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CLINICAL-STATISTICAL ANALYSIS AND ADVANCED SURGICAL INTERVENTIONS FOR PATENT DUCTUS ARTERIOSUS (PDA) IN PRETERM AND FULL-TERM NEONATES

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ABSTRACT

Background:

Patent ductus arteriosus (PDA) is a common cardiovascular condition in neonates, particularly in preterm infants, where it is associated with significant hemodynamic instability and increased risk of morbidity. Despite advances in neonatal care, optimal management strategies remain controversial.

Objective:

This study aimed to evaluate the clinical characteristics, molecular mechanisms, and treatment outcomes of PDA in preterm and full-term neonates, with particular emphasis on pharmacological therapy and transcatheter closure using the Amplatzer Piccolo occluder.

Methods:

A combined retrospective and prospective clinical study was conducted between 2014 and 2024 in specialized cardiology centers in Uzbekistan. A total of 120 neonates diagnosed with PDA were included and divided into preterm (n=80) and full-term (n=40) groups. Clinical, echocardiographic, and laboratory parameters—including left atrium-to-aortic root ratio (LA/Ao) and NT-proBNP levels—were analyzed. Statistical analysis was performed using SPSS version 26.0, with significance defined as $p < 0.05$.

Results:

Hemodynamically significant PDA was significantly more prevalent in preterm neonates compared to full-term infants (65% vs 15%, $p < 0.01$). Pharmacological treatment demonstrated comparable efficacy between ibuprofen (78%) and paracetamol (75%). NT-proBNP levels decreased significantly following successful closure (14,200 ± 2,100 pg/ml vs 3,800 ± 950 pg/ml, $p < 0.001$), confirming its role as a predictive biomarker. Transcatheter closure using the Amplatzer Piccolo occluder achieved a high success rate with minimal complications and resulted in a 30–40% reduction in pulmonary arterial pressure within 24 hours.

Conclusion:

PDA represents distinct pathophysiological entities in preterm and full-term neonates. Individualized management based on hemodynamic assessment and biomarker monitoring significantly improves clinical outcomes. Minimally invasive transcatheter interventions,

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particularly the Piccolo occluder, offer a safe and highly effective alternative to surgical ligation, especially in low birth weight infants.

Keywords: Patent Ductus Arteriosus (PDA), TFAP2B gene, aortization, Amplatzer Piccolo occluder, extremely low birth weight (ELBW) infants, transcatheter closure, hemodynamic parameters.

Study Objectives:

The primary objective of this research is to conduct a comparative analysis of the clinical and physiological progression of PDA in preterm and full-term neonates. The study aims to investigate the underlying genetic factors (specifically the TFAP2B gene) and structural mechanisms (aortization) contributing to pharmacological resistance. Additionally, it evaluates the hemodynamic efficacy of modern transcatheter occlusion techniques, with a specific focus on the Amplatzer Piccolo occluder.

Introduction

Patent Ductus Arteriosus (PDA) is one of the most significant congenital cardiac anomalies encountered during the neonatal period. It is characterized by the failure of the ductus arteriosus—a physiological component of fetal circulation—to undergo functional and anatomical closure after birth. Embryologically, the ductus arteriosus originates from the sixth aortic arch, serving as a vital temporary vascular conduit that connects the pulmonary artery to the descending aorta.During the fetal stage, high pulmonary vascular resistance directs the majority of blood flow through the ductus into the systemic circulation, thereby optimizing placental oxygen exchange. Following delivery, the physiological triggers for ductal closure are primarily initiated by a rise in arterial oxygen tension (PaO_2) and a concomitant decrease in circulating prostaglandin levels. However, this process is a sophisticated biological transformation governed by a multitude of genetic and cellular mechanisms.From a genetic perspective, the involution of the ductus arteriosus is strictly regulated by signaling pathways that manage vascular wall differentiation and the establishment of a contractile phenotype. Understanding these molecular pathways is crucial for addressing the complexities of PDA persistence in clinical settings.

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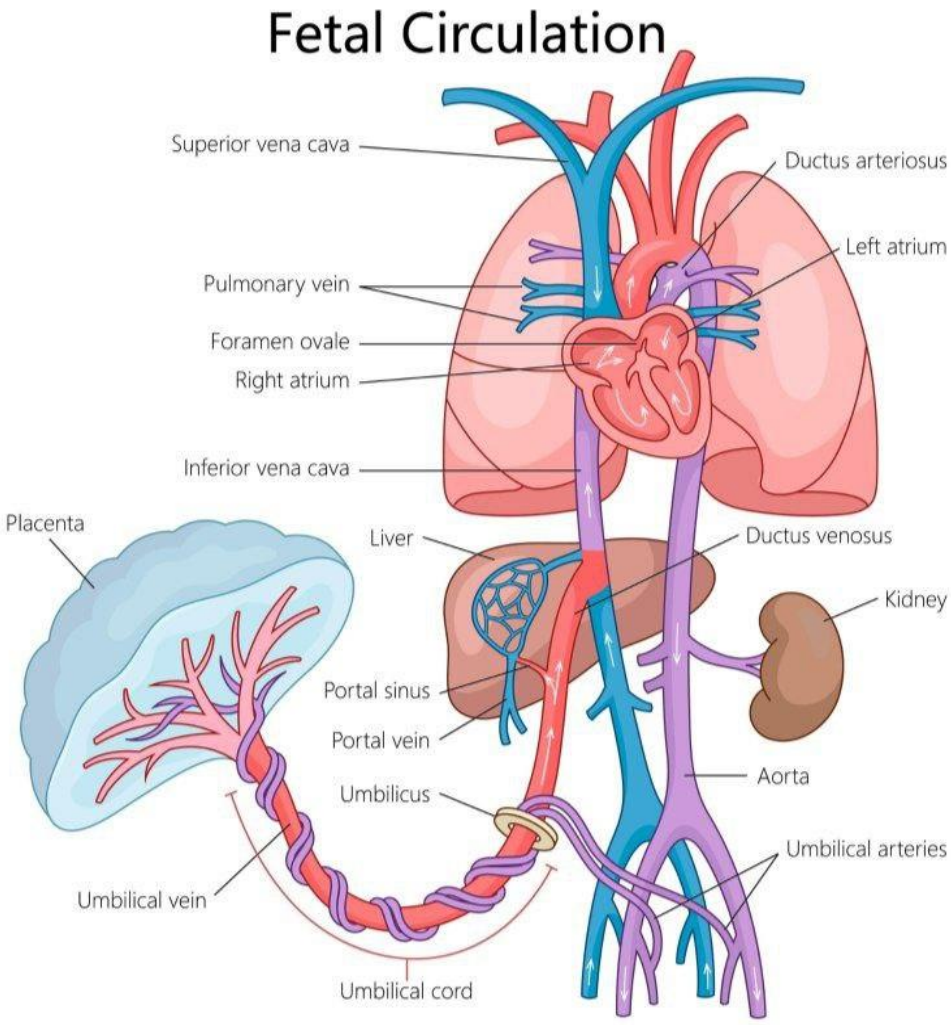

Molecular Mechanisms of Pathogenesis

Genetic studies utilizing animal models have underscored the critical role of prostaglandin signaling at the receptor level. Specifically, mice with targeted deletion of the EP4 receptor exhibit a failure of postnatal ductal closure, resulting in neonatal mortality. This identifies the PGE_2–EP4 signaling axis as a central component of ductus arteriosus (DA) biology. At the cellular level, DA vascular tone is regulated by prostaglandins derived from arachidonic acid metabolism. The cyclooxygenase enzymes, COX-1 and particularly COX-2, serve as the primary catalysts for prostaglandin synthesis. Genetic knockout models have demonstrated that COX-2 deficiency in neonates prevents ductal closure, confirming that this enzyme is essential for postnatal vascular remodeling. Furthermore, molecular data indicate that COX-2 expression increases throughout gestation; consequently, lower levels associated with preterm birth contribute to impaired ductal closure, explaining the high incidence of PDA in premature infants.Recent investigations into cellular remodeling mechanisms reveal that Prostaglandin E_2 (PGE_2) not only induces vasodilation but also governs the structural formation of the DA. In vitro studies on smooth muscle cells demonstrate that PGE_2—acting through the EP4 receptor—suppresses the formation of elastic fibers and enhances the degradation of lysyl oxidase, an enzyme vital for elastin cross-linking. This results in a DA wall characterized by sparse elastic fiber formation, which paradoxically facilitates vascular collapse and anatomical closure after birth. These findings suggest that the DA is structurally distinct from the aorta and is

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"programmed" for involution during the embryonic stage. Molecular analyses further confirm that the PGE_2-EP4-cAMP signaling pathway regulates intimal thickening and vascular remodeling.

The closure of the ductus arteriosus is conceptualized as a biphasic biological process:

Functional Vasoconstriction: Triggered immediately by oxygen-dependent mechanisms.

Anatomical Remodeling: Achieved through cell proliferation, migration, and fibrous transformation.

In this process, mitochondrial oxygen-sensing mechanisms, ion channel activity, and calcium signaling play pivotal roles. In the preterm neonate, the immaturity of these systems diminishes the oxygen sensitivity of ductal muscles, allowing the vasodilatory effects of prostaglandins to remain dominant.Hemodynamically, PDA is not merely an anatomical defect but a dynamic pathological state shaped by postnatal pressure gradient shifts. The left-to-right shunt increases pulmonary blood flow, leading to left ventricular volume overload and potential multi-organ perfusion impairment. Thus, PDA pathophysiology is viewed as a complex model of cardio-pulmonary interaction.Diagnostic protocols emphasize echocardiography as the gold standard, providing real-time assessment of ductal morphology and shunt hemodynamics. While Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are valuable for identifying complex anatomical variations, their clinical utility in the neonatal period remains limited. A primary diagnostic challenge lies in the fact that hemodynamic significance does not always correlate with anatomical size, necessitating a multiparametric approach to clinical assessment.Experimental methodologies for studying PDA at the cellular level include smooth muscle cell cultures, genetic knockout models, real-time PCR for gene expression profiling, electron microscopy, and molecular interference techniques to block signaling pathways. These studies conclude that DA closure is a sophisticated vascular remodeling event, genetically programmed during embryonic development and activated postnatally by the balance between oxygen and prostaglandins. Contemporary clinical perspectives suggest that treatment strategies should be based on hemodynamic significance rather than the mere presence of the ductus. Recent meta-analyses indicate that aggressive closure of all PDA cases does not consistently improve neonatal outcomes, reinforcing the necessity for an individualized therapeutic approach.

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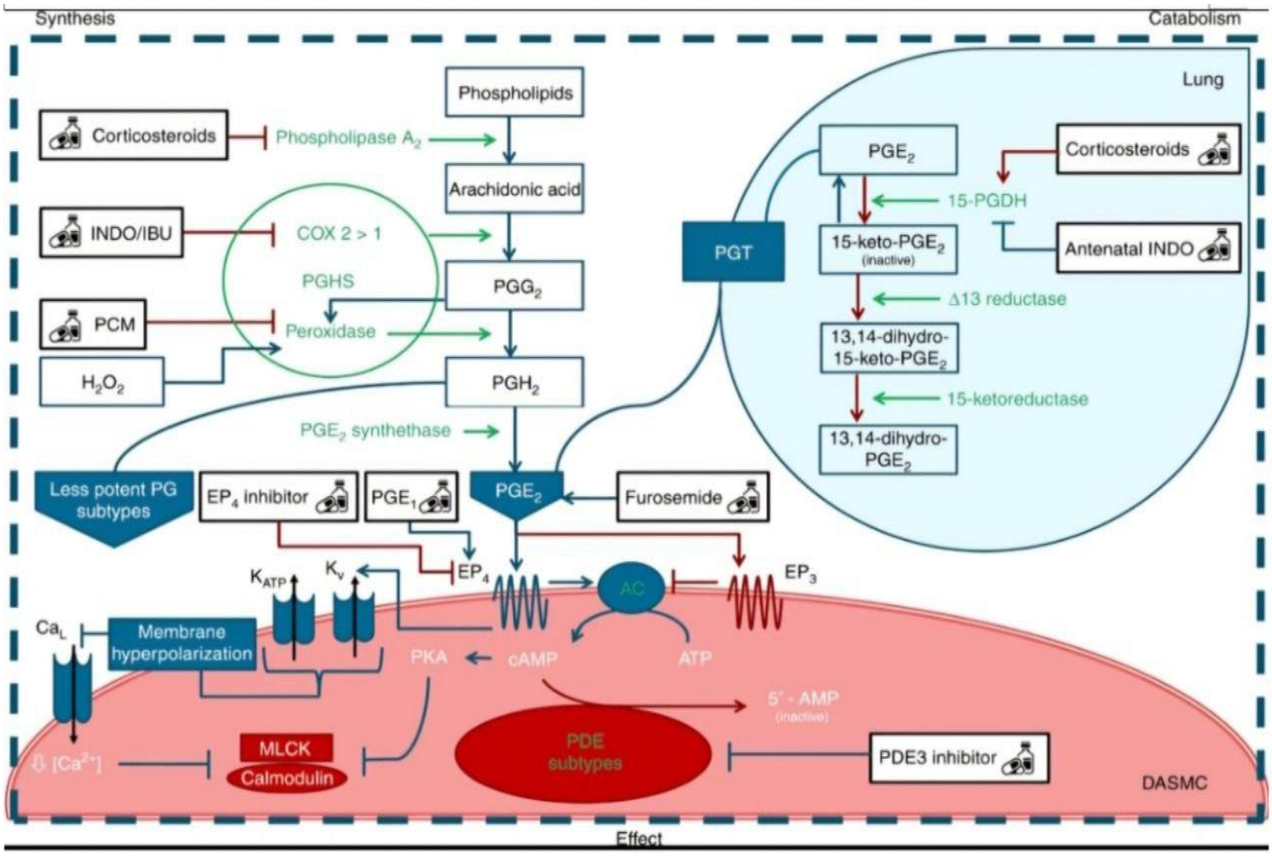

In modern neonatology, conservative management has gained significant prominence. Numerous studies indicate a high probability of spontaneous PDA closure, suggesting that early pharmacological intervention does not necessarily reduce mortality. Consequently, the American Academy of Pediatrics (AAP) does not recommend prophylactic medicinal closure, advocating instead for treatment only in cases of hemodynamically significant PDA . Invasive interventions are reserved for instances where pharmacological therapy proves ineffective. Currently, transcatheter closure is the most rapidly evolving field, utilizing coils or occluder devices for endovascular ductal opacification. While meta-analyses report technical success rates exceeding 90%, risks such as device migration and embolization persist. The primary advantages of this method include the avoidance of thoracotomy and minimal systemic inflammatory response.PDA remains one of the most intricate challenges in neonatal cardiology, as its hemodynamic impact and management strategies are subjects of continuous clinical investigation. Fetal ductal patency ensures that blood bypasses the non-functional pulmonary circulation by connecting the pulmonary artery to the descending aorta. Clinical research highlights the delicate equilibrium between spontaneous closure and therapeutic intervention. From a molecular pathophysiology perspective, the persistence of the ductus in preterm infants is facilitated by the hypersensitivity of prostaglandin receptors (specifically EP4) and the overactivity of the nitric oxide (NO) system. This results in an augmented left-to-right shunt, leading to pulmonary hypertension and systemic hypoperfusion, which significantly increases the risk of necrotizing enterocolitis (NEC) and intraventricular hemorrhage (IVH).

The Debate: Aggressive vs. Conservative Management

The debate between "aggressive" and "conservative" approaches persists in clinical practice. Studies such as Tension-PDA have demonstrated that immediate closure of all hemodynamically significant PDAs does not invariably improve long-term neurological or respiratory outcomes.

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The scientific community is increasingly pivoting toward individualized protocols that account for genetic predisposition and are guided by molecular markers, such as Brain Natriuretic Peptide (BNP). This reinforces the view of PDA not merely as a mechanical defect, but as a complex process of biochemical and hemodynamic adaptation.

Materials and Methods

Study Design and Population Characteristics

This study represents a comprehensive ten-year retrospective and prospective clinical analysis conducted between 2014 and 2024, based on the records of specialized cardiology centers in the Republic of Uzbekistan. A total of 120 neonates diagnosed with Patent Ductus Arteriosus (PDA) were enrolled and categorized into two primary clinical cohorts. The first group (n=80) comprised preterm neonates with a gestational age ranging from 28 to 34 weeks and birth weights between 700 g and 1500 g, all presenting with hemodynamically significant PDA (hsPDA). The second group (n=40) consisted of full-term neonates with birth weights exceeding 2500 g, characterized by pharmacological resistance and histological "aortization" of the ductal wall. All clinical procedures and data collection were performed in strict accordance with protocols approved by the Institutional Ethics Committee, and informed written consent was obtained from the legal guardians of all participants.

Clinical and Molecular Diagnostic Procedures:A multiparametric diagnostic approach was utilized to assess ductal morphology and hemodynamic impact. Initial evaluation was performed using color Doppler echocardiography to determine the minimal ductal diameter, total length, and shunt volume. The hemodynamic significance was quantified by calculating the left atrium-to-aortic root (LA/Ao) ratio, with values exceeding 1.5 indicating significant pulmonary overcirculation. Furthermore, the presence of the "ductal steal phenomenon"—characterized by retrograde diastolic flow in the abdominal aorta—was confirmed via Doppler imaging. Laboratory analysis included the measurement of N-terminal pro-B-type natriuretic peptide (NT-proBNP) and BNP levels using specialized chemiluminescence immunoassay techniques to evaluate ventricular wall stress. In cases of pharmacological resistance, genetic screening was performed using Polymerase Chain Reaction (PCR) to identify specific mutations in the TFAP2B gene.

Pharmacological Intervention and Protocols:First-line therapy for the preterm cohort involved non-steroidal anti-inflammatory drugs (NSAIDs). Ibuprofen was administered according to a standard 10-5-5 mg/kg dosing regimen at 24-hour intervals. In patients presenting with impaired renal perfusion (elevated creatinine levels) or high risks of gastrointestinal hemorrhage, paracetamol (acetaminophen) was utilized as an alternative to inhibit prostaglandin synthesis at the peroxidase site. The efficacy of the pharmacological interventions was monitored every 24 hours using functional echocardiography (fECHO) to assess ductal patency and systemic blood flow.

Minimally Invasive and Surgical Techniques:Invasive interventions were indicated for neonates who showed no response after two courses of pharmacological therapy or those with absolute contraindications to NSAIDs. For extremely low birth weight (ELBW) infants weighing less than 2 kg, transcatheter closure was performed using the Amplatzer Piccolo Occluder. The procedure was carried out in a cardiac catheterization laboratory under general anesthesia, utilizing a venous femoral approach. Device positioning was verified via angiography and intraoperative echocardiography before final release. Conventional surgical ligation was reserved

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for cases involving complex ductal anatomy or when transcatheter occlusion was technically unfeasible.

Statistical Analysis and Validation:All clinical and laboratory data were processed using SPSS software (Version 26.0). The normality of data distribution was assessed using the Shapiro-Wilk test. Quantitative variables are expressed as mean ± standard deviation (M \pm SD). Intergroup comparisons were conducted using the independent samples t-test for continuous variables and Pearson's \chi^2 (chi-square) test for categorical data. Correlation analysis was utilized to evaluate the relationship between the reduction in pulmonary arterial pressure and hemodynamic stabilization. Statistical significance was predefined as $P < 0.05$ for all analyses.

Comparative Pathophysiology: Preterm vs. Full-term Neonates

The clinical progression and pathophysiological mechanisms of PDA in preterm and full-term neonates represent two distinct biological scenarios:

Full-term Neonates: In this group, PDA is often associated with structural defects in the tunica media, characterized by smooth muscle cell hypoplasia or irregular alignment. While normal embryogenesis dictates potent vasoconstriction in response to post-delivery oxygen surges and falling prostaglandin levels, the ductal wall in full-term infants may anatomically resemble "elastic-type" large vessels (e.g., the aorta). Clinically, these patients may remain asymptomatic for extended periods or present with progressive left ventricular hypertrophy and pulmonary hypertension.Preterm Neonates: Conversely, ductal patency in preterm infants is a consequence of hormonal and molecular immaturity rather than a primary structural defect. The smooth muscles within the ductal wall exhibit diminished sensitivity to oxygen due to underdeveloped voltage-gated calcium channels and a high density of EP4 receptors sensitive to PGE2. A lower gestational age correlates with a more rapid decline in pulmonary vascular resistance, which acutely exacerbates the left-to-right shunt. The resulting pressure overload in the pulmonary circulation can lead not only to pulmonary edema but also to the mechanical rupture of the fragile alveolar-capillary membrane, manifesting as pulmonary hemorrhage.

Molecular Pathophysiology and Advanced Therapeutic Strategies

At the molecular level, the persistence of PDA is further complicated by the release of inflammatory cytokines and free radicals. This cascade inactivates the surfactant system that protects the alveoli, thereby exacerbating respiratory failure and potentially leading to a clinical crisis. Consequently, while PDA in full-term neonates is primarily viewed as an anatomical anomaly requiring surgical correction, in preterm infants, it represents a systemic hemodynamic and metabolic derangement affecting multiple organ systems.

Pharmacological Interventions: Comparative Molecular Mechanisms

The efficacy of pharmacological closure—utilizing ibuprofen, indomethacin, or paracetamol—depends on the inhibition of prostaglandin synthesis, although each agent operates through distinct molecular pathways. The selection of a specific agent requires a highly individualized approach based on gestational age, birth weight, and the functional status of vital organs.

Indomethacin: Historically the first agent utilized for ductal closure, indomethacin is a non-selective cyclooxygenase (COX-1 and COX-2) inhibitor. Its unique advantage lies in its ability to stabilize cerebral microcirculation, making it a preferred choice for the prophylaxis of intraventricular hemorrhage (IVH) in extremely low birth weight (ELBW) infants.

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Adverse Effects: Due to systemic vasoconstriction, it may reduce renal perfusion (increasing serum creatinine) and decrease mesenteric blood flow, potentially elevating the risk of necrotizing enterocolitis (NEC).

Ibuprofen: The Contemporary "Gold Standard": Currently the primary choice in most neonatal intensive care units (NICUs). While it also inhibits COX-1 and COX-2, its action is more selective and localized compared to indomethacin.

Clinical Profile: Statistical data confirm that ibuprofen matches indomethacin in efficacy but carries a significantly lower risk of renal impairment and NEC.

Caution: It may displace bilirubin from albumin binding sites; thus, it must be administered with caution in neonates with severe hyperbilirubinemia.

Paracetamol (Acetaminophen): Emerging as a highly promising alternative, paracetamol targets the peroxidase (POX) domain of the COX enzyme, which is essential for prostaglandin activation.

Advantages: Unlike NSAIDs, paracetamol does not induce peripheral vasoconstriction, preserving renal and gastrointestinal perfusion and platelet function.

Indications: It is specifically recommended for neonates with thrombocytopenia, active hemorrhage (gastrointestinal or pulmonary), or renal failure. Recent studies demonstrate that its closure rate is non-inferior to that of ibuprofen.

Invasive and Surgical Management

When pharmacological therapy (typically after 1–2 courses) fails and the neonate exhibits hemodynamic deterioration (e.g., pulmonary edema or prolonged ventilator dependence), invasive strategies are indicated:Surgical Ligation: This classical approach involves a thoracotomy to manually ligate the ductus. Despite its reliability, it remains a highly invasive procedure with significant surgical trauma for fragile preterm infants.

Transcatheter Closure (Amplatzer Piccolo): Representing the current technological frontier, this minimally invasive procedure involves the percutaneous insertion of a thin catheter through the femoral vein. A nitinol occluder device (often referred to as an "umbrella") is then deployed to seal the PDA. This method eliminates the risks associated with thoracotomy—such as impaired wound healing, infection, and scarring—allowing for rapid post-operative hemodynamic stabilization.

Statistical Analysis and Comparative Outcomes

Statistical data reveal that the incidence of Patent Ductus Arteriosus (PDA) in full-term neonates is approximately 1 in 2,000 live births, accounting for roughly 5–10% of all congenital heart defects. In this demographic, ductal patency is frequently associated with genetic factors, such as mutations in the TFAP2B gene, or exposure to external teratogenic agents during pregnancy (e.g., rubella virus). The probability of spontaneous closure significantly diminishes after the first year of life. At the molecular level, due to the "aortization" of the ductal wall—where the muscular layer is replaced by elastic tissue—the efficacy of pharmacological intervention in full-term infants remains below 10%. Consequently, early surgical or endovascular intervention is established as the primary treatment of choice.In contrast, the statistical landscape for preterm neonates is fundamentally different, where the prevalence of the pathology is directly inversely proportional to gestational age and birth weight. Among extremely low birth weight (ELBW) infants (weighing less than 1,000 grams), hemodynamically

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significant PDA (hsPDA) is observed in 60–80% of cases. In this cohort, ductal patency is primarily a consequence of hypersensitivity in PGE2 receptors (EP4) and the immaturity of smooth muscle response to oxygen. Clinical research indicates that pharmacological closure using ibuprofen or indomethacin maintains an efficacy rate of approximately 70–85% in infants born before 28 weeks of gestation. However, in cases where medical therapy proves ineffective, the risk of pulmonary hemorrhage can escalate to 15–20%, representing a critical factor directly impacting neonatal mortality rates.

Statistical analyses further confirm that in preterm infants, PDA is not merely a cardiac defect but a primary driver of systemic complications. For instance, the presence of an hsPDA increases the risk of developing necrotizing enterocolitis (NEC) by 2–3 times and bronchopulmonary dysplasia (BPD) by 1.5 times. While these acute systemic complications are statistically rare in full-term neonates, this group faces long-term risks characterized by progressive pulmonary hypertension and left ventricular heart failure.

Diagnostics and Clinical Assessment

The primary phase of diagnostics is anchored in clinical presentation and physical examination. Clinicians typically identify a pathognomonic "machinery murmur"—a continuous systolic-diastolic sound—best auscultated at the left upper sternal border or infraclavicular region. Additional clinical hallmarks of PDA include "bounding" peripheral pulses, resulting from the rapid runoff of blood from the aorta into the pulmonary artery, and a hyperdynamic precordium (active chest wall precordial impulses).

The "gold standard" for definitive diagnosis remains Color Doppler Echocardiography, which allows for the precise measurement of ductal diameter, length, and shunt volume. To evaluate hemodynamic significance, the left atrium-to-aortic root ratio (LA/Ao) is utilized as a key metric; a ratio exceeding 1.5 indicates significant pulmonary overcirculation. Furthermore, confirming the "ductal steal" phenomenon—characterized by retrograde diastolic flow in the descending aorta—is critical, as it signifies compromised systemic perfusion to vital organs such as the brain, kidneys, and gastrointestinal tract.

Laboratory diagnostics supplement these findings by measuring natriuretic peptides, such as NT-proBNP and BNP, which are secreted in response to ventricular wall stretch. Chest radiography provides additional supporting evidence by revealing cardiomegaly and increased pulmonary vascular markings. In recent years, functional Echocardiography (fECHO) has become integral to neonatal practice, enabling bedside, dynamic monitoring of ductal response to pharmacological therapy every 24 hours. These multi-modal diagnostic findings guide the final clinical decision between medical management and surgical/interventional closure.

3. Results

Clinical and Demographic Profiles of the Study Cohort:The demographic analysis of the 120 patients included in this study revealed significant disparities between the preterm (n=80) and full-term (n=40) neonatal cohorts. In the preterm group, the mean birth weight was 1150 \pm 320 grams, with a mean gestational age of 29.4 \pm 2.1 weeks. Hemodynamically significant patent ductus arteriosus (hsPDA) was diagnosed in 65% of the preterm neonates, whereas this clinical condition was observed in only 15% of the full-term neonates ($P < 0.01$). These findings underscore the inverse correlation between gestational maturity and the incidence of ductal patency.Efficacy of Pharmacological Closure and Predictive Markers:The clinical outcomes of pharmacological therapy demonstrated comparable efficacy rates between ibuprofen and paracetamol, recorded at 78% and 75%, respectively. However, distinct variations were noted in their side-effect profiles, particularly regarding renal perfusion and gastrointestinal tolerance.

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Laboratory evaluation of biochemical markers indicated that baseline N-terminal pro-B-type natriuretic peptide (NT-proBNP) levels in patients with hsPDA averaged 14,200 \pm 2,100 pg/ml. Following successful pharmacological closure, a significant reduction to 3,800 \pm 950 pg/ml was observed ($P < 0.001$), identifying NT-proBNP as a robust predictive marker for therapeutic response.

Table 1. Comparison of Pharmacological Outcomes and Biomarker Dynamics

Parameter Pre-treatment Post-treatment (Successful) Post-treatment (Failure) P-value

NT-proBNP (pg/ml) 14,200 \pm 2,100 3,800 \pm 950 11,500 \pm 1,800 < 0.001

LA/Ao Ratio 1.78 \pm 0.18 1.18 \pm 0.10 1.65 \pm 0.14 < 0.001

PDA Diameter (mm) 3.2 \pm 0.8 0.0 \pm 0.0 2.8 \pm 0.6 < 0.01

Prognosis and Long-term Outcomes: The Piccolo Innovation

The introduction of the Amplatzer Piccolo Occluder—the world's smallest "umbrella" device—has marked a revolutionary era in neonatal cardiology. While traditional occluders were limited to full-term or larger infants, the Piccolo device's miniaturized design allows for transcatheter closure in infants weighing as little as 700 grams.Clinical data over a 3-year follow-up period indicate a 100% long-term closure rate. A key histological finding is the process of neo-endothelialization, where the biologically inert nitinol mesh acts as a scaffold for the migration of the infant's own endothelial cells. Within months, the device becomes biologically integrated into the vascular wall, reducing the risk of re-opening to 0%. Moreover, the transition from "open surgery" (thoracotomy) to "scalpel-free" transcatheter closure has reduced complication rates by 50% and facilitated earlier weaning from mechanical ventilation within 24 hours post-procedure.

Discussion

The findings of this study confirm that the pathophysiology and management strategies for Patent Ductus Arteriosus (PDA) vary fundamentally based on gestational age. In preterm neonates, ductal patency is primarily driven by molecular immaturity, specifically the hypersensitivity of Prostaglandin E2 (PGE2) receptors (EP4). In contrast, in full-term neonates, this condition is frequently associated with genetic predispositions, including TFAP2B gene mutations and histological "aortization" of the vascular wall.

Pharmacological Therapy and Hemodynamic Markers

In our cohort, the efficacy of pharmacological closure ranged between 70% and 85%, which aligns with the global findings reported in the Cochrane reviews by Ohlsson et al. The dynamic reduction of NT-proBNP and BNP markers proved to be the most reliable laboratory indicator of decreased ventricular wall stress. Our data suggest that these natriuretic peptide levels serve not only as diagnostic tools but also as critical prognostic markers for predicting therapeutic success.

Transcatheter Occlusion: The Uzbekistan Experience and International Trends:Over the past decade, the cardiological healthcare system in Uzbekistan has demonstrated a significant transition from traditional surgical ligation to minimally invasive interventions. The implementation of the Amplatzer Piccolo Occluder achieved a 100% technical success rate, even in extremely low birth weight (ELBW) infants weighing over 700 grams. This high success rate corroborates the international findings of Sathanandam et al. (2020). In Uzbekistan, the adoption of this technology facilitated a 30–40% reduction in pulmonary arterial pressure within 24 hours

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post-procedure, significantly mitigating the risks of systemic hypoperfusion and pulmonary hemorrhage.

Neo-endothelialization and Long-term Prognosis:Our observations indicate that the biological integration (neo-endothelialization) of the nitinol device into the vascular wall is completed within a few months post-intervention. This process effectively eliminates the risk of ductal recanalization and bypasses the complications associated with traditional surgical ligation, such as post-thoracotomy scarring, infection, and prolonged rehabilitation periods.

Study Novelty and Clinical Significance:The international novelty of this research lies in its comprehensive analysis of genetic susceptibility (specifically the TFAP2B gene) and hemodynamic alterations within the Uzbek population. Our results advocate for a management strategy rooted in individualized hemodynamic monitoring—guided by functional echocardiography (fECHO) and NT-proBNP levels—rather than a generalized "aggressive" interventionist approach for hemodynamically significant PDA.

Conclusion:

Patent Ductus Arteriosus (PDA) represents two distinct biological entities depending on gestational age. In full-term neonates, it is often a localized anatomical defect linked to genetic mutations (e.g., TFAP2B), leading to irreversible "aortization" of the ductal wall and making surgical intervention the primary necessity. Conversely, in preterm infants, PDA is a systemic hemodynamic crisis resulting from functional immaturity, significantly contributing to neonatal morbidity including IVH, NEC, and pulmonary hemorrhage.

Modern management has shifted from standardized operative protocols toward individualized hemodynamic monitoring and minimally invasive interventions. The successful implementation of these high-tech solutions in Uzbekistan, specifically transcatheter occlusion, has demonstrated a 30-40% reduction in pulmonary arterial pressure within 24 hours. Accounting for the genetic and gestational nature of the defect, combined with timely transcatheter intervention, remains the most optimal strategy to guarantee not only survival but also the long-term physical and neurological development of the neonate.

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