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CASE REPORT

Potency of Non-fluoroscopy Guided Patent Ductus Arteriosus Closure: a Case Report

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Abstract

Transcatheter patent ductus arteriosus (PDA) closure under fluoroscopy imaging is the standardized method; however, it is imperative to utilize alternative methods due to cumulative damaging effects of radiation agents on operator and patient health. An 11-year-old boy with 9-mm-sized type A patent ductus arteriosus (PDA) had progressive limitation of his daily activities. During physical examination, he was hemodynamically stable, and continuous murmur could be heard in the second left intercostal space. The patient was sedated and intubated in the cathlab with endotracheal tube No. 6.0. Hemodynamic data was acquired with non-fluoroscopic technique combined with pressure tracking to observe the catheter position. The value of flow ratio (FR) was 2.2, pulmonary artery resistance index (PARi) was 2.3 W.U/m^2, and the ratio of pulmonary vascular ratio to systemic vascular resistance (PVR/SVR) was 0.13. PDA closure was performed by antegrade transvenous approach using Heart-R PDA Occluder No. 18/16 mm which was inserted through 9F delivery sheath, with one of the discs inflated in the descending aorta and the other disc in the pulmonary artery with the help of pressure tracking. Evaluation of transthoracic echocardiography and transesophageal echocardiography showed good device position and the device was detached. No residual shunt observed in the patient with total procedural time of 53 min. Echocardiography-guided closure is safer for both interventionalist and patients due to avoidance of radiation agents, but must be performed by experienced teams familiar with the conventional method prior to its limited visualization.

Keywords Case report · Non-fluoroscopy · Patent ductus arteriosus

Background

Patent ductus arteriosus (PDA) is responsible for about 5–10% of all congenital heart defect and is more frequent in premature infants with a birth weight less than 1 kg. Recent studies showed that PDA would be closed automatically in 73% preterm infants with the gestational age of 28 weeks by the end of the first week of life. Prior to its significant morbidities, PDA must be closed [1–3].

Transcatheter closure of PDA under angiography guidance has been the wanted therapeutic methods in pediatric patients over the last four decades. Even though the course of action could be carried out with restricted nonionic contrast and fluoroscopic exposure nowadays, possible injury on health outcomes must not be took no notice of, mainly interventionalist who repeatedly carried out the procedures, patients with kidney malfunction, allergic composition, or even pediatric populations. Echocardiography-guided transcatheter PDA closure served as another alternative and had already been utilized in several centers, though had not been used universally. An established guidance is required, as to use venous or arterial access, the category of the infants birth weight, or even the size of the delivery sheath. Thus, a case report was created to analyze the feasibility of non-fluoroscopy PDA closure [4–6].

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Main Text

Case Illustration

An 11-year-old boy with 9-mm-sized type A patent ductus arteriosus (PDA) had progressive limitation of his daily activities (Fig. 1a). During physical examination, he was hemodynamically stable and continuous murmur could be heard in the second left intercostal space. The patient was sedated and intubated in the cathlab with endotracheal tube No. 6.0. Hemodynamic data was acquired with non-fluoroscopic technique combined with pressure tracking to observe the catheter position. The value of flow ratio (FR) was 2.2, pulmonary artery resistance index (PARi) was 2.3 W.U/m^2, and the ratio of pulmonary vascular ratio to systemic vascular resistance (PVR/SVR) was 0.13. PDA closure was performed by antegrade transvenous approach using 5F multipurpose sidehole catheter. The 5F multipurpose sidehole catheter was advanced from the IVC, RA, RV, and through the MPA and LPA with the assistance of Lunderquist wire 0.035″. 5F multipurpose sidehole catheter was retrieved and 9F delivery sheath was inserted (Fig. 2a–d). Heart-R PDA Occluder No. 18/16 mm was inserted through 9F delivery sheath, with one of the discs inflated in the descending aorta and the other disc in the pulmonary artery with the help of pressure tracking (Fig. 2e, f). Evaluation of transthoracic echocardiography and transesophageal echocardiography showed good device position and the device was detached. No residual shunt observed in the patient (Fig. 1b) with total procedural time of 53 min. Post intervention, patient was in good condition with the pulmonary artery pressure (PA) was 25/6(13) mmHg and descending aorta (AoD) pressure was 115/73(87) mmHg with peripheral saturation of 100%.

Methods

An extensive literature search was done in four databases (Pubmed, Ebscohost, Scopus, and Cochrane) on May 2020 using Boolean operators with keyword listed in Table 1, including the selected articles. All screened articles were assessed for eligibilities, involving title and abstracts skimming, double-checking for full text availability, and final selecting based on inclusion–exclusion criteria in Fig. 3. Data extraction from each study could be seen in Table 2. This case report is made according to CARE checklist case reports guidelines. Based on the literature search results, 6 studies involving more than 500 patients predominantly in China fulfill the inclusion criteria. All of the included studies were case-series research on people undergoing non-fluoroscopy guidance PDA closure.

Results and Discussion

Procedural Time and Outcomes of Echocardiography-Guided Occlusion

Patent ductus arteriosus (PDA) is regarded as one of the most common acyanotic congenital heart diseases, and in the last few decades, rapid improvements of percutaneous occlusions have been performed in adolescents and adults alike with satisfying results (96–100%) under fluoroscopy guidance [2, 4]. In response to the expedetious growth of

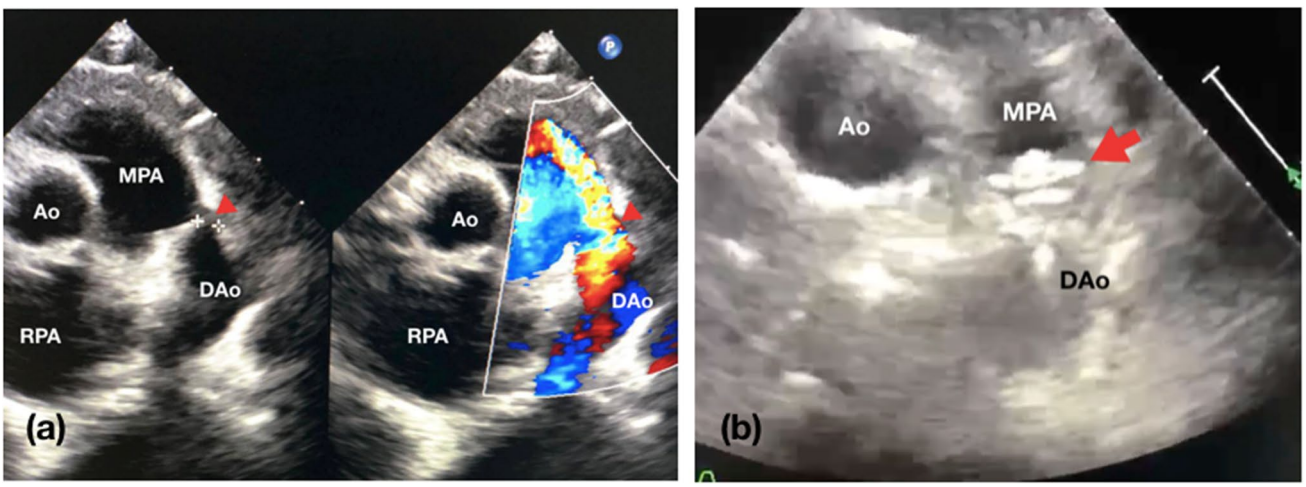

Fig. 1 **a** A 9-mm patent ductus arteriosus (PDA) shown by transesophageal echocardiography (indicated by red arrowhead). **b** Device implantation in the ductus arteriosus (indicated by red arrow). Ao, aorta; MPA, main pulmonary artery; DAo, descending aorta; RPA, right pulmonary artery

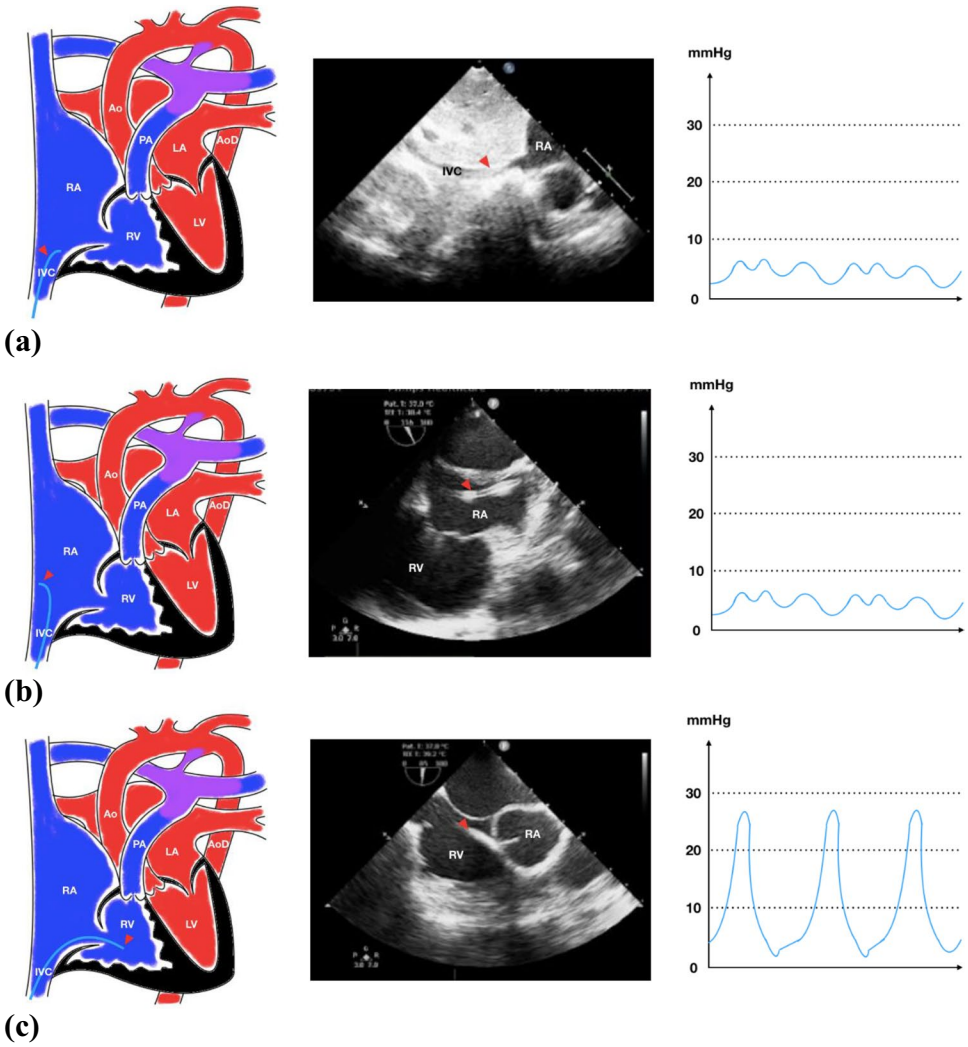

Fig. 2 Antegrade transvenous approach of percutaneous patent ductus arteriosus (PDA) closure. **a** Catheter is seen in IVC in transthoracic echocardiography (TTE) subxiphoid view. **b** Catheter is seen in RA in TEE bicaval view (90–110°). **c** Catheter in RV TEE 90° view. **d** Catheter enters PA in TEE 90° view. **e** Catheter crossed from PA towards AoD through PDA in TTE arch view. **f** The device is stowed in place in TEE (40–50°). IVC, inferior vena cava; RA, right atrium; RV, right ventricle; PA, pulmonary artery; Ao, aorta; LA, left atrium; LV, left ventricle; AoD, descending aorta; PDA, patent ductus arteriosus. Red arrowhead shows the catheter head. Green arrowhead indicates the occluder device

the occluder devices and operator experiences, X-ray radiation exposure in fluoroscopy and contrast agent usage has been lowered significantly. Many efforts have been done to keep away from fluoroscopy completely, such as by performing echocardiography-only guidance during the procedure. Transesophageal echocardiography (TEE) is a good alternative to have a satisfactory visualization such as for assessing residual shunt including pulmonary artery and the aortic valve, but it is loathed in pediatric populations prior to the requirement of general anesthesia. However, a small number of complications were still reported such as hemolysis, residual shunts, device embolization, or infection. Device embolization was one of the most significant complications of interventional PDA occlusion with varying rates reported, between 0 and 16%, while hemolysis varies between 0 and 3.5% [6–8].

All of the paper showed that the procedural times were varying with Weizhi et al. [12] with the lowest procedural time 21 min (10–65 min) and Cao et al. [11] with the longest procedural time 30 to 110 min (50.42 ± 2.8 min). Chen et al. [8] did not mention procedural time in their paper. Ye et al. [7], the only study which compares the echocardiography and fluoroscopy-guided closure, even mentioned that the procedural time for echocardiography guided was 35.6 ± 6.4 min, which is slightly shorter than the control group (48.6 ± 8.6 min). Even though echocardiography only permitted a single section of visualization at a time, all of the paper showed that echocardiography is not inferior to the fluoroscopy, and an experienced team could change the practice to avoid the stochastic effects from the X-ray radiations [7–12].

Interestingly, almost all of the papers have a mean success rate above 97%. Weizhi et al. [12] showed the lowest success rate with the number of 97.1% while Binobaidan et al. [10], Cao et al. [11], and Ye et al. [7] correspondingly showed success rate of 100% in the duct closure. Follow-up of the patients' post-intervention variably from 1 month to 2 years with most of the studies showed no residual shunt nor severe complications. Pan et al. [9] showed 8 cases of small residual shunts in 24 h but resolved afterwards. The

Fig. 2 (continued)

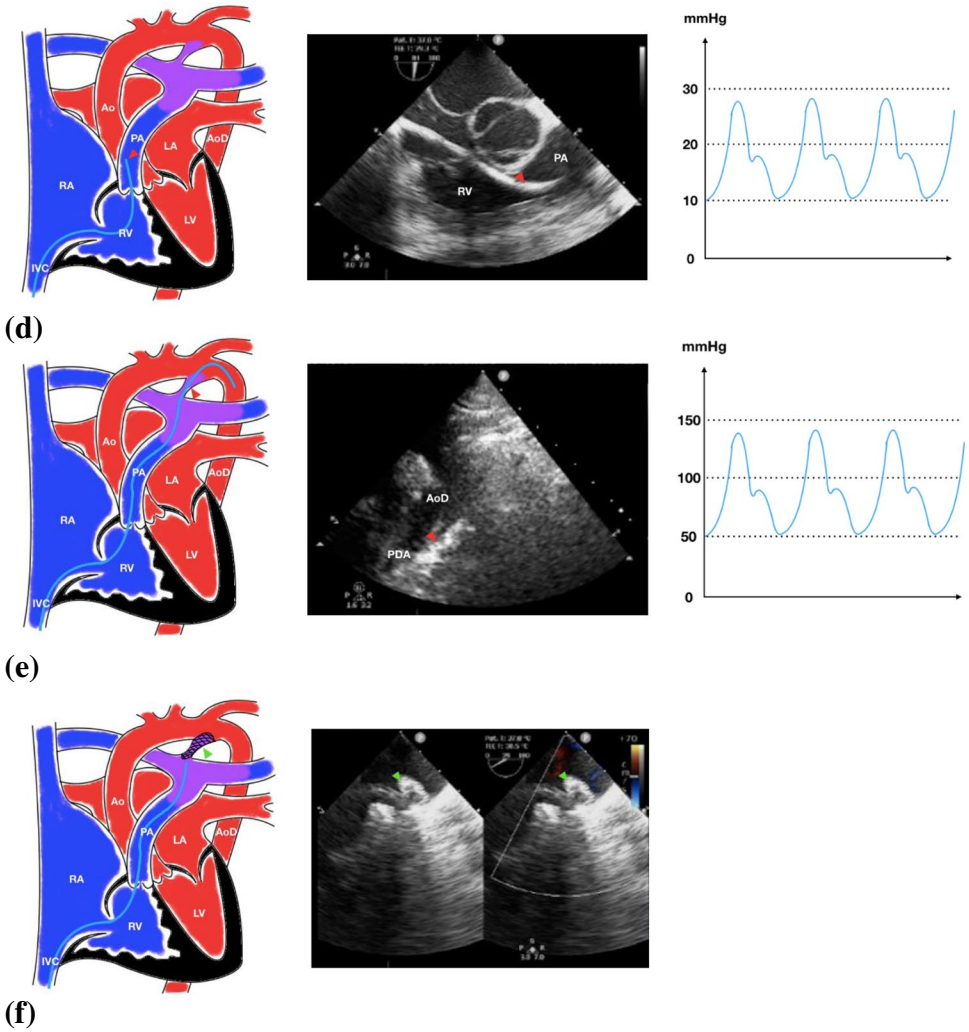

Table 1 Search strategies of the included database

Database	Search query	Hits	Selected articles
Pubmed	("zero fluoroscopy"[All Fields] OR OR "echocardiography"[All Fields] OR "transthoracic echocardiography"[All Fields] OR TTE[All Fields]) AND ("pda closure"[All Fields] OR "pda occlusion"[All Fields]) AND ("humans"[All Fields] OR "human"[All Fields])	150	4
Ebscohost	("zero fluoroscopy" OR "echocardiography" OR "transthoracic echocardiography" OR TTE) AND ("pda closure" OR "pda occlusion") AND human	195	5
Scopus	("zero fluoroscopy" OR "echocardiography" OR "transthoracic echocardiography" OR TTE) AND ("pda closure" OR "pda occlusion") AND human	258	4
Cochrane	("zero fluoroscopy" OR "echocardiography" OR "transthoracic echocardiography" OR TTE) AND ("pda closure" OR "pda occlusion") AND human	0	0

complications in all of these studies include device embolization, acute occluder dislodgement, and small residual shunts [7–12]. Device embolization might be due to larger PDA size than measured ones, possibility whether the PDA is stretchable and therefore the size might be variable with catheter and sheath manipulation [13, 14].

In comparison to fluoroscopic guidance, the largest hurdle of echocardiography-guided closure is to track the guidewire, catheter, and delivery sheath in the two-dimensional echo view plane which is related to safety and procedural time. Wealth knowledge of cardiac anatomy and physiology of the interventionalist and echocardiographist in

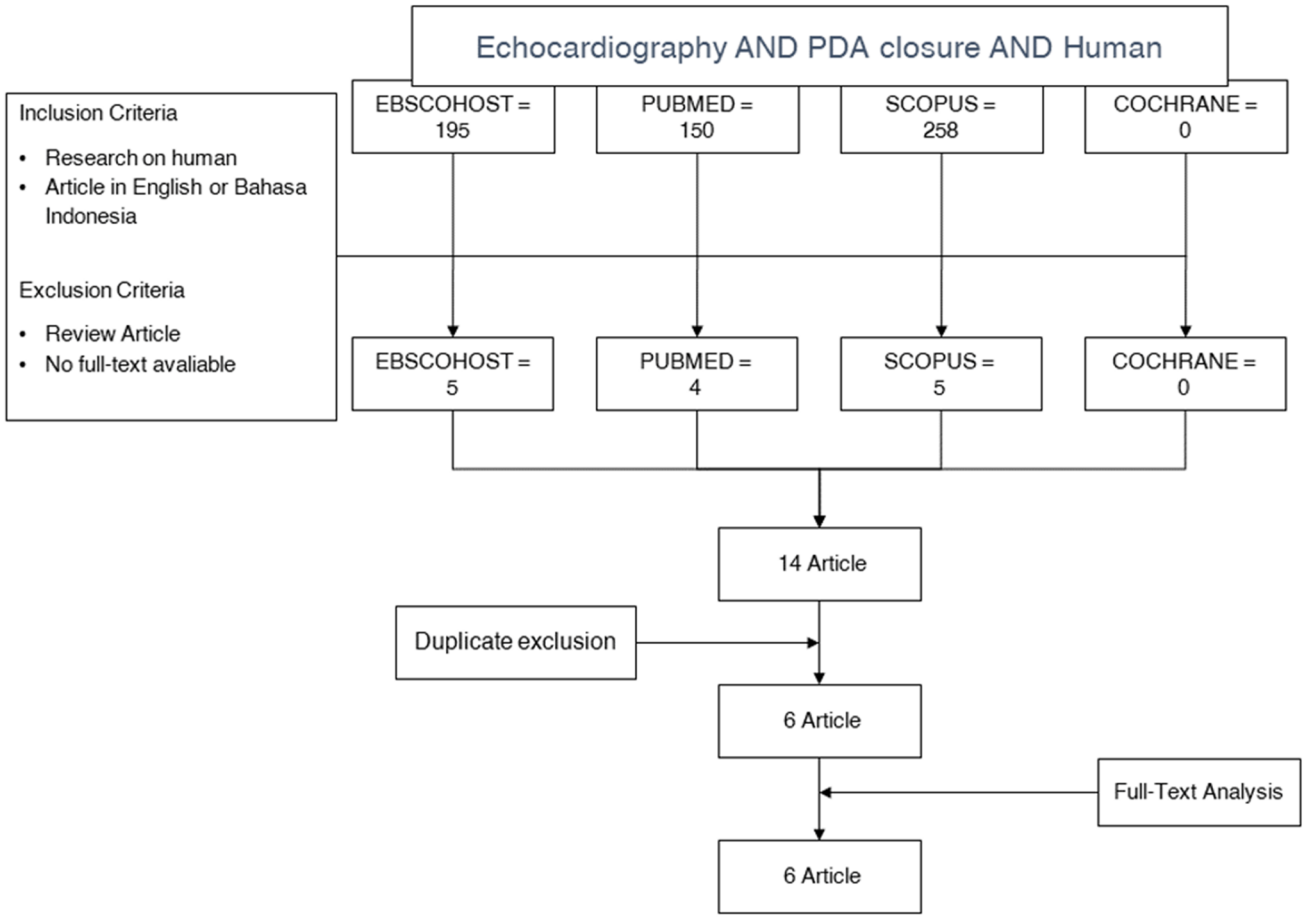

Fig. 3 Flowchart of searching strategy

concordance with the utilization of appropriate guide wire, catheter, delivery sheath, and positioning of the ultrasound probe would reduce the complications [2, 7, 11].

Device Size and Approaches

In our case, the patient was punctured in the right femoral vein with antegrade approach. It was also possible to be done in our patient with type A PDA. Pan et al. [9] showed successful type A, C, and E PDA closure. However, procedure was not done in tortuous, multiple constrictions Type D PDA due to failure of delivery sheath avoiding PDA rupture. With regard to type B PDA, percutaneous occlusion through femoral artery using ADO II occluder is not recommended due to risk of device embolization. Cao et al. [11] mentioned that diameter of PDA was measured in parasternal view transthoracal echocardiography, and the occluder size was diameter of PDA added by 4 to 8 mm. Chen et al. [8] demonstrated that closure for all PDA types is technically feasible but somehow challenging because of suboptimal visualization quality and complex anatomy of type D and E ductus. Weizhe et al. [12] had done the procedure in 76 type A conical, 7 type B window, 15 type C tubular, and 7 type E elongated PDA.

Both femoral veins and arteries access towards PDA by transthoracal echocardiography (TTE) were very accommodating in deploying the device. A skillful echocardiographist could envision the direction of the catheter and its sheath. Correspondingly, challenges in visualizing the catheter course in the cardiac structure interior were conquered by arterial access to cross the PDA through a straight course from the aorta. Hence, the TTE-based PDA measurements (diameter, length, and ampulla) were attainable. Some papers stated that TTE and angiography measurements had difference of approximately 0.5–0.8 mm [1–6].

Transcatheter PDA closure without X-ray positioning highlighted the importance of spatial perception of the interventionalist and periodical conveyance with the echocardiographist. An interventionalist with no sufficient experience is commended for standard procedure [4–6]. Fundamental differences between echocardiography and fluoroscopy should be considered, one of which was the requirement of lengthy and technically challenging learning curve. Conventional intervention techniques emphasize on the simplicity

Table 2 Data extraction of included studies [7–12]

Study (year)	Settings	Study design	Length of study	No. of patients	PDA diameter	Non-fluoroscopy method	Closure device	Approach	Median age	Median weight	Procedural time	Outcome	Follow-up evaluation
Binobaidan et al. (2016) [10]	Saudi Arabia	Observational study	July 2013 to May 2015	10	1.8–4.3 mm	TTE	ADOS, ADO-II, AVP2	Retrograde	7 months (4–23 months)	8 kg (3.2–11 kg)	30 min (15–45 min)	One patient device embolization	Not mentioned
Cao et al. (2018) [11]	Fujian Medical University, China	Retrospective study	January to December 2015	12	8–14 mm	TTE	Amplatzer PDA device	Retrograde	12–35 years	30–65 kg	30 to 110 min (50.42 ± 2.8 min)	No migration, residual shunt or thrombotic complication observed	1–2 years
Chen et al. (2014) [8]	Fujian Medical University, China	Single-center observational study	January 2006 to December 2012	296	1–4.2 mm	TTE	ADO	Antegrade	17 years (0.75–64.50 years)	50.57 kg (7.52–71.20 kg)	Not mentioned	Acute occluder dislodgement found in one patient (0.3%)	1, 6, and 12 months
Pan et al. (2016) [9]	Fuwai Hospital, China	Single-center observational study	June 2013 to May 2015	63	2–5.5 mm (3.3 ± 1.1 mm)	TTE and TEE	ADO-II	Retrograde	4.6 ± 2.9 years	18.5 ± 7.5 kg	24.3 ± 7.0 min	8 cases show small residual shunt in 24 h. No occluder migration, hemolysis observed	1, 3, 6, and annually
Weizhi et al. (2018) [12]	China	Retrospective observational study	June 2014 to May 2016	102	4.2 mm (3.1–7.5)	TTE and TEE	PDA occluder	Antegrade	2.3 years (1 to 14 years)	11.6 kg (6 to 46 kg)	21 min (10–65 min)	No acute procedural complications or severe adverse events	1, 3, 6, 12, and 24 months
Ye et al. (2020) [7]	Beijing Children's Hospital, China	Single-center observational study	March 2018 to February 2020	32	2–5 mm	TTE	AGA ADO II occluder	Retrograde	5.12 ± 1.32 years	17.32 ± 3.6 kg	35.6 ± 6.4 min	No residual shunts	1 and 3 months of follow-up

of the catheter location determination as fluoroscopy detects through projection. However, echocardiography detects by facets and therefore, may not precisely exhibit the catheter position.

Undesirable Effects of Fluoroscopy

Effects of radiation in both pediatric patients and the interventionalist are a problem that must be addressed with diligent radiation management. The concept of radiation injury with fluoroscopically guided pediatric populations seems inconsistent with the concept that dose rates are much lower in children since they are much smaller than adults. Fluoroscopically guided intervention in children and adults is that radiation injury is very rare and that there are certain factors that exacerbate the severity of radiation-induced injury, such as long procedures that involve a fixed orientation over the same skin entrance sites or lax radiation management practices. Injuries may include dermatitis, sometimes severe, on the hands and arms of interventionalists, radiation-induced cataract, and hair loss on the legs. It is known that children and fetuses are at risk of cancer from medical radiation; greater concerns are risks of leukemia, female breast cancer, thyroid cancer, lung cancer, and brain cancer [15–17].

Deterministic and stochastic effects in children and in practitioners are possible, and certain measures can be taken to limit their likelihood or to eliminate them. Vano et al. [16] have reported on radiation-induced skin injury in the right arms of two pediatric cardiology patients due to prolonged electrophysiological and ablation procedures. Prolonged and repeated procedures during which the same skin area is irradiated and which involve oblique, lateral, or similar beam projections place the skin at potential risk [15–17].

Improving Technology Safety and Expediting the Learning Curve

The non-fluoroscopy PDA closure technique requires an experienced team in which the interventionalist was skillful in the standardized percutaneous fluoroscopy-guided PDA closure and must possess vast knowledge of heart anatomy and physiology. Correspondingly, the echocardiographist should be able to work seamlessly with the operator [1–5]. Calculating the interval in between the left second intercostal parasternal space and the right femoral artery puncture site before the procedure and then marked the corresponding distance on the catheter would be useful [18, 19].

Unlike fluoroscopy, echocardiography only permitted a single section of visualization at a time; hence, the catheter and guide wire tip locations might not be distinctly recognized. Selecting a large tip shape catheter would make it easily to be detected [2, 13]. Likewise, precise positioning of the catheter and ultrasound probe would be helpful. For instances, suprasternal view showing the long−axis representation of aortic arch performed by placing the probe on the suprasternal notch to keep track of the release of the occluder in the aortic side [3–6].

Conclusion

Non-fluoroscopy guided PDA closure has shown high success rate and minimal post-operative complication in the included studies, thus may be safer for both interventionalist and patients with avoidance towards the radiation agent in fluoroscopy. Nevertheless, echocardiography possesses limited visualization, and it is imperative to be performed by an experienced operator and echocardiographist to obtain accurate occluder size for the ductus. Inaccurate measurements would lead to higher procedural risk and cost.

Abbreviations AoD: Descending aorta; Kg: Kilograms; Min: Minutes; Mm: Millimeters; PA: Pulmonary artery; PDA: Patent ductus arteriosus; TEE: Transesophageal echocardiography; TTE: Transthoracal echocardiography

Author Contribution BM has contributed in design of the work, interpretation of the patient's data, and editing the figures. RP and BFA have contributed in elaborating the discussions. All authors have read and approved the manuscript.

Data Availability Not applicable.

Code Availability Not applicable.

Declarations

Ethics Approval and Consent to Participate Patient in the case report has agreed and fulfilled Ethics Committee Faculty of Medicine, Universitas Indonesia, Jakarta, Indonesia.

Consent for Publication Informed consent of patient's data was obtained from the patient's guardian.

Conflict of Interest The authors declare no competing interests.

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