Inducibility of Intra-atrial Reentrant Tachycardia After the First Two Stages of the Fontan Sequence

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OBJECTIVES We sought to examine the incidence and possible factors for inducible intra-atrial reentrant tachycardia (IART) in a group of patients after two stages of the Fontan sequence but before the operation.

BACKGROUND Intra-atrial reentrant tachycardia occurs in 10% to 40% of patients after the Fontan operation. No data are available regarding the potential for IART after the first two stages of the Fontan sequence but before the operation.

METHODS The IART induction protocol included programmed extrastimulation and rapid atrial pacing, with and without isoproterenol.

RESULTS The median age of the study group (n = 44, 27 males) was 1.7 years (range 1.2 to 5.2). Forty patients were in sinus rhythm. Twelve patients (27%) had inducible, sustained (>1 min) IART. Three patients (8%) had inducible, nonsustained IART. Bivariate analysis revealed that patients with sustained IART were significantly older at their second operation (median 0.54 vs. 0.40 years, p = 0.05). Multivariate logistic modeling revealed that older age (≥0.55 years) at the second palliative operation (p = 0.04), older age (≥1.95 years) at evaluation before the Fontan sequence (p = 0.04) and female gender (p = 0.03) were independently associated with sustained IART. A trend toward a greater frequency of sustained IART was seen in those patients with moderate or severe atrioventricular valve regurgitation (p = 0.07) and in those with resection of the atrial septum (p = 0.06).

CONCLUSIONS The rate of inducible, sustained IART in a group of patients before the Fontan operation is 27% and is associated with older age at the time of second-stage palliation, older age at pre-Fontan evaluation and female gender. (J Am Coll Cardiol 2001;37:231–7) © 2001 by the American College of Cardiology

Children with single-ventricle pathologic and physiologic findings require either a two- or three-stage surgical approach—the Fontan sequence—for optimal palliation. The Norwood operation is performed in the first or second week of life in those infants with a severely hypoplastic left ventricle. In patients with a hypoplastic right ventricle, an aortopulmonary anastomosis may be sufficient. At 6 to 12 months, the second stage, either a bidirectional Glenn operation (BDG) or a hemi-Fontan procedure (HFP), is performed. Usually between 18 and 36 months of life, the final Fontan operation is performed, completing the bypass of either the right or left hypoplastic ventricle (1). Intra-atrial reentrant tachycardia (IART), also known as “incisional” reentrant tachycardia, which occurs in 10% to 40% of patients, is a well-known sequela of the final stage-3 Fontan operation (2–7). A number of retrospective studies have implicated sinus node dysfunction (4,8), atrioventricular valve regurgitation (3,4), right atrial hypertension (9) and distention (5), older age at Fontan operation (3,4,10) and a longer follow-up interval (4,7) as factors that may contribute to an increase in the frequency of IART. Several modifications to the Fontan operation, including the extracardiac conduit Fontan procedure, have been adopted in an attempt to decrease the incidence of IART, but none of them have convincingly been shown to be effective (2–4,11,12). In addition, intracardiac electrophysiologic studies in patients who have had the Fontan operation have found abnormal sinus node function, prolonged atrial refractoriness, delayed intra-atrial conduction, as well as sustained, inducible IART in 23% (13). Canine models simulating the Fontan operation (12) and endocardial mapping studies in patients undergoing the Fontan operation (13) have suggested that this final palliation for patients with single-ventricle anatomy alters electrophysiologic properties of the atria, creating the substrate for laboratory and clinical arrhythmias. The purpose of this investigation was to determine whether the potential for IART exists before the final stage 3 of the Fontan sequence.

METHODS

Study group. The study group consisted of all patients with single-ventricle anatomy admitted to the University of Michigan Congenital Heart Center and Departments of Pediatrics and Surgery, University of Michigan Health Systems, Ann Arbor, Michigan. This study was supported in part by Grant #R01-HL59107 from the National Institutes of Health, Bethesda, Maryland; and the Save-A-Heart Foundation, Ann Arbor, Michigan. Manuscript received March 9, 2000; revised manuscript received August 9, 2000, accepted September 28, 2000.
Michigan Congenital Heart Center between March 18, 1998 and January 1, 2000 for the Fontan operation, who had undergone their second-stage operation at our center. Sixty-eight patients presented, 13 families declined participation and 11 others had heart catheterization performed at referring centers, and therefore were excluded from the study group. The remaining 44 patients comprised the study group. Patient demographic, echocardiographic and heart catheterization data, as well as follow-up course, were recorded. Twenty-eight patients had the Norwood operation; all were on cardiopulmonary bypass and all had right atriotomy and resection of the atrial septum; none had balloon atrial septostomy. The remainder of the patients had aortopulmonary anastomosis. Second-stage palliations were classified as HFP or BDG. The HFP consisted of creating an anastomosis from the right atrial appendage to the pulmonary arteries and placing an intra-atrial baffle within the right atrium to direct superior vena cava (SVC) blood flow to the arteriopulmonary connection. The BDG consisted of transecting the SVC, creating an anastomosis from the cephalad portion of the SVC to the pulmonary arteries in an end-to-side fashion and ligating the caudal portion of the SVC. Both operations were performed while the patient was supported with cardiopulmonary bypass and included right atriotomy. The University of Michigan Institutional Review Board for Investigations Using Human Subjects approved the investigational protocol, and written, informed consent was obtained from all the patients.

**Electrophysiologic study.** Electrophysiologic studies were performed after diagnostic heart catheterization. Patients were sedated with midazolam or ketamine, or both, as well as morphine during the heart catheterization and electrophysiologic study. A 4F or 5F quadripolar electrophysiologic (Cordis Webster, Diamond Bar, California) catheter was placed in the high right atrium for electrophysiologic stimulation and recording. Access to the right atrium was done using the inferior approach (n = 24, femoral vein) when possible, and using the superior approach (n = 20, right subclavian vein) when inferior access was not available. Atrial stimulus strength was at twice the diastolic threshold in milliamperes and 2 ms in pulse width duration.

Sinus node recovery time (SNRT) and total sinoatrial conduction time (TSACT) (Strauss method) were measured as previously described (14). Atrial and atrioventricular node refractory periods were obtained by programmed extrastimulus coupled to sinus rhythm and to at least one additional drive train, and atrioventricular node Wenckebach periods were obtained by rapid atrial pacing, as previously described (15). Stimulation and recording were performed using a Bloom stimulator (Bloom Associates Ltd., Norberth, Pennsylvania) and Quinton Electrophysiologic laboratory equipment (Quinton Instrument Co., Bothell, Washington) or Electrophysiologic MedSystems Workmate, Version 2.11.5 (Mt. Arlington, New Jersey). An arrhythmia induction protocol was then performed with both atrial burst (10- to 20-ms decrements) and ramp pacing down to a cycle length of 150 ms. The arrhythmia induction protocol was repeated during isoproterenol infusion at 0.01 to 0.1 μg/kg body weight per minute to increase the heart rate by 20% or >150 beats/min if the initial trial did not initiate IART. The diagnosis of IART was made by inducing the tachycardia by programmed extrastimulation or rapid atrial pacing, or both, with the following characteristics: nonsinus p wave morphology, constant intra-atrial cycle length, rapid deflection atrial electrograms with isoelectric intra-atrial baseline (Fig. 1), variable atrioventricular conduction and conversion with overdrive pacing or direct current cardioversion. Tachyarrhythmias were considered sustained if they lasted >1 min. The arrhythmia induction protocol was discontinued after an arrhythmia was induced. Overdrive pacing was used to convert reentrant atrial arrhythmias to sinus rhythm. Transthoracic direct current cardioversion was used when overdrive pacing was unsuccessful (n = 1).

**Statistical analysis.** Statistical analysis was performed using Statview version 5.0 (Abacus Concepts Inc. Berkeley, California) and SAS version 7.0 (SAS Institute Inc., Cary, North Carolina) software packages. Univariate analysis was performed on all variables. Normally distributed continuous data are reported as the mean value ± SD; nonparametric data are reported as the median value (minimum, maximum). The primary outcome variable was inducibility of sustained IART. Bivariate analysis to test for an association was performed using the t test for parametric data and the Kruskal–Wallis test for nonparametric data. Categorical data were compared by using the Fischer exact test. In addition, multivariate logistic modeling was performed. For these models, age at second-stage palliation and age at electrophysiologic study were divided at the 75th percentile to form binomial variables. Logistic models were used to test the independent odds of sustained IART with older age at second-stage palliation, older age at electrophysiologic study, moderate or greater atrioventricular valve regurgitation and female gender. A p value ≤0.05 indicated statistical significance.

**RESULTS**

The median age at the time of second-stage palliation was 0.45 years (range 0.18 to 1.4) and 1.7 years (range 1.2 to 5.2) at the time of electrophysiologic study. The mean weight at the time of electrophysiologic study was 11.0 kg (range 6.5 to 14.7). The diagnoses included hypoplastic left heart
syndrome (n = 23), pulmonary atresia with intact ventricular septum (n = 5), tricuspid atresia (n = 3), double-inlet left ventricle (n = 3), unbalanced atrioventricular septal defect (n = 5), double-outlet right ventricle (n = 3) and Ebstein's anomaly (n = 2). Forty patients underwent HFP and four patients underwent BDG as their second stage of palliation.

Cardiac rhythm on the 12-lead electrocardiogram before electrophysiologic study was sinus (upright p waves in leads I and II, with inverted p waves in lead aVR) in 40 patients, left atrial (inverted p waves in lead I, isoelectric p waves in lead aVF and upright p waves in lead aVR) in 2 patients, low right atrial (inverted p waves in leads I and II, with upright p waves in lead aVR) in 1 patient and junctional (no discernible p waves) in 1 patient. The mean basic cycle length was 553 ± 94 ms.

Twelve patients (27%) had inducible, sustained IART (>1 min) at a mean cycle length of 203 ± 17 ms (range 160 to 320), nine patients underwent HFP and two had the BDG operation. The majority were induced with atrial burst pacing (n = 10) at a mean cycle length of 190 ± 53 ms (range 150 to 333); two patients were induced with programmed extrastimulation. Only two patients required isoproterenol infusion for the induction of an atrial arrhythmia. Another three patients (8%) had inducible, nonsustained IART, all after HFP; one required isoproterenol. One patient developed clinical IART eight months after the Fontan operation. This patient had sustained IART at the time of electrophysiologic study, before the Fontan operation. Because of the low incidence of clinical IART in this study group to date, no further statistical analysis to examine for a possible relation between clinical and inducible, sustained IART was performed.

We compared the electrophysiologic data of those patients with sustained IART to the data of those patients without sustained IART (Table 1). Bivariate analysis revealed that patients who had sustained IART were significantly older at the time of their second palliative surgery (median 0.54 vs. 0.40 years, p = 0.05). Sustained IART was seen more frequently in females than in males (50% vs. 19%, p = 0.06) and more frequently in patients with moderate or severe atrioventricular valve regurgitation than in those with no or mild cases of it (100% vs. 24%, p = 0.07). No statistically significant differences were found in the patients' cardiac diagnoses, electrophysiologic variables, pulmonary artery or venous pressure, pulmonary vascular resistance, ventricular function, semilunar valve regurgitation or type of second-stage palliation (HFP vs. BDG). Univariate

**Figure 1.** A representative surface electrocardiogram (ECG) and mid-right atrial intracardiac tracing (RA 1–2) from a study participant. The left panel demonstrates sinus rhythm. The right panel demonstrates IART with low amplitude, biphasic p waves in lead I and upright, nonsinus p waves in leads II and III, along with 2:1 atrioventricular conduction. I = ECG lead I; II = lead II; III = lead III; aVR = lead aVR; aVL = lead aVL; aVF = lead aVF; RA = right atrial electrogram; A = atrial electrogram; V = ventricular electrogram.
Table 1. Comparison of Patients With and Without Inducible, Sustained IART

<table>
<thead>
<tr>
<th></th>
<th>Nonsustained IART</th>
<th>Sustained* IART</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at second-stage surgery (years)</td>
<td>0.40 (0.18–0.92; n = 32)</td>
<td>0.55 (0.26–1.4; n = 12)</td>
<td>0.050</td>
</tr>
<tr>
<td>Age at EP study (years)</td>
<td>1.62 (1.16–2.42; n = 32)</td>
<td>1.85 (1.5–5.2; n = 12)</td>
<td>0.075</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>27/5</td>
<td>6/6</td>
<td>0.059</td>
</tr>
<tr>
<td>Second-stage surgery (HFP/BDG)</td>
<td>30/2</td>
<td>10/2</td>
<td>0.28</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>10.7 ± 1.7 (n = 32)</td>
<td>11.7 ± 1.7 (n = 12)</td>
<td>0.084</td>
</tr>
<tr>
<td>Basic cycle length (ms)</td>
<td>539 ± 101 (n = 32)</td>
<td>590 ± 57 (n = 12)</td>
<td>0.11</td>
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<tr>
<td>mcSNRT (ms)</td>
<td>188 ± 152 (n = 30)</td>
<td>280 ± 243 (n = 11)</td>
<td>0.15</td>
</tr>
<tr>
<td>AERP (ms)</td>
<td>180 ± 35 (n = 31)</td>
<td>187 ± 33 (n = 12)</td>
<td>0.59</td>
</tr>
<tr>
<td>AVERP (ms)</td>
<td>202 ± 61 (n = 31)</td>
<td>232 ± 74 (n = 12)</td>
<td>0.18</td>
</tr>
<tr>
<td>TSACT (ms)</td>
<td>129 ± 68 (n = 27)</td>
<td>191 ± 138 (n = 10)</td>
<td>0.076</td>
</tr>
<tr>
<td>AV Wenckebach cycle length (ms)</td>
<td>255 ± 55 (n = 31)</td>
<td>297 ± 95 (n = 11)</td>
<td>0.081</td>
</tr>
<tr>
<td>PAP (mm Hg)</td>
<td>10.8 ± 2.8 (n = 32)</td>
<td>11.5 ± 2.1 (n = 12)</td>
<td>0.40</td>
</tr>
<tr>
<td>PVR (mm Hg)</td>
<td>6.6 ± 3.7 (n = 31)</td>
<td>5.4 ± 1.9 (n = 12)</td>
<td>0.30</td>
</tr>
<tr>
<td>Ventricle function (good to mildly depressed/moderately depressed or greater)</td>
<td>7.4 (1.2–44)</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Atrial septum resection (yes/no)</td>
<td>20/11</td>
<td>11/1</td>
<td>0.06</td>
</tr>
<tr>
<td>AVERP (ms) with resection of atrial septum</td>
<td>217 ± 66 (n = 17)</td>
<td>244 ± 71 (n = 13)</td>
<td>0.005†</td>
</tr>
<tr>
<td>AVERP (ms) without resection of atrial septum</td>
<td>170 ± 35 (n = 12)</td>
<td>150 (n = 1)</td>
<td>0.11</td>
</tr>
<tr>
<td>Wenckebach CL (ms) with resection of atrial septum</td>
<td>261 ± 61 (n = 18)</td>
<td>305 ± 91 (n = 12)</td>
<td>0.09‡</td>
</tr>
<tr>
<td>Wenckebach CL (ms) without resection of atrial septum</td>
<td>237 ± 33 (n = 11)</td>
<td>200 (n = 1)</td>
<td>0.15</td>
</tr>
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</table>

*Sustained (>1 min). †Sustained IART with resection versus nonsustained IART and no resection. ‡Sustained IART with resection versus nonsustained IART and no resection. Parameteric data are expressed as the mean value ± SD; nonparametric data are expressed as the median value (minimum–maximum).

Analysis demonstrated a 75th percentile cut-off value for age at second-stage palliation at 0.55 years and for age at electrophysiologic study at 1.95 years. Multivariant logistic modeling revealed increased odds of sustained IART to be independently associated with older age at second-stage palliation (≥0.55 years, odds ratio 6.8), older age at electrophysiologic study (≥1.95 years, odds ratio 6.8) and female gender (odds ratio 7.4) (Table 2).

Twenty-eight patients had resection of the atrial septum during the Norwood operation; another three patients had resection at the time of their shunt procedure. Bivariate analysis demonstrated a trend (p = 0.06) toward a greater incidence of sustained IART in patients with resection of the atrium septum (42%), as compared with those without resection (8%). In addition, the atrioventricular conduction system (atrioventricular node and His-Purkinje system), as indicated by the atrioventricular conduction system effective refractory period (168 ± 39 vs. 228 ± 86 ms; p = 0.005) and by the Wenckebach cycle length (115 ± 31 vs. 162 ± 112 ms, p = 0.06), was impaired in those patients with resection as compared with those without it. This association of atrioventricular conduction system impairment with resection of the atrial septum was also present when one compared patients with sustained IART to those without it (Table 1).

**DISCUSSION**

Intra-atrial reentrant tachycardia has been well described in the Fontan population. Much of the effort to treat and prevent tachyarrhythmias has been focused on changes that occur during and after the Fontan operation. Little is known about the electrophysiologic and anatomic changes that might occur in the atria of the single-ventricle heart before the Fontan operation or after the second- and third-stage operations. This study uncovered an incidence of inducible, sustained IART before the Fontan operation similar to that reported in retrospective studies (2–5,9) and/or invasive electrophysiologic testing (16) after the Fontan operation, and it delineated potential factors that, if present before the Fontan operation, may potentiate the development of IART in these patients. These factors are increased age at second-stage palliation, increased age at electrophysiologic study and the female gender.

**Age.** Durongpisitkul et al. (3) found that patients who underwent the Fontan operation at <3 years of age or >10 years of age had an increased risk of developing late-onset supraventricular arrhythmias. Fishberger et al. (4) found that atrial flutter was more likely to occur earlier if the Fontan operation was performed at an older age. They also found that a longer follow-up interval after the Fontan operation was associated with a higher frequency of atrial
flutter. In a large study by Garson et al. (17), the incidence of atrial flutter increased with age at follow-up among children with cardiac disease. We found similar results during a 10-year retrospective study of patients who had the Fontan operation (6). Older age at operation and longer duration of follow-up were associated with IART, regardless of single-ventricle anatomy or type of Fontan operation. This current prospective study confirms age as a determinant in the frequency of sustained IART and is in agreement with previous retrospective studies. Importantly, it also suggests that the anatomic and electrophysiologic changes that occur in the atria of the patient with a single ventricle may be as much dependent on time or other operative interventions as they are dependent on changes ascribed to the Fontan operation per se.

Female gender. Females are known to exhibit a faster rest heart rate, longer corrected QT interval (18) and higher incidence of torsade de pointes as compared with males (19–21). Our study found an association between female gender and inducible IART, even though females comprised only 25% of the group. Further analysis was performed to determine whether our female patients differed from the male patients in terms of age or diagnosis; however, no differences were found. The clinical significance linking female gender and sustained IART is currently unknown. Our study group consists of very young patients with severe forms of congenital heart disease; thus, it is not comparable to adult patients in whom the gender differences have been observed.

Atrioventricular valve regurgitation. Moderate or severe atrioventricular valve regurgitation, as shown on the echocardiogram, exhibited a trend toward a statistically significant increase in the risk of sustained IART. Atrial distention secondary to atrioventricular valve regurgitation has been found to change the electrophysiologic properties of the atria predisposing to supraventricular arrhythmias (22,23). Several retrospective studies of Fontan patients with clinical IART have found that atrioventricular valve regurgitation and increased right atrial size increase the likelihood of IART (3–5). It would seem reasonable that atrioventricular valve regurgitation in the pre-Fontan population would increase the risk of sustained IART. However, in our group, right atrial enlargement is not uniform. In fact, because the flow pathway of HFP and BDG largely bypasses the atria, in the absence of atrioventricular valve regurgitation, right atrial size is relatively preserved. The lack of uniform atrial enlargement in our patients with sustained IART would suggest that this physiologic change is not essential to the development of IART. This interpretation is supported by studies comparing the total cavopulmonary connection in the Fontan operation to the atrio pulmonary connection Fontan modification. Although atrial enlargement is common after the atrio pulmonary connection in the Fontan operation, but not after the total cavopulmonary connection Fontan modification, large retrospective studies have not found a significant difference in the occurrence of atrial arrhythmias between the two groups (3,4).

Electrophysiologic data. Kurer et al. (16) previously reported the electrophysiologic changes that occur at a mean of two years after the Fontan operation. Intracardiac electrophysiologic studies revealed abnormal sinus node function, prolonged atrial refractoriness, delayed intra-atrial conduction and inducible atrial arrhythmias. Sustained IART was induced by programmed atrial stimulation in 7 (23%) of 30 study patients. One patient had atrioventricular node reentrant tachycardia. Nonsustained atrial arrhythmias occurred in an additional 10%. These authors concluded that prolonged atrial conduction and right atrial enlargement could increase the probability that atrial arrhythmias will develop.

In our study, atrial conduction was not directly measured. However, the basic cycle length, maximal corrected SNRT and TSACT tended to be longer in the sustained IART group (Table 1). As measures of sinus node function, these data suggest that sinus node impairment may be associated with sustained IART. Manning et al. (8) reported similar findings of altered sinoatrial node function after placement of a cavopulmonary shunt as a factor associated with atrial arrhythmias after the Fontan operation. In their comparison of patients who directly had the Fontan operation with those who underwent the staged Fontan operation, the latter group had a greater incidence of atrial arrhythmias after the Fontan procedure. Injury to the sinus node or sinus node artery at the time of the second stage was proposed as a possible cause of sinus node dysfunction. Our study is congruent with this observation and supports the idea that second-stage palliation may be as important as the Fontan operation for creating the substrate for IART. Interestingly, although HFP places the sinus node and sinus node artery at greater risk, as compared with BDG, no significant difference was found in the incidence of sustained IART. In fact, the patients who underwent BDG, albeit only four, had a significantly longer maximal corrected SNRT (389 ± 347 vs. 194 ± 152 ms, p = 0.041). However, other measures of sinus node function in the BDG group were not prolonged.

Fishberger et al. (4) found that the presence of sinus node dysfunction after the Fontan operation was associated with a higher incidence of atrial flutter. Studies of sinus node dysfunction, including animal models and retrospective studies, have primarily focused on changes that occur after the Fontan operation. Our data suggest that sinus node dysfunction may occur before the Fontan operation, warranting further investigation into surgical techniques performed during HFP and BDG, or earlier palliations.

Resection of the atrial septum. All patients had atriotomy at the second stage (HFP or BDG); therefore, no analysis or inference can be made about the impact of an atrial free wall incision on the incidence of IART. In contrast, resection of the atrial septum performed at the first stage in 31 patients significantly altered atrioventricular conduction, but not...
sinus node function, particularly in those who later had inducible IART. This observation suggests that interruption of atrial septal tissue providing input to the atrioventricular node, as well as interruption of the preferential conducting pathways between the sinus and atrioventricular nodes, can alter the electrophysiologic properties at and around the atrioventricular node, potentially contributing to an arrhythmogenic substrate. Abnormalities in the electrophysiologic properties of the atria that may provide the substrate for arrhythmias have been shown to exist both before and after repair of much simpler defects, such as ostium secundum atrial septal defects (24–29). This observation underscores both the importance of the pre-Fontan findings in this study and the potential for creating a local environment that supports the emergence of clinical arrhythmias.

**Follow-up.** The correlation between inducible IART and the development of clinical IART is not known. It is interesting to note that the patient who was found to have clinical IART after the Fontan operation had inducible, sustained IART during the electrophysiologic study before the Fontan operation. As discussed previously, longer follow-up intervals are associated with an increased frequency of clinical IART. Further follow-up is necessary to determine a possible correlation between inducible and clinical IART.

**Study limitations.** The intent of this study was to investigate the inducibility of sustained IART before the Fontan operation. Programmed electrophysiologic testing was performed during clinically indicated heart catheterizations before the Fontan operation. Venous access was limited to that which was required to acquire hemodynamic and angiographic data. Thus, complete access to the right atrium was not available. Mapping of the intra-atrial reentrant circuit was not possible; therefore, the location of the reentry circuit, the heterogeneity of atrial refractoriness and the atrial conduction velocity could not be determined. Furthermore, the variety of single-ventricle anatomy comprising the study group does not allow for inferences to be made about any specific lesion.

**Conclusions.** Intra-atrial reentrant tachycardia is a well-described and hemodynamically compromising sequela of the Fontan operation. To our knowledge, this is the first study to investigate the inducibility of sustained IART and its risk factors before the Fontan operation. The findings suggest that the electrophysiologic substrate for IART exists before the Fontan operation and may be influenced by resection of the atrial septum. Furthermore, patients who do not progress beyond the second stage of palliation may still be at risk of developing IART. Finally, these findings suggest that factors that give rise to the atrial arrhythmias after the Fontan operation may not be attributed to the Fontan operation alone.

**REFERENCES**


