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Results of Closure of Patent Ductus Arteriosus in Adult Population Using Cardiopulmonary Bypass

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ABSTRACT

Background: Surgical repair of patent ductus arteriosus (PDA) in adults is more challenging compared to children. This study was conducted to report our experience using cardiopulmonary bypass (CPB) in adult cases with PDA.

Aim of the work: The objective of this study is to evaluate the safety and efficacy of the usage of the cardiopulmonary bypass in management of PDA in the adult population, not suitable for trans-catheter closure.

Patients and methods: This is a retrospective study that included all adult cases with PDA who had surgical closure for 5 years **(**July 2014 to July 2019) at the Cardiothoracic Surgery Department at Mansoura University, Egypt. All demographic, clinical, and Echo-derived data were collected, **New York Heart Association** (NYHA) class was calculated for all cases before operation. All cases underwent PDA repair using CBP. Postoperatively, clinical and radiological assessments were performed 6 months after surgery.

Results: The study included a total of 10 cases (7 males and 3 females). Their mean age was 32.2 years. Eight cases of them had NYHA class II, and the remaining cases had NYHA class III. Direct closure was performed in 6 cases (60%), and the other 4 cases had patch closure. The mean CBP and aortic clamping times were 97 and 45.5 minutes respectively. The mean esophageal temperature was 30.50 ºC. Neither mortality nor reoperation was encountered in the current study. Six months after the operation, pulmonary artery pressure decreased from 43.6 mmHg down to 25 mmHg and NYHA class I was present in 8 cases while the other 2 cases had NYHA class II. **Conclusions:** A cardiopulmonary bypass is a safe option for adult cases with patent ductus arteriosus unsuitable for percutaneous or minimally invasive closure.

Keywords: Patent ductus arteriosus, Adult congenital heart disease, Cardiopulmonary bypass.

INTRODUCTION

Multiple medical and interventional options are currently available to manage pediatric patients with patent ductus arteriosus (PDA) [1, 2]. Although most patent ductus arteriosus patients undergo closure during childhood, some cases may be missed until a later age [3]. Recently, less invasive procedures are getting more interest, either by transcatheter device closure or minimally invasive surgical ligation thru video-assisted thoracoscopic surgery (VATS), however, open surgical intervention is still needed in selected cases such as short, wide, or tortuous PDA, or if it is associated with another concomitant cardiac procedure [3]. Cardiopulmonary bypass (CPB) is usually recommended in such cases due to the stiff, less-mobilized, and friable nature of the ductal tissue in the adult population [4]. This study was conducted to report our results on PDA closure in the adult population using cardiopulmonary bypass.

PATIENTS AND METHODS

This is a retrospective study that included adult cases (> 18 years) who underwent PDA closure using CPB at the Cardiothoracic Surgery Department at Mansoura University during the period from July 2014 to July 2019 after approval of **the Institutional Research Board** (IRB) of the Faculty of Medicine of Mansoura University. Patients with the following criteria were included: (1) Age is more than 18 years, (2) diagnosed with PDA, and (3) underwent open surgical closure. Patients with other cardiovascular anomalies, except for small-sized atrial septal defect or patent foramen ovale (< 5 mm), were excluded. Patients were initially referred for surgical closure whenever the ductus criteria were not suitable for the trans-catheter approach per the cardiology team. All demographic, clinical, and radiological data of the selected patients were collected including New York Heart Association (NYHA) classification. All patients had grade I-II tricuspid regurgitation (TR), so we can get the systolic pulmonary artery pressure by echocardiography. In addition, all patients had a diagnostic catheterization before surgery to assess the pulmonary artery pressure (PAP) and resistance (PVR) and the ratio of pulmonary to systemic blood flows (Qp/Qs). All patients had follow-up echocardiography 6 months after surgery where the right-side function, left-side volumes, and pulmonary artery systolic pressure were evaluated.

Surgical procedure

A median sternotomy incision was used to expose the heart. CBP was established with mild hypothermia (32º C) after inserting the arterial and venous cannulas. Then, the PDA was temporarily controlled by external compression while the pulmonary trunk was opened longitudinally extending toward the confluence, then a Foley's Catheter size 20 was introduced thru the pulmonary end of the PDA, and its balloon was inflated to control the blood flowing from the aorta, then the size of the defect is assessed and then closed either by a piece of Dacron patch or direct suture, if it is slit-like, with the withdrawal of the catheter before the last 2-3 stitches, a momentary cessation of the CPB may be required at this step.

Postoperative course

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All patients were extubated in the operating room under mild sedation and analgesia. All patients received Milrinone at a dose of 0.5 mcg/kg/min for 24 hours after surgery. All patients were discharged from the intensive care unit on postoperative day 1.

Ethical Consideration

This work was carried out following The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans and has been approved by the Institutional Review Board of the Faculty of Medicine, Menoufia University, Egypt. All patients provided informed written consent before enrollment.

Statistical analysis

Variables were presented as numbers and percentages if categorical, or as mean, median, minimum, and maximum values if continuous. Rates of events were presented by Kaplan-Meier curves. Risk factors were tested by Cox's hazard model. P-value is considered significant if it is less than 0.05. Statistical Package for the Social Sciences (SPSS release 22, Chicago, IL) was used for the analysis.

RESULTS

A total of 10 cases were included in the present study (7 males and 3 males). The mean age of them was 32.2 years. Eight of the included cases had NYHA class II, while the remaining 2 cases had NYHA III. An electrocardiogram (ECG) revealed atrial fibrillation (AF) in 3 cases, whereas the remaining cases had sinus rhythm. The mean PASP was 43.6 mmHg. The mean pulmonary vascular resistance (iPVR) was 4.31 Woods unit. Both Q_p/Q_s and P_p/P_s ratios had a mean of 2.44 and 0.32 respectively. Calcification was detected in 2 cases preoperatively. These data are shown in **table (1).**

Table (1): Preoperative patient characteristics

Criteria		All patients (n= 10)
Age (years)		32.20 ± 7.115 (23-42)
Gender	**Male**	7
	Female	3
NYHA	**II**	8
	III	2
ECG	**Sinus**	7
	AF	3
PAP		43.60 ± 14.894 (28 - 72)
Qp/Qs		2.44 ± 0.812 (1.64 - 4.03)
Pp/Ps		0.32 ± 0.122 (0.21 - 0.56)
PVR		4.31 ± 2.62 (1.42 - 7.13)
Calcification		2
Data are expressed as mean, standard deviation, range, or percentage, and frequency.		

We performed direct closure in 6 cases, and the other 4 cases had patch closure. The mean CBP time was 97 minutes, while the mean duration of aortic clamping was 45.5 minutes. The mean esophageal temperature was 30º C. Neither mortality nor reoperation was encountered in the current study. Besides, no recurrent laryngeal nerve injury was detected. These data are illustrated in **table (2).**

Table (2): Intraoperative factors

Criteria		All patients (n= 10)
Procedure	**Direct closure**	6 cases
	Patch closure	4 cases
CPB Time (minutes)		97.00 ± 240.060 (50 - 120)
Aortic Clamp Time		45.50 ± 14.615 (20 - 65)
Esophageal Temperature		30.50 ± 1.434 (28 - 33)
Extubation (hours)		12.60 ± 3.534 (8 - 18)
ICU stay (days)		5.40 ± 2.366 (2 - 8)
Mortality		0% (0)
Reoperation		0% (0)
Left recurrent laryngeal damage		0% (0)
Data are expressed as mean, standard deviation, range, or percentage, and frequency.		

At 6-month follow-up, NYHA has improved compared to the preoperative findings, like class, I was present in 8 cases while class II was present in 2 cases. The mean pulmonary artery pressure decreased down to 25 mmHg, and Qp/Qs ratio decreased to normal. **Table (3)** illustrates these data.

Table (3): Postoperative (6-month) Patients' characteristics and complications

Postoperative		All patients (n= 10)
NYHA	**I**	8
	II	2
ECG	**Sinus**	8
	AF	2
PAP		25.00 ± 8.110 (16 - 40)
Data are expressed as mean, standard deviation, range, or percentage, and frequency.		

DISCUSSION

Most surgeons may consider CBP a safe option since massive hemorrhage may be encountered from injured ductus that may accidentally occur during division or ligation of the ductus which may be fatal [(4)].

In our study, seven cases were males and 2 cases had NYHA class III before surgery while the rest were NYHA class II. **Djukanovic *et al.*** reported that 66.67% of his cohort were females, and all of them had NYHA class II [(3)].

In our study, the mean values of Qp/Qs and Pp/Ps ratios were 2.44 and 0.32 respectively. The mean value of pulmonary artery pressure was 43.6 mmHg. In the study conducted by **Djukanovic *et al.***, the mean value of the Qp/Qs ratio was 2.27 (1.73 – 3.12), whereas pulmonary artery pressure had a mean of 52.2 (34 – 78) [(3)]. In another study, all the included patients had pulmonary hypertension as the mean preoperative systolic pulmonary artery pressure was 62.0 mmHg. The mean P_P/P_S and Q_P/Q_S ratios were 0.48 and 2.2 respectively [(5)]. In the current study, sinus rhythm was

present in 7 cases, while the other 3 cases had atrial fibrillation. **Toda *et al.*** reported that sinus rhythm was present in 7 cases, while atrial fibrillation was diagnosed in 2 cases [4]. Calcification was detected in 2 cases before operation in the current study. It was previously reported that the presence of calcification is a risk factor for difficult PDA surgery [3]. In the current study, 6 cases underwent direct closure, while patch closure was performed in 4 cases. In the study of **Toda *et al.*** 5 cases underwent direct closure, while the remaining 4 cases had patch closure [4]. **Omari *et al.*** reported that the application of a Foley catheter balloon was safe and effective in both direct and patch repairs. It was applied for short and wide adult PDA cases. The authors recommended careful techniques to prevent balloon rupture [6]. **Taira and Akita** described a method using a patch mounted on a Fogarty catheter via a trans-pulmonary route under cardiopulmonary bypass [7].

In our study, the mean duration of cardiopulmonary bypass and aortic clamping was 97 and 45.5 minutes respectively. In the study of **Toda *et al.*** CPB time was 76.7 minutes (range 34 to 147 minutes) while the mean aortic cross-clamp time was 37.4 (range, 11 – 68 minutes) which is similar to our data [4]. **Robinson *et al.*** used deep hypothermic circulatory arrest in the surgical treatment of adult cases with PDA with good results [8]. It is believed that cardioplegic arrest is not required for direct or patch closure using a transpulmonary approach under cardiopulmonary bypass [4].

Some authors described a method in which ductal closure was done under cardiopulmonary bypass with profound hypothermia and a low-flow state without the need for balloon occlusion [9].

No intraoperative or in-hospital mortality was encountered in the current study. Additionally, no postoperative complications including recurrent laryngeal nerve injuries were experienced in our study. **Jatene *et al*.** mentioned an incidence of 8.8% regarding vocal cord affection and a rate of 14.7% regarding abnormal voicing (Dysphonia) after surgery [10].
There is still a possibility of recurrence or aneurysmal formation of PDA that might complicate the procedure late postoperative [11, 12]. Neither of these complications has been noticed in our study. Nevertheless, regular echocardiographic assessment is recommended for early detection of these complications.

CONCLUSION

A cardiopulmonary bypass is a safe option for adult cases with complicated patent ductus arteriosus unsuitable for trans-catheter or minimally invasive closure.

Study Limitations

The limited count of the study subjects and the retrospective course of the study have been limiting factors to our study. The larger size of the study sample, postoperative diagnostic catheterization, and adding a comparable group treated by interventional catheterization would be more informative and statistically leading than our study.

LIST OF ABBREVIATIONS

Patent ductus arteriosus (PDA), New York Heart Association (NYHA), Cardiopulmonary bypass (CPB), Video-assisted thoracoscopic surgery (VATS), Pulmonary artery systolic pressure (PASP), Electrocardiography (ECG), Atrial fibrillation (AF).

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