ARRHYTHMIAS AND THROMBOEMBOLIC COMPLICATIONS AFTER THE EXTRACARDIAC FONTAN OPERATION

Lance K. Shirai, MD
David N. Rosenthal, MD
Bruce A. Reitz, MD
Robert C. Robbins, MD
Anne M. Dubin, MD

Background: Late morbidity and mortality after the Fontan operation are largely due to atrial arrhythmias, ventricular failure, and thrombus formation. The extracardiac Fontan procedure avoids extensive atrial manipulation and suture lines, theoretically minimizing the impetus for these events. We examined our experience with the extracardiac Fontan operation with particular attention to thromboembolism and arrhythmias. **Methods and results:** We retrospectively reviewed the medical and surgical records of all 16 patients who underwent an extracardiac Fontan operation between July 1993 and May 1996. Fifteen patients (94%) were in sinus rhythm before the operation. In the immediate postoperative period, seven (44%) had arrhythmias consisting of accelerated junctional rhythm and ectopic atrial rhythm. No associated hemodynamic compromise and no early deaths occurred. Patients were followed up for 3 to 34 months after the Fontan operation. Arrhythmias were detected in eight patients (50%) on surface electrocardiograms, and seven (44%) showed evidence of sinus node dysfunction on 24-hour Holter monitor studies. Thrombi were found in three patients (19%). All patients were asymptomatic, with no evidence of conduit obstruction by echocardiogram. **Conclusions:** The incidence of hemodynamically significant tachyarrhythmias appears to be reduced after the extracardiac Fontan operation. A significant percentage of patients have evidence of sinus node dysfunction, suggesting the presence of other surgical or nonsurgical factors responsible for this finding. Our incidence of thrombotic events is similar to previous reports with other Fontan modifications. It appears to be a reasonable option to maintain these patients on anticoagulation indefinitely. (J Thorac Cardiovasc Surg 1998; 115:499-505)

Since it was first described in 1971 by Fontan and Baudet,¹ the Fontan operation has become the standard method of palliation for functional univentricular congenital heart disease. Late morbidity and mortality after the Fontan operation are largely due to atrial arrhythmias, ventricular failure, and thrombus formation.²⁻¹⁰ Several modifications of this op-

eration have been devised in an attempt to decrease the incidence of these postoperative complications.¹¹⁻¹⁶ The most widely used of these, the total cavopulmonary connection, attempts to address these problems by maintaining laminar flow and minimizing energy loss within the venous pathway. Thus, in theory, it decreases the risk of thrombus development within the Fontan circuit.¹³ Nonetheless, the total cavopulmonary connection procedure still requires extensive atrial suture lines, which may contribute to the development of late arrhythmias.¹⁷ Recently, Rosenthal and colleagues⁹ showed a high incidence of thrombus formation in patients undergoing the Fontan operation irrespective of the modification used. In 1990, Giannico and coworkers¹⁸ developed the extracardiac Fontan procedure with the expectation that some of these problems might be minimized. With the use of a polytetrafluoroeth-

From the Departments of Pediatrics and Cardiovascular Surgery, Stanford University, Stanford, Calif.

Received for publication May 7, 1997; revisions requested August 20, 1997; revisions received Nov. 19, 1997; accepted for publication Dec. 11, 1997.

Address for reprints: Anne M. Dubin, MD, Division of Pediatric Cardiology, Stanford University, 750 Welch Rd., Suite 305, Palo Alto, CA 94304.

Copyright © 1998 by Mosby, Inc.

0022-5223/98 \$5.00 + 0 12/1/88212

ylene conduit* between the inferior vena cava and right pulmonary artery, the right heart is bypassed in a manner that minimizes atrial manipulation and eliminates atrial incision and suture lines.

Since the initial report of this procedure in 1990, few reports have described immediate and intermediate postoperative follow-up.^{15, 19-21} In this article we review our experience with the extracardiac Fontan operation with particular attention to thromboembolism and arrhythmias.

Methods

Since July 1993, it has been the Stanford University Hospital institutional practice to use the extracardiac total cavopulmonary connection to perform all Fontan procedures.

Patients. We retrospectively reviewed the medical and surgical records of all 16 patients who underwent an extracardiac Fontan operation at the Stanford University Hospital between July 1993 and May 1996. All operations were performed by one of two surgeons (B.A.R., R.C.R.).

Surgical technique. The extracardiac Fontan operation is performed through a median sternotomy. After bicaval and aortic cannulation, cardiopulmonary bypass is instituted. The inferior vena cava is transected, and the cardiac end is oversewn. A 16 to 22 mm flexible polytetrafluoroethylene tube graft is sutured to the distal inferior vena cava. The graft is brought to the underside of the right pulmonary artery and sutured end to side to the right pulmonary artery in a running fashion. In selected patients, a functional fenestration is created through anastomosis of a 3.5 to 4 mm polytetrafluoroethylene tube graft between the extracardiac conduit and the right atrium. In those patients who required additional reconstructive surgery, aortic crossclamping was used.

The bidirectional Glenn shunt is performed via a median sternotomy. Cannulation of the superior vena cava, inferior vena cava, and aorta are performed and cardiopulmonary bypass is instituted when dictated by anatomy. The superior vena cava is divided at the entrance to the heart. The cardiac end is oversewn. The vena cava and pulmonary artery are joined end to side with a running suture line with augmentation of the pulmonary artery as needed.

In both procedures, special care is taken to preserve the sinus node artery and to avoid trauma to the sinus node. In addition to the above procedures, atrial septectomy was performed either at the time of the Glenn operation or during a prior operation when indicated.

Cardiac evaluation. Results of preoperative and postoperative electrocardiograms (ECGs) and 24-hour Holter monitor recordings were reviewed. All documented arrhythmias and their subsequent therapy were included. The diagnosis of sinus node dysfunction was made using surface ECG criteria as defined by Kugler.²² These crite-

ria include sinus bradycardia, severe sinus arrhythmia, sinus pause or arrest, and slow escape rhythms.

Thrombi were identified during routine transthoracic echocardiograms, or in patients in whom there was a clinical suspicion of thrombus formation. In cases in which the presence of thrombus was questionable on transthoracic echocardiography, a transesophageal echocardiogram was performed for confirmation. Location and size of the thrombus and any signs of obstruction were noted.

The following echocardiographic variables were compared before and after the operations: atrioventricular valve regurgitation, presence or absence of flow through a fenestration, and ventricular function. Because of the difficulty quantitating ventricular function in patients with single ventricles, myocardial contractility was graded qualitatively as poor, fair, or good by an echocardiographer who was unaware of the clinical data.

Results

Patient characteristics. Between July 1993 and May 1996, 16 patients underwent the extracardiac Fontan operation. The median age at the time of the operation was 29 months (range 20 to 132 months). Ten were boys and six girls. The major anatomic diagnoses included transposition of the great arteries variant ($n = 6$), hypoplastic left heart syndrome ($n = 4$), unbalanced atrioventricular canal ($n = 3$), tricuspid atresia ($n = 2$), and Ebstein's anomaly ($n = 1$). All patients had undergone previous palliative procedures, including 15 patients who had a previous bidirectional Glenn operation. In all, two patients had one previous operation and 14 patients had two previous operations. Patients were followed up for a median of 13 months (3 to 34 months), for a total follow-up time of 195 patient-months.

Surgical data. Of the 16 extracardiac Fontan operations performed, nine were fenestrated. Criteria for fenestration were flexible. In general, fenestration was used for any combination of the following factors: elevated pulmonary artery pressures or abnormal pulmonary artery anatomy, systemic right ventricle, or significant atrioventricular valve regurgitation.

The median duration of cardiopulmonary bypass was 66 minutes (range 43 to 122 minutes). Aortic crossclamping was used in four patients (25%) to remedy associated cardiac defects. Median cross-clamp time was 40 minutes with a range of 30 to 88 minutes. Twelve of the 16 patients had undergone previous atrial surgery as described earlier.

On intermediate-term follow-up there was one death in a patient with congenital pulmonary vein stenosis. This patient had a stent placed in the left upper pulmonary vein at the time of the Fontan

* Gore-Tex graft, registered trademark of W. L. Gore & Associates, Inc., Elkton, Md.

Fig. 1. Bar graph showing plot of the number of patients in normal sinus rhythm (NSR), ectopic atrial rhythm, and junctional rhythm in the preoperative period and on immediate and midterm follow-up after the extracardiac Fontan operation.

operation. Eight months after the Fontan operation a cardiac catheterization demonstrated total obstruction of the left pulmonary veins. Approximately 2 to 3 weeks later the patient died of respiratory complications.

Arrhythmias. Findings for preoperative and postoperative arrhythmias are depicted in Fig. 1. Preoperative ECGs were available in all 16 patients. Fifteen patients (94%) were in sinus rhythm on standard 12-lead ECG. The one remaining patient, with an unbalanced atrioventricular septal defect, had an ectopic atrial rhythm.

In the early postoperative period, ECGs were available for all 16 patients. These were obtained a median of 1 day (range 0 to 22 days) after the operation. Early arrhythmias occurred in seven patients (44%), consisting of accelerated junctional rhythm (heart rates of 110 to 160 beats/min) in five and ectopic atrial rhythm (heart rates of 130 to 144 beats/min) in two patients, both aged 2 years. There was no evidence of hemodynamic compromise in any of the patients. In all patients with accelerated junctional rhythm the rhythm reverted to sinus rhythm within 24 to 48 hours without specific intervention; by contrast, both patients with ectopic atrial rhythm have remained in their respective rhythms up to the most recent follow-up. No ventricular arrhythmia or atrial flutter was detected in the early postoperative period.

At subsequent follow-up, ECGs were reviewed in all 15 patients and 24-hour Holter studies in 13 of the patients. ECGs were obtained a median of 11 months (2.5 to 34 months) from the time of the operation. Holter studies were obtained a median of 13 months (2.5 to 34 months) after the operation. On surface ECG, normal sinus rhythm was present in eight patients. Arrhythmias were detected in eight patients (50%), of whom six had ectopic atrial rhythm (heart rates of 60 to 100 beats/min) and two had junctional rhythm (heart rates of 100 to 120 beats/min). Of the 13 patients in whom Holter data were available, seven (44%) had sinus node dysfunction, manifested as slow sinus rhythm, sinus pauses, or slow junctional escape rhythm on 24-hour Holter study. These included four of the patients in normal sinus rhythm on surface ECG. Thus there was evidence of some arrhythmia in 11 of the 15 patients. Table I presents each patient's ECG and Holter findings of sinus node dysfunction. There were no cases of atrial flutter or sustained ventricular ectopy or tachycardia. All patients with arrhythmias were free of symptoms and none required treatment. Table II compares the arrhythmias in our series of patients at both immediate and intermediate follow-up with those from other groups.

Thrombotic complications. Preoperative echocardiograms were available in all 16 patients, a median of 69 days before the operation. There were

Table 1. ECG and Holter monitor findings in patients with sinus node dysfunction

Patient	Age at Fontan operation (yr)	Age at study (yr)	ECG findings	Holter findings
1	2.5	3.1	Sinus, 100 beats/min	SB, 45 beats/min; SP with junctional escape of 40 beats/min
2	2	3.0	EAR, 70 beats/min	SB, 55 beats/min; EAR; SP with junctional escapes of 50 beats/min
3	3.5	3.9	SP with junctional escape of 44 beats/min	SP
4	2	4.4	EAR, 60 beats/min	SP
5	1.7	4.0	Sinus, 80 beats/min	SB, 50 beats/min
6	2.3	3.9	Sinus, 120 beats/min	SB, 48 beats/min
7	2.8	5.4	Sinus, 80 beats/min	SB, 48 beats/min; SP with junctional escape of 45 beats/min

EAR, Ectopic atrial rhythm; SB, sinus bradycardia; SP, sinus pause.

no echocardiographically detected intracardiac thrombi. Ventricular function was graded as qualitatively good in 12 patients (75%) and fair in four (25%). Echocardiograms were available for all patients in the early postoperative period. Ventricular function was graded as good in 13 patients (81%) and fair in three patients (19%). Atrioventricular valve regurgitation was absent or mild in 15 patients (94%) and moderate in one (6%). No intracardiac thrombi were identified. However, a thrombus was evident in one patient 8 days after the operation, located within the external conduit adjacent to the right atrium. In this patient, ventricular function was good, flow across the fenestration was seen, there was mild atrioventricular valve regurgitation, and the patient was in normal sinus rhythm. This patient had postoperative seizures and global encephalopathy. It could not be determined whether these events were due to thromboemboli despite extensive investigation.

On subsequent follow-up, echocardiograms were available in 15 patients, at a median of 260 days after the operations. New thrombi were detected in two additional patients, with persistence of the thrombus in the previously mentioned patient. The new thrombi were detected on routine transthoracic echocardiography 8 and 30 months after the Fontan operation. They were located in the midportion of the external Fontan conduit and at the junction of the conduit to the right pulmonary artery. There was no echocardiographic evidence of conduit obstruction in any patient. Myocardial function was graded as good in 12 patients (80%) and fair in three patients (20%). In one patient, function improved

from fair to good, and in another, function worsened. Atrioventricular valve regurgitation was graded as absent to trace in 13 patients (87%) and mild to moderate in two patients (13%). Color flow Doppler ultrasonography detected fenestrations in two patients (13%). No intracardiac thrombi were seen and no systemic thromboembolic phenomena were observed. In all patients with thrombi, function was good, there was no atrioventricular valve regurgitation, no fenestrations were seen, and all were in normal sinus rhythm. Extrapolating to a linear event rate, thrombi occurred at a rate of 10 events per 100 patient-years.

During the period of this study, routine anticoagulation was not used in the early postoperative period or on a long-term basis. If thrombi were detected by echocardiography, warfarin therapy was initiated and maintained indefinitely. All patients with thrombi were free of symptoms at the time of detection and have remained so after institution of warfarin therapy.

Discussion

Our experience with early postoperative arrhythmias differs from previous reports of earlier modifications of the Fontan operation in one important respect: the morbidity and mortality associated with early postoperative arrhythmias in other series were essentially absent in our patients. Specifically, there were no episodes of junctional ectopic tachycardia or atrial flutter in our patients. With all episodes of arrhythmias, reversion to normal sinus rhythm occurred without specific intervention. There were no arrhythmia-associated deaths. By comparison, data

Table II. Incidence of arrhythmias in immediate and midterm follow-up in various series of Fontan operations

Group	Fontan type	Immediate postop.		Intermediate follow-up	
		Hemodynamically significant*	Total	Hemodynamically significant	Total
Balaji et al. ²³	LT	8%	N/A	9%	26%
Cecchin et al. ²⁴	LT/APC	29%	31%	16%	23%
Giannico et al. ¹⁸	ECF	7%	7%	N/A	N/A
Kurer et al. ⁸	LT	27%	94%	N/A	N/A
Laschinger et al. ^{15, 21}	ECF	0%	0%	0%	0%
Shirai et al. ^{ECF}	ECF	0%	44%	0%	62%

LT, Intraatrial lateral tunnel; APC, direct atriopulmonary connection; ECF, extracardiac Fontan operation; N/A, not available.

*Hemodynamically significant arrhythmias include atrial flutter, ectopic atrial tachycardia, junctional ectopic tachycardia (but not accelerated junctional rhythm), ventricular tachycardia, and complete heart block requiring a pacemaker.

from Kurer,⁸ Balaji,²³ Cecchin,²⁴ and their associates report hemodynamically significant arrhythmias in 8% to 29% of patients using the intraatrial lateral tunnel and direct atriopulmonary connection. In their series and other reported data, these arrhythmias caused considerable morbidity and mortality.^{5, 6}

However, we did encounter a high incidence of perioperative accelerated junctional rhythm that was not hemodynamically significant. Our incidence of such arrhythmias is higher than that reported by other groups using the extracardiac Fontan operation.^{15, 18} The reason for this difference is not clear but may represent reporting technique relating to definitions of hemodynamically insignificant arrhythmias. Our results were similar to those of these groups with respect to significant arrhythmias.

At subsequent follow-up, our patients had a high incidence of asymptomatic sinus node dysfunction as determined by noninvasive testing. The noninvasive assessment of sinus node function is generally considered to be as reliable as more invasive diagnostic tools.^{25, 26} Several other series have also used 24-hour Holter monitoring as a component of intermediate and late-term follow-up and have demonstrated a variety of arrhythmias, in particular sinus node dysfunction and atrial arrhythmias.^{23, 24} Given the avoidance of suture lines in the region of the sinoatrial node, the finding of sinus node dysfunction may appear surprising, but it is not unprecedented. Manning and colleagues²⁷ compared patients undergoing a primary versus staged approach to the Fontan procedure. Their results indicated a higher incidence of atrial arrhythmias, predominantly sinus node dysfunction, associated with a staged approach. Our data, in conjunction with the Manning study, imply that some factor preceding the Fontan operation plays a significant role in the

development of sinus node dysfunction. Whether this relates to cannulation for the staging operations or to the specific congenital heart lesion is yet to be determined. These data further suggest that yearly noninvasive assessment of sinus node dysfunction is warranted in patients who have had the Fontan operation.

Our patients did not have significant tachyarrhythmias on subsequent follow-up. Other studies have shown a substantial incidence of this problem, particularly atrial flutter, after various other modifications of the Fontan operation.^{5-8, 23, 28} Gandhi and coworkers¹⁷ have shown that the lateral tunnel suture line acts as an essential component of the atrial flutter circuit. This suggests that the incidence of atrial flutter may be reduced with the extracardiac Fontan procedure, although additional follow-up will be required to confirm these findings.

In our patients, the overall risk for development of a thrombus was 10 events per 100 patient-years, with a total incidence of 19%. The reported incidence of thrombus formation after the Fontan procedure has ranged from 3% to 20% and does not appear to be related to the modification of Fontan used.^{9, 29} It does appear, however, that transesophageal echocardiography is more sensitive than transthoracic echocardiography for detecting thrombi.³⁰ Therefore our data may underestimate the actual incidence of thrombi. However, we do not believe that we failed to detect any major thrombi, because no patient in our series had unexplained embolic phenomena.

A major concern with the extracardiac Fontan procedure is the use of artificial material, with the inherent risk of thrombus formation.^{9, 29} Although the data did not reach statistical significance, Rosenthal and colleagues⁹ showed that thromboses did not develop in any patient with a homograft or

pericardial conduit, whereas thromboses developed in 35% of patients with synthetic conduits. It remains to be seen whether the extracardiac tunnel with its use of prosthetic material will result in an increase in the incidence of thromboses, but our preliminary data are encouraging in this regard.

Although the efficacy of antithrombotic therapy in this setting is unknown, several authors have recommended routine anticoagulation for all patients who have undergone the Fontan procedure.^{2, 27, 29} Interestingly, Giannico and colleagues¹⁸ maintained all their patients on anticoagulation with aspirin after the extracardiac Fontan procedure and found no thromboembolic complications in a series of 22 patients. It was not our institutional policy to maintain anticoagulation therapy during the period of this study. However, we recently initiated prophylactic aspirin for at least 6 months after the extracardiac Fontan operation. It remains to be seen whether this will decrease the incidence of intraconduit thrombus formation. Although a large percentage of patients (43%) with thromboses in Rosenthal's study⁹ were asymptomatic, the morbidity and mortality from thromboembolic events were substantial. Consistent echocardiographic follow-up in this population is therefore of utmost importance, and the long-term benefits of oral anticoagulation in this patient population require further study.

Our study design has several limitations. The retrospective nature of the study may have resulted in underestimation of postoperative arrhythmias and thrombi. The extracardiac Fontan procedure has been performed at our institution only since 1993, so the total number of cases is small and postoperative follow-up time has been relatively short. Therefore the appearance of late-onset arrhythmias and thromboembolic events cannot be predicted, and close follow-up will clearly need to be continued. For this reason, the absence of significant tachyarrhythmias in our patients, while encouraging, must be regarded cautiously.

In summary, we report a high incidence of sinus node dysfunction after the extracardiac Fontan operation, but we did not identify significant problems with tachyarrhythmias, either early or at subsequent follow-up. We also found a nearly 20% incidence of thrombus formation within the external conduit. The cause of the sinus node dysfunction is indeterminate at present and warrants further study with prospective longitudinal evaluation.

REFERENCES

- Fontan F, Baudet E. Surgical repair of tricuspid atresia. *Thorax* 1971;26:240-8.
- Dobell AR, Trusler GA, Smallhorn JF, Williams WG. Atrial thrombi after the Fontan operation. *Ann Thorac Surg* 1986; 42:664-7.
- Driscoll DJ, Offord KP, Feldt RH, Schaff HV, Puga FJ, Danielson GK. Five- to fifteen-year follow-up after Fontan operation. *Circulation* 1992;85:469-96.
- du Plessis AJ, Chang AC, Wessel DL, et al. Cerebrovascular accidents following the Fontan operation. *Pediatr Neurol* 1995;12:230-6.
- Gelatt M, Hamilton RM, McCrindle BW, et al. Risk factors for atrial tachyarrhythmias after the Fontan operation. *J Am Coll Cardiol* 1994;24:1735-41.
- Gewillig M, Wyse R, de Leval MR, Deanfield JE. Early and later arrhythmias after the Fontan operation: predisposing factors and clinical consequences. *Br Heart J* 1992;67:72-9.
- Kavey R, Gaum WE, Byrum CJ, Smith FC, Kveselis DA. Loss of sinus rhythm after total cavopulmonary connection. *Circulation* 1995;92(Suppl):II304-8.
- Kurer CC, Tanner CS, Norwood WI, Vetter VL. Perioperative arrhythmias after Fontan repair. *Circulation* 1990; 82(Suppl):IV190-4.
- Rosenthal DN, Friedman AH, Kleinman CK, Kopf GS, Rosenfeld LE, Hellenbrand WE. Thromboembolic complications after Fontan operations. *Circulation* 1995;92(Suppl):II287-93.
- Wilson DG, Wisheart JD, Stuart AG. Systemic thromboembolism leading to myocardial infarction and stroke after fenestrated total cavopulmonary connection. *Br Heart J* 1995;73:483-5.
- Kreutzer G, Galindez E, Bono H, de Palma C, Laura P. An operation for the correction of tricuspid atresia. *J Thorac Cardiovasc Surg* 1973;66:613.
- Jonas RA, Castaneda AR. Modified Fontan procedure: atrial baffle and systemic venous to pulmonary artery anastomotic techniques. *J Card Surg* 1988;3:91-6.
- de Leval MR, Kliner P, Gewillig M, Bull C. Total cavopulmonary connection: a logical alternative to atriopulmonary connection for Fontan operations. *J Thorac Cardiovasc Surg* 1988;96:682-95.
- Bridges ND, Lock JE, Castaneda AR. Baffle fenestration with subsequent transcatheter closure: modification of the Fontan operation for patients at increased risk. *Circulation* 1990;82:1681-9.
- Laschinger JC, Ringel RE, Brenner JJ, McLaughlin JS. The extracardiac total cavopulmonary connection for definitive conversion to the Fontan circulation: summary of early experience and results. *J Card Surg* 1993;8:524-33.
- Black MD, van Son JAM, Haas GS. Extracardiac Fontan operation with adjustable communication. *Ann Thorac Surg* 1995;60:716-8.
- Gandhi SK, Bromberg BI, Rodefeld MD, et al. Lateral tunnel suture line variation reduces atrial flutter after the modified Fontan operation. *Ann Thorac Surg* 1996;61:1299-309.
- Giannico S, Corno A, Marino B, et al. Total extracardiac right heart bypass. *Circulation* 1992;86(Suppl):II110-7.
- Marcelletti C, Corno A, Giannico S, Marino B. Inferior vena cava-pulmonary artery extracardiac conduit: a new form of right heart bypass. *J Thorac Cardiovasc Surg* 1990;100:228-32.

20. Hennein HA, Kililtan HT, Sade RM. Conversion of the hemi-Fontan procedure to fenestrated total extracardiac cavopulmonary bypass. *Ann Thorac Surg* 1995;60(6 Suppl): S568-71.
21. Laschinger JC, Redmond JM, Cameron DE, Kan JS, Ringel RE. Intermediate results of the extracardiac Fontan procedure. *Ann Thorac Surg* 1996;62:1261-7.
22. Kugler JD. Sinus node dysfunction. In: Gillette PC, Garson A, editors. *Pediatric arrhythmias: electrophysiology and pacing*. 1st ed. Philadelphia: WB Saunders; 1990. p. 250-300.
23. Balaji S, Case CL, Sade RM, Gillette PC. Arrhythmias and electrocardiographic changes after the hemi-Fontan procedure. *Am J Cardiol* 1994;73:828-9.
24. Cecchin F, Johnsrude CL, Perry JC, Friedman RA. Effect of age and surgical technique on symptomatic arrhythmias after the Fontan procedure. *Am J Cardiol* 1995;76:386-91.
25. Reiffel JA, Bigger JT Jr, Cramer M, et al. Ability of Holter electrocardiographic recording and atrial stimulation to detect sinus nodal dysfunction in symptomatic and asymptomatic patients with sinus bradycardia. *Am J Cardiol* 1977;40: 189-93.
26. Thormann J, Schlepper M, Kramer W. Diurnal changes and reproducibility of corrected sinus node recovery time. *Cathet Cardiovasc Diagn* 1983;9:439-43.
27. Manning PB, Mayer JE, Wernovsky G, Fishberger SB, Walsch EP. Staged operation to Fontan increased the incidence of sinoatrial node dysfunction. *J Thorac Cardiovasc Surg* 1996;111:833-40.
28. Peters NS, Somerville J. Arrhythmias after the Fontan procedure. *Br Heart J* 1992;68:199-204.
29. Jahangiri M, Ross DB, Redington AN, Lincoln C, Shinebourne EA. Thromboembolism after the Fontan procedure and its modifications. *Ann Thorac Surg* 1994;58:1409-14.
30. Stumper O, Sutherland GR, Geuskens R, Roelandt J, Bos E, Hess J. Transesophageal echocardiography in evaluation and management after a Fontan procedure. *J Am Coll Cardiol* 1991;17:1152-60.