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High-density Mapping Catheter (Advisor™ HD Grid) Usage for Intra-atrial Reentrant Tachycardia Ablation in Children and Young Adult Patients with Congenital Heart Disease

ABSTRACT

Background: We aimed to share our experience of intra-atrial reentrant tachycardia mapping and ablation with a new grid-style multielectrode high-density mapping catheter (Advisor™ HD Grid) in pediatric and young adult patients with operated congenital heart disease.

Methods: All patients with operated congenital heart disease and intra-atrial reentrant tachycardia mapping with the new grid-style catheter between October 2019 and December 2022 were included (group 1), and the results were compared to those patients who operated with conventional catheter methods before this period (group 2). All procedures were performed using the EnSite Precision 3D mapping system (Abbott Laboratories, Abbott Park, Ill, USA) with a limited fluoroscopy approach. Data were evaluated retrospectively.

Results: In group 1 (n = 16; 9 male), the median age was 21 years (10-36), compared to 19 years (9-27) in group 2 (n = 10; 5 male). While irrigated radiofrequency ablation was preferred in all patients, the median number of 15 lesions (8-38) in group 1 was significantly less than the median of 30 lesions (8-71) in group 2 (P =.027). The median procedure duration of 159 minutes (110-233) in group 1 was significantly shorter compared to 280 minutes (180-370) in group 2 (P <.05). Acute procedural success was achieved in all patients (16/16; 100%) in group 1 compared to 8/10 patients (80%) in group 2. During the median follow-up of 27 months (11-36), there was only 1 intra-atrial reentrant tachycardia recurrence in group 1 (1/16; 6.2%) and 2 recurrences (2/8; 25%) in group 2 during the median follow-up of 110 months (56-151). No complications related to the mapping catheter itself occurred.

Conclusion: In the intra-atrial reentrant tachycardia ablation of children with congenital heart disease to increase procedural success and shorten the mapping duration, the utility of Advisor™ HD Grid mapping catheter seems to be a feasible alternative.

Keywords: Congenital heart disease, high-density mapping catheter, intra-atrial reentrant tachycardia, radiofrequency ablation

INTRODUCTION

Intra-atrial reentrant tachycardias (IARTs) are the most commonly occurring arrhythmias in pediatric and young adult patients with operated congenital heart disease (CHD).[1-6] Medical therapy offers limited value, especially for IART with complex macro-reentrant circuits around the atriotomy scars, making catheter ablation the recommended treatment method.[4-6] However, mapping with conventional methods is time consuming and a significant cause of the low success in ablation with high recurrence rates.[6,7]

Recently, newer mapping catheter technologies using multielectrodes in a complex structure revealed higher ablation success rates and lower recurrence.[8,9] However, the use of the 16-electrode, grid-style Advisor™ HD Grid catheter (Abbott Laboratories, Abbott Park, Ill, USA) (Figure 1) in adult patients with CHD is only rarely reported.[9,10] To the best of our knowledge, no study has been undertaken with this catheter in pediatric CHD patients with IART.

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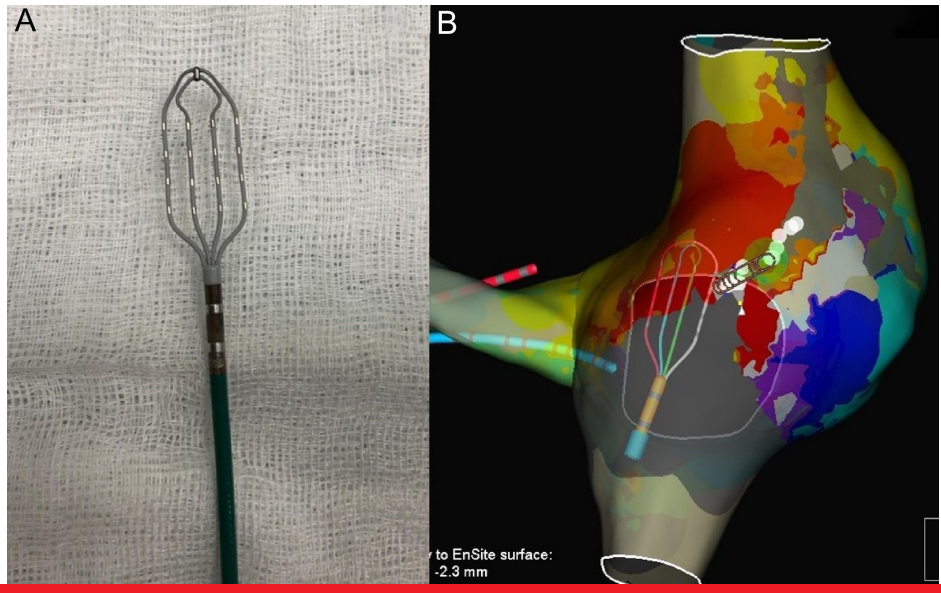

Figure 1. Sixteen-electrode, grid-style Advisor™ HD Grid catheter (Abbott). (A) Photograph of the Advisor™ HD Grid catheter with its 4 splines consisting of 4 electrodes each. The catheter is bidirectionally deflectable. (B) View of the EnSite Precision™ image of the Advisor™ HD Grid catheter and irrigated RF ablation catheter on the right atrial lateral wall.

Through this work, we seek to share our experience of IART mapping and ablation with the Advisor™ HD Grid catheter in pediatric and young adult patients with operated CHD.

METHODS

Among the 812 patients with an electrophysiological study (EPS) and ablation procedure performed between October 2019 and December 2022 at our pediatric arrhythmia center, the Advisor™ HD Grid catheter (8F, Abbott Laboratories) was used in 24 patients for mapping the tachycardia substrate. Sixteen patients with CHD and IART were enrolled in the study (group 1). Ten patients with a CHD ablated for IART using conventional diagnostic mapping catheters before this period were also enrolled in the study for comparison (group 2). Written informed consent was obtained from all patients before the procedure.

Electrophysiological Study and Catheter Ablation

A single operator (Y.E.) who is highly experienced in the mapping and ablation of IART performed all the EPS and ablation procedures. The procedures were performed under general anesthesia. Antiarrhythmic medication was discontinued at least 5 drug half-lives prior to the EPS. Cardiac computerized tomography (CT) or magnetic resonance imaging was performed before the procedure to assess the anatomy and to aid in electroanatomic mapping. Transesophageal echocardiography (TEE) was also undertaken prior to the procedure for hemodynamic assessment and to detect possible thrombi.

Vascular access was obtained via the femoral veins in all patients. The internal jugular veins were cannulated if it was compulsory. After vascular sheath insertion, 100 IU/kg (maximum 5000 IU) heparin was administered intravenously to achieve an activated clotting time of 250-300 seconds. A deflectable decapolar electrode catheter (5F, Abbott Laboratories), introduced into the coronary sinus, was used as a reference electrode for activation mapping and pacing. In patients whose coronary sinus could not be catheterized, diagnostic EP electrodes were implanted into the esophagus for atrial reference.

All the mapping procedures were performed under the guidance of the EnSite Precision™ 3D electroanatomic mapping system (Abbott Laboratories) using the AutoMap function. First, a standard quadripolar diagnostic catheter was used to create a basic electroanatomic map of the right atrium. Subsequently, using a long steerable sheath (Agilis™ NxT, 8.5F, Abbott Medical, St. Paul, MN, USA), the Advisor™ HD Grid catheter was advanced to the right atrium in group 1. Scar and activation mapping were performed simultaneously if IART was already ongoing; if a sinus rhythm was detected, only scar mapping was performed. The voltage map (up to peak-to-peak bipolar voltage < 0.05 mV and 0.05-0.5 mV) was defined as a dense scar and low voltage zone via EnSite. In group 2 patients, conventional diagnostic catheters were used for mapping [standard quadripolar diagnostic catheter, deflectable decapolar electrode catheter

HIGHLIGHTS

- In the intra-atrial reentrant tachycardia ablation of children with congenital heart disease to shorten the mapping and procedural duration, the utility of Advisor™ HD Grid mapping catheter seems to be feasible.
- Through a more detailed and precise mapping, an acute success rate of ablation could be achieved.
- Further studies involving more cases with longer follow-ups are needed to draw a definite conclusion about the safety and long-term success rate of these catheters in children.

(6F, Abbott Laboratories) or a duodecapolar electrode catheter (7F, Livewire™, St. Jude Medical)]. Subsequently, IART was induced either by programmed atrial stimulation or by atrial burst pacing if not already detected. In the patient who had previously undergone an atrial switch procedure, a standard Brockenbrough needle (98 cm, Brockenbrough BRK™, Abbott Vascular, Il, USA) was used under fluoroscopic and TEE guidance for transbaffle puncture to access the pulmonary venous atrium.

After the activation mapping of IART with the Advisor™ HD Grid catheter using the EnSite™ AutoMap function, around 10 000 to 20 000 points were obtained; among them, 3000 to 5000 points were used to characterize the reentry circuit and the substrate for IART ablation. Areas around the macro-circuit slow conduction zone, carrying small and long fractionated signals with a duration of more than 100-110 ms, were marked with target points as the critical isthmus, and line lesions were planned from these points to the nearest scar area (Figure 2). After electroanatomical mapping, classic entrainment was performed in critical isthmus locations with slow conduction in all patients. Additionally, we checked whether the area fell within the circuit. The classical cavotricuspid isthmus (CTI) was also mapped in each patient. If it was found within the macro-circuit, another line lesion was planned to cross the CTI and connect the inferior vena cava (IVC) and the first-line lesion, ending with a Y-shaped lesion.

Ablation was performed using the TactiCath SE™ force-sensing open-irrigated tip catheter (8F, 3.5 mm tip, Abbott Laboratories) in 5 patients, a monodirectional open-irrigated tip radiofrequency (RF) catheter (7F, 4 mm tip, Thermocoolflex, St. Jude Medical, St. Paul, MN, USA) in 7 patients, and a bidirectional open-irrigated tip RF catheter (8F, 4 mm tip, St. Jude Medical) in 4 patients in group 1. A monodirectional open-irrigated tip RF catheter (7F, 4 mm tip, Thermocoolflex, St. Jude Medical) was used in all patients in group 2. The generator was set for 35 W with a target temperature of 43°C, achieving a mean actual temperature of 33°C at the catheter tip. Using the TactiCath force-sensing catheter, a target catheter contact force of 10-30 g was aimed at the catheter tip in a perpendicular orientation to the endocardial surface. RF current for ablation was delivered in a point-by-point fashion, each for at least 30-60 seconds, along with the planned line lesion. Although it varies according to the patient and scar size, usually by around 20-30 points, the line ablation was planned.

Figure 2. Radiofrequency ablation of 285-ms speed Intra-atrial reentrant tachycardia (IART) performed by HD Grid mapping catheter in the 20-year-old operated ventricular septal defect patient, with a history of tricuspid valve replacement twice (the first one is by surgical mean and the second is by transcatheter method) and surgical right atrial Maze operation at another center for IART. (A) Scar mapping and critical corridor in the cavotricuspid isthmus. (B) The sparkling mapping. (C) Very low fractionated signals from bioprosthetic tricuspid valve annulus to cavotricuspid isthmus by the HD Grid catheter (especially C2-3 and D1-2). (D) Successful ablation and termination of tachycardia during line lesion at 35 Watts with irrigated RF catheter in the same region.

After the successful termination of IART during ablation and waiting for 30 minutes, induction of the IART was attempted either by programmed atrial stimulation or by atrial burst pacing both under basal conditions and after an orciprenaline or isoproterenol. Also, bidirectional blocks over the ablation site were checked. If any IART could not be induced and a bilateral conduction block over the ablation side was detected, the procedure was considered entirely successful. Complete procedural success was defined as the termination of all inducible atrial tachycardia (AT) during ablation and proof of conduction block across the lesions lines, as well as non-inducibility of AT after ablation. Partial success was defined as the ablation of the clinically relevant AT with at least one other AT being inducible at the end of the procedure.

Follow-up

Per standard practice, all patients underwent continuous telemetry monitoring, a 12-lead electrocardiogram (ECG), a 24-hour ambulatory ECG, and echocardiography before discharge. All patients were observed overnight in the hospital as part of the standard practice after catheter ablation. Additionally, patients were anticoagulated with warfarin for at least 6-8 weeks (international normalized ratio [INR] between 2 and 2.5). All patients were followed up at the outpatient clinic for symptoms suggestive of arrhythmia 1, 3, and 6 months after the procedure and then every 12 months. At each visit, a 12-lead ECG and 24-h ambulatory ECG monitoring were performed. Recurrence was defined as the detection of IART after the ablation procedure.

The study was planned in accordance with the Declaration of Helsinki after obtaining the required approval from the Local Ethics Committee (January 2023-07/03.01.2023).

Statistical Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS, Version 23.0 software, IBM). The descriptive analysis (frequency, median, and range) was used to identify the general and specific features of the studied sample. The Chi-square test [Yates (Continuity Correction) or Fisher's exact test] was used to compare categorical variables, and Mann–Whitney *U* test was used to compare continuous variables. $P < .05$ was considered statistically significant.

RESULTS

Study Population

The patients' demographic characteristics in both groups are summarized in Table 1. A total of 26 patients were included in the study, of which 16 patients were in group 1 (9 male, 56.2%) and 10 patients were in group 2 (5 male, 50%). The median age was 21 years (range: 10-36 years) in group 1 and 19 years (range 9-25 years) in group 2, and the median weights were 56.5 kg (range: 40-87 kg) and 59 kg (range 27-83 kg), respectively. Twelve patients were younger than 18 years (7 patients in group 1 and 5 in group 2). The most common presenting symptoms were palpitations, syncope, and congestive heart failure signs in 24, 8, and 7 patients, respectively. The underlying congenital heart defect was operated tetralogy of Fallot (TOF) in 10 patients, operated ventricular septal defect (VSD) in 4 patients, operated D-transposition of great arteries (D-TGA, with Senning-type atrial switch operation) in 3 patients, operated atrioventricular septal defect (AVSD) in 3 patients, operated Ebstein's anomaly in 3 patients, operated atrial septal defect (ASD) in 2 patients, and operated single ventricular physiology (Fontan procedure) in 2 patients. Most of the patients were operated on at other centers and referred for IART ablation. Seven patients also had prior ablation attempts at other centers, 1 patient had a previous Maze procedure targeting IART at another center, and 8 patients had one or more times electrical cardioversion for IART attacks before.

Table 1. Baseline Characteristics of the Patients (n = 26)

	Group 1 (n = 16)	Group 2 (n = 10)
Median age (years)	21 (12-36)	19 (10-27)
Median weight (kg)	56.5 (41-87)	59 (27-83)
Male gender (%)	9 (56.2)	5 (50)
Symptoms (patient number)		
Syncope	6	2
Palpitation	14	10
Chest pain	1	-
Fatigue/CHF signs	4	3
Prior electrophysiological study (patient number)	7*	1
Prior electrical cardioversion (patient number)	5	3
CHD type (patient number)		
ASD	1	1
AVSD	2	1
VSD	2	2
Ebstein	1	1
D-TGA (Senning)	2	1
TOF	7	3
Single ventricle (Fontan)	1	1
Echocardiographic findings		
EF (%)	55 (40-70)	50 (30-65)
Thrombus on initial TEE	3	1
Initial management		
PCICU admission	4	3
Inotropic support	3	3
Antiarrhythmics for heart rate control	16	10
Anticoagulation	16	10

Values are patient numbers (n).
*Six patients had prior successful or unsuccessful ablations, and 1 patient had a previous Maze procedure.
ASD, atrial septal defect; AVSD, atrioventricular septal defect; CHD, congenital heart disease; D-TGA, D-transposition of great arteries; EF, ejection fraction; PCICU, pediatric cardiac intensive care unit; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

Echocardiographic Findings

The echocardiography revealed severe pulmonary valve insufficiency, concomitant right heart dilatation, and right ventricular systolic dysfunction in 6 operated TOF patients.

Two of them also had a previous pulmonary valve replacement. In 2 operated D-TGA (Senning procedure) and 1 single ventricle [double inlet left ventricle (DILV) Fontan procedure] patients, the systemic ventricular function was decreased, probably secondary to incessant IART rhythm, as it was improved after the successful ablation. The latter also exhibited pericardial effusion, also attributed to congestive heart failure. Echocardiography revealed normally functioning mechanic mitral and tricuspid valves and severe pulmonary valve insufficiency in the patient with operated AVSD. Two of the patients with operated VSD had bioprosthetic tricuspid valves that had normal ventricular and tricuspid valve functions, and the other 2 patients with operated VSD did not have any apparent problems on echocardiography. Patient No. 9 in group 1 with operated VSD and bioprosthetic tricuspid valve, who also had Maze procedure previously, had a recurrence of the IART after 4 months of successful ablation, and IART was ablated again successfully, this time on the other side of the CTI, just beneath the bioprosthetic tricuspid valve. Six patients with significant residual pulmonary valve insufficiencies were referred for transcatheter valve implantation after successful IART ablation. During the initial TEE, thrombus was detected in 4 patients, and control TEE was performed after 3 months of anticoagulation. After the disappearance or stabilization of the thrombus, an ablation procedure was performed.

Electrocardiogram and Holter Data

All patients had a documented IART ECG before the ablation procedure, but only 10/16 patients in group 1 and 7/10 patients in group 2 still had incessant IART at admission to our center. Moreover, IART spontaneously converted to sinus rhythm in 3 patients before the ablation procedure when using warfarin and beta-blocker for heart rate control. So, only 14 patients had an incessant IART rhythm at basal EPS during the ablation procedure. In patients with sinus rhythm, IART was induced during the procedure; hence, in the end, all ablation procedures were performed in the IART rhythm. All but the patients with ASD and DILV had wide basal QRS, so a wide QRS tachycardia was documented. The patient with operated ASD had a narrow QRS at basal ECG and bradycardia and frequent nodal rhythms in Holter ECG recording, consistent with sinus node dysfunction. One patient with TOF showed sinus rhythm at admission. He experienced frequent premature supraventricular beats and non-sustained long R-P supraventricular tachycardia attacks, localized to the right atrial appendage during the EPS and successfully ablated. One patient with operated TGA (Senning operation) had undergone a prior ablation procedure and implanted a single chamber pacemaker (AAIR mode) for sinus nod dysfunction at our center 4 years ago. She had IART rhythm on ECG and 24-hour Holter monitoring during initial admission in another center, but we found an atrial pace rhythm at basal EPS during our procedure. One patient with VSD closure and tricuspid valve replacement suffered an aborted cardiac arrest followed by implantable cardioverter-defibrillator (ICD) implantation. He was diagnosed with recurrent IART attacks and underwent tricuspid valve replacement with a concomitant Maze operation. He also had an IART rhythm at admission to our center.

Electrophysiological Study and Ablation Characteristics

The characteristics of the procedures in both groups are summarized in Table 2. In all patients except the D-TGA patients with the Senning procedure (patients no. 10 and 11 in group 1 and 1 patient in group 2), the IART circuits were mapped to the right atrium. In patient no. 10, the IART circuit was mapped to the systemic venous baffle; contrarily, in patient no. 8, it was mapped to the pulmonary venous baffle, requiring transbaffle puncture to catheterize the pulmonary venous baffle. In the patient with operated D-TGA and Senning procedure in group 2, the IART circuit was also mapped to the systemic venous baffle. In group 1, 2 patients had double IART loops, and 2 patients had a "Figure of 8" form of the IART circuit. Two patients also had focal AT as an additional arrhythmia substrate. In 9 patients of group 1, the classic CTI region was involved in the IART circuit (CTI-dependent IART circuits). In group 2, 8 patients had a CTI-dependent IART circuit, 1 patient had a double IART loop, and 1 patient had a "Figure of 8" form of IART loop. Typically most of the IART loops in both groups were running around the atrial scar regions. In those patients with non-CTI-dependent IART loop, a single line lesion in the right atrial anterolateral wall through the previous atrial incisions' scar area was sufficient to ablate the IART successfully. The other patients with CTI-dependent IART circuits required an additional

Table 2. Electrophysiologic Characteristics of the Patients (n = 26)

	Group 1 (n = 16)	Group 2 (n = 10)	*P*
Arrhythmia/IART characteristics (n)			-
CTI dependent	10	8	
Double IART loop	2	1	
"Figure of 8" IART loop	2	-	
Add. arrhythmia (FAT)	2	1	
Median procedural time in minutes (range)	159 (110-233)	280 (180-370)	**<.001**
Median fluoroscopy time in minutes (range)	6.3 (3.1-40)	11.2 (8.6-49.7)	.452
Median lesion n = (range)	15 (8-38)	30 (8-71)	**.027**
Acute success/ recurrence (n)	16/1	8/2	**.045**
Median follow-up time in months (range)	27 (11-37)	110 (56-151)	-

Values are patient numbers (n). **P* value for comparison of acute success rates in both groups. Statistically significant findings are shown in bold.

Add., additional; ASD; atrial septal defect; AVSD, atrioventricular septal defect; CHD, congenital heart defect; CTI, cavatricuspid isthmus; EAT, ectopic atrial tachycardia; D-TGA, D-transposition of great arteries; IART, intra-atrial reentrant tachycardia; irrig. RF, irrigated radiofrequency (ablation); op, operated; RA, right atrium; RAA, right atrial appendage; TCL, tachycardia cycle length; TOF, tetralogy of Fallot; VSD, ventricular septal defect.

sideline lesion from the first vertical-line lesion through the CTI to the tricuspid annulus, creating a "Y-shaped" line lesion at the end. In patient no. 13, who had previously undergone a Maze operation, 2 IART circuits were mapped in the right atrium, one being non-CTI-dependent and the other being CTI-dependent. Also, a Y-shaped line lesion was achieved in this patient.

Additionally, in patient no. 4, sustained long-RP tachycardia (focal AT) was induced after a successful IART ablation. The arrhythmia substrate was mapped to the right atrial appendage and ablated successfully with 3 additional RF lesions. In patient no. 16, after the successful ablation of the non-CTI-dependent right atrial mid-anterior scar-related IART with 14 irrigated RF lesions, a focal AT was induced originating from the right atrial upper septum and was also successfully ablated with 3 additional RF lesions.

The median fluoroscopy time was 6.3 minutes (3.1-40 minutes), and the median fluoroscopy dose was 2.2 mGy/m^2 (ranging from 0.6 to 45) in group 1, compared to 11.2 minutes (range 8.6-49.7) and 7.45 (ranging from 4.5 to 40), respectively (P=.452). The patient with a fluoroscopy time of 40 minutes and a fluoroscopy dose of 45 mGy/m^2 in group 1 (patient no. 11) was the one with the transbaffle puncture procedure.

Using the Advisor™ HD Grid catheter and the EnSite™ AutoMap function, a median of 13 000 points (range: 8000-40 000) was obtained during mapping and a median of 3300 points (range: 2000-6000) for characterizing the reentry circuit and the substrates for IART ablation (for detailed EP and ablation characteristics of group 1 patients, look at Table 3). Neither arrhythmia nor any other complications related to the HD Grid catheter were detected. The median procedure time was 159 minutes (range: 110-233) in group 1, significantly shorter when compared to the median procedure time of 280 minutes (180-370) in group 2 (P <.05). A monodirectional irrigated RF ablation catheter (7F, 4 mm tip, Thermocoolflex) was used for ablation in 7 patients. A bidirectional irrigated RF ablation catheter (8F, 4 mm tip, St. Jude Medical) and the TactiCath SE™ force-sensing open-irrigated tip catheter (8F, 3.5 mm tip) were used for the ablation procedure in 3 and 1 patients, respectively. A median of 15 lesions was delivered (range: 8-38 lesions) for 30-60 seconds with a 35-40 Watt power and at 45°C (the target temperature) in group 1. The median lesion number was 30 (ranging from 8 to 71 lesions) in group 2, significantly more than in group 1 (P =.027).

Acute complete success was achieved in all (16/16, 100%) patients in group 1, compared to 8/10 (80%) in group 2. Only one complication was recorded. A retroperitoneal hematoma was diagnosed on the following day of the ablation procedure in patient no. 13, which was attributed to an inadvertent left femoral artery puncture. The hematoma was spontaneously resolved without any additional surgical procedure.

During the median follow-up at 27 months (range: 11-37) in group 1, there was only one patient (no. 13) where IART recurred after 4 months (1/16; recurrence rate of 6.2%). During the repeat procedure, the IART loop was diagnosed again as CTI dependent, and after ablation on the lower part of the CTI region beneath the bioprosthetic valve ring, IART was terminated and success was achieved. In group 2, there were 2 of 8 patients where recurrence of the IART occurred (25% recurrence rate), but at a median of 110 months (range from 56 to 151) follow-up.

DISCUSSION

In this study, we showed that a high-density mapping (Advisor™ HD Grid) catheter could be successfully used for postoperative scar-related IART mapping ablation in children and young adult patients with complex CHD. Although we have limited experience, we can also say that the HD Grid catheter is particularly helpful in reducing the mapping time, detecting low amplitude prevalent fractional signals that are not clearly identified with routine diagnostic catheters or RF ablation catheters, and localizing the slow conduction critical isthmus zone.

Similar to any other mapping study for a complex tachycardia substrate, the precise imaging of anatomy—and the accurate integration of these images with electrical activity—is instrumental for IART ablation in CHD.[4-7] Thanks to evolving technologies, even in complex CHD, the precise anatomy of the tachycardia substrate can be visualized with 3D electroanatomical mapping systems (such as the EnSite system). In patients with operated TOF, VSD, and AVSD, culprit circuits for IART are cavotricuspid isthmus and atriotomy scars, whereas cavotricuspid isthmus on the pulmonary venous side is a classical location in Senning/Mustard patients.[4,6] Besides 3D mapping systems, pre-perioperative CT/MR/echocardiography (TEE, ICE) delineates the localization and number of IART circuits, resulting in high ablation success rates. Additionally, the contact-force irrigated RF catheter contributes to this success by increasing the ablation depth and quality.[4] In the CHD population, IART catheter ablation acute success rate varies from 66% to 97%, recurrences from 10% to 59%, and a longer-term success rate from 53% to 92%.[4] Although acute success rates continue to increase, recurrence rates are still higher in these patients than in other arrhythmia substrates.

Despite the evolving technologies, the most challenging issues to increasing IART ablation success and reducing recurrence in CHDs are detecting low voltage signals and critical isthmus regions. Although there are some predictable IART isthmus localizations for each CHD, increasing signal quality with HD mapping systems has improved procedural success and reduced mapping times.[7-10] The lack of arrhythmogenicity, the ability to show orientation, and propagation in the arrhythmia circuits are some features that distinguish HD Grid catheters from other high-density mapping catheters.[9,11]

The Advisor™ HD Grid is a rectangular-shaped HD mapping catheter consisting of 16 electrodes that are 1 mm thick and that are equally distributed across 4 splines [4 electrodes (3 mm electrode) per spline with an interelectrode distance

Table 3. Detailed EPS and Ablation Procedural Characteristics of the Patients in Group 1

Patient No.	Age (Years)/ Weight (kg)	Operated CHD	Points Taken/Used by HD Grid Catheter During Mapping	IART Substrate Localization/ TCL (ms)	Max. Fractional Signal Duration (ms)	Ablation Catheter#/ Lesion n = (30-60 Seconds)	Procedural/ Fluoroscopy Time (Minutes)	Acute Success/ Recurrence	Follow-Up (Months)
1	15/74	TOF	>5000/>2000	RA/350	>105	7	185/6.0	Yes/No	37
2	27/52	TOF	10 000/Ns	RA/220	>110	7	150/4.6	Yes/No	34
3*	37/68	TOF	21 000/6000	RA/230	>105	7	163/6.5	Yes/No	30
4**	16/41	TOF	23 000/3000	RA/210	>110	7	155/3.1	Yes/No	29
5	31/55	TOF	>20 000/3800	RA/220	100-105	8	140/6.7	Yes/No	20
6	15/55	TOF	15 000/?	RA/230	150	8	175/7.4	Yes/No	14
7[&]	29/48	TOF	?/5500	RA/420-240	-	8	165/5.1	Yes/No	11
8	22/76	AVSD	40 000/6000	RA/250	>100	7F/34	233/10.5	Yes/No	36
9	22/75	AVSD	>10 000/>2000	RA/250	140-170	8F/10	155/6.2	Yes/No	25
10*	17/75	TGA (Senning)	18 000/2500	Systemic venous baffle/285	>110	7F/24	110/5.1	Yes/No	35
11*	30/70	TGA (Senning)	18 000/2500	Systemic and pulmonary venous baffle/270	>110	8F/27	300/40	Yes/No	29
12	12/45	ASD	26 000/3600	RA/320	180	7F/8	118/4.3	Yes/No	32
13*[,&&]	20/87	VSD, TVR, Maze	13 000/3000	RA/285-270	>110	8F/26+12	198/14.5	Yes/Yes	25
14[^]	23/58	Ebstein	13 000/3700	RA290	110-140	8F®/14	165/22.3	Yes/No	23
15	10/40	VSD, TVR	8000/2000	RA/230	100-112	8F®/15	132/9.3	Yes/No	20
16***	16/53	Fontan	10 000/1000	RA/295	-	8F®/14(+4)	130/6.2	Yes/No	11

[^]Figure of "8" configuration of the IART loop.
*(Relapsed) 2 ablation.
**Both IART (13 lesions) and right atrial appendage originating FAT (3 lesions) successfully ablated.
***Both non-CTI-dependent right atrial mid-anterior scar-related IART (14 lesions) and right atrial upper septum originating FAT (3 lesions) successfully ablated.
[&]Successful ablation of double IART loops (5+8; total 13 sessions). The second IART loop also had a "Figure of 8" configuration.
[&&]Successful ablation of 2 different IART loops (26+12; total 38 lesions). The case also had a history of Maze procedure before. Also, after successful ablation, retroperitoneal hematoma occurred as a complication due to an inadvertent arterial puncture during the left femoral venous access procedure.
#Ablation catheters used were 7F irrigated RFA catheter (Therapy™ CoolFlex™ catheter, monodirectional, StJude, Stpaule, MN), 8F irrigated RFA catheter (AbbottFlexability™ ablation catheter, Sensor enabled™, bidirectional D/F curve, StJude Medical), 8F irrigated RF® (Abbott TactiCath™ Contact Force Ablation Catheter, Sensor Enabled™, bidirectional D/F curve, StJude Medical).
ASD, atrial septal defect; AVSD, atrioventricular septal defect; CTI, cavatricuspid isthmus; EAT, ectopic atrial tachycardia; IART, intra-atrial reentrant tachycardia; irrig. RF, irrigated radiofrequency (ablation); op, operated; RA, right atrium; RAA, right atrial appendage; TCL, tachycardia cycle length; TGA, transposition of great arteries; TOF, tetralogy of Fallot; TVR, tricuspid valve replacement; VSD, ventricular septal defect.

of 3 mm]. The recording of an electrical impulse is acquired along and across the splines between adjacent electrodes. This feature allows higher mapping sensitivity regardless of the signals' direction of activation, unlike traditional mapping catheters, which only allow bipolar recording in one direction. Moreover, its flexibility and smooth shape make the HD Grid catheter particularly atraumatic, maneuverable, and, above all, not arrhythmogenic as other HD catheters.[9-11] In our general practice, we use HD Grid catheters especially in a larger atrial anatomy, at >7 years and >30 kg. While it is generally used with a long sheath and "steerable" long sheath, it is possible to use it without a long sheath in young children. Thanks to the catheter's soft structure and gentle tissue contact, we have not experienced any catheter-related arrhythmias or mechanical problems until now. Fluoroscopy support is required in a limited time, especially in complex anatomies and patients with prosthetic valves.

Even though pediatric studies involving mapping and ablation in CHD patients with HD Grid catheters are not available enough, the catheters' safety and effectiveness have been proven in adult CHD cases.[9,10] The largest AT ablation series, which included 24 adult patients with CHD, was reported recently by Krause et al.[9] In this study, the researchers achieved total success in approximately 90% (complete procedural success was achieved in 21/24 subjects, and partial success in 2/24 patients) of cases by HD Grid mapping catheter, accompanied by the EnSite Precision 3D system and irrigated RF catheter (TactiCath SE TM). The authors claimed that the HD Grid catheter increased their procedural success by about 10% in scar-related AT ablations in CHD. In this study, most cases were TOF, VSD, and AVSD (12/24). The arrhythmia substrate was typically localized in the right atrium. The average procedure and fluoroscopy time was 2071 minutes and 7.1 minutes, respectively. Furthermore, the subjects have not experienced any complications explicitly related to HD Grid catheters. Their recurrence rates were approximately 12.5% (3/24), but recurrence was more likely, especially in those with multiple arrhythmia substrates.

We used the HD Grid catheter successfully in 16 CHD-related IART ablation cases in 3 years starting from October 2019, when this catheter was available in Turkey. Almost half of our cases (7/16) were operated TOF, and all but one of them were patients exhibiting biventricular 4-chamber circulations (TOF, ASD, VSD, AVSD, and Ebstein). Using the Advisor™ HD Grid catheter and the EnSite™ AutoMap function, a median of 13 000 points was obtained during mapping and a median of 3300 points for characterizing the reentry circuit and the substrates for IART ablation. All but 2 patients with a Senning operation had an IART circuit on the right atrium, and more than half of them were CTI dependent. Only the patient with the Senning operation had a prolonged fluoroscopy time (40 minutes) secondary to the transbaffle procedure for entering the left atrium. We were successful in all cases in group 1. Only one patient (no. 9) had a recurrence after 4 months. During the repeated procedure, CTI-dependent IART was again ablated successfully, but this time on the other side of the CTI, just beneath the bioprosthetic valve ring. As a result, compared to our unpublished prior IART mapping-ablation experiences before HD Grid catheter use, the new catheter shortened the mapping times and, consequently, the total duration of the procedure. Although it is possible to attribute the higher rate of acute success and a lower rate of recurrence to the newer irrigated RF ablation systems like contact force (Tacticath™ catheter, Abbott), we believe that more precise children and young adults mapping of the IART also contributes to higher acute success rates and lower recurrence. We propose that the most important feature is its ability to precisely display areas of low voltage fraction not visible by conventional EP/or RF catheters. Finally, the HD Grid catheter provided clear tissue contact and helped to delineate anatomy, probably owing to the shape or structure of the catheter.

Study Limitations

The present study has certain limitations, being a retrospective single-center study with a relatively small sample size and a short follow-up time. Furthermore, most of our patients were referred from other centers and suffered heterogeneous cardiac pathologies with significant residual hemodynamic problems, which posed challenges in the IART ablation. So the study aims to share the early results of our experience with the HD Grid catheter in the IART ablation of pediatric and young adult patients. Obviously, multicenter, randomized prospective clinical trials are required to confirm and reassure our observations.

CONCLUSION

The utility of the Advisor™ HD Grid high-density mapping catheter in the IART ablation of children and young adults with CHD seems to be a feasible alternative to increase procedural success and shorten the procedure's duration. However, studies involving more cases are required to draw a definite conclusion about HD Grid catheters' safety and long-term success in pediatric patients.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Training and Research Hospital (January 2023-07/03.01.2023).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

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