atrial septal defect; F = female; M = male; TOF = tetralogy of fallot.

2.6 | Statistical analysis

Continuous variables were expressed as median or mean ± standard deviation, and categorical variables are presented as percentages.

3 | RESULTS

3.1 | Study cohort

All demographic and clinical characteristics of patients are listed in Table 1. The mean age of patients (19 male and 20 female) at the time of procedure was 13.32 ± 6.82 years and the mean patient weight was 44.36 ± 17.24 kg. Congenital heart disease was present in seven patients. The location of AT was right sided in 25 and left sided in 13, and in both sides in one patient. One patients had atypical atrioventricular nodal reentrant tachycardia (AVNRT), two patients had typical AVNRT, and one patient had right accessory pathway, in addition to AT.

3.2 | Procedure characteristics and ablation success

Procedural characteristics of patients featured in this study are listed in Table 2. After the EPS, RF ablation was used in 22, cryoablation was used in 10, and both RF and cryoablation were used in seven patients.

Acute success was achieved in 34 of 39 patients (87.2%). We could not achieve successful ablation in the five patients. All these patients for whom the procedure failed, had multifocal atrial tachycardia. Three of these children had significant reduction of AT episodes, indicating a partial clinical success. During a mean follow-up of 51.35 ± 12.62 months, five patients (12.8%) experienced recurrence, all of them underwent second ablation procedures and four of them were successful. Final success was achieved in 33 out of 39 patients. The final sucsess rate was 84.6%.

An uneventful pericardial needle injury occured in one patient during transseptal puncture without effusion. No other complications were noted during and after the procedure. We did not observe any major complications, such as permanent complete AV block, pericardial effusion, and thrombotic events.

TABLE 2 Procedural characteristics and results of ablation

Characteristics	*n* = 39
Procedure time (min)	184.23 ± 60.19
Fluoroscopy time* (min)	5.53 ± 5.22
RF ablation	22
Cryoablation	10
Both	7
Acute success rate (%)	87.2
Follow-up duration (months)	51.35 ± 12.62
Recurrence at follow-up, *n* (%)	5 (12.8)

Data presented as mean ± standard deviation.
*n = 14 patients; RF = radiofrequency.

3.3 | Limited fluoroscopy exposure

In our electrophysiology practice, fluoroscopy is not used in the majority of procedures unless transseptal puncture is needed or in rare situations for verifying the catheter position. All electrophysiological procedures in this study were performed using EnSite Velocity-system guidance.

The total time required for transseptal approach was not registered, but the fluoroscopy time used during the transseptal puncture was recorded. A conventional fluoroscopy-guided technique was used for all transseptal procedures. Before attempting the transseptal puncture, the presence of PFO was investigated using the previously generated 3D model as a reference. If a PFO was present, the left atrium was accessed through the foramen ovale.

Fluoroscopy was not used in 25 of 39 patients (64.1%). The mean fluoroscopy time in the remaining 14 (35.9%) patients was 5.53 ± 5.22 min. Of the 14 patients who used fluoroscopy, nine had left-sided AT and one had both sides AT. Transseptal puncture was performed in nine of these patients. In a patient with left-sided AT, left atrium was passed through the PFO. However, 0.2 min of fluoroscopy was used in this patient for verifying the catheter position. In the remaining four patients, fluoroscopy was also used for catheter position determination. As a result, the mean fluoroscopy time used for transseptal puncture was 7.96 ± 5.44 (median: 6.40 [range: 2.00-19.30]) min and for catheter manipulation was 1.66 ± 1.48 (median: 1.40 [range: 0.20-3.20]) min (Table 3).

4 | DISCUSSION

This study demonstrated that catheter ablation using 3-D electroanatomical mapping guidance is safe and effective and associated with limited floroscopy time in patients with AT.

Medical therapy has been shown to be less effective in patients with AT beyond infancy.[6] Therefore, catheter ablation has been

TABLE 3 The fluoroscopy time in patients using fluoroscopy

	Time required for transseptal puncture (mins) ($n = 9$)	Time required for other reasons (mins) ($n = 5$)	Total fluoroscopy time (mins) ($n = 14$)
Mean ± SD	7.96 ± 5.44	1.66 ± 1.48	5.53 ± 5.22
Median	6.40	1.40	3.50
Minimum	2.00	0.20	0.20
Maximum	19.30	3.20	19.30

Mins = minutes; SD = standard deviation.

recommended in older children with pharmacologically uncontrolled AT.[7] Catheter ablation of AT is also considered a firstline therapy in patients with recurrent symptoms or those with incessant tachycardias or a tachycardia-mediated cardiomyopathy.[17–19] However, it was reported that success of catheter ablation of AT was lower than catheter ablation of AVNRT or accessory pathways.[20]

Recently, the use of 3D electroanatomic mapping for catheter ablation has provided improved rates of acute and long-term success of AT. Cummings et al showed improved acute ablation success rates with a lower incidence of recurrence using 3D electroanatomic mapping compared to 2D mapping techniques in their patients undergoing RF ablation procedures for pediatric AT.[8] Similarly, Toyohara et al reported acute success in all of their pediatric AT patients (35/35) and 11% recurrence undergoing RF ablation using 3D mapping system.[13] In a recent study, Dieks et al reported acute success in 14 of 16 patients (87.5%) using modern mapping systems.[14] In their study, it was reported that after a mean follow-up of 44.3 ± 30.8 months final success was 75%. Conversely to these studies, in a multicenter study acute success rates in children who underwent ablation with a 3D electroanatomic mapping were not statistically different from those who had conventional mapping (81% vs 75%; $P = 0.42$). However, recurrence rates after acute success were less common in the electroanatomic mapping group ($P = 0.02$).[15]

Our current study also supports evidence that 3D electroanatomic mapping for catheter ablation improves outcomes in pediatric AT. In our study, acute success was achieved in 34 patients (87.2%). All five patients for whom the procedure failed had multifocal atrial tachycardia. Three of these children had significant reduction of AT episodes, indicating a partial clinical success. During a mean follow-up of 51.35 ± 12.62 months, AT recurred in five patients. These patients underwent second ablation procedures and four of them were successful. Final success was achieved in 33 out of 39 patients. The final sucsess rate was 84.6%.

In our study, we were able to achieve a lower procedure time (mean, 184.23 ± 60.19 min; median, 170 [range: 80-420]) than reported before with the use of 3D mapping systems.[8,14] Our study also demonstrates that the use of electroanatomical mapping system is associated with significantly decreased fluoroscopy time during the ablation of AT in children. Catheter ablation is the established curative therapy for tachyarrhythmias. However, exposure to ionizing radiation is of concern to both patients and care providers. Most importantly, children are more susceptible to the carcinogenic effects of ionizing radiation due to the long-life expectancy. Numerous studies of childhood exposure to radiation for treatment of benign diseases have showed radiation-related risks of cancer. Consequently, fluoroscopy is a major concern for physicians during the electrophysiological procedures.[21,22] The use of electroanatomical mapping systems during ablation of arrhythmias has been shown to be safe and effective with short fluoroscopic exposure.[23,24] Our current study also shows that the use of the EnSite system is associated with significantly decreased fluoroscopy time without sacrificing from the efficacy and safety in patients with AT. Considering the reported least fluoroscopy time of median as 13.1 (range: 4.5-22.5) min for AT ablation with 3D mapping systems in children,[14] the fluoroscopy time of median 3.50 (range: 0.20-19.30) min in our study was significantly lower in comparison, and fluoroscopy was avoided altogether in 25 of 39 patients. Fluoroscopy was used in 14 of our patients due to the transseptal puncture or for catheter position determination. Our results strongly favor the use of an electroanatomical system in order to reduce the fluoroscopy exposure.

Major complications during and after catheter ablation of AT are rare and complication rates ranged from 3 to 8% according the patients age.[20] Reported complications include 2° and/or 3° AV block, perforation, pericardial effusion, thrombus formation, damage to phrenic nerve, stroke, and cardiac arrest.[20,25–27] In our study, there were no complications except for one patient who had an uneventful pericardial needle injury during transseptal puncture without effusion.

This study is limited by the inherent nature of a retrospective study involving a small group of patients due to the rare prevalence of the disease and relatively short follow-up durations. However, we believe that the number of our patients is significant when compared to recent literature.

5 | CONCLUSIONS

Catheter ablation of AT can be performed safely and effectively in patients using a limited fluoroscopic approach with the electroanatomical-mapping systems. Accurate mapping with 3-D electroanatomical guidance and an adequate number of effective ablation applications can help in reaching a greater long-term success rate.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

AUTHORS' CONTRIBUTIONS

All authors read and approved the final versions.

Study concept and design: Ozlem Elkiran, Celal Akdeniz, Mehmet Karacan, Volkan Tuzcu. Materials, data collection, and processing: Ozlem Elkiran and Celal Akdeniz. Data analysis and interpretation: Ozlem Elkiran, Celal Akdeniz, Volkan Tuzcu. Literature search and writing: Ozlem Elkiran.

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