Factors predicting morbidity and mortality after surgical pulmonary valve replacement

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Abstract:

Background: Surgical pulmonary valve replacement is an uncommon operation. This study is designed to identify risk factors associated with postoperative morbidity and mortality in cases of surgical pulmonary valve replacement.

Methods: 80 patients underwent surgical replacement of pulmonary valves in Cairo university hospitals and Misr University for Science and Technology hospital in the period between January 2014 and September 2022.

Results: There were 44 males (55%) and 36 females (45%). The mean age was 19.36 ± 9.73 years, while the mean weight was 50.11±17.37 Kilograms. The mean cardiopulmonary bypass time was 65.56 ± 28.04 minutes, while the mean cross-clamp time was 51.53 ± 21.03 minutes. Postoperatively, 8 patients (10%) had arrhythmias, 6 patients (7.5%) had respiratory infections, and 2 patients (2.5%) needed diaphragmatic plication due to postoperative eventration. There were five mortalities (6.3%) among included patients.

Conclusion: Valve replacement before the development of advanced impairment of right ventricular function has a good outcome and associated with low operative mortality. The significant risk factors for mortality included old age and presence of signs of heart failure while the significant risk factors for a prolonged stay in the hospital included old age, previous cardiac surgery (redo cases), prolonged operative aortic cross clamp (ACC) time.

Keywords: surgical pulmonary valve replacement, factors affecting morbidity and mortality, Tetralogy of Fallot, pulmonary valve endocarditis, early outcome.

Introduction:

Diseases of the pulmonary valve and right ventricular outflow tract (RVOT) are quite common in children. During repair of pulmonary stenosis in childhood, e.g., Tetralogy of Fallot, the annulus of pulmonary valve may be incised with augmentation of RVOT with a transannular patch which creates pulmonary insufficiency and thus may necessitate either pulmonary valve replacement in adulthood with a prosthetic valve or the placement of a homograft. [1]

Endocarditis of the pulmonary valve mainly occurs in adults with history of intravenous drug abuse or in children with history of congenital heart diseases. [2]

In our study, we hope to identify the different risk factors that have been associated with postoperative morbidity and mortality in patients who underwent surgery for replacement of the pulmonary valve.

Patients and Methods:

Study design

Between January 2014 and September 2022, 80 patients underwent surgical replacement of pulmonary valves in Cairo university hospitals and Misr University for Science and Technology hospital. Patients with history of ischemic heart disease or previous coronary artery bypass grafting surgery were excluded. Approval of the local ethical committee was obtained.

Definitions:

Operative mortality, presence of a major adverse event (MAE) and hospital stay longer than 21 days were chosen as the main primary outcomes. MAE outcome includes any of the following postoperative complications: stroke, chest infection, renal impairment, prolonged mechanical ventilation, reopening. [3]

Operative mortality included all deaths that occurred within thirty days of the operation. [4]

Preoperative assessment:

All patients received preoperative echocardiography to establish the diagnosis, reveal degree of pulmonary regurge or stenosis, pulmonary valve annulus, right and left ventricular contractilities, and associated congenital anomalies. Many patients received Cardiac Magnetic Resonance Imaging (CMRI): to assess the right ventricular end-diastolic and end-systolic volumes indices and ejection fraction of both RV and LV.

The Selection criteria for surgery of patients who underwent total repair of Tetralogy of Fallot and had significant pulmonary regurgitation include: RV end-diastolic volume index (RVEDVI) >150 mL/m2, RV end-systolic volume index (RVESVI) >80 mL/m2, LV ejection fraction <55%, RV ejection fraction <47% and persistent tachy-arrhythmias related to RV volume overload. [5]

Operative data:

The patients were put in the supine position with exposure of the chest as well as both groins in case an emergency femoral cannulation was needed only in redo cases. The approach in all operations was full median sternotomy. Cardiopulmonary bypass was established via aorto-bicaval, common atrial or femoral cannulation. Myocardial protection was in the form of antegrade cold blood cardioplegia and systemic hypothermia to 32-28°c according to surgeon preference.

A longitudinal incision was made in the RVOT about 3 cm below the level of the pulmonary annulus and extended upwards till just below the pulmonary bifurcation. After determining the appropriate prosthetic valve size according to body surface area, the valve sewing ring was fixed to the posterior portion of the pulmonary annulus with continuous Proline 3/0 or interrupted Ethibond 2/0 sutures.

A pericardial (native or bovine) or prosthetic Dacron patch was then sutured to the RVOT below and used as a “roof” over the valve which is fixed to it anteriorly with continuous or interrupted sutures. The patch

was then sutured above to the pulmonary artery till the bifurcation in a continuous manner.

Associated pathologies were dealt with accordingly. Cases associated with severe tricuspid regurge were repaired by band annuloplasty through right atriotomy while cases associated with partial anomalous pulmonary venous drainage (PAPVD) were repaired by ASD closure by using a pericardial patch together with directing the anomalous vein(s) into the left atrium. Patients who had total repair of Tetralogy of Fallot and had stenosis of branch pulmonary artery either left or right pulmonary artery were repaired by extension of the pericardial patch to the site of stenosis of the pulmonary artery. Other cases with VSD had the VSD closed by the use of Polytetrafluoroethylene (PTFE) patch. The cases of denovo adult Tetralogy of Fallot had been operated with total repair that includes VSD closure and muscular resection through the RVOT incision together with the pulmonary valve replacement.

Statistical Analysis:

Statistical analysis of the data was by using the statistical package for the Social Sciences (SPSS) version 28 (IBM Corp., Armonk, NY, USA). Quantitative data were in the form of mean, standard deviation, median, minimum and maximum values while categorical data were represented with count and percentage. Mann-Whitney test was used for comparing the quantitative data while Chi square (X^2) test was performed for comparison of the categorical data. P-value less than 0.05 had been considered as statistically significant.

Results:

Preoperative data:

The mean age of the patients was 19.36 ± 9.73 years, 53 patients were younger than 20 years and 27 patients were older than 20 years. CMRI

was done in 46 cases (57.5%) preoperatively. Table (1) shows summary of the preoperative demographic, clinical and radiological patient data.

Table (1): summary of preoperative patient data

Preoperative data	**Value**
Age (years): < 20 years > 20 years	19.36 ± 9.73 53 (66.3%) 27 (33.7%)
Sex: Male Female	 44 (55%) 36 (45%)
Weight (kg)	50.11 ± 17.37
Distribution of cases: -Previously totally repaired TOF -Pulmonary valve endocarditis : Native valve Bioprosthetic valve -VSD/PS -Adult denovo TOF -Malfunctioning prosthetic pulmonary valve	 46 (57.5%) 19 (23.8%) 4 (5%) 7 (8.7%) 3 (3.7%) 1 (1.3%)
Associated pathologies and diseases: -PAPVD -Severe tricuspid regurge -Branch pulmonary artery stenosis -Aortic valve diseases -Mitral valve surgery -Diabetes mellitus -Systemic hypertension -Cerebrovascular diseases -Lung disease	 2 (2.5%) 11 (13.8%) 7 (8.7%) 1 (1.3%) 5 (6.3%) 1 (1.3%) 1 (1.3%) 1 (1.3 %) 1 (1.3%)
Echocardiography: -TAPSE (cm) -Pulmonary annulus (mm) -Pulmonary valve pathology: severe regurge severe stenosis malfunctioning prosthetic mechanical valve	 1.89 ± 0.34 21.64 ± 3.69 69 (86.2%) 10 (12.5%) 1 (1.3%)
CMRI: - Right ventricular end diastolic volume index (RVEDVI) (ml/m^2) - Right ventricular end systolic volume index (RVESVI) (ml/m^2)	 171.76 ± 22.34 86.41 ± 13.92

- Left ventricular ejection fraction (LVEF) (%) - Right ventricular ejection fraction (RVEF) (%)	55.55 ± 6.39 47.82 ± 6.02

Operative data:

The mean total cardiopulmonary bypass time was 65.56 ± 28.04 minutes while the mean cross clamp duration was 51.53 ± 21.03minutes. Table (2) shows operative data of the patients.

Table (2): Operative data

Operative data	**Value**
Redo cases	51 (63.8%)
Femoral cannulation (in redo cases)	20 (25%)
Operative time parameters: -Cardio-pulmonary bypass (CPB) duration (min) -Aortic cross clamp (ACC) duration (min)	 65.56 ± 28.04 51.53 ± 21.03
Cardioplegia type (intermittent antegrade): - Bretschneider solution - Cold blood cardioplegia No cardioplegia (beating heart)	 40 (50.0%) 39 (48.7%) 1 (1.3%)
Type of implanted valve: -Bioprosthetic valve -Mechanical prosthetic valve	 55 (68.8%) 25 (31.2 %)

Postoperative results:

The mean duration of mechanical ventilation was 1.86 ± 1.06 days while the mean postoperative ICU stay was 5.34 ± 2.94 days. Eight patients had arrhythmia in the form of Junctional Ectopic Tachycardia (JET) in 4 patients and atrial fibrillation (AF) in other 4 cases which had been managed medically with antiarrhythmic drugs. Seven patients were reopened due to post-operative high drainge that had been dealt with properly. Six patients developed postoperative chest infection and the used antibiotics for management were according to the culture and sensitivity results. Three patients suffered from cerebrovascular stroke and had been investigated by MRI and managed neurologically. Two patients showed postoperative low cardiac output that required increasing inotropic supports. Two patients showed diaphragmatic paresis and underwent surgery for plication. One patient had acute renal failure at

ICU with rising serum potassium and creatinine level that required multiple sessions of renal dialysis in the postoperative ICU. Two patients had superficial wound infection which was managed with frequent dressings and proper antibiotics.

Postoperative echo of the patients showed: well-functioning valves with no paravalvular leak. The median pressure gradient across the valve was 11 mmHg (range 7-20mmHg). In cases with repaired tricuspid valves the regurge was mild.

There were 5 mortality cases, one patient was below the age of 20 years and the other 4 patients were above the age of 20 years. Three of these cases developed multisystem organ failure due to severe chest infection in two patients and acute renal failure that needed renal dialysis several times in one patient. The other two mortalities were due to development of cardiogenic shock as a result of low COP in spite of maximum doses of inotropes. Table (3) shows summary of postoperative data.

Table (3): summary of postoperative data.

Postoperative data	**Value**
Duration of mechanical ventilation (day)	1.86 ± 1.06
ICU stay (day)	5.34 ± 2.94
Hospital stay (day)	13.55 ±7.62
Postoperative complications	
-Arrhythmia	8 (10%)
-Re-opening for bleeding control	7 (8.7%)
-Respiratory infection	6 (7.5%)
-Cerebrovascular stroke	3 (3.7%)
-Diaphragmatic eventration	2 (2.5%)
-Low COP	2 (2.5%)
-Renal failure required renal dialysis	1 (1.3%)
-Wound infection	2 (2.5%)
Mortality	5 (6.3%)

OUTCOME:

A) Mortality

The mortality included 5 patients (6.3%). The old age with age older than 20 years (OR 24.48) and appearance of signs of heart failure (OR 12.66) were significant risk factors for mortality.

B) Major Adverse Event

25 patients (31.25%) experienced a major adverse event (MAE) after surgical pulmonary valve replacement. Aortic cross clamp (ACC) time (OR 1.02) was the significant risk factor.

C) ICU Length of Stay

26 patients (32.5%) remained in the postoperative cardiac ICU more than 5 days. Appearance of signs of heart failure (OR 3.59) and aortic cross clamp (ACC) time (OR 1.05) were significant risk factors for a prolonged stay in ICU.

D) Hospital Length of Stay

10 patients (12.5%) stayed in the hospital more than 21 days. The old age with age older than 20 years (OR 34.28), previous cardiac surgery (redo cases) (OR 18.40), and aortic cross clamp (ACC) time (OR 1.04) were significant risk factors for a prolonged stay in the hospital.

Table (4): Multivariate analyses to detect independent predictors of morbidity and mortality.

Outcome	Characteristic	P value	OR	95% C.I.	
				Lower	Upper
Mortality	Age (years) (>20)	**0.016**	24.48	1.82	330
	signs of heart failure	**0.029**	12.66	1.29	124
Morbidity	ACC time (min)	**0.047**	1.02	0.999	1.05
Prolonged ICU stay	signs of heart failure	**0.026**	3.59	1.16	11.09
	ACC time (min)	**0.003**	1.05	1.02	1.08
Prolonged hospital stay	Age (years) (>20)	**0.002**	34.28	3.61	326
	Previous operation	**0.011**	18.40	1.94	175
	ACC time (min)	**0.034**	1.04	1.00	1.08

Discussion:

There are few studies demonstrating risk factors that predict morbidity and mortality in patients that have pulmonary valve non-repairable diseases e.g., pulmonary infective endocarditis, pulmonary insufficiency after Fallot repair or native pulmonary stenosis and have been treated surgically with pulmonary valve replacement either by biological or mechanical valves. [6]

Longstanding pulmonary valve affection either regurge or stenosis had been recognized to have deteriorating effects on RV function. The main risk in these patients is sudden death due to fatal arrhythmias as a result of right ventricular dysfunction, thus restoration of right ventricular function might reduce that risk. [7] However, the ideal time for pulmonary valve replacement (PVR) remains a debatable issue. [8]

When we compare results of our study to other studies regarding the mean age and weight, we find that older mean ages and higher body weights are detected and thus reflecting the variability in determining the timing of surgical intervention according to the policy of each institute.[6] We have adopted at our institute the policy of early PVR once the diagnosis of severe regurge or stenosis has been established and associated with clinical symptoms or radiological signs of RV dysfunction relaying on the theory that PVR can be performed with low operative risk before the development of irreversible RV dysfunction.

In our study 55 patients received biological valves and 25 patients received mechanical valves. Regarding durability, mechanical valves are superior but have the drawback of lifelong anticoagulation with the possibility of occurrence of either hemorrhage or thromboembolic events, while biological valves have the benefit of lack of the need for anticoagulant medications but on the other hand have less durability. However evolution of new generations of biological valves with longer durability as well as the catheter implanted valves has its impact in choosing the appropriate strategy for pulmonary valve intervention. [9][10][11]

Twenty five patients (31.25%) experienced a major adverse event (MAE) after surgical pulmonary valve replacement in our study, the significant risk factor for MAE was prolonged aortic cross clamp (ACC) time while in other studies it was concomitant surgery. [6] Our study shows mortality

in five patients (6.3%), four of them were older than 20 years. In addition, presence of low cardiac output or prolonged mechanical ventilation and so prolonged ICU stay were significant risk factors for mortality while prolonged hospital stay was associated with cases of previous cardiac surgery (redo cases), age older than 20 years and prolonged aortic cross clamp (ACC) time. Other studies addressed significant risk factors for mortality and morbidity included the presence of preoperative arrhythmias, concomitant surgery, prolonged ventilatory support, lower extremity compartment syndrome and partial gastrectomy for gastrointestinal bleeding. [6][12]

According to our study, early surgical intervention for pulmonary valve replacement had a good outcome and was associated with low operative mortality.

Limitations:

Our study has some limitations due to relatively low number of patients included; in addition the study addresses only early outcomes with no long or intermediate term follow-up, so we recommend to do further studies of both surgical and interventional pulmonary valve replacement that have longer follow up periods and include larger sample sizes in order to study factors predicting morbidity in the long run.

Conclusion:

Early pulmonary valve replacement prior to the development of advanced impairment of right ventricular function was associated with good outcome together with low operative risk. However, the significant risk factors for mortality in cases of surgical pulmonary valve replacement included old age and prolonged ICU stay either due to prolonged ventilator support or the presence of profound low cardiac output while risk factors for a prolonged stay in the hospital included previous cardiac surgery (redo cases), old age and prolonged operative aortic cross clamp (ACC) time..

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