The incidence and risk factors of arrhythmias in the early period after cardiac surgery in pediatric patients

Selman Vefa Yıldırım[1], Kürşad Tokel[1], Belma Saygılı[2], Birgül Varan[1]

[1]Division of Pediatric Cardiology, and [2]Department of Pediatrics, Başkent University Faculty of Medicine, Ankara, Turkey

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Rhythm disturbances that develop after pediatric surgery for heart disease significantly increase mortality and morbidity risk. The aim of this study was to determine incidence rates of different arrhythmias and identify risk factors for these disturbances in this patient group.

The study involved 580 children in the pediatric cardiovascular intensive care unit who had undergone cardiac surgery between May 2001 and December 2002. Each was followed until discharge. The patient who sustained arrhythmia was recorded.

Fifty-one of the patients (8.8%, mean age 1.7±2.3 years) developed arrhythmias. Twenty-one (41.1%) had supraventricular tachycardia, 12 (23.5%) had junctional ectopic tachycardia, 10 (19.6%) had complete atrioventricular block, 3 (5.8%) had ventricular arrhythmias, and 5 (9.8%) had atrial fibrillation and atrioventricular dissociation. There was a trend toward higher incidence of arrhythmia (rate, 43.1%) in the 0-6 months age group. The incidence rates of arrhythmia after certain procedures were as follows: 75% after Rastelli operation, 16.7% after total anomalous pulmonary venous return repair, 13.8% after ventricular septal defect repair, 12.8% after the arterial switch operation or arterial switch with ventricular septal defect closure for transposition of the great arteries, 12.5% after atrioventricular septal defect repair, 12.1% after total correction of tetralogy of Fallot, 9.1% after bidirectional cava-pulmonary connection and Fontan procedure, and 6.6% after other miscellaneous procedures. The mean cardiopulmonary bypass time was 105.4±54.1 min. At the time of arrhythmia appearance, the mean values for electrolyte (sodium 144±5 mEq/L, potassium 3.78±0.91 mEq/L, ionized calcium 1.15±0.33 mmol/L) and arterial blood gas parameters (pH 7.40±0.12 and HCO3 24.7±6.3 mmol/L) were all in the normal range. Fifteen (29.4%) of the patients with arrhythmias died and in 7 of these cases, the death was directly linked to resistant arrhythmia.

Arrhythmias can be life-threatening especially in the early period after pediatric heart surgery. The incidence of arrhythmia in this series was 8.8%. The results identified type of operation as a major risk factor for arrhythmia after pediatric heart surgery and they also suggest that age may be important as well.

Key words: arrhythmia, cardiac surgery, children, postoperative.

Rhythm disturbances that develop after pediatric surgery for heart disease significantly increase mortality and morbidity[1-3]. Such disturbances can be of atrial or ventricular origin. Atrial arrhythmias typically arise after Fontan or Senning type operations, whereas ventricular arrhythmias most often occur after total correction of tetralogy of Fallot[1,2]. Junctional ectopic tachycardia (JET) may develop after surgery for closure of ventricular septal defects (VSD), and complete atrioventricular block (CAVB) can occur after any operation that interferes with the His-Purkinje system[1,2,8].

The purpose of this study was to investigate incidence rates for different types of rhythm disturbances that develop after pediatric heart surgery, and to identify possible risk factors involved.

Material and Methods

We evaluated 580 children in the pediatric cardiovascular intensive care unit who had undergone cardiac surgery for correction of congenital or acquired cardiac disease between May 2001 and December 2002. All patients were followed until they were discharged from hospital. Data was collected retrospectively from the "pediatric cardiac intensive care unit surveillance data sheet".

Each child was monitored routinely in intensive care during the early postoperative period. Upon detection of a sustained arrhythmia (≥30 seconds duration, recurrences and/or effect on hemodynamic parameters), electrocardiography (ECG) was performed. All the ECG records were assessed by the same pediatric cardiologist. For each case, we collected demographic data and recorded the cardiac diagnosis, operational procedures, perioperative parameters (cardiopulmonary bypass [CPB] time, aorta clamping time, total surgery time), and postoperative parameters (electrolyte levels, oxygen saturation findings, blood pH, serum calcium level, and doses of inotropic agents required).

Statistical Analysis

Statistical calculations were made using the software SPSS for Windows (version 11.0). Data were analyzed; categorical variables were compared with independent t (two-tailed) test, and logistic regression was performed for some risk factors. P values <0.05 and R values <0.05 were considered statistically significant.

Results

The ages of the 580 children ranged from 1 day to 17 years. Four hundred and forty-six (76.9%) of the cardiac surgeries were open-heart procedures and 134 (23.1%) were closed-heart procedures.

Fifty-one patients (13 females, 38 males; 8.8% of total) developed rhythm disturbances, and the mean age of this group was 1.7±2.3 years (range, 1 day to 9 years). Three of these patients had undergone closed-heart surgery (2.2% of all closed-heart cases) and 48 had undergone open-heart surgery (10.8% of all open-heart cases). Fifteen (29.4%) of the 51 patients with rhythm disturbance died and 36 (70.6%) were discharged from hospital. Seven (13.7%) of the 51 patients died due to resistant arrhythmia.

Types of Arrhythmia

Of the 51 patients with rhythm disturbance, 10 (19.6%) had CAVB, 12 (23.5%) had JET, 21 (41.2%) had supraventricular tachycardia (SVT), 5 (9.8%) had atrial fibrillation (AF) and AV dissociation (AVD), and 3 (5.9%) had ventricular fibrillation (VF) and frequent ventricular extrasystole (VES).

Relationships Between Diagnosis, Surgery Type, and Arrhythmia

Forty-eight of the rhythm disturbances arose after open-heart operations. Three arose after Rastelli operation (75% of 4 such operations); 2 occurred after repair of total anomalous pulmonary venous return (16.7% of 12 such operations); 12 developed after VSD closure (and elimination of left or right ventricle obstruction) (13.8% of 87 such operations); 6 developed after arterial switch operation (ASO) for transposition of the great arteries (TGA), or after ASO with VSD closure (12.8% of 47 such operations); 4 arose after atrioventricular septal defect (AVSD) repair (12.5% of 32 such operations); 7 developed after total correction of TOF (12.1% of 58 such operations); 1 occurred after a bidirectional cava-pulmonary connection (9.1% of 11 such procedures), and 13 appeared after other types of surgery (simple [such as ASD closure, isolated double chamber right ventricle repair], complex [such as Senning operation with VSD closure, truncus arteriosus repair with VSD closure], valvular [such as tricuspid valve replacement]) (6.7% of 195 such procedures). Table I lists the incidences of arrhythmia for the different types of open-heart surgery that were performed.

All the arrhythmias were also analyzed according to time of appearance. Complete atrioventricular block (CAVB) and AVD appeared in the perioperative period (while the patient was still in the operating room). The other types of arrhythmias developed a mean of 44.0±77.7 hours after surgery (range, 1 hour to 288 hours). Of the 36 arrhythmias excluding the CAVB and AVD, 25 (69.4%) arose in the first 24 hours, 2 (5.6%) between 24 and 48 hours, 3 (8.3%) between 48 and 72 hours, and 6 (16.7%) later than 72 hours post-surgery.

When the 10 cases of CAVB were disregarded, 30 (73.2%) of the 41 remaining rhythm disturbances caused hemodynamic instability.

Table I. Incidence of Arrhythmia According to the Different Surgical Procedures

Surgical procedure	Arrhythmia incidence N %
VSD closure (+ elimination of right or left obstruction)	12/87 13.8
TOF correction	7/58 12.1
ASO, ASO+VSD closure	6/47 12.8
TAPVC repair	2/12 16.7
AVSD repair	4/32 12.5
BCPC and Fontan	1/11 9.1
Rastelli operation	3/4 75.0
Other (simple, complex and valvular)	13/95 13.7

ASO: Arterial switch operation. AVSD: Atrioventricular septal defect. BCPC: Bidirectional cava-pulmonary connection. TOF: Tetralogy of Fallot. TAPVC: Total anomalous pulmonary venous connection. VSD: Ventricular septal defect.

Intraoperative Factors in Relation to Arrhythmias

For the 48 cases in which arrhythmia developed after open-heart surgery, the mean operation time was 188.2±66.8 min (range, 60-420 min), the mean aorta clamping time was 56.7±27.2 min (range, 11-116 min), and the mean CPB time was 105.4±54.1 min (range, 21-284 min). The mean CPB time in this group was significantly longer than that for the 446 total open heart-surgery cases (105.4±54.1 min vs. 79.6±44.1 min, respectively, $P<0.05$, $R=0.29$).

Age and Arrhythmias

Arrhythmia incidence was also assessed relative to age. Twenty-two (43.1%) of the 51 patients with rhythm disturbance were 0-6 months of age, 6 (11.8%) were 7-12 months, 10 (19.6%) were 1-2 years, 5 (9.8%) were 2-4 years, 7 (13.7%) were 4-12 years, and 1 (2.0%) was older than 12 years. There was a trend toward higher incidence of arrhythmia in the 0-6 months of age group; however, analysis revealed no significant association between age and arrhythmia incidence ($P>0.05$, $R=0.89$). Table II presents the frequencies of arrhythmia for the different age categories that were studied.

Table II. Arrhythmia Incidence and Relation with Age

Age	Arrhythmia group (n=51)	All patients (n=580)
0-6 months	22 (43.1%)	182 (31.4%)
7-12 months	6 (11.8%)	74 (12.8%)
1-2 years	10 (19.6%)	95 (16.4%)
2-4 years	5 (9.8%)	88 (15.2)
4-12 years	7 (13.7%)	119 (20.5)
≥12 years	1 (2.0%)	22 (3.8%)

Factors Known to Precipitate Arrhythmia

The patients' mean arterial blood gas findings at the time of arrhythmia appearance were as follows: pH 7.4±0.1 (range, 7.0-7.5); pCO2 41.8±15.7 (range, 20-86); pO2 111.2±71.7 (range, 10-320); HCO_3 24.7±6.4 mmol/L (range, 7-42 mmol/L), and oxygen saturation 93.5±13.0% (range, 30%-100%). The mean levels of electrolytes at this same stage were as follows: sodium 144.9±5.3 mEq/L (range, 132-159 mEq/L), potassium 3.8±0.9 mEq/L (range, 2.3-6.3 mEq/L), and ionized calcium 1.2±0.3 mmol/L (range, 0.5-2.4 mmol/L). All the mean values were in normal ranges.

Discussion

Many studies have investigated late-onset arrhythmias after cardiac surgery, but few have examined early rhythm disturbances that develop while the patient is in the intensive care unit. Arrhythmias are serious problems because they cause hemodynamic imbalance, often require aggressive treatment, and increase mortality risk[1-4].

In this study, we assessed the types, incidence rates, probable risk factors and prognosis for arrhythmias that develop while children who have undergone cardiac surgery are still in intensive care.

The overall incidence of arrhythmia in the 580 cases was 8.8%. The incidence was 2.2% for closed-heart surgery and 10.7% for open-heart surgery. Our overall incidence is significantly lower than the rates reported by Pfammater et al. (27%)[3] and Valsangiacomo et al. (48%)[2] in this patient group. The overall incidence in our study is similar to the rate of tachyarrhythmia incidence that Bronzetti et al.[5] observed in

pediatric cardiac surgery patients (8.9%). The difference here is seen to be related with the patient choice and the evaluation of arrhythmias. The patients of our study had arrhythmias that were sustained and/or caused hemodynamic imbalances. For that reason, the hemodynamic imbalance rate was found higher, contrary to Valsangiacomo et al.[2].

The risk of arrhythmia is lower after closed-heart surgery than after open-heart surgery because closed-heart surgical technique does not affect the myocardium or interfere with the conduction system; there were also no negative effects of CPB.

In contrast, arrhythmias occur more frequently after open-heart surgery. Most of these disturbances are due to myectomy, cannulation-related causes, or direct damage of the conduction system[2,3,5,8,9]. However, CPB, some medical treatments including high-dose inotropic agents, and electrolyte imbalances in the postoperative period have also been identified as important factors that promote arrhythmias[2]. In our study, we found no significant association between intraoperative factors and occurrence of arrhythmia after open-heart surgery in children except the mean CPB time. The mean CPB time in arrhythmia patients was found statistically longer compared to children without arrhythmias in open-heart surgery patients. It is known that CPB causes changes in the micro- and macro-equilibrium. The arrhythmias might have been increased because of the alterations in the myocardial conduction pathways.

We also evaluated the types of arrhythmias and surgical procedures. It was determined that complete AV blocks appeared, as had been noted before, as a result of surgical procedures such as repair of left ventricle outlet obstruction and TOF correction[1,3,9-11]. It was found that SVT and JET were related to AVSD and TOF corrections, and SVT occurred frequently after Rastelli type surgeries. However, a significant statistical relationship between arrhythmia types and operational types could not be shown.

Different from the other studies, ages and time of arrhythmia appearance were evaluated and it was shown that arrhythmias were more frequent in patients less than 6 months of age, compared to the other age groups. This can be explained by the fact that complex surgical interventions are more frequent for this age group; moreover, the sensitivity to electrolyte and acid-base disorder is higher in this age group. The degree of myocardium affection, intracardiac volume and pressure load are also higher in this group of patients, and the requirement for high-dose inotropic agents increases in order to overcome this situation. The surgical intervention and all these factors may explain the arrhythmia frequency in this age group.

When the time of arrhythmia appearance was examined, it was seen that the first 24 hours is important. There is no data about the timing of arrhythmia appearance in the previous studies; in fact, they were classified as early and late arrhythmias[2,3,7]. As postoperative arrhythmias appeared frequently in the first 24 hours, factors belonging to the myocardium, CPB and high inotropic requirement in this period should be researched. In our study, as precipitating factors, electrolyte (sodium, potassium, and ionized calcium) and acid-base disorders and oxygen saturation were evaluated, and no significant statistical relationship was found. Low magnesium level was reported as causative in JET appearance[2-6], but we could not determine the magnesium levels due to technical reasons. Despite the fact that no statistical relationship could be determined between arrhythmias and precipitating factors, it is obvious that acid-base and electrolyte disorders should be cured due to the importance of whole body metabolism.

Treatment is required in most cases because of their impact on hemodynamics. Moreover, resistant arrhythmias were more frequent than in the series of Valsangiacomo et al.[2], which explains the higher rate of mortality[4].

In conclusion, it was seen that arrhythmias in the postoperative period of cardiac surgery in the intensive care unit were related with the complex surgical interventions and were common in the 0-6 month age group. The first 24 hours after surgery is important for occurrence of arrhythmias. Complete AV blocks were seen mostly in the perioperative period and they might be life-threatening if not treated.

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