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Navigating the Challenges of Neonatal and Premature Patent Ductus Arteriosus Closure through Cardiac Surgical and Transcatheter Innovations

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Abstract **Original Research Article**

Background: In full term infants, Ductus Arteriosus (DA) undergoes complete closure at 96 hours of life. In Preterm infants, structural and physiological immaturity of the ductus is often associated with delayed closure and DA remains patent at the equivalent time of term gestation. Incidence of patent ductus arteriosus (PDA) is as high as 60% in preterm infants and 80% in low birth weight neonates <1200 g at birth while premature babies < 26w gestational age had PDA beyond 2 months postnatally. Spontaneous closure in extremely low birth weight (ELBW) infants are at 15%. ***Methods*:** Single institution, Retrospective study in prematures, neonates and infants diagnosed with PDA. Cohort of patients grouped into Surgical Ligation (SL) or Transcatheter Occlusion (TC). ***Results*:** Comparative analysis of 5 year data (2019 - 2023) with sample size of 142 patients in which Group 1(SL): Surgical ligation n= 63 (44%), Group2 (TC): Transcatheter occlusion n=79 (55%) with neonates (n=55) underwent (SL=41, TC =14). Patient above the age of 1 year old has been excluded. Comparative outcomes between 2 groups analysed on inpatient Mortality rate, Complete PDA occlusion rate, Residual PDA flow rate, Morbidity rate in both neonatal and premature population. ***Conclusion*:** The complications arising from PDA are due to redirection of oxygen-rich blood away from vital organs through the PDA to the pulmonary artery. This choreography results in a symphony of systemic hypoperfusion, pulmonary over circulation and neonatal pulmonary hypertension which orchestrates a crescendo of end-organ damage such as necrotizing enterocolitis (NEC), bronchopulmonary dysplasia (BPD), neonatal chronic lung disease (CLD), retinopathy of prematurity (ROP), and intraventricular hemorrhage (IVH), with the haunting shadow of mortality looming. Amidst the evolving melody of medical technology, the decision between surgical and transcatheter closure techniques has transformed. However, this complex composition prompts a call for a more elaborate interdisciplinary duet a holistic comparison of their clinical outcomes, a spotlight that deserves to shine particularly on the canvas of premature infants.

Keywords: Patent Ductus Arteriosus, Trancatheter Occlusion, Surgical Ligation, ELBW, Preterm Infants, Congenital Heart Disease.

BACKGROUND

In full term infants, Ductus Arteriosus (DA) undergoes complete closure at 96 hours of life. In Preterm infants, structural and physiological immaturity of the ductus is often associated with delayed closure and DA remains patent at the equivalent time of term gestation. Incidence of patent ductus arteriosus (PDA) is as high as 60% in preterm infants and 80% in low birth weight neonates <1200 g at birth while premature babies < 26w gestational age had PDA beyond 2 months postnatally. Spontaneous closure in extremely low birth weight (ELBW) infants are at 15%.

Timeline of significant events in the history of Patent Ductus Arteriosus (PDA) closure:

- 129 AD: Galen of Pergamon, a Greek anatomist, described the PDA.
- 1939: Surgical ligation technique for PDA closure was introduced by Gross and Hubbard.
- 1967: Transcatheter approach for PDA closure was pioneered by Portsmann *et al.*, They used a conical Ivalon plug.
- 1979: Rashkind and Cuaso developed an umbrella-type device for transcatheter closure of PDA.
- 1991: François Laborde introduced Video-Assisted Thoracoscopic Surgery (VATS) for PDA closure.
- 1992: A Cambier reported the use of Gianturco coils for transcatheter closure of PDA, marking the advent of transcatheter coil occlusion.

- 1997: The Amplatzer Ductal Occluder (ADO) was introduced as a device for transcatheter PDA closure.
- 2019: Piccolo received FDA approval for PDA closure in children with a body weight over 700 grams.

This timeline highlights key milestones in the evolution of techniques and devices for PDA closure, from ancient descriptions to modern innovations.

OBJECTIVES

Primary Objective: To compare early outcomes of PDA closure in surgical ligation and transcatheter occlusion.

Secondary Objective: To compare outcomes in extremely premature and ELBW group of PDA closure.

METHODS

Single institution, Retrospective study in prematures, neonates and infants diagnosed with PDA. Cohort of patients grouped into Surgical Ligation (SL) or Transcatheter Occlusion (TC).

Single Institution, Retrospective Study
Sample Population: Neonatal and Infant < 1 year old

Cohort: 2 groups
Surgical Ligation (SL): n= 63 (44%)
Transcatheter Closure (TC): n=79 (55%)

Exclusion
Patient above the age of 1 year old
Patients with an additional procedure other than PDA were excluded.

RESULTS

	Surgical Ligation	Transcatheter
Premature	38%	37%
Full Term	62%	63%

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This table provides a clear comparison of the percentages of premature and full-term infants undergoing surgical ligation versus transcatheter techniques for PDA closure.

Preprocedural Weight	Surgical Ligation	Transcatheter
<1.5kg	4	2
2kg	21	8
3kg	17	3
4kg	16	16
5kg	2	17
>5kg	3	33

This table shows the distribution of patients undergoing surgical ligation and transcatheter techniques for PDA closure based on their preprocedural weight categories. The p-value provided suggests the statistical significance of the difference between the two techniques regarding weight distribution.

Timing of Intervention	Surgical Ligation	Transcatheter
<1m	2	0
1m	16	5
2m	14	9
3m	8	5
4m	9	6
5m	8	6
6m	1	4
>6m	5	44

This table illustrates the timing of intervention for PDA closure, categorized by the age at which the procedure was performed, for both surgical ligation and transcatheter techniques.

Approach	Surgical Ligation	Transcatheter
Thoracotomy	74%	0%
Sternotomy	26%	0%
Occlusion	100%	100%
Coiling	0%	0%

This table shows the percentage distribution of different approaches for PDA closure within each technique category. It's evident that thoracotomy and sternotomy approaches are exclusively associated with surgical ligation, while transcatheter techniques primarily involve occlusion. There's no utilization of coiling reported in either approach.

Pre-Procedural Consequence	Count
PPHTN	19
IVH	2
NEC	5
BPD	14
HF	101

This table presents the number of cases with different pre-procedural consequences associated with Patent Ductus Arteriosus (PDA) closure.

Size	Surgical Ligation	Transcatheter
Small	0	6
Moderate	5	50
Large	58	23

This table illustrates the number of cases with different sizes of PDA categorized by surgical ligation and transcatheter techniques.

```
|                | Surgical Ligation | Transcatheter |
|----------------|-------------------|---------------|
| Mortality      |       4.8%        |     1.3%      |
| Survival rate  |      95.2%        |     98.7%     |
```

This table presents the mortality rate and survival rate for patients undergoing PDA closure via surgical ligation and transcatheter techniques.

```
|            | Surgical Ligation | Transcatheter |
|------------|-------------------|---------------|
| Residual   |       17%         |      3        |
| No Residual|       83%         |      97       |
```

This table shows the percentage of cases with residual PDA and cases without residual PDA after undergoing PDA closure via surgical ligation and transcatheter techniques.

```
|                   | Surgical Ligation | Transcatheter |
|-------------------|-------------------|---------------|
| Branch PA Stenosis|       6%          |      19       |
| No Stenosis       |      94%          |      81       |
```

This table indicates the percentage of cases with branch pulmonary artery stenosis and cases without stenosis after undergoing PDA closure via surgical ligation and transcatheter techniques.

```
|                     | Surgical Ligation | Transcatheter |
|---------------------|-------------------|---------------|
| Mortality Rate      |      0.10%        |     0.1%      |
| Residual PDA        |      4.70%        |     1.2%      |
| Branch PA Stenosis (%)|    1.58%        |     7.5%      |
```

This table presents the mortality rate, percentage of cases with residual PDA, and percentage of cases with branch PA stenosis after undergoing PDA closure via surgical ligation and transcatheter techniques.

Here's the data for the special population group of extremely premature infants (26-29 weeks gestational age) undergoing PDA closure via surgical ligation and transcatheter techniques:

Demographics:

- Surgical Ligation:
- Mean Birth Weight: 0.79 kg
- Mean Intervention Weight: 1.90 kg
- Transcatheter:
- Mean Birth Weight: 0.830 kg
- Mean Intervention Weight: 1.856 kg

Timing of Intervention:
- Surgical Ligation: 2.4 months
- Transcatheter: 4.5 months

Outcomes:
- Surgical Ligation:
- Residual PDA: 0.1%
- Branch PA Stenosis: 0.1%
- Mortality: 0.1%
- Transcatheter:
- Residual PDA: 0.1%
- Branch PA Stenosis: 2.5%
- Mortality: 0.1%

These statistics provide insights into the demographic characteristics, timing of intervention, and outcomes for extremely premature infants undergoing PDA closure via surgical ligation and transcatheter techniques.

Summary of Data Analysis

Comparative analysis of 5 year data (2019 - 2023) with sample size of 142 patients in which Group 1(SL): Surgical ligation n= 63 (44%), Group2 (TC): Transcatheter occlusion n=79 (55%) with neonates (n=55) underwent (SL=41, TC =14). Patient above the age of 1 year old has been excluded. Comparative outcomes between 2 groups analysed on inpatient Mortality rate, Complete PDA occlusion rate, Residual PDA flow rate, Morbidity rate in both neonatal and premature population.

CONCLUSION

Surgical ligation is the main cardiac intervention for Large PDA in neonates and infants < 6 months with weight < 3kg. Transcatheter intervention commonly performed > 6 months of age and moderate-size PDA Residual PDA commonly observed in Surgical Ligation group secondary to significantly large PDA size in this group but had lower incidence of PA Stenosis compared to the TC group. Early intervention appears to be benificial in our cohort of extremely premature and ELBW group with good outcome and less complication. Ideally in the future a prospective randomized trial should be conducted comparing catheter techniques for ductal closure. It is important to have MDT group for this fragile group of patients to have both intervention available. With advent of Picollo device, there has been shift of ELBW patient to undergo TC as opposed to SL, However SL is still extremely important in term babies.

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