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Hospital mortality in surgery for right ventricular outflow tract reconstruction using pulmonary homograft

Mortalidade hospitalar na cirurgia de reconstrução da via de saída do ventrículo direito com homeonxerto pulmonar

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Abstract

Background: **Hospital mortality in surgical reconstruction of the right ventricular outflow tract using pulmonary homograft is variable.**

Objectives: **To identify risk factors associated with hospital mortality and patients' clinical profile.**

Methods: **Study on children who had undergone reconstruction of the right ventricular outflow tract using pulmonary homograft. We analyzed as risk factors the clinical and surgical variables and prosthesis's morphological aspects.**

Results: **Ninety-two patients underwent surgery between 1998 and 2005, presenting mainly pulmonary atresia with ventricular septal defect and tetralogy of Fallot. Forty patients were treated in the first month of life. 38 patients needed Blalock Taussig surgeries due to clinical severity. The median age at surgery for total correction was 22 months, ranging from 1 to 157 months. Pulmonary homograft size ranged from 12 to 26 mm and length of cardiopulmonary bypass was 132 ± 37 minutes. Postoperatively, there were seventeen deaths (18% cases), on average 10.5 ± 7.5 days after surgery. The predominant cause was multiple organ failure. In the univariate analysis between the types of heart disease, they related to age, time of surgery, size of homograft, pulmonary valve Z value, CPB time, maintenance of the integrity of the homograft and pulmonary tree change. There was no statistical difference in hospital mortality between the variables and the type of heart disease.**

Conclusion: **The right-sided obstructive heart diseases require surgical care in the first days of life. The total correction surgery has a mortality risk rate of 18% but there was no association with any variable studied.**

Descriptors: **Heart defects, congenital. Cardiovascular surgical procedures. Transplantation, homologous. Mortality.**

Resumo

Fundamento: **Mortalidade hospitalar na cirurgia de reconstrução da via de saída do ventrículo direito com homoenxerto pulmonar é variável.**

Objetivos: **Identificar os fatores de risco associados à mortalidade hospitalar e ao perfil clínico dos pacientes.**

Métodos: **Estudo de crianças submetidas à reconstrução da via de saída do ventrículo direito com homoenxerto pulmonar. Analisados como fatores de risco as variáveis clínicas, cirúrgicas e de aspectos morfológicos da prótese.**

Resultados: **Noventa e dois pacientes foram operados entre 1998 e 2005, apresentando principalmente atresia pulmonar com comunicação interventricular e a tetralogia de Fallot. Quarenta pacientes foram atendidos no primeiro mês de vida. Necessitaram de 38 cirurgias de Blalock Taussig devido à gravidade clínica. A idade mediana na**

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cirurgia de correção total foi de 22 meses, variando de 1 mês a 157 meses. O tamanho homoenxerto pulmonar variou de 12 a 26 mm e o tempo de extracorpórea foi 132 ± 37 minutos. Após a cirurgia houve 17 óbitos (18% casos), em média 10,5 ± 7,5 dias após. A causa predominante foi falência de múltiplos órgãos. Na análise univariada entre os tipos de cardiopatia, estas diferiram na idade, momento da cirurgia, tamanho do homoenxerto, valor Z da valva pulmonar, tempo de circulação extracorpórea, manutenção da integridade do homoenxerto e alteração da árvore pulmonar. Não houve diferença estatística com relação à mortalidade hospitalar entre as variáveis e o tipo de cardiopatia.

Conclusão: **As cardiopatias obstrutivas do lado direito necessitam de atendimento cirúrgico nos primeiros dias de vida. A cirurgia de correção total apresenta risco de mortalidade de 18%, mas não houve associação com nenhuma variável estudada.**

Descritores: **Cardiopatias congênitas. Procedimentos cirúrgicos cardiovasculares. Transplante homólogo. Mortalidade.**

INTRODUCTION

The use of tube in the surgical treatment of obstructive congenital diseases of the right ventricular outflow tract started with Rastelli and colleagues in 1965, with the use of a non-valved pericardial tube [1]. In 1966, Ross and Somerville, for the first time, used the homograft to repair the right ventricular outflow tract in a case of pulmonary atresia [2].

From the 80s, the cryopreserved pulmonary homograft has become the material of choice for reconstruction of the right ventricular outflow tract due to its greater availability, lower rate of calcification and better outcomes [2,3].

In recent years, promising studies are being performed with the use of decellularized homograft for the correction of obstructive cardiopathies. They present good midterm outcomes, with decreased pulmonary failure, prolonging the graft's life [4].

The pulmonary homograft in pulmonary position has been the choice in the Cardiac Surgery Sevice of the Hospital Pequeno Príncipe for correction of various heart diseases. Reconstructive surgery is performed in cases of pulmonary atresia with interventricular communication, tetralogy of Fallot, pulmonary stenosis, transposition of the great arteries with interventricular communication and pulmonary stenosis, corrected transposition of great arteries with communication and pulmonary stenosis and truncus arteriosus.

Thus, this study aims to assess the clinical profile and factors associated with mortality in patients undergoing reconstruction of the right ventricular outflow tract using pulmonary homograft.

METHODS

In the period from 1st January 1998 to December 31, 2005, 143 patients received cryopreserved pulmonary homograft for the surgery for total correction of congenital heart disease. Of these cases, 92 were considered suitable for the study.

Inclusion criteria were the use of cryopreserved pulmonary homograft in surgical reconstruction of the right ventricular outflow tract or replacement of a heterograft implanted in this position in previous surgery, and medical records with complete data.

Patients who had undergone reconstruction of the right ventricular outflow tract with aortic homograft and pulmonary homograft treated with different technique that cryopreservation were excluded from this study.

In the medical records, data regarding gender, type of heart disease, age at first visit and at surgery, previous surgery, presence of alteration in the pulmonary tree and the results of cardiac catheterization were collected.

The surgical data assessed were homograft size - in millimeters, the Z score of the pulmonary valve, maintenance of the homograft integrity, CPB time, aortic clamping time and rectal temperature during surgery. The data assessed in the postoperative period were length of stay in intensive care unit, clinical events and death.

The Z value of pulmonary valve relates the homograft size in millimeters to the patient's body surface. The pulmonary valve Z value of 0 means the ideal size of the homograft to the patient's body surface. The negative and positive values mean a standard deviation above or below the ideal value.

The integrity of the pulmonary homograft may be altered by the surgeon, in cases on which he decreases the size of the valve ring, removes one of their leaflets or replaces them by a monocuspid with the same material or another.

Hospital mortality was considered the patient's death during surgery or during the period of stay in intensive care unit for recovery from surgery to repair the heart disease.

The surgeries were performed by the same surgical team and postoperative care given by the team of the Intensive Cardiac Care Unit of this hospital.

The patients underwent surgery through a median transsternal thoracotomy and cardiopulmonary bypass was installed after cannulation and heparinization. In 57 patients, moderate hypothermia was performed and deep hypothermia in 18. The total cardiac arrest was obtained in 26 cases and myocardial protection was performed by infusion of crystalloid cardioplegic solution into the aorta.

In patients with tetralogy of Fallot and pulmonary atresia with interventricular communication, the heart repair was performed by the transventricular approach, with closure of the interventricular communication with the use of goretex or bovine pericardial patch in a continuous suture with 5-0 or 6-0 Prolene yarn. In patients with tetralogy of Fallot the muscles of right ventriculcar outflow tract were resected if they were hypertrophic. After, pulmonary artery reconstruction with a cryopreserved pulmonary homograft was performed in both heart disease. In some cases of pulmonary atresia it was necessary interposition of a Hemashield patch in the outflow tract, by connecting the pulmonary homograft to the right ventricle.

After cardioplegia, in patients with *truncus arteriosus*, aortic incision was performed to the withdrawal of the pulmonary branches, by reconstructing the aortic wall using a patch. Following, it was occluded the interatrial communication by right ventriculotomy using bovine pericardium or goretex in continuous sutures. It was connected the posterior pulmonary wall to the pulmonary branches in the right ventricle and then the right ventriculcar outflow tract, the pulmonary annulus and pulmonary trunk were reconstructed by interposition of a pulmonary homograft.

In 12 patients with transposition of great arteries with interventricular communication and pulmonary stenosis, it was performed Rastelli operation, as well as in two cases of corrected transposition with interventricular communication and pulmonary valve stenosis. In other patients, septoplasty was performed with patch and interposition of a pulmonary homograft for reconstruction of the right ventricular outflow tract.

Concomitantly, atrioplasty was performed by running suture or patch, in 19 patients. Fourteen patients underwent enlargement of the pulmonary branches with bovine pericardium or with the branches of the pulmonary homograft. Eleven cases underwent ligation of the ductus arteriosus and 38 ligation of systemic-pulmonary shunt.

The disconnection of cardiopulmonary bypass was obtained after full heat of the patient, with reversal of heparinization and rigorous review of hemostasis, with subsequent sternotomy by anatomical planes. After hemodynamic stabilization, patients were referred to the cardiac intensive care unit.

For statistical analysis it was separated the sample into groups according to the type of heart disease. For each of the variables described above was used Fisher's exact test, on which the null hypothesis of the existence of independence between the type of heart disease and the variable analyzed was tested, versus the alternative hypothesis of dependence. Within each group of heart disease we tested each variable in relation to the outcome of death. For combined evaluation of the variables on the probability of death was adjusted a logistic regression model, considering the Wald test for decision making. In the model were included the variables that in the univariate analysis showed *P* values <0.20. P values <0.05 indicated statistical significance. Data were organized into an Excel spreadsheet and analyzed using software Statistica v.8.0.

RESULTS

The mean age at first visit was 14.3 ± 4.2 months. Forty patients were admitted during the first month of life and 66 during the first year of life. Fifty-six percent of patients were female.

Heart diseases are listed in Table 1. The cases of tetralogy of Fallot requiring reconstruction with pulmonary homograft are those with pulmonary valve agenesis or hypoplasia of the pulmonary valve, pulmonary trunk and/or of a pulmonary branch. Of the 17 cases of *truncus arteriosus*, 14 were type I, two Type II and one Type III.

The mean time of outpatient follow-up of these patients was 106 ± 62.7 months. During this period, 139 cardiac catheterization were performed, both for diagnostic and therapeutic procedure. Pulmonary atresia with interventricular communication and tetralogy of Fallot were the heart diseases that showed greater indication for cardiac catheterization.

Twenty-three examinations were for therapeutic procedures such as dilation of pulmonary homograft (one case), dilation of bovine pericardium tube (eight cases), opening of the interatrial communication (six cases), dilation of the native pulmonary valve (three cases), placemento of stent in pulmonary artery branch (three cases) and dilation of pulmonary artery branch (two cases).

The previous palliative surgeries were performed in 42 patients. Surgery of systemic-pulmonary anastomosis (Blalock-Taussig shunt) was performed in 38 patients, being more suitable in patients with pulmonary atresia and interventricular communication and tetralogy of Fallot. The mean time from palliative surgery until surgery with homograft was 48.19 ± 40.26 months.

The median age of patients at the time of surgical correction of the heart disease was 22 months, ranging from 1 to 157 months. Thirty percent of the sample (28 cases) underwent surgery before reaching one year of age.

In eight patients replacement of bovine pericardium tube was performed. Such tube was placed in previous surgery, on average 110.5 ± 24.3 months after initial surgery.

Table 1. Patients' clinical profile.

Heart disease	Number of patients	Age at first consultation (in months)*	Cardiac catheterization #	Blalock Taussig #	Age at surgical correction (in months)*	Size of the pulmonary homograft (in mm)*	Time of CPB (in minutes)*
Pulmonary atresia + CIV	26	4 (1day – 46 months)	61	24	23 (4 – 169)	22 (16 – 25)	151 (90 – 225)
Tetralogy of Fallot	24	15 (1day – 73 months)	41	10	21.5 (3 – 110)	23.5 (12 – 26)	114 (50 – 186)
Truncus arteriosus	17	2 (1day – 19 months)	18	0	3 (7 days – 24 months)	20 (15 – 26)	190 (90 – 225)
TGA + IC and PVS	16	1.5 (1day – 114 months)	40	9	41.5 (11 – 157)	22 (18 – 26)	154 (81 – 224)
Corrected TGA + IC + PVS	6	15.5 (2 – 46)	8	1	61.5 (13 – 119)	21 (19 – 23)	120 (70 – 135)
Pulmonary valve stenosis	3	0.5 (1 day – 8 months)	4	0	132 (5 – 147)	23 (12 – 26)	80 (43 – 90)

***** *median with its value interval; # total number of procedures performed due to heart disease.*
Legend: s - surgery; IC = interventricular communication; TGA = transposition of the great arteries; PVS = pulmonary valve stenosis; CPB = cardiopulmonary bypass

After surgery to implant the pulmonary homograft, an epimyocardial dual-chamber pacemaker implantation was performed in five patients due to complete atrioventricular block, four in the immediate postoperative period and one case 25 months after surgical repair.

The pulmonary homograft used in surgeries varied its size from 12 to 26 mm, mean 21.5 ± 3.2 mm and a median of 22 mm. The Z-score of the pulmonary valve ranged from less than one to five, with a mean of 2.8 ± 1.4 and median of 3. Fifty-seven percent of the homografts had their Z-scores between 0 and plus 3.

46% of the patients presented abnormal pulmonary tree with branch stenosis, lack of branch, aneurismal pulmonary branches or presence of systemic-pulmonary collaterals.

The mean cardiopulmonary bypass time was 132 ± 37 minutes, ranging from 43 to 224 minutes. The mean aortic clamping time was 98 ± 29 minutes and rectal temperature ranged from 16 to 32°C. In patients who died, the mean CPB time was 173 ± 34 minutes, with a median of 167 minutes, the mean aortic clamping was 121 ± 25 minutes and rectal temperature ranged from 17 to 30°C.

During the immediate postoperative period there were 17 (18% cases) deaths, five of them in the operating room for heart failure, with two cases of transposition of great arteries with interatrial communication and pulmonary valve stenosis, one for replacemento of calcified homograft; two cases of *truncus arteriosus* type I and one case of tetralogy of Fallot. Twelve deaths occurred in the intensive care unit, with a case of transposition of the great arteries with interatrial communication and pulmonary valve stenosis for replacement of valved tube of bovine pericardium, five patients with pulmonary atresia and interatrial communication, three with tetralogy of Fallot and three of *truncus arteriosus* type I.

The death in the intensive care unit occurred on average 10.5 ± 7.5 days after operation, with a median of 9 days, ranging from 1 to 38 days. The most common cause of death was multiple organ failure (11 cases) and among

patients with this diagnosis, five were on peritoneal dialysis and three on hemodialysis. Clinical complications presented by patients during hospital stay in the intensive care unit were right and left ventricular dysfunction, cardiac arrhythmia, pulmonary hypertension, acute renal failure, seizures, pneumonia and septicemia.

Separating the patients by type of heart disease is observed that there are differences between the groups in the variables: age at time of surgery, size of homograft, Z-score value of the pulmonary valve, maintenance of the integrity of the pulmonary homograft, presence of change in the pulmonary tree and cardiopulmonary bypass time (Table 2).

In univariate analysis, in each group of heart disease, none of the variables interfered with hospital mortality.

On patients assessment, without separating by heart disease, multivariate analysis showed CPB time over 120 minutes as the only risk factor for hospital mortality, and 4.5 times higher the chance of death than a patient with cardiopulmonary bypass time less than 120 minutes.

DISCUSSION

The use of valves and segments of vascular tissue of human origin is an important resource in the surgical treatment of congenital heart diseases and presents good outcomes. From the 80's, the use of pulmonary homograft was widespread due to improvements in preservation of graft.

In the last two decades, the literature shows a failure rate higher for the aortic homograft placed in the pulmonary position than the pulmonary homograft due to its early calcification [2,3]. Therefore, the option of this cardiac surgery service is to use the pulmonary homograft for reconstruction of the right ventricular outflow tract.

Few studies have focused on hospital mortality for surgical repair of the obstructive diseases of the right heart, citing only its rate, but rather than assessing the risk factors [5-10]. Late death and dysfunction of the pulmonary homograft were assessed with more emphasis [2,3,5-7,10-12]. In our study, hospital mortality was 18%, in accordance with the literature, on which mortality ranges from 6% to 27% [2.5-10].

The causes of death are diverse and vary according to the surgical team. In our hospital, 11 patients died due to multiple organ dysfunction and 5 cases due to heart failure in the operating room. In a study by Bando et al. [6], the causes of hospital death in descending order were: heart failure, multiple organ dysfunction and pulmonary hypertension. Brown et al. [7] and Albert et al. [11] identified the major causes of death as heart failure and septicemia.

In studies with pulmonary homograft, the risk factors involved in hospital mortality are few. The small size of the pulmonary homograft and the diagnosis of *truncus arteriosus* are involved in studies by Razzouk et al. [12] and Schorn et al. [10].

Despite the use of pulmonary homograft in surgeries of this study, the sample of patients is distinct, with differences in variables between the types of heart disease. The complexity of heart disease at the time of surgical correction leads to surgical approaches that increase the differences between the groups.

Table 2. Relationship between types of heart diseases and the variables studied.

	Pulmonary atresia + IC	Tetralogy of Fallot	Truncus arteriosus	TGA + IC and PVS	*P* value
Gender M/F	13/13	7/17	6/11	8/8	0.285
Age > 1 year / < 1 year	20/6	19/5	3/14	15/1	< 0.001
Homograft size >22 /< 22 mm	16/10	21/3	6/11	10/6	0.007
PV Z value 1,2,3 / -1, 0, 4,5	20/6	11/13	5/12	8/8	0.009
Homograft integrity yes/no	7/18	6/18	15/2	2/14	< 0.001
PT change no/yes	8/18	10/14	14/3	9/7	0.009
Previous surgery no/yes	20/6	20/4	16/1	10/6	0.181
CPB time <120/ ≥120 min	8/18	16/8	4/13	6/10	0.024
AoCl time < 80 /≥ 80 min	8/18	12/12	3/14	4/12	0.113
Death yes/no	5/21	4/20	5/12	3/13	0.161

Legend: M = male; F = female; mm = millimeter; PV = pulmonary valve; PT = pulmonary tree; CPB = cardiopulmonary bypass; min = minutes; AoCl = aortic clamping; TGA = transposition of the great arteries; IC = interventricular communication; PVS = pulmonary valve stenosis

In the case of *truncus arteriosus*, patients underwent surgery at younger age compared to other groups, the size of the pulmonary homograft was lower, their cardiopulmonary bypass time was on average larger and the surgeon opted for maintaining the integrity of the pulmonary homograft, preserving pulmonary leaflets due to pulmonary hypertension.

In patients with tetralogy of Fallot, pulmonary atresia with interventricular communication and transposition of the great base vessels with interventricular communication and pulmonary stenosis, age at surgical repair was later, by chosing surgery in patients over a year old. The average size of the homograft was higher and the option of the surgeon to maintain the integrity of the homograft, decreasing the size of the leaflets or their replacement by a goretex monocuspid.

Although the option of the surgeon by implantation of pulmonary homograft with the largest possible size, in respect to the patient's body surface, smaller homografts were used in cases of *truncus arteriosus*, perhaps due to lower age at surgical repair and the smaller size of the thoracic cavity.

Stenosis or hypoplasia of the pulmonary branches and prior reconstructive surgery may be factors of increased mortality because there is prolongation of surgical time and cardiopulmonary bypass, by increasing the occurrence of cardiac dysfunction, intraoperative bleeding and cardiac arrhythmias. However, in our study the aforementioned facts were not considered as a risk factor for death.

The cardiopulmonary bypass time differs depending on the complexity of heart disease and the difficulty of surgical correction. The mean cardiopulmonary bypass time was consistent with the literature, respecting the differences between the heart diseases. The shorter time of cardiopulmonary bypass in tetralogy of Fallot is consistent with the study by Moraes Neto et al. [13,14], which present an early mortality between 2% and 6%.

Dearani et al. [2] reported mean cardiopulmonary bypass time of 145 ± 51 minutes, with early mortality of 20%, and Perron et al. [8], mean time of 145 ± 56 minutes, with 14% mortality. In a previous study of this service with pulmonary homograft, the mean time of CPB was 120 ± 29 minutes, with a mortality of 12% [5].

The CPB time was not a risk factor for mortality when assessed separately in each heart disease, however, analysis of the entire sample, without separation into groups according to heart disease, it was found that the CPB time over 120 minutes increases the risk of death by 4.5 times.

Consistent with the major cause of death in our patients in the intensive care unit, which was the failure of multiple organs, it is known that prolonged cardiopulmonary bypass time in neonates and children leads to a stronger activation of the inflammatory cascade, causing dysfunction of various organs, increasing the patient's stay in the intensive care unit and his mortality [15].

Surgical intervention or hemodynamics in obstructive heart disease of the right side is indicated soon after diagnosis, to maintain an adequate pulmonary circulation. Reconstructive surgery of the right outflow tract using pulmonary homograft has a hospital mortality of 18%, but any risk factor was found when studied for each heart disease separately. However, prolonged cardiopulmonary bypass time was shown as a risk factor when the whole sample is studied, without separation by heart disease.

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