

Risk factors for postoperative arrhythmia in patients with physiologic univentricular hearts undergoing Fontan procedure

Fontan sirkülasyonu yapılmış fizyolojik univentriküler kalplerde postoperatif aritmi için risk faktörleri

Mehmet Çelik, Bülent Sarıtaş, Tolga Tatar, Murat Özkan, Tankut Akay, Sait Aşlamacı

Department of Cardiovascular Surgery, Faculty of Medicine, Başkent University, Ankara-Turkey

ABSTRACT

Objective: Advanced age, dilated right atrium, increased preoperative pulmonary artery pressure, increased right atrial pressure, technique of operation, and poor ventricular function were reported to be risk factors for postoperative arrhythmia. Aim of this study is to determine the risk factor for postoperative arrhythmia after Fontan operation with regard to ventricle dominance and hemodynamic parameters.

Methods: In this retrospective study, the data of the patients including age, weight, dominant ventricle, type of cardiac anomaly, previous operations, duration of cardiopulmonary bypass (CPB), duration of aortic clamping, cardiac rhythm, pulmonary artery pressure, the Nakata Index, systemic atrioventricular (AV) valve insufficiency were obtained from the hospital records, the echocardiographic files, and cardiac catheterization records. Patients were assigned to dominant left ventricle or dominant right ventricle groups. Statistical analysis was performed using the Mann-Whitney U test.

Results: Arrhythmia was observed in 21 (52.5%) patients in the postoperative period. No postoperative arrhythmia was observed in patients with a right atrial pressure of <5 mmHg, whereas postoperative arrhythmias were observed in patients with a right atrial pressure of ≥5 mmHg ($p<0.05$). When the effects of preoperative and postoperative pulmonary artery pressures on postoperative arrhythmia were evaluated, postoperative arrhythmia was determined in only 2 (12.5%) of 8 patients with a preoperative mean pulmonary artery pressure of ≤9 mmHg, whereas postoperative arrhythmia was observed in 19 (59.3%) of 32 patients with a preoperative pulmonary artery pressure of ≥10 mmHg. A preoperative mean pulmonary artery pressure of >10 mmHg increased the risk of postoperative arrhythmia ($p<0.02$). Postoperative arrhythmia was determined in 8 (53%) of 15 patients with a dominant right ventricle, and in 13 (52%) of 25 patients with a dominant left ventricle ($p>0.05$).

Conclusion: While a preoperative mean pulmonary artery pressure of >10 mmHg and a preoperative right atrial pressure of >5 mmHg were the risk factors for postoperative arrhythmia in patients undergoing Fontan procedure, the right or left ventricular dominance was not a risk factor. (*Anadolu Kardiyol Derg 2012; 12: 347-51*)

Key words: Univentricular heart, Fontan operation, arrhythmia, risk factors

ÖZET

Amaç: Literatürde yapılan çalışmalarda ileri yaş, sağ atriyum boyutunun büyüklüğü, ortalama pulmoner arter basıncı, sağ atriyum basıncı, sistemik ventrikülün düşük ejeksiyon fraksiyonu, ameliyat tekniği postoperatif aritmi için risk faktörü olarak saptanmıştır. Bu çalışmada sistemik dolaşımı sağlayan 'dominant ventrikül' ün sağ ventrikül ya da sol ventrikül olmasının ve hemodinamik parametrelerin postoperatif aritmi açısından risk faktörü olup olmadığı araştırılmıştır.

Yöntemler: Fontan ameliyatı yapılmış 1997 ve 2008 yılları arasındaki 40 hastanın verileri retrospektif olarak değerlendirildi. Hastaların ekokardiyografi notları, kardiyak kateterizasyon notları, ameliyat notları, yaş, kilo, dominant ventrikül tipi, kardiyak anomali tipi, geçirilmiş operasyonlar, kardiyopulmoner baypas süresi, aort klemp süresi, kardiyak ritim, pulmoner arter basıncı, Nakata indeksi, sistemik atrioventriküler kapak yetmezliği kaydedilerek çalışmamıza dahil edilmiştir. Hastalar dominant sol ventrikül ve dominant sağ ventrikül olarak ayrıştırıldılar. İstatistiksel analiz Mann-Whitney U test kullanılarak gerçekleştirildi.

Bulgular: Postoperatif dönemde toplam 21 hastada (%52.5) aritmi görülmüştür. Preoperatif sağ atriyum basınçlarına bakıldığında sağ atriyum basıncı 5 mmHg'dan düşük hastalarda postoperatif aritmi gözlenmezken sağ atriyum basıncı 5 mmHg ve daha yüksek olan hastalarda postoperatif arit-

Address for Correspondence/Yazışma Adresi: Dr. Mehmet Çelik, Turgut Özal Mahallesi Güneyvadi Sitesi A/18 Batıkent/Ankara-Türkiye
Phone: +90 312 566 10 85 Fax: +90 216 651 98 58 E-mail: mehmet1981@yahoo.com

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miler görülmüştür ($p<0.05$). Preoperatif ve postoperatif ortalama pulmoner arter basınçlarının postoperatif aritmiye etkisi incelendiğinde preoperatif pulmoner arter basıncı 9 mmHg ve altında olan 8 hastanın sadece 2'sinde (%12.5) postoperatif aritmi saptanırken, preoperatif pulmoner arter basıncı 10 mmHg ve üstünde olan 32 hastanın 19'ünde (%59.3) postoperatif dönemde aritmi saptanmıştır. Preoperatif ortalama pulmoner arter basıncının 10mmHg'dan yüksek olması postoperatif aritmi riskini arttırmaktadır ($p<0.02$). Sağ ventrikül dominansı olan 15 hastanın 8'inde (%53) ve sol ventrikül dominansı olan 25 hastanın 13'ünde (%52) postoperatif aritmi saptanmıştır ($p>0.05$).

Sonuç: Fontan ameliyatı yapılan hastalarda 10 mmHg'dan yüksek preoperatif ortalama pulmoner arter basıncı ve 5 mmHg'dan yüksek preoperatif sağ atriyum basıncı postoperatif aritmi için bir risk faktörü iken, ventrikül dominansı bir risk faktörü değildir. (*Anadolu Kardiyol Derg 2012; 12: 347-51*)

Anahtar kelimeler: Üniventriküler kalp, Fontan operasyonu, aritmi, risk faktörleri

Introduction

In patients with hypoplastic ventricle, biventricular repair is not possible and Fontan circulation provides a surgical solution of palliative nature. The Fontan operation is a palliative surgical procedure utilized to divert the systemic venous return to the pulmonary system, without passing through the heart.

Development of postoperative arrhythmias in patients undergoing the Fontan operation carries a significant morbidity. For this purpose, the risk factors with respect to postoperative arrhythmia following the Fontan operation have been evaluated in previous studies (1-4). While the extracardiac conduit procedure was determined to be a risk factor in the early postoperative period in the study by Kumar et al. (1), Chowdhury et al. (2) determined bilateral superior vena cava (SVC) and systemic ventricular dysfunction to be risk factors for supraventricular arrhythmia following the extracardiac conduit Fontan operation. In the studies by Gewillig et al. (3) and Peters et al. (4), advanced age, dilated right atrium, increased preoperative pulmonary artery pressure, increased right atrial pressure, and poor ventricular function were reported to be risk factors.

In the present study, 40 patients who had undergone the Fontan operation in our clinic between 1997 and 2007 were evaluated retrospectively.

Different from the literature, we aimed to evaluate the preoperative hemodynamic parameters and whether or not the right or the left ventricles supporting the systemic circulation as a "dominant ventricle" pose a risk for postoperative arrhythmia.

Methods

Study design and patients population

The study was designed as a retrospective observational study. The data of 40 patients who had undergone the Fontan operation between the years of 1997 and 2008 were obtained from the Avicenna program, which is the databank of our hospital, and from the operation notes and the patients' files, evaluated retrospectively.

The data of the patients including age, weight, dominant ventricle, type of cardiac anomaly, previous operations, duration of cardiopulmonary bypass (CPB), duration of aortic clamping, oxygen saturation level, cardiac rhythm, pulmonary artery pressure, the Nakata Index (area of the right and left pulmonary artery at hilus/ body surface area- mm^2/m^2), systemic atrioventricular (AV) valve insufficiency, and duration of follow-up were obtained from

medical history records, echocardiographic files, and cardiac catheterization files. Patients were assigned to dominant left ventricle (dLV) or dominant right ventricle (dRV) groups.

Type of cardiac anomaly is presented in Table 1. Of the 40 patients (21 male, 19 female) included in the study, the left ventricle was the ventricle supporting the systemic circulation in 25 (62.5%) and the right ventricle was the ventricle supporting the systemic circulation in 15 (37.5%) patients. Of the patients with the right ventricle supporting the systemic circulation, 6 (40%) were boys and 9 (60%) were girls, whereas of those with the left ventricle supporting the systemic circulation, 15 (60%) were boys and 10 (40%) were girls.

Only the patients who completed a follow-up period of at least one year were included in our study. While the mean duration of follow-up in patients with the right ventricle supporting the systemic circulation was 5.9 ± 3.1 years, the mean duration of follow-up in patients with the left ventricle supporting the systemic circulation was 5.8 ± 3.2 years. The mean duration of follow-up was similar in the two groups.

The present study was approved by the Ethics Committee of Başkent University Faculty of Medicine (approval number: KA09/149).

Arrhythmia evaluation

Continuous electrocardiogram (ECG) recording to obtain valuable data for postoperative arrhythmia was provided. The 12-lead ECG was performed routinely on admission to the intensive care unit and immediately when arrhythmia was observed

Table 1. Type of cardiac anomaly

Anomaly	Patients with a dominant right ventricle (n)	Patients with a dominant left ventricle (n)	Total
DORV+CAVSD	11	1	12
DORV+TAPVC	2	0	2
TA	0	15	0
EBSTEIN	0	4	4
IVSPA	0	5	5
MITRAL ATRESIA	3	0	3
Total	15	25	40

CAVSD - complete atrioventricular septal defect, DORV - double outlet right ventricle, IVSPA - pulmonary atresia with intact ventricular septum, TA - tricuspid atresia, TAPVC - total anomalous pulmonary venous connection

on the monitor. The incidence of tachy- and bradyarrhythmias was recorded.

Operative technique

All the operations were performed by the same surgical team at the hospital. In all patients, the heart was achieved through a median sternotomy. CPB was initiated following the bicaval and aortic cannulation in all patients. Before the initiation of CPB, the patent ductus arteriosus (PDA) or the Blalock-Taussig (BT) shunts, if exist, were closed. Apart from the four patients who underwent the extracardiac conduit procedure, aortic clamp was placed in all the remaining patients after CPB was established, and cardioplegic arrest was achieved by the administration of a single dose of crystalloid cardioplegia. Contegra (Medtronic, Minneapolis, MN, USA) and Polytetrafluoroethylene (PTFE) grafts were used in patients undergoing the extracardiac conduit procedure. In patients undergoing the lateral tunnel procedure, a tunnel was created using the autogenic pericardium, xenograft pericardium, and atrial tissue. Following repair, the pulmonary artery pressure was measured and recorded in all patients.

The patients were postoperatively followed-up at the Pediatric Intensive Care Unit of Department of Cardiovascular Surgery. The systemic arterial pressures and the central venous pressures were monitored invasively, whereas the cardiac rhythms, oxygen saturations, and body temperatures were monitored non-invasively.

Statistical analysis

The Statistical Program for Social Sciences (SPSS, Inc., Chicago, IL, USA) version 13.0 was used for statistical calculations. The collected data were analyzed electronically and classified. Continuous variables were compared using the Mann-Whitney U test, and were expressed as mean±standard deviation and median (min-max) values. The categorical variables were expressed as number (percentage) and were compared using the Chi-square test. Patients were grouped as those with the right ventricle supporting the systemic circulation and those with the left ventricle supporting the systemic circulation, these groups were compared according to the determined parameters.

Results

The demographic characteristics of the patients are presented in Table 2. Of the 15 patients with a dominant right ventricle, 14 (93.3%) were operated on using the lateral tunnel procedure and one (6.7%) was operated on using the extracardiac conduit (PTFE vascular graft) procedure. Of the patients with a dominant left ventricle, 19 (76%) were operated on using the lateral tunnel procedure and six (24%) were operated on using the extracardiac conduit (5 PTFE, 1 Dacron graft) procedure. All patients in both groups had normal sinus rhythm preoperatively.

The mean duration of CPB, the mean duration of aortic clamping and the mean body temperature of the patients are

Table 2. The demographic and clinical data of the patients

Anomaly	Patients with a dominant right ventricle (n=15)	Patients with a dominant left ventricle (n=25)	*p
Age, years	6.8±3.3 6 (2-14)	4.8±2.8 4 (2-12)	>0.05
Weight, kg	21.4±6.7 20 (12-33)	16.2±5.2 16 (9-27)	>0.05
Duration of aortic clamping, minute	70.6±26.2 78 (0-106)	47.7±27.6 49 (0-108)	<0.05
Duration of CPB, minute	115.7±17.1 119 (73-137)	95.7±28.3 97 (30-159)	<0.05
Body temperature during operation, °C	26.2±1.8 26 (24-32)	26.7±4 26 (20-37)	>0.05
Preoperative left atrial size, mm	20.5±5.3 22 (13-25)	22.6±6.1 20 (16-38)	>0.05
Preoperative PA pressure, mmHg	12.7±2.7 13 (8-16)	11.5±3 12 (5-16)	>0.05
Postoperative PA pressure, mmHg	15.3±2.2 15 (11-20)	14.7±2.7 14 (10-20)	>0.05
Nakata index, mm ² /m ²	376.1±114.7 306 (300-550)	336.2±66.6 350 (210-420)	>0.05
Preoperative oxygen saturation, %	81.4±5.2 81 (67-87)	78.1±10 82 (58-93)	>0.05
Postoperative oxygen saturation, %	93.8±6.2 95 (80-100)	97.4±2.7 98 (90-100)	>0.05
Postoperative follow-up duration, years	5.9±3.1 5 (1-11)	5.8±3.2 4 (1-12)	>0.05
Data are expressed as Mean±SD, median (minimum,maximum) values *Mann-Whitney U test CBP - cardiopulmonary bypass, PA - pulmonary artery, SD - standard deviation			

demonstrated in Table 2. Accordingly, the mean duration of aortic clamping and the mean duration of CPB was found to be longer in the group with the right ventricle supporting the systemic circulation than that in the group with the left ventricle supporting the systemic circulation (p<0.05).

Arrhythmia was observed in 21 (13 patients in dominant left ventricle and 8 patients in dominant right ventricle) patients in the postoperative period. Rhythm disturbances in the postoperative follow-ups were atrial fibrillation (7 patients, 4 vs 3), nodal rhythm (5 patients, 3 vs 2), supraventricular tachycardia (4 patients, 3 vs 1), AV block (one patient required a temporary pacemaker and two patients required a permanent pacemaker). Junctional ectopic tachycardia (2 patients, 1 vs 1). Some patients had more than one rhythm disturbance in the postoperative follow-up. A normal sinus rhythm could not be achieved in 4 of the patients with rhythm disturbances. Of these patients, 2 had nodal rhythm, and 2 had pacemaker rhythm.

Hemodynamic parameters

When the preoperative right atrial pressures were evaluated, no postoperative arrhythmia was observed in patients with a

right atrial pressure of <5 mmHg, whereas postoperative arrhythmias were observed in patients with a right atrial pressure of ≥5 mmHg (p<0.05) (Table 3).

When the effects of preoperative and postoperative pulmonary artery pressures on postoperative arrhythmia were evaluated, postoperative arrhythmia was determined in only 2 (12.5%) of 8 patients with a preoperative pulmonary artery pressure of ≤9 mmHg, whereas postoperative arrhythmia was observed in 19 (59.3%) of 32 patients with a preoperative pulmonary artery pressure of ≥10 mmHg. A preoperative pulmonary artery pressure of >10 mmHg increased the risk of postoperative arrhythmia (p<0.02).

Ventricle property

When the effect of ventricular dominance on postoperative arrhythmia was evaluated, postoperative arrhythmia was determined in 8 (53%) of 15 patients with a dominant right ventricle, and in 13 (52%) of 25 patients with a dominant left ventricle. Accordingly, it was determined in our study that ventricular dominance did not have an effect on postoperative arrhythmia.

Discussion

In the present single-centered study, we performed Fontan procedure on patients with the right and left ventricles supporting the systemic circulation and evaluated their postoperative arrhythmias. Accordingly, even though preoperative mean pulmonary artery pressure more than 10 mm-Hg and a preoperative right atrial pressure more than 5 mm-Hg were the most important risk factor for arrhythmia. There were no statistically significant differences between the two groups in terms of age, duration of aortic clamping, preoperative left atrial size, preoperative and postoperative oxygen saturation, preoperative and postoperative pulmonary artery pressures, duration of postoperative follow-up, and previous palliative surgical procedures. In the light of these data, it could be suggested that our study was performed on a homogeneous group of patients.

Table 3. Arrhythmia incidence with regard to right atrial pressure and pulmonary artery relations

Variables		Patients with a dominant right ventricle (n=15)	Patients with a dominant left ventricle (n=25)	*p
Patients with right atrial pressure	<5 mmHg, n (%)	0/2 (0%)	0/4 (0%)	>0.05
	≥5 mmHg, n (%)	13/13 (100%)	8/21 (38%)	<0.05
Patients with pulmonary arterial pressure	<9 mmHg, n (%)	1/3 (33%)	1/5 (20%)	>0.05
	>10 mmHg, n (%)	7/12 (58%)	12/20 (60%)	>0.05

Data are expressed as number (percentage)
*Chi-square test

The possible causes of tachyarrhythmia and bradyarrhythmia following the Fontan procedure may include damage to the sinoatrial (SA) node or the artery, extensive atrial suture lines and incisions, and exposure of the atrial myocardium to prolonged high pressure. The predisposing factors for atrial arrhythmias following the Fontan procedure are extensive sutures performed on the right atrium resulting in healed non-conductive scar tissue, damage to the sinus node or the artery in previously performed hemi-Fontan procedures, injury to the crista terminalis, extensive right atrial incisions performed in intracardiac repair operations, and multi-step operations (5-7). Electroanatomical studies have demonstrated that scar tissue in the crista terminalis and in the right atrium are not conductive, and that these scar tissues predispose intraatrial reentrant tachyarrhythmias (8, 9).

In their study, Kumar et al. (1) found a high incidence of early postoperative SA node dysfunction in patients who were operated on using the extra cardiac conduit procedure. However, they reported no statistically significant difference in the long-term follow-up period in terms of SA node dysfunction between the patients undergoing the extra cardiac conduit procedure and those undergoing the lateral tunnel technique (1). Chowdhury et al. (2) stated that supraventricular tachycardias developing after the Fontan operation were likely to be multifactorial and reported that postoperative supraventricular tachycardia was observed more frequently in patients with bilateral SVC and systemic ventricular dysfunction who were operated on using the extra cardiac conduit procedure (2). In the light of the data in our study group, arrhythmia was observed in the postoperative period in 2 of the 7 patients operated on using the extra cardiac conduit procedure. Due to the small sample size of the patients who were operated on using the extra cardiac conduit procedure, a significant difference could not be achieved in the comparison of the results of these patients with that of those operated on using the lateral tunnel procedure.

In the study performed by Gewillig et al. (3) in 1992 on 104 patients to evaluate the incidence and risk factors of arrhythmia and to determine the clinically significant arrhythmias after the Fontan operation, the risk factors for late postoperative arrhythmias were determined as advanced age, an increased right atrial size, and an elevated mean pulmonary artery pressure. In that particular study, they also reported that the preoperative oxygen saturation was not a risk factor for postoperative arrhythmia (3). Different from the study by Gewillig et al. (3), we investigated the preoperative right atrial pressure rather than the preoperative right atrial size. While postoperative arrhythmia was not observed in the patients with a preoperative right atrial pressure of <5 mmHg, postoperative arrhythmia was observed in those with a preoperative right atrial pressure of ≥5 mmHg; and a high right atrial pressure was found to be associated with postoperative arrhythmia.

While postoperative arrhythmia was determined in 2 of 8 patients with a preoperative pulmonary artery pressure of <10 mmHg, arrhythmia was determined in the postoperative period in 19 of 32 patients with a preoperative pulmonary artery pres-

sure of ≥ 10 mmHg. These results were similar to that found in the study by Gewillig et al. (3); we also determined a correlation between a preoperative pulmonary artery pressure of >10 mmHg and postoperative arrhythmia. This finding was similar to that found in the study by Gewillig et al. (3).

In the study performed on 74 patients by Nürnberg et al. (10) in 2004, the lateral tunnel procedure was found to be a risk factor for the development of tachyarrhythmias in the early postoperative period in patients with the right ventricle supporting the systemic circulation. In our study, a sufficient distribution was achieved in order to perform a statistical analysis between the patients with the right ventricle supporting the systemic circulation and those with the left ventricle supporting the systemic circulation; however, a similar distribution to compare those operated on using the extra cardiac conduit procedure with those operated on using lateral tunnel procedure could not be achieved due to the small sample size of the patients operated on using the extra cardiac conduit procedure. While postoperative arrhythmia was determined in 2 of 8 patients operated on using the extra cardiac conduit procedure, postoperative arrhythmia was observed in 19 of 33 patients operated on using the lateral tunnel procedure. No significant difference was determined between the patients with the right ventricle supporting the systemic circulation and those with the left ventricle supporting the systemic circulation with respect to postoperative arrhythmia.

Peters et al. (4) evaluated arrhythmias following the Fontan operation in 60 patients and reported the incidence of early and late postoperative arrhythmias to be high in patients with a high right atrial pressure and a low ejection fraction. They also reported that there were no preoperative indicators other than the high right atrial pressure for arrhythmias developing in the early postoperative period and deaths associated with arrhythmias (4). Similar to the findings reported by Peters et al. (4), we found the incidence of arrhythmias in the early postoperative period to be high in patients with a high right atrial pressure in our study. The rate of early postoperative arrhythmia was 52.5% (21 patients). In the long-term follow-ups, there were no serious hemodynamic abnormalities in our patients with nodal rhythm and with pacemaker rhythm.

Study limitations

Our results are demonstrated that preoperative mean pulmonary artery pressure and right atrial pressure is the most important predictor of the arrhythmia after Fontan operation. On the other hand, this result reflects the early postoperative period. There are no long-term results of the patients undergoing Fontan operation.

Conclusion

While a preoperative mean pulmonary artery pressure of >10 mmHg and a preoperative right atrial pressure of >5 mmHg were the risk factors for postoperative arrhythmia in patients undergoing Fontan procedure, the right or left ventricular dominance was not a risk factor.

Conflict of interest: None declared.

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