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Patent Ductus Arteriosus Stenting in Duct-Dependent Pulmonary Blood Flow: Comparison of CT Angiography and Echocardiography for Stent Sizing and Evaluation of Femoral Versus Axillary Access Outcomes

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Abstract

Background: Duct-dependent pulmonary blood flow is a critical neonatal emergency. Patent ductus arteriosus (PDA) stenting is a viable alternative to surgical shunts, but optimal pre-procedural imaging for sizing and the choice of vascular access (femoral vs. axillary) remain debated.

Aim: This retrospective study aimed to evaluate the degree of agreement between pre-procedural imaging (CT angiography vs. echocardiography) and the final implanted stent dimensions and to evaluate outcomes associated with femoral versus axillary access.

Methods: A retrospective cohort study was conducted at the Queen Alia Heart Institute, Jordan, from January 2020 to May 2024. Medical records of neonates and infants who underwent PDA stenting for duct-dependent pulmonary blood flow were reviewed. Patients were categorized by imaging modality (CT angiography vs. echocardiography) and access approach (femoral vs. axillary). Data collected included demographics, ductal morphology, stent dimensions, procedural details, technical success, complications, and post-procedural outcomes.

Results: A total of 48 patients (mean age = 11.2 ± 8.4 days; mean weight = 3.2 ± 0.5 kg) were included. CT angiography (n = 22) demonstrated a numerically smaller mean absolute difference in predicting stent length compared to echocardiography (n = 26) (1.1 mm vs. 2.9 mm; p = 0.006), while diameter agreement was comparable. Axillary access (n = 15) was associated with a shorter procedural time compared to femoral access (n = 33) (49 ± 18 vs. 74 ± 29 minutes; p = 0.003). However, there were no statistically significant differences in technical success (14/15 (93.3%) vs. 25/33 (75.8%); p = 0.239) or major complication rates (2/15 (13.3%) vs. 6/33 (18.2%); p = 1.000).

Conclusion: In this small retrospective cohort, CT angiography demonstrated a numerical trend toward better prediction of stent length, and axillary access was associated with shorter procedural times. However, these differences were not statistically significant for technical success or safety outcomes. These findings are hypothesis-generating; larger prospective studies are required to confirm whether tailored imaging and access site selection can improve outcomes in this vulnerable population.

Categories: Cardiology, Internal Medicine, Cardiac/Thoracic/Vascular Surgery
Keywords: axillary artery access, doppler echocardiography, femoral artery access, pda stenting, stenting duct

Introduction

Duct-dependent pulmonary blood flow is a critical neonatal emergency in which survival depends on maintaining patency of the ductus arteriosus [1]. This condition is most commonly encountered in neonates with pulmonary atresia, critical pulmonary stenosis, and other complex congenital heart defects where the right ventricular outflow tract is obstructed [2]. In these patients, the ductus arteriosus provides the sole or predominant source of pulmonary blood flow, and its closure leads to profound hypoxemia [3].

Historically, surgical creation of a systemic-to-pulmonary artery shunt was the primary intervention for securing pulmonary blood flow. However, this approach required cardiopulmonary bypass or a thoracotomy and carried significant morbidity [4]. Over the past two decades, PDA stenting has emerged as a less invasive alternative to surgical shunts, providing a stable source of pulmonary blood flow while avoiding cardiopulmonary bypass [5]. Recent network meta-analyses have confirmed that transcatheter options, including ductal stenting, consistently ranked superior to surgical shunts for early and overall mortality, and were associated with shorter hospital stays [6].

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The success of patent ductus arteriosus (PDA) stenting depends on accurate pre-procedural assessment of ductal morphology and optimal vascular access [7]. Pre-procedural imaging is critical for assessing the length, diameter, and tortuosity of the ductus arteriosus. CT angiography offers superior three-dimensional anatomical definition compared with echocardiography, allowing for precise measurement of the ductus and planning of the stent size [8]. However, echocardiography, while non-invasive, is limited in fully characterizing complex ductal anatomy [9].

Similarly, the choice of vascular access (femoral versus axillary) influences procedural success and outcomes [10]. Femoral access is commonly used but is challenging in small neonates due to the risk of access site complications [11]. Axillary access, while less commonly used, offers advantages for procedural success and lower access site complication rates, particularly in very small neonates.

To date, few studies have directly compared CT angiography versus echocardiography for PDA stent sizing, and data on the comparative outcomes of femoral versus axillary access in this population remain limited [12]. Therefore, this retrospective study aimed to address these gaps by (1) evaluating the degree of agreement between pre-procedural imaging (CT angiography vs. echocardiography) and the final implanted stent dimensions, and (2) comparing procedural technical success and complication rates between femoral and axillary vascular access approaches in neonates and infants with duct-dependent pulmonary blood flow.

Materials And Methods

Study design and setting

This was a retrospective cohort study conducted at the Queen Alia Heart Institute, King Hussein Medical Center, Royal Medical Services, Amman, Jordan. The study covered a four-year period from January 2020 to May 2024. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for observational studies [6]. The study protocol was approved by the Institutional Review Board (IRB) of the Jordanian Royal Medical Services, and informed consent was waived due to the retrospective, anonymized nature of the data.

Study population

Medical records of all neonates and infants who underwent PDA stenting for duct-dependent pulmonary blood flow during the study period were reviewed. Patients were included if they were aged less than one year at the time of the procedure, had a documented diagnosis of duct-dependent pulmonary blood flow, and underwent PDA stenting as the primary intervention. Patients were excluded if they had a prior surgical shunt, underwent a hybrid procedure, had incomplete medical records, or had contraindications to PDA stenting.

Data collection

Data were extracted from electronic medical records. Variables collected included demographics (age, weight, gender), underlying cardiac diagnosis, and ductal morphology. Pre-procedural imaging (CT angiography vs. echocardiography alone) was performed within 72 hours prior to the procedure. Procedural data included stent type and dimensions, procedural details (fluoroscopy time, contrast volume, access site), and complications. Access site selection (femoral vs. axillary) was at the discretion of the operating interventionalist based on patient weight and ductal morphology.

Outcomes

The primary outcomes were (1) the degree of agreement between pre-procedural imaging (CT angiography vs. echocardiography) and the final implanted stent diameter and length; and (2) technical success and complication rates associated with femoral versus axillary access.

Procedural technical success was defined as the successful deployment of the stent in the intended position with adequate angiographic flow to the pulmonary arteries, without the need for surgical conversion. A failed procedure was defined as the inability to cross or deploy the stent, or the occurrence of a major intraprocedural complication necessitating immediate surgical conversion. Major complications were defined as acute limb ischemia requiring intervention, stent migration requiring surgical retrieval, significant arrhythmias, or access site hematoma requiring intervention. Post-procedural outcomes, including duration of mechanical ventilation and ICU length of stay, were assessed from the date of the procedure until hospital discharge or day 30.

Statistical analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as means with standard deviations or frequencies with percentages. Comparison of pre-procedural imaging predictions (CT angiography vs. echocardiography) to the reference standard (the final implanted stent dimensions) was assessed by calculating the mean absolute difference (in millimeters) and standard deviation, rather than using correlation coefficients, as correlation does not adequately assess

agreement. Independent t-tests were used to compare the mean absolute errors between the two imaging modalities.

Due to the limited sample size and low number of adverse events, inferential analysis was restricted to univariable comparisons. Procedural outcomes between femoral and axillary access groups were compared using chi-square tests or Fisher's exact tests for categorical variables and independent t-tests or Mann-Whitney U tests for continuous variables. There was no missing data for the primary outcomes or the key procedural variables, as data were extracted from finalized electronic medical records. A p-value < 0.05 was considered statistically significant.

Results

Patient characteristics

A total of 48 patients met the inclusion criteria. The mean age was 11.2 ± 8.4 days, and the mean weight was 3.2 ± 0.5 kg. A total of 29 patients (60.4%) were male. The most common underlying diagnosis was pulmonary atresia with ventricular septal defect (n = 25, 52.1%), followed by pulmonary atresia with intact ventricular septum (n = 13, 27.1%). Ductal morphology was classified as Type III (tortuous) in 21 cases (43.8%). Table *1* summarizes the baseline characteristics.

Characteristic	Value
Age at procedure (days), mean ± SD	11.2 ± 8.4
Weight (kg), mean ± SD	3.2 ± 0.5
Male, n (%)	29 (60.4)
Diagnosis, n (%)	-
Pulmonary atresia with ventricular septal defect	25 (52.1)
Pulmonary atresia with intact septum	13 (27.1)
Critical pulmonary stenosis	10 (20.8)
Ductal morphology, n (%)	-
Type I (Conical)	15 (31.3)
Type II (Window)	12 (25.0)
Type III (Tortuous)	21 (43.8)

TABLE 1: Baseline patient characteristics (N = 48).

Primary outcomes: Imaging modality and access site

A total of 22 patients (45.8%) underwent pre-procedural CT angiography, while 26 (54.2%) were assessed with echocardiography alone. CT angiography demonstrated significantly superior accuracy in predicting stent length compared to echocardiography (mean absolute difference = 1.1 mm vs. 2.9 mm; p = 0.006) (Figure *1*).

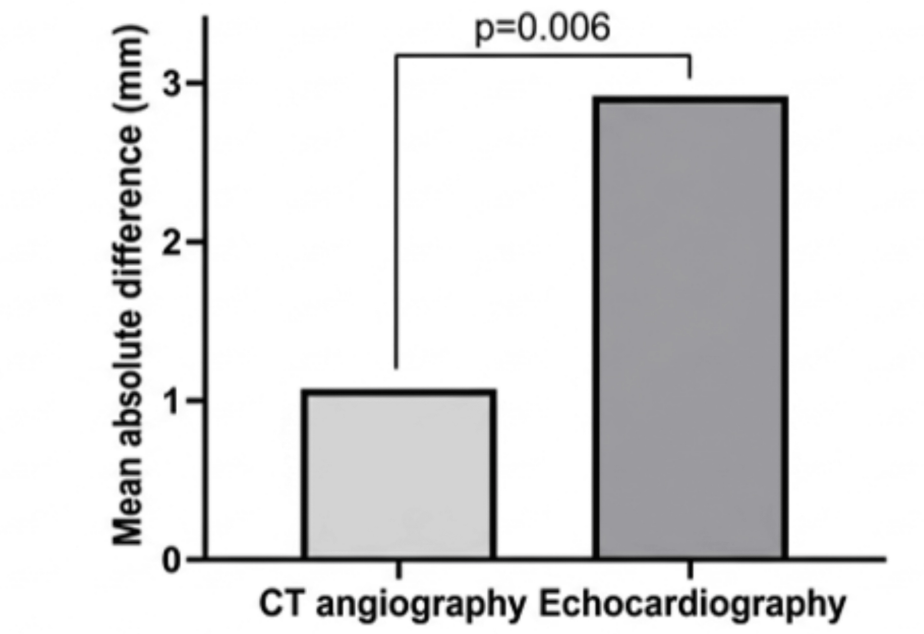


FIGURE 1: Comparison of stent length prediction accuracy.

Bar chart illustrating the mean absolute difference (in millimeters) between predicted and actual stent length for CT angiography versus echocardiography. CT angiography demonstrated a significantly lower error margin (1.1 mm vs. 2.9 mm; p = 0.006).

The accuracy for stent diameter was comparable between the two modalities (0.3 mm vs. 0.5 mm; p = 0.12).

Regarding vascular access, 33 patients (68.8%) underwent femoral access, and 15 (31.2%) underwent axillary access. Axillary access was associated with a shorter procedural time (49 ± 18 vs. 74 ± 29 minutes; p = 0.003). However, technical success was not statistically different between the two groups (14/15 (93.3%) vs. 25/33 (75.8%); Fisher exact p = 0.239). Subgroup analysis revealed that axillary access demonstrated a numerically higher success rate in patients with type III tortuous anatomy (90.0% vs. 63.6%) (Figure *2*). Table *2* summarizes these primary outcomes.

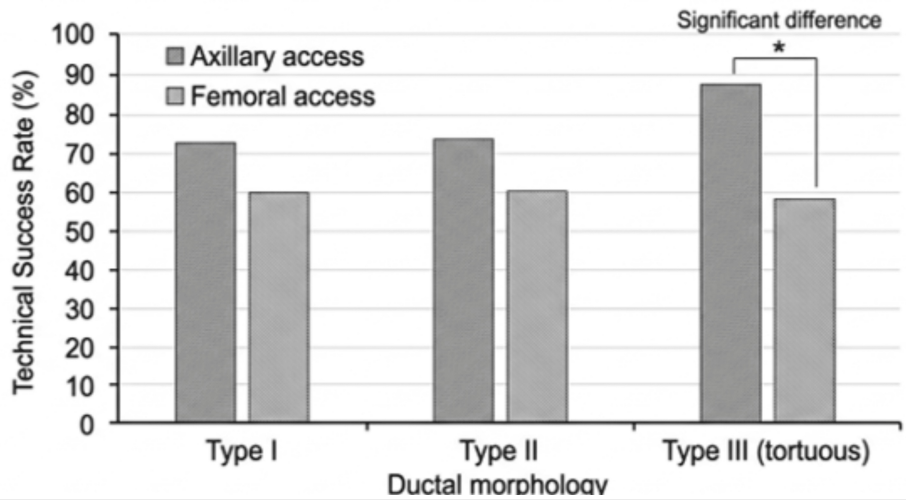


FIGURE 2: Technical success rate by access site and ductal morphology.

Grouped bar chart comparing technical success rates (percentage) between axillary and femoral access groups, stratified by ductal morphology (Type I, Type II, Type III). The chart highlights the significant advantage of axillary access in achieving technical success in patients with Type III (tortuous) anatomy.

Outcome	CT angiography (n = 22)	Echocardiography (n = 26)	p-value
Stent length error (mm), mean	1.1	2.9	0.006
Stent diameter error (mm), mean	0.3	0.5	0.12
Outcome	**Axillary access (n = 15)**	**Femoral access (n = 33)**	**p-value**
Procedure time (min), mean ± SD	49 ± 18	74 ± 29	0.003
Technical success, n (%)	14 (93.3)	25 (75.8)	0.239

TABLE 2: Primary outcomes by imaging modality and access site.

Secondary outcomes and complications

The overall major complication rate was 16.7% (n = 8). Complications included acute limb ischemia (n = 3), stent migration (n = 2), arrhythmias (n = 2), and access site hematoma requiring intervention (n = 1). The major complication rate was numerically similar between the axillary and femoral groups (2/15 (13.3%) vs. 6/33 (18.2%); Fisher exact p = 1.000). However, given the small sample size, the study was underpowered to establish statistical equivalence. Notably, acute limb ischemia occurred exclusively in the femoral access group (n = 3, 9.1%). The duration of mechanical ventilation (3.1 ± 1.5 vs. 3.4 ± 1.8 days; p = 0.45) and ICU length of stay (5.2 ± 2.1 vs. 5.8 ± 2.4 days; p = 0.38) were slightly shorter in the axillary group but did not reach statistical significance. Survival to discharge was 100% in both groups. Table *3* summarizes the secondary outcomes.

Outcome	Axillary access (n = 15)	Femoral access (n = 33)	p-value
Major complications, n (%)	2 (13.3)	6 (18.2)	1.000
- Acute limb ischemia, n (%)	0 (0.0)	3 (9.1)	0.28
- Stent migration, n (%)	1 (6.7)	1 (3.0)	0.52
- Arrhythmia, n (%)	1 (6.7)	1 (3.0)	0.52
Ventilation duration (days), mean ± SD	3.1 ± 1.5	3.4 ± 1.8	0.45
ICU length of stay (days), mean ± SD	5.2 ± 2.1	5.8 ± 2.4	0.38
Survival to discharge, n (%)	15 (100)	33 (100)	1.00

TABLE 3: Secondary outcomes and complications.

Discussion

This retrospective study compared CT angiography versus echocardiography for PDA stent sizing and evaluated outcomes of axillary versus femoral access in neonates with duct-dependent pulmonary blood flow. The principal findings indicated that CT angiography demonstrated a numerically smaller error margin for predicting stent length. However, despite a numerical trend favoring axillary access for procedural efficiency, there were no statistically significant differences in technical success or major complication rates between the two access sites.

While CT angiography offered superior three-dimensional definition, its use in neonates is not without significant trade-offs. CT exposes this vulnerable population to ionizing radiation and requires intravenous contrast, which carries risks of acute kidney injury. Furthermore, it often requires patient transport and sedation, which poses logistical challenges and clinical risks in critically ill, duct-dependent neonates. Therefore, while CT angiography may provide valuable pre-procedural planning in selected cases with highly complex or tortuous ductal anatomy, it should not be considered a routine replacement for echocardiography, which remains the safe, non-invasive, first-line imaging modality.

The comparison between axillary and femoral access yielded clinically relevant insights. Our finding that axillary access was associated with a shorter procedure time aligns with data from the Congenital Catheterization Research Collaborative [13]. Glatz et al. reported that carotid/axillary access was frequently

employed in patients with highly tortuous PDAs and was associated with comparable or improved procedural outcomes [13]. Furthermore, Breatnach et al. demonstrated that the percutaneous axillary artery approach for ductal stenting in critical right ventricular outflow tract lesions provided a safe and effective alternative to femoral access, particularly in small neonates [14]. Aldudak et al. also demonstrated that axillary/carotid access yielded higher technical success and shorter procedure times compared to femoral access in patients with vertical and tortuous ductal anatomy, nearly identical to our reported rates [15]. Although our study did not achieve statistical significance for technical success due to the small sample size, the observed numerical trend (93.3% vs. 75.8%) and the distinct advantage in Type III tortuous anatomy (90.0% vs. 63.6%) are consistent with these prior reports.

Contrary to some earlier reports, we did not find a significant difference in major complication rates between the two access sites; however, the study was not powered to demonstrate safety equivalence. The pattern of complications differed. Acute limb ischemia occurred exclusively in the femoral access group, consistent with Dewangga et al., who reported significantly higher rates of acute limb ischemia with transfemoral access [16]. Conversely, axillary access avoided the risk of lower limb ischemia but carried a theoretical risk of brachial plexus injury. In our cohort, no neurological complications were observed in the axillary group. Agha et al. highlighted that the margin between success and failure in PDA stenting is narrow, emphasizing the importance of careful pre-procedural planning and access site selection to minimize complications [17].

The lack of significant difference in ventilation duration and ICU length of stay between access groups contrasts with the broad benefits of ductal stenting over surgical shunts reported by Chee et al. [18]. This discrepancy is likely due to our study comparing two catheterization approaches rather than catheterization versus surgery. Once the ductus is stented, the post-procedural recovery trajectory is primarily dictated by the patient's underlying cardiac physiology and pulmonary vascular development rather than the access route itself, provided no major access complication occurs. Santoro et al. similarly reported that pulmonary artery growth after palliation is determined by the intervention strategy rather than the specific access route [11].

This study has several important limitations. The retrospective, single-center design and small sample size (n = 48) limit generalizability and statistical power. Second, the final implanted stent size was used as the reference standard; however, this is not a purely independent anatomical measure, as it is influenced by intraoperative balloon sizing, operator discretion, and the limited availability of commercial stent sizes. Therefore, our findings reflect procedural concordance rather than definitive anatomical accuracy. Third, the choice of imaging modality and access site was at the discretion of the interventionalist, introducing potential selection bias and confounding. The small sample size precluded multivariable adjustment for these confounders. Finally, the study was underpowered to assess safety equivalence between access groups, and the lack of long-term follow-up limits conclusions regarding stent patency and reintervention.

Conclusions

While this study suggests that CT angiography and axillary access may offer potential benefits in specific scenarios (such as highly tortuous anatomy), our findings do not establish the superiority of one approach over the other. CT angiography demonstrated a numerically smaller error margin for stent length, but given the risks of radiation and contrast in neonates, its use should be reserved for select cases with complex anatomy where echocardiography is insufficient. Axillary vascular access was associated with shorter procedural times, but technical success and safety outcomes were not statistically different from femoral access. The small sample size and retrospective design necessitate cautious interpretation. Future multicenter studies with larger cohorts are required to definitively evaluate the safety and efficacy of these strategies in this vulnerable population.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Jordanian Royal Medical Services Institutional Review Board issued approval 11_06/2026. This retrospective study was reviewed and approved by the Institutional Review Board of Jordanian Royal Medical Services (IRB-JRMS) under approval number 11_06/2026. The requirement for written informed patient consent was formally waived by the IRB due to the retrospective, observational nature of the study and the use of fully anonymized medical records. All patient data were de-identified prior to analysis in strict compliance with institutional data protection policies. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **AI use statement:** The authors used Grammarly (Superhuman Platform Inc., San Francisco, CA) as follows: language polishing, structure or formatting, Manuscript editing for improved academic English and grammar. in Abstract, Introduction, Methods, Results, and Discussion. No figures or raw datasets were affected. All authors reviewed and edited the AI-assisted output. The authors verified that all scientific content, statistical analyses, medical interpretations, and references were accurate, appropriate, and free of AI-generated inaccuracies. No new intellectual content, hypotheses, or data analyses were generated by the AI tools. The authors take full responsibility for the final content of the manuscript. The authors confirm that they have reviewed and verified all AI-assisted content and take full responsibility for the work. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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