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Outcome of Intra-Atrial Re-Entrant Tachycardia Catheter Ablation in Adults With Congenital Heart Disease

Negative Impact of Age and Complex Atrial Surgery

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Objectives The aim of this study was to determine the acute and long-term outcome of radiofrequency catheter ablation (RFCA) for intra-atrial re-entrant tachycardia (IART) in adults with congenital heart disease (CHD), and predictors of these outcomes.

Background Atrial myopathy can be progressive in CHD and contributes to the substrate for IART. Although the outcome of RFCA for IART has been well described in children and adolescents with CHD, it is unclear whether these results are similar in the adult population.

Methods Clinical records of adults with CHD undergoing attempted RFCA of IART were analyzed retrospectively. Multivariate analyses identified clinical and procedural factors that predicted acute and long-term outcomes.

Results A total of 193 procedures was performed in 130 patients (mean age 40 ± 13 years); 82 of 118 (69%) initially attempted RFCA were successful, defined as termination of all IART circuits. The use of electroanatomic mapping was associated with a successful RFCA, whereas Fontan palliation and Mustard repair were associated with an unsuccessful RFCA. Median clinical follow-up of 77 patients (≥2 months of follow-up) after a successful RFCA was 3.7 years (range 0.2 to 10.2 years). IART recurrence was noted in 48%, cardioversion/reablation in 42%, and death in 4%. Older age and Fontan palliation were independent predictors of IART recurrence.

Conclusions In adults with CHD, acute and long-term outcomes of RFCA for IART are similar to those reported for younger cohorts. Complex atrial surgery limits the success of RFCA, and older age is associated with a higher risk of IART recurrence. (J Am Coll Cardiol 2010;56:1589–96) © 2010 by the American College of Cardiology Foundation

Intra-atrial re-entrant tachycardia (IART) is the most common arrhythmia (12% to 41%) among the rapidly growing population of adult survivors of surgically corrected congenital heart disease (CHD) (1–3). Although IART can occur after any CHD surgery, the frequency is highest among patients who have undergone complex atrial surgeries such as atrial switch operations for complete transposition of the great arteries (Mustard/Senning operation) or Fontan palliation for single ventricle physiology (1,4).

Radiofrequency catheter ablation (RFCA) represents an important therapeutic strategy for patients with IART (4–12), considering the unsatisfactory results with antiarrhythmic drug therapy alone, or in combination with antitachycardia pacing (13). The reported acute success rates in pediatric, adolescent, and young adult populations are in the range of 66% to 100% (4–11), with a high IART recurrence rate (43%) at long-term follow-up (4).

In the older patient with CHD, more advanced atrial hypertrophy and/or fibrosis, atrial dilation, and ventricular dysfunction may impact negatively on the acute and long-term outcomes of RFCA for IART. Therefore, we sought to determine whether the older adult CHD patient could anticipate an acute and long-term outcome with RFCA of IART comparable to that reported for younger patient cohorts. In addition, we tried to identify patient and procedural factors associated with these outcomes.

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Abbreviations and Acronyms

ASD = atrial septal defect
CHD = congenital heart disease
CI = confidence interval
CTI = cavotricuspid-isthmus
IART = intra-atrial re-entrant tachycardia
RF = radiofrequency
RFCA = radiofrequency catheter ablation
TOF = tetralogy of Fallot

Methods

Patient selection and data collection. A retrospective analysis of the acute and long-term outcomes of all adults (≥18 years of age) with CHD undergoing attempted ablation of IART at the Toronto Congenital Cardiac Center for Adults between January 1993 and September 2009 was performed. All patients had a history of sustained and/or recurrent atrial tachycardia. Written informed consent for RFCA was obtained in all patients in accordance with institutional guidelines. To analyze long-term outcome, patients with a clinical follow-up duration <2 months were excluded. The study was approved by the institutional ethics review board.

Review of medical records and procedure notes was used to ascertain the dates of occurrence of the following clinical events: 1) electrocardiographically documented occurrence of IART; 2) IART cardioversion by countershock, pacing, or intravenous drug therapy; 3) IART reablation; and 4) death. Patients were interviewed by telephone to ensure continuous clinical follow-up for all patients within 1 year of closure of the study period in September 2009.

Definition of IART. IART was defined as a re-entrant atrial rhythm independent of atrioventricular conduction, characterized by sudden onset and termination and a constant cycle length (14). Re-entry was confirmed by electroanatomic mapping and/or by entrainment.

Mapping and ablation technique. Vascular access was typically obtained from the femoral vein, and less commonly, the subclavian or internal jugular veins if the femoral veins were inaccessible. After June 1, 2001, electroanatomic mapping (CARTO System, Biosense Webster, Diamond Bar, California) was used at the discretion of the operator. Activation mapping of IART was initially performed in the systemic venous atrium, and then the pulmonary venous atrium if necessary, through the retrograde aortic approach. If IART was not present at the commencement of the procedure, IART induction was attempted with programmed atrial stimulation using 2 different drive cycle lengths and as many as 3 extrastimuli from the high and low right atrium. Programmed stimulation was repeated with isoproterenol at the discretion of the operator if IART was still noninducible. During activation mapping, areas with low-amplitude electrograms (generally ≤0.03 mV) were considered regions of scar or a surgical patch. Double potentials indicated crista terminalis, lines of functional block, old ablation line, atriotomy incision, or other suture lines. Zones of slow conduction, possibly critical to the maintenance of the IART circuit, were identified by low-amplitude fractionated atrial electrograms occurring in atrial electrical diastole. These zones were further defined by their relation to known anatomic areas (e.g., tricuspid valve annulus and superior or inferior vena cava) or electrophysiologically identified areas of conduction block (e.g., atriotomies or baffle suture lines identified as lines of double potentials). Entrainment mapping was used in limited instances to clarify the critical limbs of large re-entrant circuits particularly if figure-of-8 re-entry was suspected.

Standard ablation was performed using a 4-mm, 8-mm, or 10-mm tip radiofrequency (RF) ablation catheter; after June 1, 2001, irrigated ablation was performed with an 8F, open saline-irrigated tip RF ablation catheter (Navistar Thermocool, Biosense Webster) at the discretion of the operator. Saline irrigation at 20 to 30 cc/min was infused during powers of 30 to 50 W. When possible, linear lesions were created between areas of anatomic or functional block, and the development of local widely split potentials during RF delivery was used to define conduction block (15). After IART termination during RF delivery, programmed stimulation was repeated as before, and further mapping and ablation was performed if additional IART circuits were induced. This was repeated until IART noninducibility was rendered at the discretion of the operator.

Acute outcome measures. Successful RFCA was defined as a procedure in which all targeted IART circuits were terminated during RF application, and were subsequently not inducible by programmed stimulation. Unsuccessful RFCA or procedural failures included patients in whom 1) no IART was inducible at the commencement of the procedure; 2) not all IART circuits were ablated; 3) the IART degenerated to atrial fibrillation before mapping was completed; or 4) the IART was unmappable because of hemodynamic compromise requiring cardioversion.

Statistical analysis. All statistics were performed using SPSS for Windows Version 15.0 (SPSS Inc., Chicago, Illinois). Continuous data were presented as mean ± SD or median (range), as appropriate. Exact binomial 95% confidence intervals (CIs) were calculated for both acute success rate and IART recurrence rate. Univariate comparisons were made using the unpaired Student *t* test or Mann-Whitney *U* test for continuous variables, and the chi-square test or Fisher exact test for categorical data. Cumulative freedom from IART recurrence was constructed with the use of the Kaplan-Meier method and groups were compared by log-rank statistics.

Predictors of successful initial RFCA were determined using a backward-stepwise multivariate logistic regression analysis. Age at ablation, sex, Fontan palliation, Mustard repair, history of atrial fibrillation, recent onset IART (<1 year), electroanatomic mapping, irrigated ablation, presence of >1 IART circuit, and baseline IART at commencement of procedure were entered into the model. Predictors of IART recurrence after RFCA were determined using a backward-stepwise multivariable Cox regression analysis. The variables described in the preceding text were entered into the model, with the

addition of successful RFCA for the intention-to-treat analysis. For both multivariate analyses, p-enter was chosen to be 0.05 and p-remove was 0.10.

Results

Patient population. The study group consisted of 130 patients, with a mean age of 40 ± 13 years (range 18 to 76 years) at initial RFCA. The most common underlying anatomic diagnoses were secundum atrial septum defect (ASD), complete transposition of the great arteries, variants of single ventricle physiology, and tetralogy of Fallot (TOF). Most patients (94%) had prior cardiac surgical intervention (Table 1). None of the Fontan patients had an extracardiac conduit. The types of Fontan palliation were as follows: 1) atriopulmonary anastomosis (n = 12); 2) atrioventricular connection (n = 5); or 3) lateral atrial tunnel (n = 2).

A total of 193 RFCA procedures was performed between July 1993 and September 2009, and included 28 patients who had 2 procedures, 4 patients who had 3 procedures, 5 patients who had 4 procedures, and 3 patients who had 5 procedures. Table 2 shows baseline and procedural characteristics of the initial RFCA. The use of electroanatomic mapping was associated with a longer total procedure time (median 240 min electroanatomic mapping vs. 185 min fluoroscopy, p = 0.001) but a similar fluoroscopy time (median 42 min electroanatomic mapping vs. 47 min fluoroscopy, p = 0.270).

Acute outcomes of initial RFCA. Of the 130 patients, vascular access difficulties precluded mapping/ablation in 6 patients (4.6%), and no spontaneous or inducible IART precluded mapping/ablation in 6 patients (4.6%). Isoproterenol was used in 8 of 12 patients (67%) without baseline spontaneous or induced IART, and was successful in inducing sustained IART in 6 of 8 patients (75%). When restricted to patients where an ablation was performed, successful RFCA was accomplished in 82 of 118 patients (69%; 95% confidence interval [CI]: 60% to 78%). Reasons for an unsuccessful RFCA were failed ablation of all IART (n = 26, 20%) and ablation of some but not all IART (n = 10, 7.7%). The overall success rate was 82 of 130 patients (63%; 95% CI: 54% to 71%) (Table 2). Multivariate logistic regression analysis showed that patients with Fontan palliation or atrial switch operations were less likely to have acute procedural success, and that patients who had electroanatomic mapping were more likely to have an acute procedural success (Table 3).

Patients with Fontan palliation were more likely to exhibit a noncavotricuspid isthmus (CTI)-dependent IART circuit compared with other CHD patients (79% vs. 51%, p = 0.021). Reasons for an unsuccessful RFCA in patients with Fontan palliation were failed ablation of non–CTI-dependent IART (44%); failed ablation of CTI-dependent IART (33%); and no spontaneous or inducible IART precluding mapping/ablation (22%).

In patients with atrial switch operations who had a successful RFCA, the location of successful RF ablation was the CTI in 29% of patients. In Mustard patients with a CTI-dependent IART, for whom surgical data were avail-

Table 1 Anatomic Diagnosis and Surgical Status (n = 130)

Ostium secundum atrial septal defect	
Repaired	21 (16%)
Unrepaired	6 (5%)
Complete transposition of the great arteries	
Mustard repair	21 (16%)
Rastelli repair	3 (2%)
Single ventricle physiology	
Fontan repair	19 (15%)
Central shunt	3 (2%)
Tetralogy of Fallot repaired	18 (14%)
Partial/total anomalous pulmonary venous return	
Repaired	9 (7%)
Unrepaired	1 (1%)
Atrioventricular septal defect repaired	9 (7%)
Ventricular septal defect repaired	5 (4%)
Other biventricular congenital heart disease	
Repaired	14 (11%)
Unrepaired	1 (1%)

Table 2 Clinical and Procedural Characteristics at Initial Radiofrequency Catheter Ablation (n = 130)

Clinical characteristics	
Age, yrs	40.4 ± 12.8
Male	58 (45%)
History of atrial fibrillation	26 (20%)
History of cardioversion	78 (60%)
Pacemaker	26 (20%)
Duration of first IART to RFCA, yrs	2.5 (0.01–30.2)
AAD therapy	107 (82%)
Digoxin	23 (18%)
AAD class I	6 (5%)
AAD class II	51 (39%)
AAD class III	60 (46%)
AAD class IV	10 (8%)
Echocardiogram	
Subaortic ventricular dysfunction, moderate or greater	26 (20%)
Subpulmonary ventricular dysfunction, moderate or greater	18 (14%)
Right atrial dilation, moderate or greater	46 (35%)
Procedural characteristics	
Electroanatomic mapping	84 (65%)
Irrigated-tip ablation catheter	89 (69%)
Large-tip (8- or 10-mm) ablation catheter	32 (25%)
Procedure time, min	225 (78–530)
Fluoroscopy time, min	42.4 (13.0–165.1)
Ablation time, s	1,161 (40–4,074)
Number of radiofrequency lesions	24 (4–74)
>1 IART circuits	32 (25%)
Acute procedural outcome	
Successful RFCA	82 (63%)
Unsuccessful RFCA	48 (37%)

AAD = antiarrhythmic drug; IART = intra-atrial re-entrant tachycardia; RFCA = radiofrequency catheter ablation.

Table 3 Predictors of Acute Procedural Success of Initial Radiofrequency Catheter Ablation

	Univariate Analysis			Multivariate Analysis		
	Odds Ratio	95% CI	p Value	Odds Ratio	95% CI	p Value
Patient factors						
Age at ablation, yrs	1.010	0.982–1.039	0.487			
Male	0.809	0.396–1.656	0.563			
Fontan palliation	0.602	0.226–1.606	0.310	0.385	0.134–1.107	0.076
Mustard repair	0.370	0.143–0.958	0.041	0.230	0.079–0.665	0.007
History of atrial fibrillation	1.133	0.461–2.788	0.785			
Recent onset IART, <1 yr	0.757	0.345–1.663	0.489			
Technology						
Electroanatomic mapping	1.335	0.637–2.796	0.444	2.112	0.917–4.867	0.079
Irrigated ablation	1.140	0.532–2.443	0.736			
Procedural complexity						
>1 IART circuit	0.812	0.358–1.839	0.618			
Baseline rhythm IART	0.741	0.362–1.516	0.411			

CI = confidence interval; other abbreviations as in Table 2.

able, the coronary sinus was kept on the pulmonary venous side or surgically incised to permit redirection to the systemic venous atrium in 4 of 5 patients (80%). In the other patient, the suture line was placed anterior to the coronary sinus ostium, keeping it and a proportion of the medial isthmus on the systemic venous side. Reasons for an unsuccessful RFCA in patients with Mustard repair were failed ablation of CTI-dependent IART (42%); failed ablation of non–CTI-dependent IART (25%); inability to map pulmonary venous atrium due to vascular access difficulties (25%); and no spontaneous/inducible IART precluding mapping/ablation (8%).

Overall, procedural complications were encountered in 13 of 193 (7%) procedures. Five (3%) patients needed a permanent pacemaker, including 4 patients (underlying diagnosis of atrioventricular septal defect, Ebstein's anomaly, supravalvular aortic stenosis, and TOF) who had complete heart block after ablation of a CTI-dependent IART and 1 patient with Mustard repair and prior sinus node dysfunction who had sinus arrest after successful RF ablation between the baffle and superior vena caval orifice. Other complications included vascular access complications (n = 3, 2%), congestive heart failure due to volume overload (n = 2, 1%), transient complete heart block requiring a temporary pacemaker (n = 1, 0.5%), retroperitoneal hematoma (n = 1, 0.5%), and groin hematoma (n = 1, 0.5%).

Long-term arrhythmia outcomes after initial RFCA. In total, 118 of 130 patients (91%) had at least 2 months of follow-up after their initial ablation procedure. A total of 641 clinical visits was available for analysis in 118 patients for whom a clinical visit was recorded at ≥2 months after RFCA (mean 5.4 clinical visits per patient). During a median follow-up duration of 3.4 years (range 0.2 to 16.0 years), IART recurred in 67 patients (57%; 95% CI: 47% to 66%) (Table 4). Of patients who had recurrence, 31% did so within 1 month of ablation, and 63% did so within 1 year. Cumulative IART recurrence rates at 2 and 4 years after an ablation procedure were 46 ± 5% and 61 ± 5%, respectively. Patients who had a successful RFCA were less likely to have IART recurrence than patients who had an unsuccessful RFCA (p = 0.001) (Fig. 1). Multivariate Cox regression analysis showed that independent factors associated with IART recurrence after RFCA were age at time of ablation, male sex, history of Fontan palliation, and successful RFCA (Table 5).

Outcome after initial successful RFCA. Seventy-seven of 82 patients (94%) with successful RFCA had late follow-up. There was a significant reduction in the proportion of patients using antiarrhythmic agents at hospital discharge compared to before successful RFCA (86% vs. 66%, p = 0.005). Patients discharged with antiarrhythmic agents (n = 51) used the following antiarrhythmic drugs: digoxin (20%), flecainide (2%), beta-blockers (55%), amiodarone (41%), sotalol (12%), and calcium-channel blockers (6%).

During a median follow-up duration of 3.7 years (range 0.2 to 10.2 years), IART recurred in 48% (95% CI: 37% to 60%) of patients who had a successful RFCA (Table 4). Cumulative IART recurrence rates at 2 and 4 years from successful RFCA were 39 ± 6% and 51 ± 6%, respectively. Acute procedural success and cumulative freedom from IART recurrence (at 6 months, 2 years, and 4 years) after a

Table 4 Long-Term Outcome After RFCA

Outcome	Intention-to-Treat Analysis (n = 118)	After Successful RFCA (n = 77)
Duration of follow-up, yrs	3.4 (0.2–16.0)	3.7 (0.2–10.2)
IART recurrence	67 (57%)	37 (48%)
Cardioversion or reablation	50 (42%)	32 (42%)
Reablation	41 (35%)	27 (35%)
Cardioversion	29 (25%)	16 (21%)
Atrial fibrillation	19 (16%)	10 (13%)
Death	8 (7%)	3 (4%)

Abbreviations as in Tables 2 and 3.

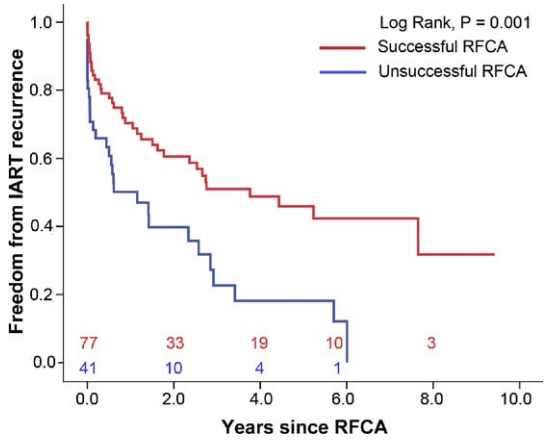

Figure 1 **Freedom From IART Recurrence Stratified by Acute Procedural Outcome**

Kaplan-Meier survival curve presenting time to first documented intra-atrial re-entrant tachycardia (IART) recurrence in patients who underwent successful radiofrequency catheter ablation (RFCA) **(red line)** and unsuccessful RFCA **(blue line)**.

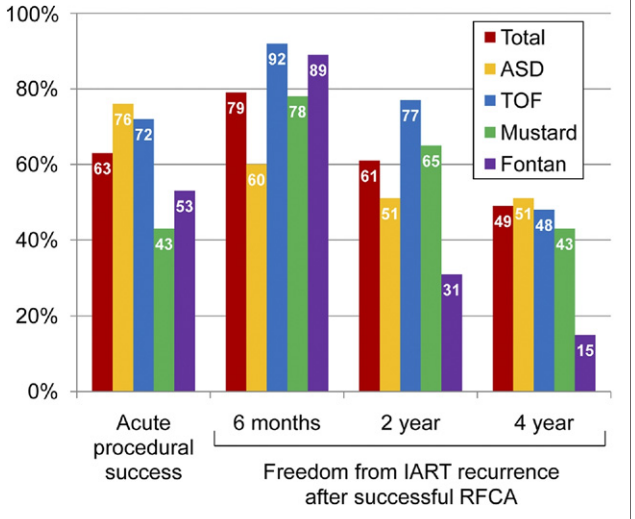

Figure 2 **Acute Procedural Success and Freedom From IART Recurrence After Successful RFCA**

Data for acute procedural success and freedom from intra-atrial re-entrant tachycardia (IART) recurrence after successful radiofrequency catheter ablation (RFCA) are separated for the total group **(red bars)** and for the 4 most common surgical groups: atrial septal defect **(yellow bars)**, tetralogy of Fallot **(blue bars)**, Mustard repair **(green bars)**, and Fontan palliation **(purple bars)**.

successful RFCA are depicted for the 4 most common surgical groups in Figure 2. When compared to other CHD groups, patients with repaired ASD were older (48 ± 13 years vs. 39 ± 13 years, p = 0.019), and discontinuation of 1 or all antiarrhythmic drugs (53% vs. 24%, p = 0.027) was more common. Multivariate Cox regression analysis showed that independent factors associated with IART recurrence after successful RFCA were older age at time of ablation (hazard ratio: 1.032; 95% CI: 1.005 to 1.060, p = 0.020) and history of Fontan palliation (hazard ratio: 2.527; 95% CI: 0.974 to 6.557, p = 0.057).

Reablation was performed in 27 of 77 (35%) patients, and was successful in 16 of 27 (59%). The location of a successful RFCA was different from the previously successful RFCA in 10 of 16 (62%) patients and was similar in 38% of patients. When comparing the frequency of antiarrhythmic drugs used before successful RFCA and at last follow-up, there was still a significant decrease in antiarrhythmic drug use (86% vs. 66%, p = 0.005).

Late mortality after RFCA. Eight of the 118 (7%) patients with a follow-up duration ≥2 months after initial RFCA died during follow-up, with a mean time of 3.3 ± 1.7 years to death after RFCA. The cause of death was perioperative mortality in 4 patients (heart transplantation in TOF patient, bidirectional cavopulmonary shunt in

Table 5 **Predictors of IART Recurrence After Radiofrequency Catheter Ablation**

	Univariate Analysis			Multivariate Analysis		
	Hazard Ratio	95% CI	p Value	Hazard Ratio	95% CI	p Value
Patient factors						
Age at ablation, yrs	1.021	1.002–1.040	0.034	1.028	1.008–1.049	0.007
Male	1.356	0.838–2.197	0.215	1.516	0.930–2.473	0.095
Fontan palliation	1.746	0.930–3.280	0.083	2.178	1.117–4.249	0.022
Mustard repair	0.816	0.416–1.600	0.554			
History of atrial fibrillation	1.346	0.733–2.474	0.338			
Recent onset IART, <1 yr	1.060	0.628–1.790	0.827			
Technology						
Electroanatomic mapping	0.844	0.517–1.378	0.498			
Irrigated ablation	0.925	0.562–1.523	0.759			
Procedural complexity						
>1 IART circuit	1.020	0.599–1.736	0.943			
Baseline rhythm IART	1.019	0.627–1.655	0.940			
Successful RFCA	0.445	0.273–0.727	0.001	0.478	0.293–0.781	0.003

Abbreviations as in Tables 2, 3, and 4.

patient with double-outlet right ventricle with ventricular dysfunction, Fontan revision due to endocarditis, emergent Fontan revision after pulmonary embolism), and congestive heart failure in 3 patients; 1 patient died of multiorgan failure secondary to pneumosepsis. Cumulative survival rates at 2 and 4 years were 98 ± 2% and 93 ± 3%, respectively. A successful RFCA was associated with a trend toward better survival compared with an unsuccessful RFCA (hazard ratio: 0.267; 95% CI: 0.063 to 1.120, p = 0.071).

Discussion

In this older cohort of adult CHD patients (mean age 40 years) with IART, the acute and late success of RFCA was similar to that reported for younger patient cohorts including pediatric and adolescent patients. RFCA was successful in 69% of patients in whom ablation was actually attempted. Acute procedural success was associated with the use of electroanatomic mapping, but was less successful in patients with Fontan palliation or atrial switch operations. Patients who had a successful RFCA had a lower IART recurrence rate when compared with patients who had an unsuccessful RFCA. In late follow-up, IART recurred in 48% of patients who had an initially successful RFCA, and these recurrences were associated with older age at the time of RFCA and Fontan palliation.

Acute outcome. The overall acute success rate in our population is comparable to that of a previous large study of younger patients with CHD (63% vs. 66%) using the same definition for procedural success (ablation of all IART circuits) (4). In their study, Triedman et al. (4) included CHD patients with a mean age of 25 years and a higher percentage of Fontan palliation compared to our study (47% vs. 15%). Other smaller studies have shown a higher acute success rate ranging from 73% to 100% (5–12). However, some of these studies included only patients with 1 specific CHD diagnosis (10,12).

In our study, Fontan palliation and Mustard repair, notorious for their complex atrial anatomy, were associated with higher RFCA procedural failure rates. Several factors reduce the acute success rate of RFCA in patients with Fontan palliation, including markedly enlarged, scarred right atria with wall thickening and high right atrial pressures. That may result in multiple or large complex macro–re-entrant flutter circuits that require multiple or long linear transmural ablation lesions to transect (11). Completion of these linear lesions with conduction block may be challenging, given the substrate at hand. Our patients with Fontan palliation had multiple IART circuits, which were usually not CTI dependent (79%). The most common reason for an unsuccessful ablation in our Fontan patients was a failed ablation of a non–CTI-dependent IART.

The treatment of IART in adult patients with the Mustard/Senning operation is also challenging. In contrast to the pediatric/adolescent population (16), the location of successful ablation in our Mustard patients was usually not the cavotricuspid isthmus (29% versus 57%). The most common reason for an unsuccessful RF ablation in our Mustard population was a failed ablation of a CTI-dependent IART because the retrograde aortic approach did not permit adequate accessibility and catheter stability to complete the linear lesion across the CTI. Accessibility was impaired by the tendency of the ablation catheter to migrate lateral to the CTI. Furthermore, catheter stability was compromised by the large pulmonary venous atrium and moderate to severe tricuspid regurgitation in all patients. By comparison, the retrograde aortic approach may be less problematic in the younger Mustard patient because of their smaller atrial size and less severe tricuspid regurgitation (10). We did not perform CTI ablation through a transbaffle approach, which may have potentially improved accessibility and catheter stability (17). Some pediatric/adolescent reports have described successful CTI ablation exclusively from the systemic venous atrium (10,18). In our study population, CTI ablation in the systemic venous atrium did not interrupt the IART, and extension of the CTI lesion in the pulmonary venous atrium was necessary. That is probably related to the surgical handling of the inferior suture line of the atrial baffle, as in most of our Mustard patients with a CTI-dependent IART, the coronary sinus was kept on the pulmonary venous side or surgically incised to permit redirection to the systemic venous atrium, rendering a majority of the isthmus on the pulmonary venous side.

Three-dimensional activation mapping of IART has improved the understanding of clinical mechanisms of IART circuits in patients with CHD and the relations of these circuits to the underlying atrial myocardial substrate (19–21). In the present study, better definition of critical isthmuses with the use of electroanatomic mapping resulted in an improved acute procedural success (2 times higher likelihood of successful RFCA). The improved acute procedural success using electroanatomic mapping was associated with an increase in procedural time, but a similar fluoroscopy time. In comparison, Triedman et al. (4) showed longer procedural and fluoroscopy time when using electroanatomic mapping. Despite the greater likelihood of acute procedural success, electroanatomic mapping was not associated with greater freedom from IART recurrence.

Overall, approximately 5% of procedures resulted in a major complication unrelated to vascular access, including the need of a permanent pacemaker, congestive heart failure, and retroperitoneal hematoma. The risk of permanent pacing (3%) requires special attention when counseling CHD patients who may be candidates for RFCA of IART. There is a low risk of complete heart block in patients undergoing CTI ablation even in patients without inferiorly displaced AV nodes outside the triangle of Koch (e.g., atrioventricular septal defects) (1). Furthermore, successful ablation of IART may unmask pre-existing sinus node

dysfunction, requiring permanent pacing, as shown in our study.

Long-term outcome. Our adult population had a long-term IART recurrence rate of approximately 48% after successful RFCA during a median follow-up of 3.7 years. This rate is similar to that of other CHD studies (41% to 52%), which included pediatric patients, a higher proportion of Fontan palliation, and shorter duration of follow-up (4,6,7,9).

Prior studies have not examined predictors of IART recurrence using multivariate analysis. We demonstrated that older age at ablation and Fontan palliation were consistent predictors of IART recurrence after RFCA, using either intention-to-treat analysis or including only patients with a successful RFCA. That older age at ablation is a predictor of IART recurrence, whereas the overall IART recurrence rate is comparable to previous studies with a younger cohort, could be explained by the lower proportion of Fontan palliation in our study cohort (4,6,7). Our data suggest that adult patients with Fontan palliation are the least likely to benefit from RFCA, with a low acute success rate and high IART recurrence rate. Despite 1 or more documented IART recurrences in Fontan patients, Triedman et al. (4) have shown that there is a substantial decrease in the burden of arrhythmia after RFCA as evidenced by a decrease in the frequency and severity of IART symptoms and need for therapy.

Interestingly, despite the lower acute success rate in patients with Mustard repair, reflecting their procedural complexity, the IART recurrence rate is similar to that of other patients with a biventricular repair after a successful RFCA (Fig. 2). This finding implies that their tendency to have IART recurrence after a successful RFCA is comparable to that of other CHD patients with biventricular repair.

There was a high early IART recurrence rate in patients with repaired ASD (Fig. 2), although their late recurrence rate is relatively favorable. Magnin-Poull et al. (21) previously demonstrated a similar high early recurrence rate (59%) among patients with repaired ASD (mean age 45 years) after successful RFCA, necessitating an additional RFCA. The high early recurrence rate in our study may be related to the higher percentage of ASD patients discontinuing their antiarrhythmic drug therapy after successful RFCA and their older age at RFCA.

Mortality. Overall, mortality in our study group was high, at 1.8% per patient-year of follow-up. This rate is similar to that of prior CHD studies evaluating the outcome of RFCA of IART, but in a younger study population (4). This relatively high mortality rate emphasizes the overall severity of disease in this group and suggests that IART may predict poor outcome independent of age. A recent study showed that atrial arrhythmias in adults with CHD was associated with a nearly 50% increase in mortality compared with patients not having atrial arrhythmias (22). In our study, there was a trend toward a lower risk of death among patients who had a successful RFCA compared with patients who had an unsuccessful RFCA. The most common cause of death was perioperative mortality, followed by congestive heart failure.

Study limitations. Data for this study were acquired retrospectively, and number, interval, and documentation of clinical visits varied between patients. Although the Toronto Congenital Cardiac Center for Adults is a tertiary referral center, with the potential for underdetection of IART recurrence, the majority of patients resided in the greater Toronto area and had ongoing close follow-up in the clinic.

Although first recurrence of tachycardia has traditionally been used as a gold standard for evaluating arrhythmia therapy efficacy, several authors have proposed a frequency-based outcome measure or a multi-axis severity scale, given the intermittent character of arrhythmia recurrence (4,23). As these outcome measures have not been validated against other measures of arrhythmia activity or quality-of-life indexes, we chose to implement the more conventional outcome measure of time to first recurrence.

All procedures were performed at a single center by a small number of operators, and this could have contributed to a learning curve effect. Such a confounding effect may have contributed to a higher acute success rate associated with electroanatomic mapping in our study. Finally, validation of our observations in an independent data set may be required because of the potential of overfitting and the single-center design.

Conclusions

Despite age-related structural changes such as atrial hypertrophy and/or fibrosis, atrial dilation, and ventricular dysfunction, the older adult patient with CHD can anticipate an outcome with RFCA of IART comparable to that reported in the younger patient with CHD. Older age, however, is associated with a higher risk of IART recurrence. That probably reflects the complex and evolving underlying pathophysiologic substrate in CHD, as a different IART circuit from that of the initial presentation was encountered in the majority of our patients experiencing a recurrence. In addition, complex atrial surgery (i.e., Fontan procedures and atrial switch operations) limits the success of RFCA for IART in adults.

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Key Words: atrial flutter ■ catheter ablation ■ congenital heart defect ■ Fontan procedure ■ tachyarrhythmia.