Comparative study between Extra-pleural versus Trans-pleural approaches in Surgical PDA Ligation in Pediatrics

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Abstract

Background: Patent ductus arteriosus (PDA) is a common congenital heart defect, that can cause cardiorespiratory morbidity, and closure is crucial to prevent complications. New PDA surgical ligation techniques have evolved to improve outcomes and reduce hospital stays.

Objectives: To compare the outcome of the extra-pleural versus trans-pleural approaches in surgical PDA ligation.

Patients and methods: The study involves 40 PDA patients, divided into two groups: Group A (n=20) ligated via a trans-pleural approach and Group B (n=20) ligated via an extra-pleural approach. The study compares the operative time, intra-operative complications, hospital stays, and post-operative complications.

Results: PDA was successfully ligated in all cases except one case which needed redo surgery. The mean age was 7.47 ± 5.1 months with a female-to-male ratio of 2:1. The mean duct size was 4.67 ± 1.36 millimeters. The study found significant differences between the two approaches regarding the operative time (P-Value <0.001), at which group B consumed only 38.67% of total operative time. The surgical morbidities were reduced and intra-operative injuries were better avoided in group B with group A having 77.8% of total intra-operative complications (P-Value <0.001). Post-operative complications were more common in group A (P-Value 0.014). The post-operative hospital stay was markedly reduced in group B (P-Value <0.001). The study also showed significant improvement in LV systolic function, dimensions, and LA/AO ratio at 3 and 6 months post-ligation.

Conclusion: The extra-pleural approach is a safer and more effective surgical method for PDA closure due to its reduced morbidities, improved visualization, and shorter operative times.

Keywords: PDA; Extrapleural, Transpleural; PDA Surgical Ligation.

DOI: 10.21608/SVUIJM.2024.236290.1763

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Received: 28 December,2023.
Revised: 13 January, 2024.
Accepted: 21 January, 2024.
Published: 19 June, 2025

Cite this article as Mohammed Abdelmoatty Mohammed, Mahmoud Khairy Abdelateef, Ahmed Abdelmoneim Abdelrasheed, Mohamed Abdel Bary Ahmed.(2025). Comparative study between Extra-pleural versus Trans-pleural approaches in Surgical PDA Ligation in Pediatrics. *SVU-International Journal of Medical Sciences*. Vol.8, Issue 2, pp: 33-42.

Introduction

Patent ductus arteriosus (PDA), is a persistent communication between the descending thoracic aorta and the pulmonary artery resulting from failure of normal physiological closure of the fetal ductus. The physiological impact and clinical significance of the PDA depend largely on its size and the underlying cardiovascular status of the patient. The PDA may be "silent" (not evident clinically but diagnosed incidentally by echocardiography done for a different reason), small, moderate or large; regardless of the size, complications may arise **(Abdel-Bary et al., 2019)**. A confined PDA is noticeable among the most common congenital heart defects (CHD); as its incidence is up to 8 for every 10,000 live births among term infants **(Reller et al., 2008; Semberova et al., 2017)**.

PDA may be associated with cardiorespiratory morbidity. So, its closure should be performed once diagnosed to prevent chronic left ventricular volume overload and pulmonary hypertension that lead to the development of irreversible pulmonary vascular obstructive disease. Surgical ligation is indicated in huge PDA and is not appropriate for percutaneous intervention; as well as in developing countries **(Sehgal et al., 2018; Jeong et al., 2007; Weisz et al., 2014)**. Several surgical techniques have been evolved for PDA closure. In the treatment of PDA with a mortality rate approaching zero **(Mavroudis et al., 1994)**, the emphasis is currently on cost-effectiveness and decreasing morbidity.

We aim to compare the outcome of the extra-pleural versus trans-pleural approaches in surgical PDA ligation.

Patients and methods

The study was conducted at Qena University Hospital in Egypt, focusing on patients diagnosed with Patent Ductus Arteriosus, involving forty patients. The patients were divided into two groups: Group A, which included 20 PDA cases ligated via a trans-pleural approach, and Group B, which included 20 PDA cases ligated via an extra-pleural approach. The study used various tools, including history and clinical examination, pre-operative echocardiography, operative and post-operative data, and follow-up. The clinical examination included a general examination of the child's heart rate, oxygen saturation, and weight, as well as a detailed examination of the cardiovascular and respiratory systems. Transthoracic 2D echocardiography was performed for all cases, with some requiring sedation. Measurements included PDA size, pulmonary artery pressure, shunt volume, left atrium and left ventricle sizes, aorta diameter, left atrial to aortic diameter ratio, left ventricular end-diastolic and left ventricular end-systolic diameters, fractional shortening, and ejection fraction.

The PDA ligation was performed under general anesthesia, with patients receiving intravenous access before standard anesthesia for induction. The children were positioned in the right lateral recumbent position following the induction of anesthesia using a single endotracheal tube. Through a sub-scapular left posterolateral mini-thoracotomy with muscle-sparing incision, the 3rd or 4th intercostal space is opened. The trans-pleural approach involved opening the parietal pleura, retraction of the left lung, identifying the PDA and adjacent structures, and dissecting the PDA carefully **(Mumtaz et al., 2012)**. In contrast, the extra-pleural approach involved separating the pleura from the chest wall by blunt dissection while being cautious not to enter the pleural space, partial retraction of the left lung until the PDA becomes visible then it is dissected from the surrounding tissues (**Pradegan et al., 2020)**. In both approaches, the PDA was dissected from the surrounding

structures with the help of right-angle forceps and doubly ligated using silk ligature. Lung re-expansion and chest closure were then carried out after adequate hemostasis. A chest tube for drainage was inserted for group A, but not in group B in which the chest was closed without drainage after lung expansion. Subcuticular sutures were used for skin closure.

Post-operative data and follow-up included monitoring patients in the recovery room, ward, and outpatient clinic. Patients were monitored for heart rate, oxygen saturation, wound condition, intercostal tube, fever, chest x-ray, and day 1 echocardiography. After three and six months, patients were reassessed by echocardiography and general condition revision in the outpatient clinic.

The primary aim of the study was to evaluate the outcome of trans-pleural and extra-pleural approaches for PDA surgical ligation. Additionally, the secondary outcome is to evaluate the success rate of trans-pleural and extra-pleural approaches for PDA surgical ligation in our center.

Ethical approval: The research was granted an exemption from the research ethics committee of the Faculty of Medicine, South Valley University, Code SVU-MED-SUR011-1-22-5-398.

Statistical analysis

Data were arranged and analyzed utilizing Version 20 of the SPSS program (Statistical Package for Social Sciences). Continuous variables were compared using the Student paired t-test and are expressed as mean values ± standard deviation. Pearson Chi-Square tests were used to detect differences among groups for categorical variables. A P-value of < 0.05 was considered of significance.

Results

This prospective comparative study was conducted between April 2022 and August 2023 at the Department of Cardiothoracic Surgery, Qena University Hospitals, with institutional ethics committee permission.

Forty PDA patients underwent surgical closure, patients were divided randomly into two groups: group A (n = 20) ligated via a trans-pleural approach, and group B (n = 20) ligated via an extra-pleural approach.

PDA was successfully ligated in all cases except one case of a female infant born preterm at 36 weeks gestation with Down syndrome ligated via the trans-pleural approach, which required redo surgery due to residual PDA of 4.9 mm size in the three-months post ligation follow-up ECHO.

There was no statistically significant difference between both groups in the context of demographic and preoperative data (**Table.1**). The mean age was 7.47 ± 5.1 months a range between 2 months and 2 years with a female-to-male ratio 2:1. The mean duct size was 4.67 ± 1.36 millimeters.

Table 1. Demographic and preoperative characteristics

Variables	Group A	Group B	P-Value
AGE (months)			
Median	4.50	7.50	
(Mean ± SD)	(5.70 ± 3.5)	(9.25 ± 5.9)	0.013
Sex			
Male	6	7	
Female	14	13	

Male: Female Ratio	1:2		
Duct Size (millimeters)			
Median	4.25	4.50	
(Mean ± SD)	(4.57 ± 1.24)	(4.77 ± 1.48)	0.323

The study focused on the comparison between the two approaches regarding the operative time consumed, the occurrence of intra-operative complications, the period of hospital stays and postoperative complications (**Table.2**). The results showed significant differences between both groups in which the operative time was markedly decreased in group B; 38.67% of total operative time in both groups was consumed in group B (**Fig.1**). The surgical morbidities were significantly reduced and intra-operative injuries of adjacent structures to PDA were better avoided in group B (**Fig.2**). Bleeding accounts for the most common intra-operative complication in our study (50%), three-quarters of them occurred in group A. An intercostal tube was inserted for all cases in group A and none in group B.

Table 2. Operative data.

Variables	Group A	Group B	P-Value
Operative Time (hours)			
Median	1.00	0.5	
(Mean ± SD)	(1.15 ± 0.29)	(0.73 ± 0.26)	<0.001
Intra-Operative Complications			
Bleeding	3	1	
RLN Injury	1	0	
Thoracic Duct Injury	1	0	
Lung Injury	2	0	
(Mean ± SD)	(0.35 ± 0.49)	(0.05 ± 0.22)	<0.001
ICT Use (N)	20	0	<0.001

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RLN; Recurrent laryngeal nerve, ICT; Intercostal tube

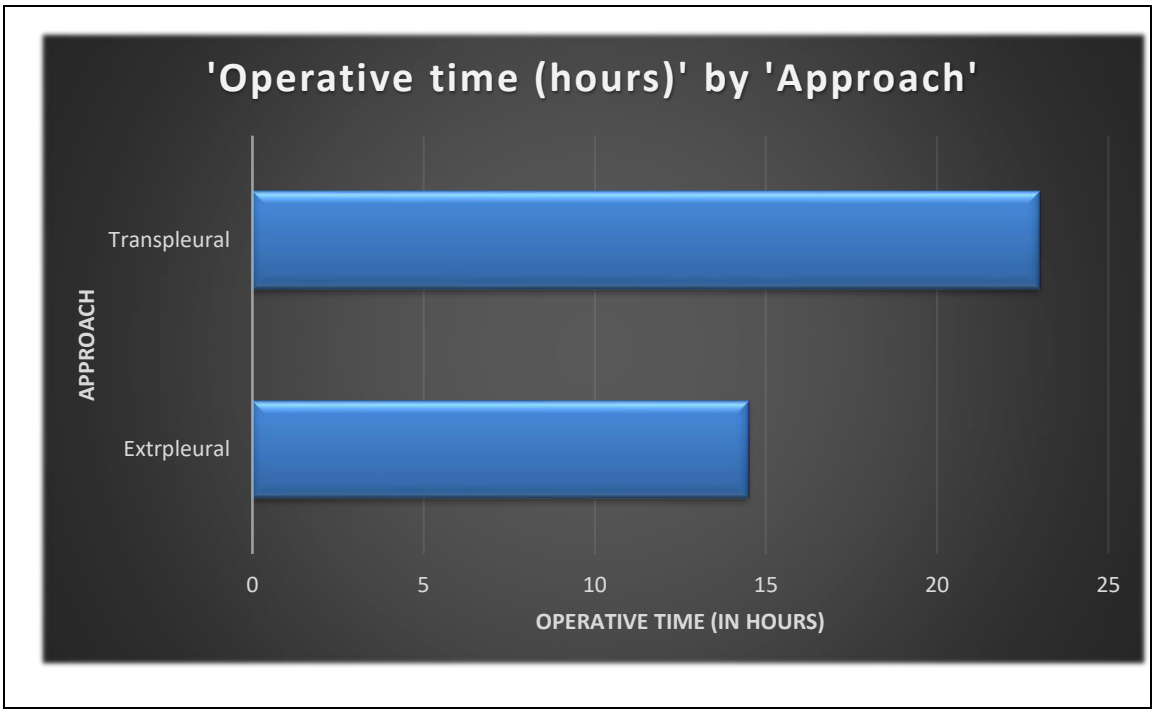

Fig.1. Operative time according to approach

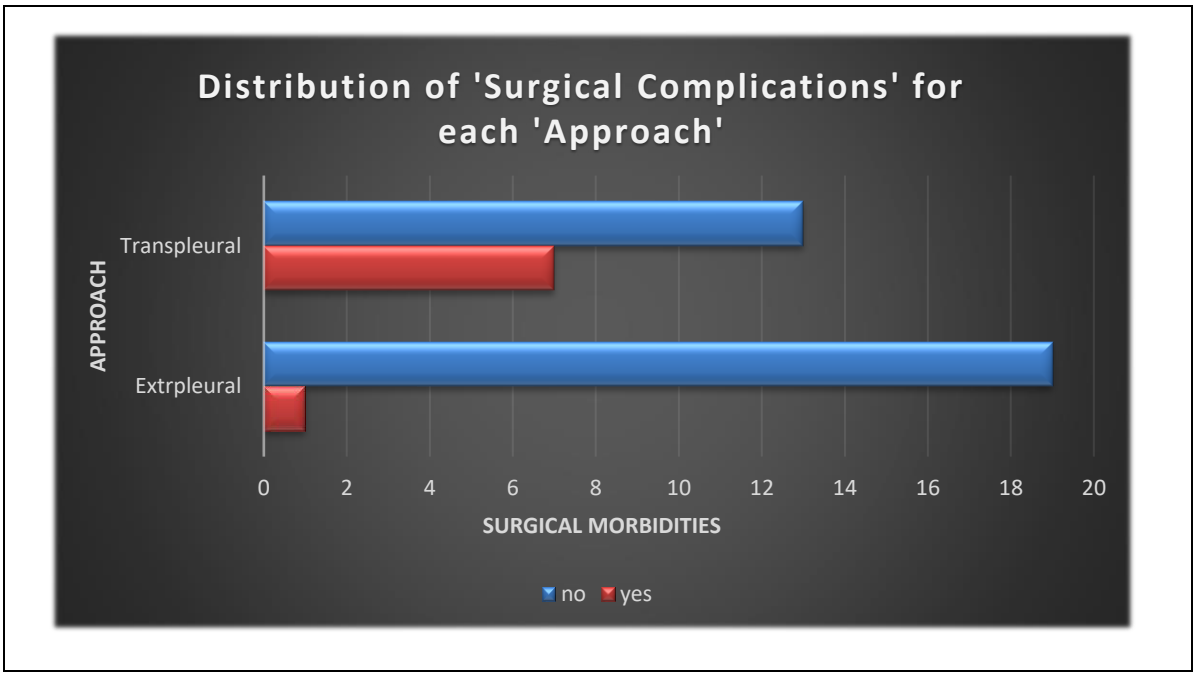

Fig.2. Distribution of surgical complications according to approach

The postoperative complications tend to be more in group A (77.8%) with fever accounting for the most observed post-operative complication (**Table.3**, **Fig.3**). Two cases in group A needed admission to the pediatric intensive care unit (PICU) for tachycardia, high-grade fever and chest infection; at which one of them was discovered to be COVID-infected and managed successfully. The results

show a marked reduction in the hospital stays of patients during the post-operative period in group B (32.8%) (**Fig.4**).

Table 3: The post-operative events.

Variables	Group A	Group B	P-Value
Need for PICU Admission	2	0	<0.001
Post-Operative Complications			
Fever	4	2	
Wound Infection	1	0	
Chest Infection	2	0	
Mean	(0.40 ± 0.50)	(0.10 ± 0.31)	0.014
Post-Operative Hospital Stay (days)			
Median	2.00	1.00	
(Mean ± SD)	(2.25 ± 1.48)	(1.10 ± 0.30)	<0.001

PICU; Pediatrics intensive care unit

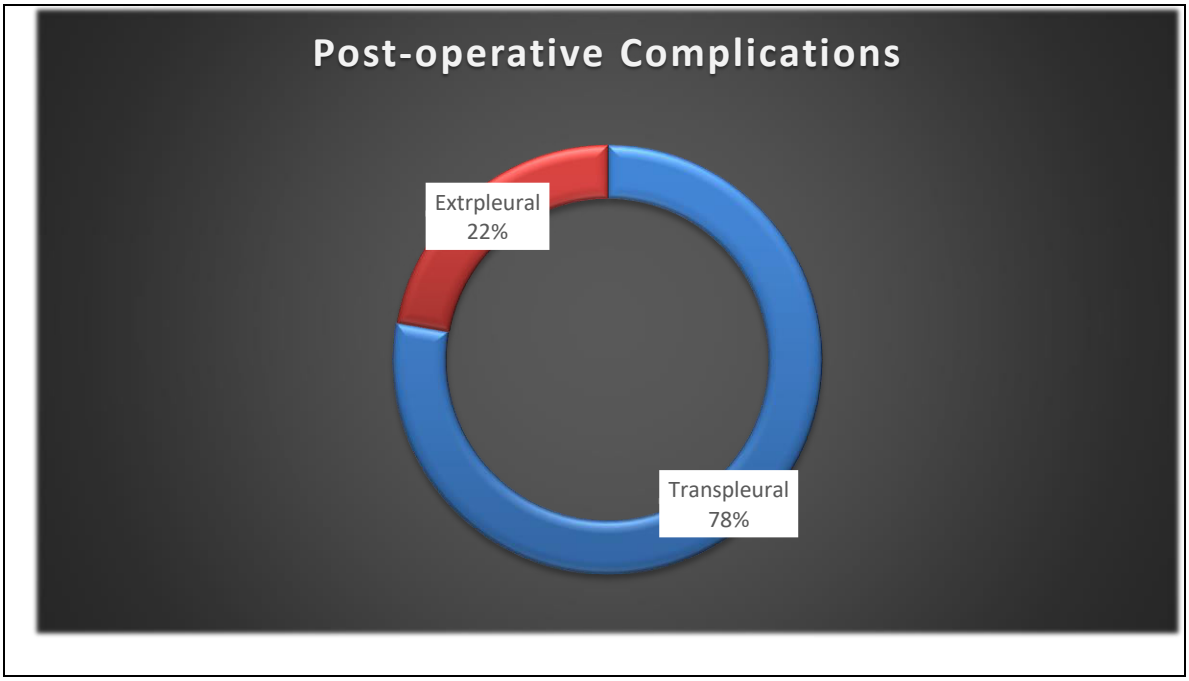

Fig. 3.Percentage of post-operative complications according to approach

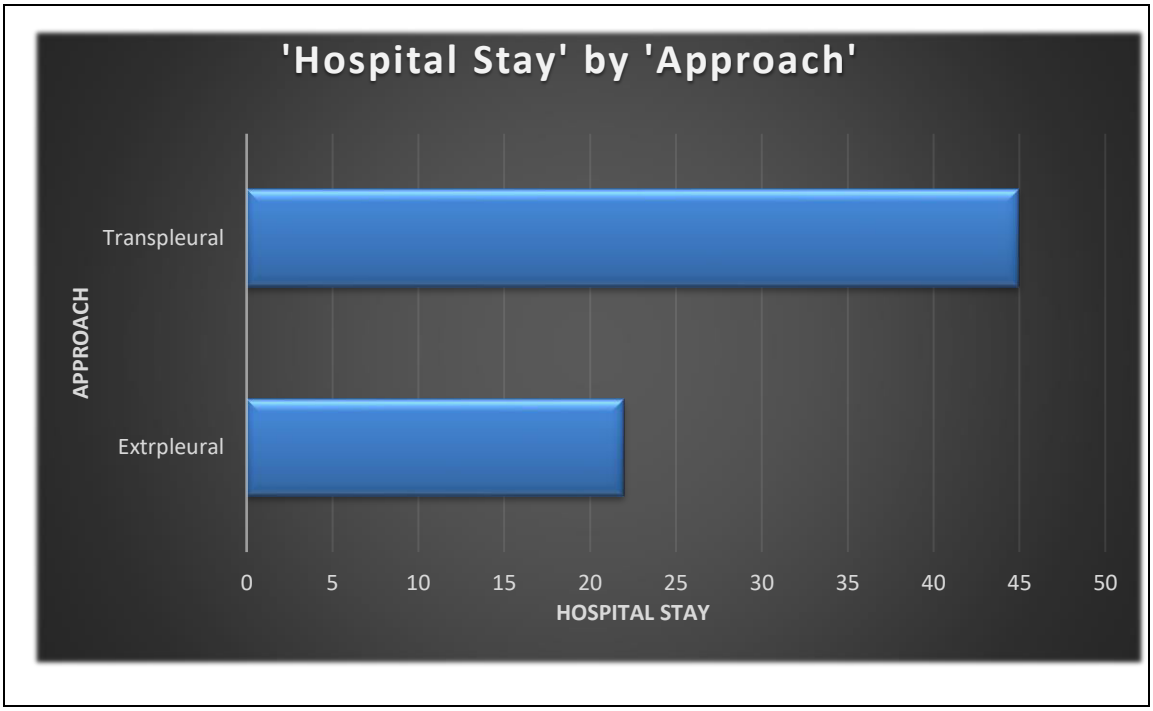

Figure 4: Hospital stay in days for each approach

The study also compares the pre and post-ligation ECHO findings regarding LV systolic function, dimensions and LA/AO ratio with results showing significant improvement at 3 months and 6 months post-ligation follow-up in comparison to pre-ligation measures. The results also show a significant decrease in the LV systolic function on the first day of ligation which improved notably in the three-month and six-month post-ligation follow-up (**Table.4**). 5 cases needed, because of early post-ligation LV dysfunction, anti-failure medications to be given.

Table 4: Comparison of ECHO findings.

Variables	LVESd (mm)	LVEDd (mm)	LA/Ao ratio	FS (%)	EF (%)
Pre-ligation (I)	1.67 ± 0.24	2.97 ± 0.35	1.39 ± 0.23	43.54 ± 6.01	72.11 ± 3.21
First-day post ligation (II)	1.61 ± 0.18	2.71 ± 0.23	1.15 ± 0.20	38.23 ± 6.86	68.07 ± 2.90
Three-months post ligation (III)	1.58 ± 0.14	2.63 ± 0.20	1.10 ± 0.16	44.13 ± 5.30	71.11 ± 2.48
Six-months post ligation	1.41 ± 0.22	2.27 ± 0.18	1.04 ± 0.14	44.32 ± 5.94	73.24 ± 2.15

(IV)					
P-Value (I & II)	0.104	< 0.001	< 0.001	< 0.001	< 0.001
P-Value (I & III)	0.021	< 0.001	< 0.001	0.321	0.061
P-Value (I & IV)	< 0.001	< 0.001	< 0.001	0.280	0.034

LVESd; left ventricular end-systolic diameter, LVEDd; left ventricular end-diastolic diameter, LA/Ao; left atrial to aortic diameter ratio, FS; fractional shortening, EF; ejection fraction

Discussion

PDA was successfully ligated in all cases except one case of a female infant born preterm at 36 weeks gestation with Down syndrome ligated via the trans-pleural approach, which required redo surgery due to residual PDA of 4.9 mm size in the three-months post ligation follow-up ECHO. **Demir et al. (2007)** found that residual shunting can occur even after double ligation and transfixion of the duct, necessitating longer follow-up for residual flow.

The study found that group B avoided intra-operative hazards better due to better exposure to the PDA and visualization of adjacent structures like the recurrent laryngeal nerve and thoracic duct. This resulted in a significant reduction in operative time, consistent with previous studies (**Mazzera et al., 2002**; **Avila-Alvarez et al., 2017; Aghaei et al., 2021**). Bleeding was the most common intra-operative complication, more common in group A due to injury or tear in the PDA or aorta. All cases of bleeding were successfully managed. Four patients in group A also experienced mild and manageable injuries of RLN, thoracic duct and lung parenchyma.

The use of an intercostal tube in group A patients may have increased the risk of chest and wound infections, potentially contributing to post-operative complications. A recent study by **Lee et al. (2023)** found that most patients do not experience significant pleural effusion or air leakage after PDA ligation and chest tube drainage is typically inserted for the evacuation of trapped air after skin closure. However, preterm neonates are at a higher risk of infection or sepsis due to their fragile lung parenchyma. The study of **Lee** found no significant postoperative complications and no fluid and air were found with or without chest tube drainage in the pleural cavity, corroborating the unnecessity of routine chest tube drainage after PDA ligation in preterm neonates.

Our study found that post-operative complications were more common in group A, with fever being the most common. Two patients were admitted to the PICU for pneumonia, and one was found to be COVID-infected with no mortality. The patient, aged 3.5 months, had a large duct size of 6.5 mm and pre-operative investigations were not suggestive of COVID-19 infection. However, a study by **Aghaei et al. (2021)** concluded that children with a history of previous CHD surgery are more susceptible to infections, especially those with pulmonary involvement, which can worsen their condition and increase their risk of COVID-19 infection compared to healthy children.

The study shows a significant decrease in post-operative patient hospital stays in group B, aligning with a study by **Avila-Alvarez et al. (2017)** which found shorter time to extubation, discontinuation of supplemental oxygen, and hospital discharge in the EP group compared to the TP group.

The study also compares pre and post-ligation ECHO findings, showing significant improvement at 3 and 6 months post-ligation. LV systolic function decreased on the first day of ligation but improved at 3 and 6 months. This aligns with **Abdel-Bary et al. (2019)** conclusion that PDA ligation can cause a significant reduction in LV systolic function, and may require anti-failure measures, prolonged hospital stays, and regular monitoring. Factors like PDA size, age, and preoperative LVEDd can predict this.

Conclusion

The extra-pleural approach offers advantages over traditional trans-pleural methods, including fewer morbidities, better visualization of PDA and associated structures, preservation of pleural space integrity, avoidance of chest tube insertion, shorter operative times, and quicker recovery periods. Therefore, it is recommended as an effective and safer surgical approach for PDA closure.

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