

Catheter ablation of left-sided accessory pathways in small children

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Abstract

Background: Accessory pathways (APs) are a common reason for supraventricular tachycardia in small children. Trans-septal puncture (TSP) approach is commonly used for the ablation of left-sided APs, however it may be challenging in small children. The aim of this study was to assess the efficacy and safety of trans-septal approach radiofrequency (RF) ablation of left-sided APs in children weighing up to 30 kg.

Methods: Of the 658 children who underwent catheter ablation of APs since 06/2002, 86 children had left-sided AP and weighed less than 30 kg. TSP approach guided with TEE and fluoroscopy was used for left atrium access.

Results: The mean age, height, and body weight were 7.6 ± 1.9 years, 122.4 ± 9.3 cm and 24.0 ± 4.2 kg, respectively. Forty-three children (50%) were male, 46 of 86 (53%) had manifest AP, 17 of 86 (20%) weighed less than 20 kg and in 24 of 86 children (28%) a three-dimensional system (3DS) was used to reduce fluoroscopy time. The acute success rate was 98.8% (85/86), with a recurrence rate of 2.4% (2/85) in a mean follow-up of 66.2 ± 42.7 (9.1-184.2) months. The mean procedure time and fluoroscopy time were significantly lower for the 3DS group compared to the standard fluoroscopy group 131 ± 41 (55-262) and 2.4 ± 1.5 (1-6) minutes vs 164 ± 51 (62-249) and 27 ± 13 (8-77) minutes, $P < 0.01$ and $P < 0.0001$, respectively. There were no ablation-related complications.

Conclusions: RF ablation of left-sided APs using TSP approach in small children had an excellent efficacy and safety profile. The use of 3DS significantly reduces the procedure and fluoroscopy time.

KEYWORDS

left-sided accessory pathway, radiofrequency catheter ablation, three-dimensional system, trans-septal puncture, Wolf-Parkinson-White syndrome

Abbreviations: 3DS, three-dimensional system; AP, accessory pathways; AVRT, atrioventricular reciprocating tachycardia; RF, Radiofrequency; SVT, supraventricular tachycardia; TSP, Trans-septal puncture; WPW, Wolf-Parkinson-White.

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1 | INTRODUCTION

Radiofrequency (RF) catheter ablation (RFCA) of atrioventricular (AV) accessory pathways (APs) has become the established therapy for the treatment of pediatric supraventricular tachycardia—SVT.^{1,2} Young age and low body weight are reported to be independent risk factors for complications during RFCA of Aps.^{3–5} Trans-septal puncture (TSP) is commonly used for ablation of left-sided Aps.^{6–8} However, in small children, TSP may be challenging because of the narrow access vessels and small left atria. The aim of this study was to assess the efficacy and safety of trans-septal approach RFCA of left-sided APs in children weighing up to 30 kg.

2 | PATIENTS AND METHODS

This study was conducted at The Schneider Children's Hospital of Israel, Division of Cardiology, Petach Tiqva, Israel. The database was built prospectively and the patients' records were reviewed with the approval of the institutional review board at the Schneider Children's Hospital of Israel.

3 | PATIENTS

From June 2002 to December 2015, 658 children underwent 725 RFCA or Cryo-ablation procedures for APs. Among them, the study group includes 88 procedures that were attempted in 86 children with left-sided AP who weighed up to 30 kg. All of them underwent a trans-septal approach RFCA of the left-sided APs. The demographic and clinical data collected included the patient's age, gender, ethnicity, height, weight, body surface area, and clinical manifestations.

4 | ELECTROPHYSIOLOGICAL STUDY

Antiarrhythmic medications were discontinued at least five half-lives before the electrophysiological study (EPS) in all patients. After obtaining informed consent, EPS was performed on patients under general anesthesia (Intubated and mechanical ventilation and using Propofol, Fentanyl and Isoflurane). Standard 12-lead ECGs were recorded along with bipolar intracardiac electrograms. Catheters were positioned at the coronary sinus via the left subclavian vein (LSCV) and at the right ventricular apex, His-bundle area and the right atrium using the femoral vein approach (see details later). All patients underwent EPS under the same protocol by two senior adult/pediatric electro-physiologists. Sixty-two had the RFCA using standard fluoroscopy and the other 24 had RFCA using a 3DS (EnSite NavX™, St. Jude Medical, St Paul, MN, US).^{8,9} An EPS was performed for two reasons, (a) risk stratification for WPW and (b) to test for AVRT induction. The EPS included single,

double, and burst atrial extra stimuli at standard variable drive-paced cycle lengths, both with and without an isoproterenol infusion, as required for arrhythmia induction. Children with manifest or concealed left AP with induction of AVRT and/or with high-risk criteria for sudden death were ablated.

5 | DEFINITIONS

High-risk APs were so defined if the AP—effective refractory period—(AP-ERP) was <240 ms and/or short preexcited RR interval (SPRRI) during atrial fibrillation was <240 ms. Acute ablation success was defined as the elimination of all AP conduction in direct response to RF ablation. The time to effect was defined as the duration of time from the beginning of RF application to the disappearance of the AP. All patients were observed for at least 30 minutes following the apparent successful ablation. A repeat full EPS with and without isoproterenol was performed postablation in order to ensure an inability to re-induce AVRT or any conduction via the AP.

6 | TRANS-ESOPHAGEAL ECHOCARDIOGRAPHY AND FLUOROSCOPY GUIDED TRANS-SEPTAL PUNCTURE

A conventional 71 cm Brockenbrough needle (BRK Trans-septal Needle, St Jude Medical, Minneapolis, MN, USA) and a 7-French 63 cm trans-septal guiding introducer (Swartz, Medtronic) were used for TSP. The TSP was guided using both fluoroscopy and trans-esophageal echocardiography (TEE). Under fluoroscopic guidance, first the guide-wire and then the long sheath and dilator were introduced into and placed in the superior vena cava. Then, under TEE imaging a TSP needle was advanced until it was 1 cm from the end of the dilator. The TSP needle, dilator, and long sheath assembly were then withdrawn down into the RA and moved to the fossa ovalis (FO). Once the engagement of the FO was confirmed by tenting of the septum on TEE, the trans-septal needle was advanced for puncture. Puncture was confirmed by injection of saline demonstrating left-sided bubbling on TEE. In one child, because of a highly flexible atrial septum, we had to use a trans-septal guide-wire (SafeSept, Oscor Inc. Palm Harbor, FL, USA). After the TSP, 50 IU/kg heparin was given IV and then additional heparin was delivered as necessary in order to maintain the activated clotting time of ≥ 250 seconds.

7 | FOLLOW-UP

All patients were observed overnight in hospital and a repeat 12-lead ECG was recorded before discharge. Outpatient follow-up visits were arranged for 1 and 12 month postablation. Recurrence was defined as the return of clinical symptoms, documented SVT or the return of ventricular preexcitation.

8 | STATISTICS

All data were reported as median and range or mean and standard deviations for continuous variables and frequency for categorical variables. Independent Samples *T* Test and One way ANOVA with Bonferroni's correction were used as needed for continuous variables. Comparisons of categorical data were performed using a χ^2 (Fisher's exact test for cell counts < 5). Statistical analysis was performed using the SPSS version 17.0 statistical package. $P < 0.05$ was considered significant.

9 | RESULTS

From June 2006 to December 2015, 658 children underwent catheter ablation of APs; among them 86 had both left-sided AP and body weight up to 30 kg. These 86 children underwent 88 ablation procedures. Thirty seven had WPW and supraventricular tachycardia (SVT), 46 had concealed AP with SVT and three had asymptomatic WPW. The mean age, height, body weight, and BMI were 7.6 ± 1.9 (3.5-10.6) years, 122.4 ± 9.3 (100-145) cm, 24.0 ± 4.2 (15-30) kg and 16 ± 2 (9.5-21.9), respectively (Figure 1 and Table 1). Four children had a structurally abnormal heart (two children had ventricular septal defect—VSD, one had Ebstein's anomaly and one had atrial septal defect—ASD, the rest had normal heart. Four children had undergone an ablation in the past in another center. Forty-three (50%) were male, 46 (53%) had manifest AP, 17 (20%) weighed up to 20 kg, and in the last consecutive 24 children (28%), a 3D system (3DS) was used to reduce fluoroscopy time. TSP approach guided with TEE and fluoroscopy was used for left atrium access in all children. The acute success rate was 98.8% (85/86), with a recurrence rate of 2.4% (2/85) in a mean follow-up of 66.2 ± 42.7 (9.1-184.2) months. The failed procedure was of a 7.9 year old boy with a body weight of 29 kg who had two concealed APs (successful ablation of left lateral AP and failed ablation of left posteroseptal AP). The two children with the recurrence had the second successful ablation 6 and 15 months after the first procedure, respectively. No difficulties were observed with the TSP and the ablation.

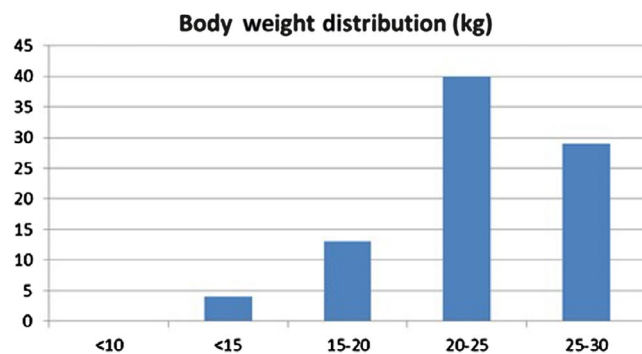


FIGURE 1 Body weight distribution (kg)

TABLE 1 Baseline characteristic of patients (n = 86)

Age (y)	7.6 ± 1.9 (3.5-10.6)
Body weight (kg):	24.0 ± 4.2 (15-30)
Height (cm)	122.4 ± 9.3 (100-145)
BMI	16 ± 2 (9.5-21.9)
SVT (CL): average ± STD range	299 ± 45 (226-422) (n = 79)
AVRT only (concealed AP)	46/86 (53.5%)
WPW and AVRT	37/86 (43%)
Asymptomatic WPW	3/86 (3.5%)
Fluoroscopy time (min)	20.3 ± 15.8 (1-77)
Procedure time (min)	155 ± 48 (55-262)
Acute success rate	85/86 (98.8%)
Recurrence rate	2/85 (2.4%)
Follow-up period (mo)	66.2 ± 42.7 (9.1-184.2)

10 | ELECTROPHYSIOLOGICAL CHARACTERISTICS

The mean accessory pathway effective refractory period (AP-ERP), SPRRI, and SVT-SVT cycle length (CL) were 306 ± 43 ms, 316 ± 109 ms and 299 ± 45 ms, respectively. The mean AVN-ERP and SVT-CL was significantly shorter in females compared to males (287 ± 55 ms vs 326 ± 80 ms, $P < 0.05$ and 288 ± 38 ms vs 308 ± 49 ms, $P < 0.02$, respectively).

11 | MALE VS FEMALE AND MANIFEST VS CONCEALED GROUPS

A comparison between the male (n = 43) group and the female group (n = 43) reveals a comparable procedure time, fluoroscopy time, number of applications, time to disappearance of AP, acute success rate, and recurrence rate. A comparison between the manifest (n = 46) group and the concealed group (n = 40) reveals a comparable procedure time, fluoroscopy time, number of applications, time to disappearance of AP, acute success rate, and recurrence rate.

12 | 3DS USES VS NON-3DS USES

We observed a modest reduction in the mean procedure time for the 3DS (n = 24) group compared to the standard fluoroscopy (n = 62) group (from 164 ± 51 (62-249) minutes to 131 ± 41 (55-262) minutes, $P < 0.01$). Moreover, a reduction of 91% in the fluoroscopy time was observed in the 3DS group compared to non-3DS group (from 27.1 ± 13.3 (8.3-77) minutes to 2.4 ± 1.5 (1-6) minutes, $P < 0.001$) (Figure 2, Table 2). The number of applications, time to effect, acute success rate, and recurrence rate were comparable for both group.

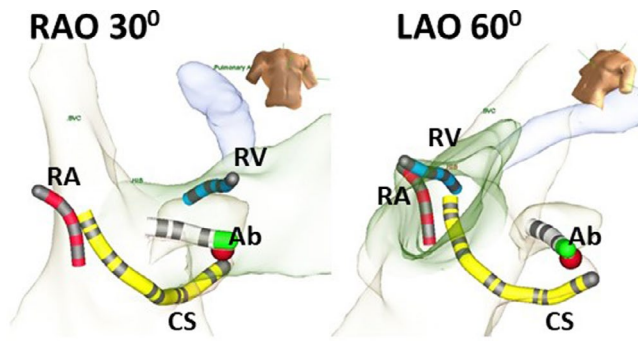


FIGURE 2 3D RAO and LAO projection of the velocity navigating system, note the comparability of catheters orientation in the 3DS projections to the familiar fluoroscopy imaging

TABLE 2 Comparison of procedures performed with non-3DS with procedures performed with 3DS

	Non 3DS used (n = 62)	3DS used (n = 24)	P value
Procedure time (min)	164 ± 51 (62-249)	131 ± 41 (55-262)	<0.01
Fluoroscopy time (min)	27.1 ± 13.3 (8.3-77)	2.4 ± 1.5 (1-6)	<0.001
No. of application	4.4 ± 2.8 (1-14)	3.8 ± 2.3 (2-10)	NS
Time to effect (sec)	5.1 ± 2.6 (0.8-10)	4.5 ± 2.4 (1-10)	NS
Acute success	61/62 (98.4%)	24/24 (100%)	NS
Recurrence rate	1/61 (1.6%)	1/24 (4.2%)	NS

13 | WEIGHT UNDER 20 KG VS WEIGHT OF 20-30 KG

A comparison between the group that weighed under 20 kg (n = 17) to the 21-30 kg group (n = 69) reveals a comparable procedure time, fluoroscopy time, number of applications, time to disappearance of AP, and acute success rate, however, a higher recurrence rate was observed in the under 20 kg group (2/17 (11.1%) vs 0/68 (0%), $P < 0.01$, respectively). These two children with the recurrence were male, had a concealed left-sided AP, had the ablation at age 4.7 and 6 years, and weighed 15.5 and 17 kg, respectively (Table 3).

14 | COMPLICATIONS

There were no ablation-related complications—neither major (tamponade, AV block, stroke, pneumothorax or death) nor minor (pericardial effusion, mitral regurgitation, aortic regurgitation or hematoma). Transient catheter-induced mechanical block of the AP was observed in one child (1.2%). No pericardial effusion or tamponade was observed.

TABLE 3 Comparison of procedures performed in children weight up to 20 kg to children weight 20-30 kg

	Up to 20 kg (n = 17)	Over 20 kg (n = 69)	P value
Procedure time (min)	157 ± 51 (55-249)	154 ± 61 (62-262)	NS
Fluoroscopy Time (min)	22.9 ± 17.9 (1.5-56)	19.6 ± 15.2 (1-77)	<0.001
No. of application	4.3 ± 2.1 (2-10)	4.2 ± 2.8 (1-14)	NS
Time to effect (s)	5.1 ± 3.1 (1-10)	4.9 ± 2.4 (0.8-10)	NS
Acute success	17/17 (100%)	68/69 (98.6%)	NS
Recurrence rate	2/17 (11.1%)	0/68 (0%)	NS

15 | FOLLOW-UP

The short-term success rate was 98.8% (85/86). At a mean follow-up time of 66.2 ± 42.7 months (range 9.1-184.2 months), two patients [2/85 (2.4%)] had a recurrence. The two children with the recurrence were male who had concealed AP and weighed less than 20 kg, and both had the second successful ablation 6 and 15 months after the first procedure, respectively.

16 | DISCUSSION

In this study we report our experience with left-sided AP ablation using TSP in 86 children weighing up to 30 kg.

Our primary findings include:

1. TSP approach for ablation of left-sided AP in small children is very safe and effective.
2. The safety of TSP is achieved using combined fluoroscopy and TEE.
3. Using 3DS significantly reduces the procedure time (from an average of 164 to 131 minutes) and further reduces the fluoroscopy time (from an average of 27.1 to 2.4 minutes).
4. The procedure time, the fluoroscopy time, the number of applications, the time to effect, the acute success rate, and the recurrence rate were comparable for manifest vs concealed and for female vs male. However, a significantly higher recurrence rate was observed in children weighing up to 20 kg.

Radiofrequency catheter ablation therapy is a common practice for the treatment of pediatric arrhythmias.¹⁰ However, in small children, the procedure might be more difficult because of the small blood vessels and heart cavities and the need for general anesthesia. Small patient size has been reported to be associated with a higher rate of major complications after radiofrequency ablation compared with older children.^{4,11,12}

The preferred technique for the left accessory pathway ablation in Europe is a retrograde trans-aortic approach in two-thirds of the hospitals (64.10%), the remaining centers use the trans-septal technique.¹³ The TSP in small children may be challenging because of smaller left atrial sizes.⁷

This work showed that ablation of the left-sided AP using TSP approach is safe and effective even in small children weighing up to 30 kg, in our work without any complications such as perforation, pericardial fluid, or tamponade. In our opinion, the combined use of fluoroscopy and TEE enables maximum safety in TSP performance.

Antiarrhythmic drugs are still the first choice of therapy for preschool children, however, persistent SVT in small children can lead to cardiac dysfunction, and pharmacological therapy often yields unsatisfactory results. In our center, we usually prefer to perform elective ablation when the weight of the child is over 20 kg. In this work, 17 children weighed less than 20 kg and were experiencing recurrent or sustained SVT under antiarrhythmic drugs. We showed that the TSP approach for left-sided AP in this group also was safe and effective. However, the two AP recurrences in this study were in this group of children who weighed less than 20 kg, which also supports the notion to wait until the child weighs over 20 kg if possible before ablation implementation.

In addition, starting in December 2013, we began to perform all ablation operations using a three-dimensional navigation system

(Velocity, EnSite NavX™, St. Jude Medical, St Paul, MN, US) in order to reduce the fluoroscopy time, improve the success rate and increase the accuracy of ablation. In this work, the last 24 children [24/86 (28%)] had ablation of left-sided AP using a 3DS. Comparable safety and efficacy were observed (3DS used vs non-3DS used groups), as well as a significant reduction in the procedure time from 164 to 131 minutes on average and over 90% reduction in fluoroscopy time from 27.1 to 2.4 minutes in average was observed. The reduction in the procedure time is because of the continuous imaging and mapping using 3DS. Though, Scaglione et al.¹⁴ reported a zero fluoroscopy time in 44 children with AP using the CARTO-3 mapping system with an acute success rate of 100%, it was associated with a high recurrence rate of 16% (7/44) and the use of a retrograde approach instead of a trans-septal approach for children with LSAP.

Yoshida et al. also demonstrated safety and high efficiency using TSP for left-sided AP in children up to 30 kg.⁷ They reported about their experience in 43 cases, in this study we describe our experience with 86 children. The successes rate was comparable 100% vs 98.8%. They had one complication (1/43 (2.3%)), we had no complication. Our work supports and reinforces the results of their work. We routinely used TEE in all children, but they used it when the TSP was achieved by using an RF needle. They consider RF needle is likely safer in children with small atria since the operator does not have to use mechanical force to advance across the septum. Using

30° LAO projection

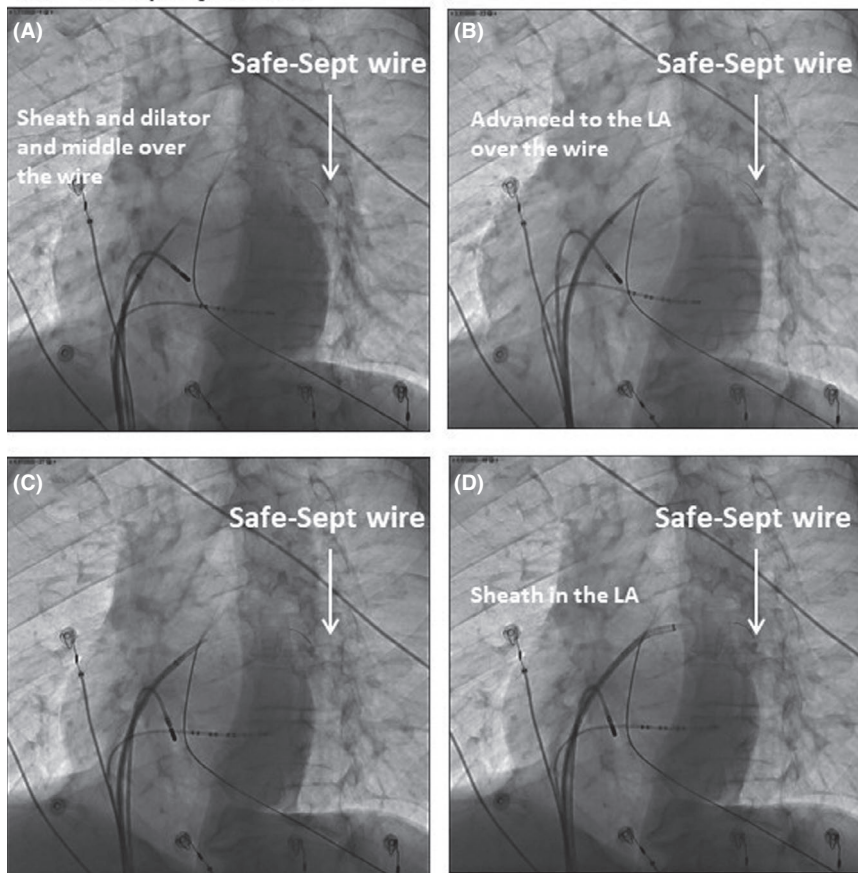


FIGURE 3 Trans-septal puncture (TSP) using safe-sept wire. A, safe-sept wire in the left superior pulmonary vein. B, Advancing safely the dilator and the sheath into the left atrium (LA) over the safe-sept wire. C, advancing the sheath over the dilator ABD the safe-sept wire into the LA. D, the sheath is inside the LA

that method, they reported a significant decrease in fluoroscopy time from 30.5 minutes on average to 24.5 minutes, whereas, as mentioned, using 3DS we show a more than 90% reduction (from 27.1 to 2.4 minutes) in the fluoroscopy time.

Although we demonstrated an extreme safety of combined TEE and fluoroscopy for TSP in children, we have a good experience with safe-sept wire (Safe Sept, Pressure Products, Inc., USA) for TSP in adults for atrial fibrillation ablation. Using Safe-Sept can greatly improve the safety of TSP in small children. In this work, we used this wire in one patient with a very flexible atrial septum, with repeated attempts under fluoroscopy and where TEE failed to cross the septum. At this point, the safe-sept wire was inserted through the BRK needle and, because of its thinness and sharpness; it easily punctured and passed the elastic septum and was introduced to the left superior pulmonary vein enable a safe passage of the BRK needle proceeds with a safe passage of the trans-septal sheath to the left atrium, Figure 3. In our experience with adults, the use of safe-sept wire for TSP is comfortable and safe and makes it unnecessary to use TEE. A comparative study of the use of fluoroscopy and TEE vs fluoroscopy and safe-sept wire without TEE for TSP in children should be considered.

In conclusion, RF ablation of left-sided APs using the TSP approach in small children had an excellent efficacy and safety profile. This might be attributed to the combined uses of fluoroscopy and TEE for the TSP. In addition, 3DS uses significantly reduce the procedure and fluoroscopy time.

CONFLICT OF INTEREST

Authors declare no conflict of interests for this article.

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REFERENCES

1. Kugler JD, Danford DA, Deal BJ, Gillette PC, Perry JC, Silka MJ, et al. Radiofrequency catheter ablation for tachyarrhythmias in children and adolescents. *N Engl J Med*. 1994;330:1481–7.
2. Kugler JD, Danford DA, Houston K, Felix G. Radiofrequency catheter ablation for paroxysmal supraventricular tachycardia in children and adolescents without structural heart disease. *Am J Cardiol*. 1997;80:1438–43.
3. Jiang HE, Li XM, Li YH, Zhang Y, Liu HJ. Efficacy and safety of radiofrequency catheter ablation of tachyarrhythmias in 123 children under 3 years of age. *Pacing Clin Electrophysiol*. 2016;39(8):792–6.
4. Friedman RA, Walsh EP, Silka MJ, Calkins H, Stevenson WG, Rhodes LA, et al. Expert Consensus Conference: radiofrequency catheter ablation in children with and without congenital heart disease. Report of the writing committee. *Pacing Clin Electrophysiol*. 2002;25:1000–17.
5. Backhoff D, Klehs S, Müller MJ, Schneider H, Kriebel T, Paul T, et al. Radiofrequency catheter ablation of accessory atrioventricular pathways in infants and toddlers ≤ 15 kg. *Pediatr Cardiol*. 2016;37(5):892–8.
6. von Alvensleben JC, Dick M, Bradley DJ, LaPage MJ. Transseptal access in pediatric and congenital electrophysiology procedures: defining risk. *J Interv Card Electrophysiol*. 2014;41:273–7.
7. Yoshida S, Suzuki T, Yoshida Y, Watanabe S, Nakamura K, Sasaki T, et al. Feasibility and safety of transseptal puncture procedures for radiofrequency catheter ablation in small children weighing below 30 kg: single-centre experience. *Europace*. 2016;18(10):1581–6.
8. Swissa M, Birk E, Dagan T, Naimer SA, Fogelman M, Einbinder T, et al. Limited fluoroscopy catheter ablation of accessory pathways in children. *J Cardiol*. 2017;pii: S0914-5087(17):30024-2.
9. Swissa M, Birk E, Dagan T, Naimer SA, Fogelman M, Einbinder T, et al. Radiofrequency catheter ablation of atrioventricular node reentrant tachycardia in children with limited fluoroscopy. *Int J Cardiol*. 2017;236:198–202.
10. Brugada J, Blom N, Sarquella-Brugada G, Blomstrom-Lundqvist C, Deanfield J, Janousek J, et al. Pharmacological and non-pharmacological therapy for arrhythmias in the pediatric population: EHRA and AEPC-Arrhythmia Working Group joint consensus statement. *Europace*. 2013;15:1337–82.
11. Van hare GF, Javitz H, Carmelli D, Saul JP, Tanel RE, Fischbach PS, et al. Prospective assessment after pediatric cardiac ablation: demographics, medical profiles, and initial outcomes. *J Cardiovasc Electrophysiol*. 2004;15:759–70.
12. Kubu P, Vit P, Gebauer RA, Zaoral L, Peichl P, Fiala M, et al. Long-term results of paediatric radiofrequency catheter ablation: a population-based study. *Europace*. 2014;16:1808–13.
13. Hernandez-Madrid A, Hocini M, Chen J, Potpara T, Pison L, Blomstrom-Lundqvist C; et al. How are arrhythmias managed in the paediatric population in Europe? results of the European Heart Rhythm survey. *Europace*. 2014;16(12):1852–6.
14. Scaglione M, Ebrille E, Caponi D, Siboldi A, Bertero G, Di Donna P, et al. Zero-fluoroscopy ablation of accessory pathways in children and adolescents: CARTO3 electroanatomic mapping combined with RF and cryoenergy. *PACE*. 2015;38:675–81.

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