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Long Term Outcomes of Pediatric Patients After Catheter Ablation for Possible Arrhythmia Induced Cardiomyopathy

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Abstract

Background: Arrhythmia induced cardiomyopathy (AiCM) is reversible, and catheter ablation has become the standard treatment for most arrhythmias. Given the potential overlap between different forms of cardiomyopathy and the frequent absence of documentation of slow tachycardia before first presentation, the diagnosis of AiCM can often made only in retrospective.

Methods: A single center retrospective study including patients who had ablation for presumed AiCM after January 2011 to assess the outcomes of ablation, and the final diagnosis. Patient demographics, types of arrhythmias, procedural details and follow up data were obtained from medical records.

Results: 20 patients (10 female) were included in the study with the following distribution of arrhythmias: Atrial Ectopic Tachycardia (AET) = 8, Permanent Junctional Reciprocating Tachycardia (PJRT) = 6, Ventricular Tachycardia = 3, Premature Ventricular Contraction = 1, Atrial Flutter = 1, Atrioventricular Reciprocating Tachycardia = 1. 13/20 (65%) had successful primary ablation resulting in recovery of function and/or discontinuation of antiarrhythmic medication. In 8/20 (20%) ablation was performed under mechanical circulatory support, 3/20 (15%) had arrhythmia recurrence. Overall long-term control of arrhythmia with ablation alone was achieved in 17/20 (85%). One AET patient showed no recovery of function despite successful ablation, consequently requiring heart transplant due to later confirmed gene-positive cardiomyopathy. Overall, 19 patients (95%) showed normal cardiac function at the end of study period with diagnosis of AiCM. There was one significant complication with AV block due to RF ablation on ECMO in a newborn with PJRT.

Conclusions: When carefully selected, ablation for pediatric patients in AICM has a high success rate including long term recovery of the ventricular function, even for small patients. Very rarely ventricular function will not recover despite successful ablation as genetic cardiomyopathies can present with secondary arrhythmia.

Introduction

Arrhythmia induced cardiomyopathy (AiCM) is a condition where arrhythmias cause left ventricle (LV) dysfunction, often resulting in heart failure. Different types of arrhythmias, such as atrial tachycardia, frequent premature ventricular contractions (PVCs) and atrial fibrillation (AF) are known to cause AiCM, and many are reversible once the culprit arrhythmia is controlled [1, 2]. Among AiCM, those caused by tachycardia have traditionally been called Tachycardia-Induced cardiomyopathy (T-CM). Catheter ablation has become the mainstream of treatment for almost any types of arrhythmias in modern era and is considered as first-line therapy for pediatric patients with T-CM [3]. Procedural risk is higher in infants with smaller body weight [4], or those who are on mechanical circulatory support (MCS) [5]. Previous studies in pediatric T-CM patients have provided insights to predict recovery [6], or to discriminate patients from those with idiopathic Dilated cardiomyopathy (DCM) [7]. However, as the diagnosis of AiCM can be only confirmed retrospectively once functional recovery is seen with controlling of the underlying arrhythmia [1, 2]. Especially differencing genetic cardiomyopathy and

secondary arrhythmia from AiCM is basically impossible. We therefore sought to assess the outcomes and the final diagnosis for those who had catheter ablation for presumed AiCM.

Materials & Methods

This was a single-center retrospective study at the Royal Children's Hospital, Melbourne, approved by the institutional review board (ERM Number: 115050). All patients who had catheter ablation for presumed AiCM after January 2011 (following the criteria as described by Moore [7]) were included in the study. Patients who presented with decreased LV function (defined as LV ejection fraction (LVEF) < 50%), dilated LV and in the setting of arrhythmia were provisionally diagnosed with AiCM according to the criteria published by Moore et al [7, 8]. Arrhythmias were assessed carefully by two electrophysiologists especially for those presenting with tachycardia (presumed T-CM patients), to discriminate from sinus tachycardia, and existing literatures [7, 8] were referred accordingly in this process. While LV end-diastolic dimension (LVEDD) ≧ 2 SD commonly used for LV dilation [5, 6], one patient did not meet this criterion (LVEDD of 1.8 SD, though with LVEF of 15.7%) and one patient had no reliable measurement before immediately going on ECMO (however, contractility was obviously and significantly reduced). These patients were still included as the clinical picture matched with AiCM. Patient demographics, treatment course, outcomes and final diagnosis of each patient at the end of the follow up period were collected from the electronic medical records. Successful ablation was defined as elimination of the documented arrhythmia, resulting in LV functional recovery and/or discontinuation of antiarrhythmic medication. Continuous variables are expressed as median (and interquartile range: IQR). Statistical analysis was performed using SPSS ver. 30.0 (IBM corp., Armonk, New York, USA).

Results

During the study period, there were 20 patients (10 female, 50%) in total who had catheter ablation for presumed AiCM. The classification of arrhythmia was: Atrial Ectopic Tachycardia (AET) = 8, Permanent Junctional Reciprocating Tachycardia (PJRT) = 6, Ventricular Tachycardia (VT) = 3, frequent Premature Ventricular Contraction (PVC) = 1, Atrial Flutter (AFL) = 1, Atrioventricular Reciprocating Tachycardia (AVRT) = 1. At the time of initial assessment, all patients had initial left ventricular ejection fraction (LVEF) of less than 50% (measured with Teicholtz method) and all but two had left ventricular end-diastolic dimension (LVEDD) Z score above 2. Median (and IQR) for LVEF and LVEDD Z score was 29.7 (21.4–38.8), and 4.0 (2.5–5.4) respectively. Median age at presentation was 6.1 (IQR = 0.6–12.8, range = 0-15.2) years and there were two neonates. Median follow up duration was 5.2 (IQR = 2.4–8.4) years. Body weight and age at initial ablation was 19.4 (IQR = 15.4–49.4, rage = 3.2–71.0) kg, and 6.2 (IQR = 3.8–13.4, range = 0-16.3) years respectively, with four ablations performed under MCS. Median time for LVEF and LVEDD recovery (defined as LVEF reaching ≧ 50% consistently, and LVEDD < 2SD consistently) since diagnosis was 132 (46–221) days and 126 (66–261) days respectively. Eight patients had mechanical support at initial presentation, five on Extracorporeal membrane oxygenation (ECMO), and three on Left Ventricular Assist Device (LVAD). Six patients have been already considered or referred for transplantation. Patient demographics are summarized in Table 1.

10/20 (50%) had more than a month period of medical management prior to catheter ablation, with four (21%) having normalization of LVEF/LVEDD before catheter ablation. Of these ten patients treated more than a month medically prior to catheter ablation, three were treated without antiarrhythmic medication (16% of the entire cohort). Two of three managed without antiarrhythmic medication were on a LVAD who could not achieve functional recovery. The other patient had VT, with transient functional recovery though deteriorated soon after recurrence of VT and then had semi-urgent catheter ablation. Among the seven patients who had antiarrhythmic medication as initial management, flecainide was the most commonly used medication (4/7 patients). Other medications included beta blockers, verapamil, mexiletine and amiodarone. Four of the seven patient who were managed medically initially, had functional recovery, all of these with flecainide (3 PJRT, 2 were initially on Extra Corporeal Membranous Oxygenation (ECMO), 1 had frequent PVC). Among the four patient who had functional recovery with medication prior to catheter ablation, two had successful ablation later allowing them to stop antiarrhythmic medication.

Overall, 17/20 (85%) had successful ablation therapy, 13/20 (65%) had a successful ablation in the first session without recurrence. One ablation (5%) resulted in complete AVB requiring Pacemaker implantation (PMI), but had successful functional recovery. This patient was a neonate presenting with PJRT who could not come off ECMO despite medical therapy, hence had an ablation under ECMO support. At the time of the procedure, it was clear that AV block might be a likely outcome and though not ideal would end the incessant tachycardia. 3/20 (15%) had recurrence of their tachycardia within six months (1; 0.6-year-old girl presenting with PJRT, but function recovered after ablation. Managed for a long time with flecainide with no deterioration in cardiac function, as further ablation was not successful. This patient recently had successful ablation and now off flecainide, for 6 months. 2; A neonate baby boy with AFL, had successful second session with an irrigated tip catheter. 3; 12.9-year-old girl presenting with VT, had successful second session. 3/20 (15%) were not successful at first session, and patient summaries as follows. 1) 5-year-old boy presenting with AET on ECMO, which was not inducible at the time of EP study. Managed with flecainide and has successful second session. 2) 12.5-year-old boy with multifocal AET who had the first session under LVAD support. Had successful second session allowing him to come off LVAD, also turned out to have RYR2 variant later. 3) 10-year-old girl with frequent PVC ‘s (originating from posterior papillary muscle) who was managed with flecainide, resulting in functional recovery.

The 17 patients who had successful ablation do not include a 6.6-year-old boy with AET who had a successful ablation of AET while on LVAD support, but then had no functional recovery. His genetic testing revealed a pathogenic TNNT2 variant, he later had a heart transplant. This was the only patient who did not achieve functional recovery in the cohort. Of note, six patients were previously referred or considered for heart transplant with five of them successfully recovering after ablation. All but the above patient with TNNT2 variation maintained normal LVEF and LVEDD at the latest follow up. Clinical outcomes are summarized as flow chart in Fig. 1.

During the follow up period, none of the patient had readmission due to heart failure symptoms after initial presentation.

Discussion

AiCM is a rare but reversible cause of ventricular dysfunction in pediatric population, and while there is an algorithm to help with the diagnosis [7], final diagnosis can only made retrospectively once good functional recover has been confirmed after controlling the responsible arrhythmia. In this condition it is especially important to have a high degree of suspicion. AiCM due to tachycardia (or T-CM) can be misdiagnosed as dilated cardiomyopathy with secondary sinus tachycardia [9]. As such, it is not surprising that there were six patients in total who have been referred for consideration of heart transplant. Of the 15 patients with T-CM (AET, AVRT and PJRT as causative arrhythmia), all but one patient with AET matched with the risk score proposed by Moore et al, to diagnose T-CM [7]. This AET patient had a slow AET of right atrial appendage origin. The p wave morphology of this appendage origin AET was very similar to the morphology in sinus rhythm [10], which makes it difficult to differentiate. In our cohort, both positive and negative predictive value of 93%, which proves the risk score to be reasonably reliable,

There is one recent study suggesting late gadolinium enhancement (LGE) to differentiate T-CM due to supraventricular tachycardia (SVT) from DCM [11], though another study could not confirm this and lower LVEDD at the time of diagnosis was the only relevant predictor for diagnosis of AiCM, [12]. None of the patients where the diagnosis of AiCM was rather questionable have been eligible for a MRI due to the size of the patient, the presence of an assist device or other contraindications, so we have no MRI data. Instead, meticulous observation of PR interval or P wave morphology and repeat Holter ECGs to watch HR variability and pauses are very important to suspect AET. Those who do not achieve functional recovery after arrhythmia management should be worked up for possible underlying dilated cardiomyopathy [6].

Our study showed that catheter ablation was successful after the first ablation in 65%, and overall success rate was 85% when patient had further ablations. Of the eight patients who had sessions under MCS (5 ECMO, 3 LVAD), four have been permanently successful at first session (4/8, 50%). One had successful second session under LVAD, and another had successful second session after coming off ECMO on medical management. Overall, 5/8 (63%) had successful ablation under MCS, and there was only one severe complication (13%), which is comparable to a previous study [5]. Catheter ablation – both as initial or delayed intervention is a good option for pediatric patients with AiCM, timing should still be tailored for each patient, especially for neonates or those on MCS.

Apart from the one patient with *TNNT2* variant requiring heart transplant, patients (19/20, 95%) maintained normal LVEF/LVEDD once they recovered during the average follow up of 5.5 years. Our study proves that AiCM has very good prognosis once the causative arrhythmia been controlled (either medically or with catheter ablation). There were six patient who had readmission throughout the course,

all due to recurrence of tachycardia and its management, and none had recurrence of heart failure. This seems to be quite different from adult population with AF-AiCM where the recurrence of AF frequently causing heart failure [13]. Sudden death in the T-iCM adult cohort due to recurrent tachycardia has been reported, though the underlying arrhythmia has been AF in all case [14]. PVC-induced cardiomyopathy is another major form of AiCM in adults with acute success rate of 84% in a large multi-center registry [15], 17% of patient who had successful ablation for PVC-induced cardiomyopathy had recurrence of PVC burden which accompanies deterioration of LVEF [16]. PVC's rarely cause cardiomyopathy in children, so most arrhythmias in our cohort were tachycardia-induced, predominantly SVT. There were no patients with AF, and only one patient with frequent PVCs. The pediatric group therefore seems to be different with no recurrence of heart failure despite recurrence of arrhythmia.

Conclusions

Catheter ablation for AiCM in the pediatric population with a median age of 6.1 years (including two neonates) had an overall success rate of 80% with acceptable complication risk even in the setting of severe ventricular dysfunction needing mechanical support. Recurrences can be treated with repeat ablation or medication and the long-term outcome is favorable with 95% of the patients maintaining normal LVEF/LVEDD. Those who cannot achieve successful recovery with combination of catheter ablation and medical therapy should worked up for an underlying cardiomyopathy.

Declarations

This study was approved by the local institutional review board and the need of individual informed consent was weaved by the local IRB for this was a retrospective study.

Author Contribution

Dr Doi, Dr Tien, Dr Davis and Dr Pflaumer all contributed to writing the manuscript and reviewed it before submission.

Acknowledgments

None

Conflict of Interest Statement

The authors declare no conflict of interest for this article.

Data Availability

The data that support the findings of this study is securely stored in our hospital system, and access will be considered upon reasonable request.

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Table

Table 1. Patient demographics

Total number of patients	20
Female	10/20 (50%)
Age at presentation (years)	6.1 (0.6 - 12.8)
Body weight at the time of catheter ablation (kg)	19.4 (15.4 - 49.4)
LVEF at presentation (%)	29.7 (21.4 - 38.8)
LVEDD at presentation (Z score)	4.0 (2.5 - 5.4)
Types of arrhythmias	AET 8 PJRT 6 VT 3 Frequent PVCs 1 AFL 1 AVRT 1
Follow up period (years)	5.2 (2.4 - 7.7)
Time to LVEF recovery since diagnosis (days)	132 (46 - 221)
Time to LVEDD recovery since diagnosis (days)	126 (66 - 261)

Values are median (IQR: Q1 – Q3), AET = Atrial Ectopic Tachycardia; AFL = Atrial Flutter; AVRT = Atrioventricular Reciprocating Tachycardia; LVEF = Left Ventricular Ejection Fraction; LVEDD = Left Ventricular End Diastolic Dimension; PJRT = Permanent Junctional Reciprocating Tachycardia; PVC = Premature Ventricular Contraction

Figures

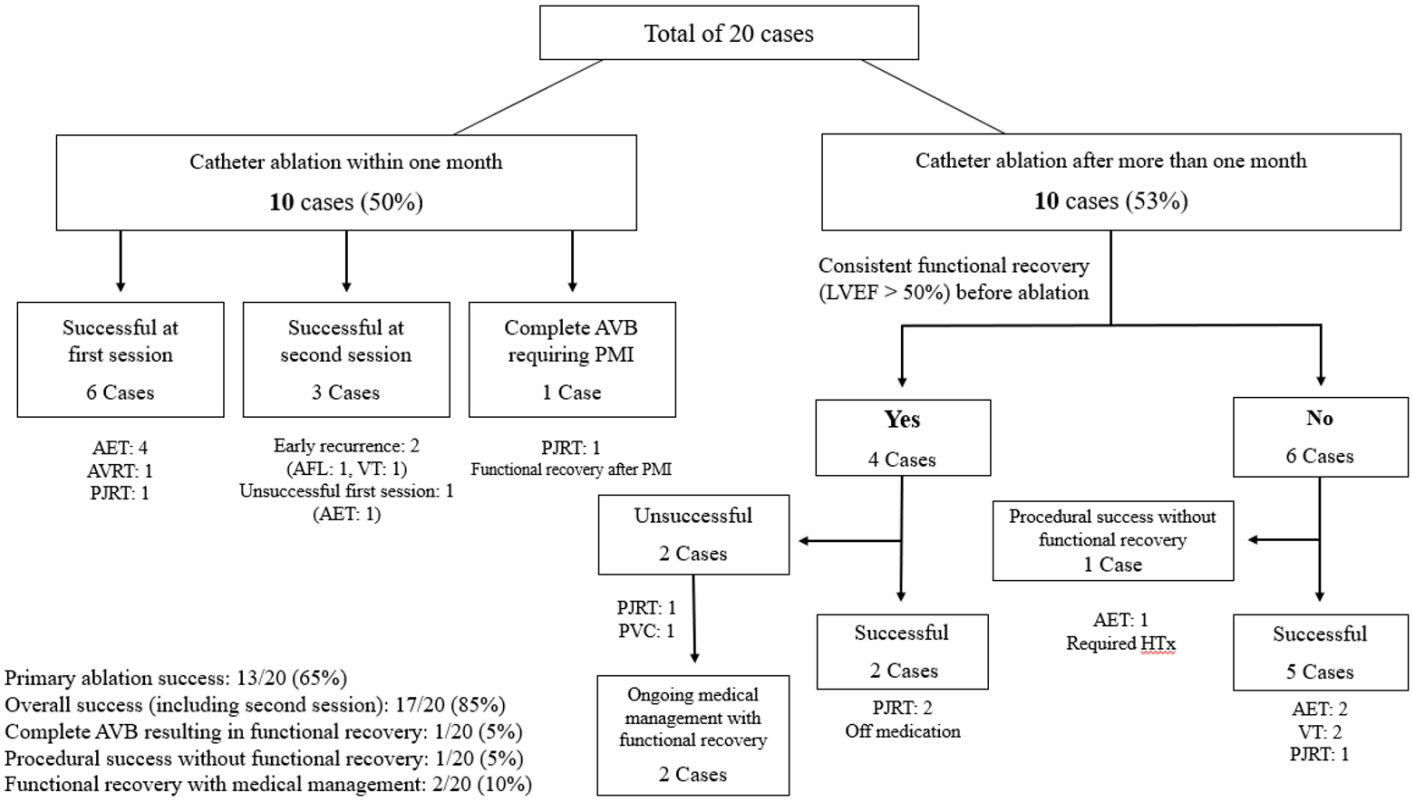


Figure 1

Flow chart showing the outcomes of the cohort. AET = Atrial Ectopic Tachycardia; AFL = Atrial Flutter; AVRT = Atrioventricular Reciprocating Tachycardia; LVEF = Left Ventricular Ejection Fraction; HTx = Heart Transplant; PJRT = Permanent Junctional Reciprocating Tachycardia; PVC = Premature Ventricular Contraction; VT = Ventricular Tachycardia