Transcatheter patent ductus arteriosus closure with echocardiographic guidance: can radiation exposure be reduced?

Kateter yoluyla duktus arteriyozus açıklığının kapatılması sırasında ekokardiyografik değerlendirme: Radyasyona maruz kalma azaltılabilir mi?

İbrahim Cansaran Tanıdır, M.D., Alper Güzeltaş, M.D., Yakup Ergül, M.D., Erkut Öztürk, M.D., İsa Özyılmaz, M.D., Ender Ödemiş, M.D.

Department of Pediatric Cardiology, İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Center and Research Hospital, Istanbul

ABSTRACT

Objectives: The radiation dose from interventional cardiac catheterization is particularly relevant when treating children because of their greater radiosensitivity compared to adults. The transcatheter closure of patent ductus arteriosus (PDA), as well as other more complex pediatric interventions, have raised concerns regarding radiation exposure, particularly relevant when treating children. The purpose of this study is to show how to perform the transcatheter closure of PDA in children while giving less ionized radiation and to prove that the amount of radiation and contrast material can be reduced.

Study design: Following appropriate device selection based on PDA morphology and diameter, transthorasic echocardiography images and control aortography findings were analyzed. The following devices were used during the procedure: Gianturco coils (10/63), an Amplatzer Duct Occluder (ADO, 31/63), Flipper coils (19/63), and an Amplatzer vascular plug (3/63).

Results: The scopy time, radiation dose, and contrast were 12±6.4 mins, 28.1±14.7 cmGy/cm^2/kg, and 4.2 ± 2.3 cc/kg, respectively. In the control aortography shortly after the procedure, residual shunt was detected at various levels in 39.7% of patients, and 9.5% demonstrated residual shunt in real-time echocardiography. In the control aortography, the exposure to radiation was 13.3% of the total, and the amount of infused contrast was 27.2% of the total.

Conclusion: Patients may be exposed to less radiation and contrast material if an echocardiographic evaluation, instead of a final control aortography injection, is performed after the transcatheter closure of PDA.

ÖZET

Amaç: Çocuk hastalar, erişkinlere göre radyasyonun etkilerine karşı daha hassas oldukları için, girişimsel kalp kateterizasyonu sırasında aldıkları radyasyon dozları gün geçtikçe daha da önem arz etmektedir. Diğer girişimsel işlemlerde olduğu gibi, transkateter duktus arteriyozus açıklığı (DAA) kapatılması işleminde de, çocuk hastaları tedavi ederken, radyasyon maruziyeti ön plana çıkmaktadır. Bu çalışmanın amacı, çocuklarda transkateter DAA kapatılması sırasında, nasıl daha az iyonize radyasyon verilerek işlemin yapılabileceğini göstermek ve aynı zamanda gereksiz yere verilen kontrast madde miktarının düşürülebileceğini gösterebilmektir.

Çalışma planı: Duktus çapına ve morfolojisine uygun cihaz seçimi sonrası, transkateter DAA kapatılması yapılan hastalarda, işlem sonrası uygulanan transtorasik ekokardiyografi ve kontrol aortografi bulguları değerlendirildi. İşlemler sırasında Gianturco coil (10/63), Amplatzer Duct Occluder (ADO, 31/63), Flipper coil (19/63) ve Amplatzer vascular plug (3/63) kullanıldı.

Bulgular: Skopi süresi, toplam radyasyon dozu ve kullanılan kontrast madde miktarı sırası ile; 12±6.4 dakika, 28.1±14.7 cmGy/cm^2/kg ve 4.2 ± 2.3 cc/kg idi. İşlem tamamlandıktan sonra yapılan kontrol anjiyografide hastaların %39.7'sinde değişik düzeylerde rezidü izlenirken eş zamanlı yapılan ekokardiyografide bu oran %9.5 olarak saptandı. Kontrol aortografi sırasında hastaların toplam aldıkları radyasyon dozunun %13,3'ünü ve kontrast miktarının ise %27.2'sini aldıkları saptandı.

Sonuç: Transkateter DAA kapatılması sonrasında kontrol aortografi yerine ekokardiyografik değerlendirme yapılması durumunda hastaların daha az radyasyona ve kontrast maddeye maruz kalacağını düşünmekteyiz.

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Correspondence: Dr. İbrahim Cansaran Tanıdır. İstanbul Mehmet Akif Ersoy Eğitim ve Araştırma Hastanesi, İstasyon Mahallesi, İstanbul Caddesi, Bezirganbahçe Mevki, Küçükçekmece, 34303 İstanbul.
Tel: +90 212 - 692 20 00 e-mail: cansaran@yahoo.com

Patent ductus arteriosus (PDA) accounts for 8-10% of all congenital heart diseases.[1,2] Transcatheter closure of PDA is currently the preferred therapeutic alternative to surgical ligation in infants, children, and adults.[1,3] However, the radiation dose and contrast amount patients are exposed to during PDA closure have not been reduced. Growing and developing tissues and organs are more sensitive to the effects of radiation than their fully mature equivalents. Moreover, the oncogenic effects of radiation require a long latency period (decades) that varies with the type of malignancy. Thus, an infant or child patient has a 2-3-times higher and longer lifetime risk of developing radiation-induced cancers than adults.[4-6] The likelihood of contracting a fatal cancer is 0.07-0.1% per fluoroscopically-guided cardiac procedure.[4,5,7] A recent study showed that the rate of cancer development in children may be higher than we thought.[7] The as low as reasonably achievable (ALARA) concept has been known since 1980 and is becoming more common. The goal of the ALARA concept, as applied to cardiac catheterization, is to provide the maximal diagnostic and therapeutic benefit while requiring the lowest possible radiation dose.[8]

Abbreviations:

ADO	*Amplatzer duct occluder*
ALARA	*As low as reasonably achievable*
AVP	*Amplatzer vascular plug*
ECHO	*Echocardiography*
PDA	*Patent ductus arteriosus*

In the historical timeline of the transcatheter closure of PDA in children, many devices, especially coils and the Amplatzer duct occluder (ADO), have been used and reported to be successful.[9-12] The most important factor in determining device success is certainly the non-existence of residual defects, and the gold standard method to determine this is post-procedural control aortography.[13] With or without residual shunt, patient follow-ups perform via echocardiography (ECHO), and some studies report that the post-procedural evaluation can be performed through echocardiographic guidance,[13,14] so exposure to radiation/contrast may be reduced.

The primary goals of this prospective study are to show how to perform the transcatheter closure of PDA in children while exposing them to less ionized radiation, and to prove that the amount of radiation, as well as unnecessary additional contrast material, can be reduced. In the patients with transcatheter PDA closure, shortly after the procedure, the transthorasic echocardiographic images and control aortography were analyzed. The findings were compared in terms of the presence of residue, the amount of contrast material, radiation dose and clinical follow-ups.

PATIENTS AND METHODS

Study population

We included 63 patients between the ages of 6 months to 18 years who were taken to the catheter laboratory for transcatheter PDA closure between January 2010 and August 2011. We excluded those with additional congenital heart diseases or pulmonary hypertension, as well as those who had complications during the procedure or required extraordinary interventions, more than one device, or device changes. The study protocol was approved by the institutional review board, and all patients provided written informed consent prior to procedure.

Procedures

PDA closure procedures

All procedures were performed under general anesthesia and deep sedation. Following PDA imaging in the standard positions, the standard procedures reported for the gianturco coil (Cook Cardiology, Bloomington, Ind.), the Flipper detachable coil (Cook Cardiology, Bloomington, Ind.), the ADO (AGA, MN, USA), or the Amplatzer vascular plug (AVP) (AGA, MN, USA) devices were used for closure.[9-12,15]

Angiographic classification of residue shunt

15 min after the release of the PDA device in all patients, we applied a 700 PSI, 1 cc/kg dose pressure at a 90° lateral position, using catheters of the appropriate size for angiographic controls. Post-procedural residual shunt evaluation was performed by two independent pediatric cardiologists, and patients were divided into five groups based on residual shunt:[15]

1. No residual shunt
2. Trivial: presence of a fine jet of contrast that is limited the immediate area of the device
3. Mild: opacification of some part of the pulmonary artery and the left branch pulmonary artery
4. Moderate: opacification of the pulmonary artery to the level of the pulmonary valve and

dense opacification of both pulmonary arteries

5. Severe: opacification of the same density in the arteries, lung, and aorta.

Evaluation of residual shunt via ECHO

10 min after releasing the PDA device, echocardiographic controls were performed with 3S and/or 7S probes of the GE Vivid S5 (General Electric, Waukesha, WI, USA) echocardiographic device via the standard parasternal short axis, ductal, and suprasternal windows by a single pediatric cardiologist. According to the Doppler echocardiographic findings, these patients were classified into three groups:[13]

1. Group 1: complete occlusion without residual shunt
2. Group 2 (non-significant residual PDA): residual PDA diameter <1 mm and no continuous waveforms detected
3. Group 3 (significant residual PDA): residual PDA diameter > or =1 mm or continuous waveforms.

Follow-up echocardiographic studies were done the day after the procedure, and 3, 6, 12 months following the procedure.

Angiographic procedure standards

Cardiac catheterization and interventional radiology procedures: a monoplane imaging system (Toshiba healthcare) was used. In general, the procedures were performed using a digital cine X-ray system with an image intensifier at an acquisition rate of 30 frames/s, along with pulsed fluoroscopy (15 pulses/s). Scopy doses during the entire procedure and control angiography were separately recorded. A non-ionic contrast material (iodixanol) was used for all patients. In controls, a 1 cm^3/kg (max 30 cm^3) dose of contrast material was injected. Post-procedural control angiographic and echocardiographic findings were compared.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) for Windows (Version 15.0, SPSS Inc., Chicago, IL, USA) was used for the analysis. Groups were compared via the Kruskal-Wallis test. Comparisons between the two groups were done using the Mann-Whitney U-test method. $P<0.05$ was considered to be significant.

RESULTS

General findings and device selection

Over an approximately 2-year period, a total of 63 patients experienced transcatheter PDA closure. 43 (68%) were female, and 20 (33%) were male. At the time of the procedure, the mean age was 5.1±4.4 years (10 months-18 years), and mean body weight was 19.3±14.7 kg (6.5-75). According to the ductal morphologic evaluation during the pre-procedural angiographic imaging, 46 (73%) had Type A ductus, 16 (25.4%) Type E ductus, and 1 had Type C ductus.[16] Ductal sizes were as follows: the average ductal aortic ampulla was 7.8±2.9 mm (1.3-16 mm), the average of the narrowest diameter was 3.0±1.2 mm (1.1-6.1 mm), and the mean length was 8±2.9 mm (3.4-20 mm). Following device selection based on defect size, morphology, and the preferences of the interventional cardiologist:

1. 31 patients (49.2%) were treated with an ADO (25 ADO-I, 6 ADO-II)
2. 29 (46%) were treated with a coil (19 flipper detachable coil, 10 Gianturco coil), and,
3. 3 (4.8%) were treated with an AVP.

Procedural characteristics, contrast and radiation exposure

For PDA closures with various devices, clinical data, procedure characteristics, and post-procedural control angiography and echocardiographic data were summarized in Table 1. The average procedure duration was 56.4±19.4 min (30-105 min), the scopy duration was 12±6.4 min (3.4-31.4 min), the average total radiation dose was 28.1±14.7 cmGy/cm^2/kg (6-66.9 cmGy/cm^2/kg), the number of injections was 4.9±1.9 (2-9), and the contrast amount 4.2±2.3 cm^3/kg (0.6-12.8 cm^3).

When comparing devices, no statistically significant difference was detected between device procedures in terms of total scopy duration, total radiation dose, or total contrast amount ($p>0.05$). When evaluated for procedure duration and injection number, the procedure duration and injection number for ADO were higher than those for coils ($p=0.011$ and 0.001, respectively). Procedure duration and injection number were also higher in patients whose PDA was closed via AVP when compared to those closed with coils (for both, $p=0.012$).

Table 1. Clinical and procedural characteristics of patients

Characteristics	Overall (n=63, 100%)	ADO-I (n=25, 39.7%)	ADO-II (n=6, 9.5%)	Gianturco (n=10, 15.8%)	Flipper (n=19, 30.2%)	AVP (n=3, 4.8%)
Age (years), ±SD (range)	5.1±4.4 (0.8-18)	6.0±5.5 (0.8-18)	5.2±5.1 (1.5-15)	5.1±3 (1.9-12)	4±3.0 (0.8-11)	4.5±5.6 (1-11)
Weight (kg), ±SD (range)	19.3±14.7 (6.5-75)	20.6±18 (6.5-64)	24.9±24.8 (11-75)	18.8±7.8 (12.5-34)	16±7.6 (8-33)	18.3±16.1 (8-37)
Minimal PDA diameter (mm) (angiographic size), ±SD (range)	3±1.2 (1.1-6.1)	4±1.1 (2.4-6.1)	2.8±0.5 (2-3.5)	1.6±0.4 (1.1-2.7)	2.4±0.5 (1.1-3)	3±0.5 (2.5-3.5)
Ductal classification (Krichenko)	63	25	6	10	19	3
Conical	46 (73)	23	4	7	11	1
Tubular	1 (1.6)	1	0	0	0	0
Elongate	16 (25.4)	1	2	3	8	2
Total procedure time (min), ±SD (range)	56.4±19.4 (30-105)	60.6±17.2 (40-90)	66.7±25.6 (30-90)	41.5±9.4 (30-60)	51.6±16.5 (30-90)	80±31.2 (45-105)
Total fluoroscopy time (min), ±SD (range)	12.0±6.4 (3.4-31.4)	11.6±5 (4-22.3)	14.6±7.5 (4.3-24)	11.2± 7.6 (3.7-30)	11.8±6 (4-26.9)	15±14.6 (3.4-31.4)
Number of injections (n), ±SD (range)	4.9±1.9 (2-9)	5.8±1.5 (4-9)	4.8±1.6 (2-6)	2.5±0.9 (2-4)	4.7±1.7 (2-9)	7±2.7 (4-9)
Total radiation dosage (cmGy/cm^2/kg), ±SD (range)	28.1±14.7 (6-66.9)	28.4±13.9 (8-62.8)	38.3±15.7 (25.2-63.4)	23.9±17.8 (6-66.9)	27.9 / 14 (11.2-56.7)	18.9±10.5 (11.9-31)
Total contrast volume (cc/kg), ±SD (range)	4.2±2.3 (0.6-12.8)	4.8±2.5 (1.2-12.8)	3.9-1.9 (0.6-6.3)	2.7±1 (1.3-4.7)	4.4±2.5 (1.5-11)	4.1±0.7 (3.7-5)
Radiation dosage of control aortogram (cmGy/cm^2/kg), ±SD (range)	3.8±5.7 (0.4-40.2)	2.1±1.8 (0.4-7.7)	11.1±15.3 (1.2-40.2)	5.5±4.6 (1.2-13.4)	3.2±3 (0.4-12)	0.7±0.2 (0.5-1)
Contrast volume of control aortogram (cc/kg), ±SD (range)	0.9±0.1 (0.3-1.3)	0.9±0.2 (0.4-1.3)	0.8±0.2 (0.3-1.1)	1±0.1 (0.7-1.2)	0.9±0.1 (0.7-1.1)	0.9±0.2 (0.6-1.2)

ADO: Amplatzer duct occluder; AVP: Amplatzer vascular plug; PDA: Patent ductus arteriosus; SD: Standard deviation.

The echocardiographic and angiographic control findings following PDA closure are summarized in Table 2. In patients on whom echocardiographic evaluation was performed shortly after the procedure (10 min later), 57 patients (90.5%) showed complete occlusion without any residual shunt (Group 1), and six (9.5%) showed a non-significant residual shunt (Group 2). A significant residual shunt (Group 3) was not detected in any patient. Five patients of Group 2 were among those closed with a coil (three gianturco and two flipper coils), and only one was closed with ADO-I. When the same patients were evaluated with post-procedural control angiography, 38 patients (60.3%) had no residual shunt, 11 (17.5%) had trivial shunt, 8 (12.7%) had mild shunt, and 6 (9.5%) had moderate residual shunt. No severe residual shunt was demonstrated. Among those residual shunts detected with the aortography, 14 were closed with ADO-I, nine with coil (three gianturco, six flipper), and two with AVP. Interestingly, among the 14 ADO-I patients whose residual shunt was detected via control aortography, only one had non-significant residual shunt in ECHO, and in the patients whose moderate residual shunt was detected through aortography, echocardiographic residual defect was not detected. In two patients who had PDA closure with AVP, trivial and mild residual shunts were detected via aortography, and no residue was detected during echocardiographic evaluation. Most importantly, residual defects were not detected in any of patients among those who were shown to be without post-procedural residue via ECHO.

During control aortography, after device release, the radiation dose was 3.8±5.7 cmGy/cm^2/kg (0.4-40.2 cmGy/cm^2/kg), and the amount of contrast material was 0.9±0.1 cc/kg (0.3-1.3 cm^3/kg). In control aortography, the ratio of the exposed radiation dose to the total was 13.3±17.1% (1-83%), and the average exposed amount of contrast material to the total was 27.2±12.3% (8-62%).

Follow-up

The average follow-up duration was 17.2±5.9

Table 2. Post procedural control angiographic and echocardiographic properties of patients

Characteristics	Overall (n=63)	ADO-I (n=25, 39.7%)	ADO-II (n=6, 9.5%)	Gianturco (n=10, 15.8%)	Flipper (n=19, 30.2%)	AVP (n=3, 4.8%)
Control aortographic findings						
No residual shunt	38	11	6	7	13	1
Trivial residual shunt	11 (ECHO, n=4)*	3	0	3 (ECHO, n=3)*	4 (ECHO, n=1)*	1
Mild residual shunt	8 (ECHO, n=2)*	6 (ECHO, n=1)*	0	0	1 (ECHO, n=1)*	1
Moderate residual shunt	6	5	0	0	1	0
Severe residual shunt	0					
Immediate post procedural echocardiographic findings						
No residual shunt	57	24	6	7	17	3
Non-significant residual shunt	6	1	0	3	2	0
Significant residual shunt	0					
Follow-up ECHO findings						
No residual shunt	61					
Non-significant residual shunt	1			1		
Significant residual shunt	0					

ECHO: Echocardiography; ADO: Amplatzer ductal occluder; AVP: Amplatzer vascular plug; *Residual shunt detected by ECHO.

months (9-27 months). Follow-ups were based entirely on clinical examination and ECHO. In the echocardiographic evaluation shortly after the procedure, non-significant residual shunt was detected in six patients; in ECHO one day after the procedure, complete occlusion was detected in five patients. One patient still had a non-significant residual shunt at 3 months, 6 months, and 1-year follow-ups. One of the most important findings of this study was that none of the patients in whom residual shunt was not detected in the post-procedure echocardiogram (whether shunt was present in aortography or not) showed residual shunt from PDA at follow-up.

DISCUSSION

PDA represents one of the most common lesions in the field of congenital cardiac disease. Strategies for its management continue to evolve. For the treatment of PDA, a transcatheter approach is a less invasive alternative to surgery.[10] Many new PDA closure devices were discovered following Postman et al.'s use of an Ivalon plug with the transcatheter technique in 1967. Especially with coils and ADO devices, transcatheter PDA closure outside of the neonatal period is applied with high success and low complication rates.[1-3,9-12] Many studies suggest the use of gianturco and/or flipper coils in defects in which the narrowest diameter is <2-3 mm, while ADO and other devices are recommended for moderate and large defects.[9-12] In our study, the average PDA diameter was 1.6 mm in those for which gianturco coils were used, 2.4 mm for flipper coils, and 4 mm for ADO.

Although many new devices have been developed for and used in transcatheter PDA closure based on defect diameter and ductal morphology, radiation dose and the amount of contrast given during the procedure have still not decreased. While some studies declare that fluoroscopy time during PDA closure is not different from that during diagnostic cardiac catheterization (mean 10.1 min),[17] median fluoroscopy duration was almost 40 min (range 13-152 min) in the studies in which large PDAs were closed (minimal diameter >4 mm).[17] One of the recent, prospective, multicenter studies with the largest series was done using 359 patients. This was conducted by Brunetti et al.[9] In this multicenter MAGIC PDA study, the mean fluoroscopy time was 12.2 min (range 1-55.2 min), and especially in gianturco coil users, fluoroscopy duration and contrast exposure were lower than for

devices. For the various devices in this study, mean fluoroscopy durations were as follows: gianturco coil (n=161) 8.7 min, ADO (n=174) 14.4 min, and flipper coil (n=18) 17.1 min. In our study, the mean fluoroscopy duration was 12 min (range 3.4-31.4 min). However, no significant difference was detected between devices in terms of fluoroscopy durations. The mean fluoroscopy durations for the gianturco coil, ADO-I, and the flipper coil were 11.2 min, 11.6 min, and 11.8 min, respectively. These findings show that mean fluoroscopy duration in our unit could not be reduced to <12 min, even if the most appropriate device was selected.

Among 14 ADO-I patients with a residual shunt, based on post-procedural control aortography, only one patient had a residual shunt that was shown via ECHO, and this was resolved in 24 h when examined via control ECHO. Also, another interesting result was in the subgroup of patients with moderate shunt. None of these 5 patients had any shunt with transthoracic ECHO. This made us believe that the passage during high-pressure (700 PSI) aorta injections inside of the device body after the procedure might not be the real residual shunt. On the other hand, clinicians should determine the origin of this shunt. Is it just the flow passing though the device, or are there any complications that lead to this shunt? Interventional cardiologists should be aware of any complication in this particular situation.

The most important factor to use in determining device success is certainly the non-existence of residual defect, and the gold standard method used to determine this is post-procedural control aortography.[9,10,12] Nevertheless, post-procedural exposure to extra radiation and contrast injection may not be suitable for younger children.[13] On the other hand, while complete occlusion rates are quite high in PDA cases closed with coils or ADO (90-100%), immediate residual shunt may be very common, depending on the selected device; incidence ranges from 32% to 40% in published series.[2,13,18-24] In this study, in cases of immediate aortography after the procedure, 39.7% had residual shunt in various degrees, and the complete occlusion rate was 98.4% in the 1st day ECHO evaluation.

Transthoracic ECHO is routinely used to follow up with patients after PDA closure; however, there are few publications regarding its routine use in the catheter laboratory.[13,14] In a study of post-procedural early ECHO evaluation in 52 patients who had PDA occlusion with a gianturco coil, Liang et al.[13] showed successful PDA closures in those patients with residual shunts <1 mm and without the continuous flow after the procedure. Those studies mentioned that ECHO use may decrease radiation and contrast doses; however, how much of a decrease in radiation would be seen has not been documented. In a second study on this topic, Meraji et al.[14] performed PDA closure with an ADO in 39 patients, using only a venous approach in 35 of these patients. They described the fact that ECHO can evaluate procedural success and that the procedure can be completed without aortography of the arterial line. In this study, there are no data showing that echocardiographic guidance can reduce fluoroscopy duration and radiation dose. In our study, we compared the findings of control aortography and ECHO, which were first performed after the procedure. Among 25 patients with residual observed via control aortography, only six had residual shunt in ECHO, and there was only one patient with residual shunt in the ECHO control 1 day later. Furthermore, when control aortography was not performed, the required radiation dose may be decreased by 13.3%, and contrast material exposure may be decreased by 27.2%. Especially in children with long lifetime expectations and high radiation sensitivity, we think that decreased radiation and contrast exposure is crucial.

The radiation dose from cardiac catheterization is particularly relevant when treating children.[5,6] Growing tissues are both more sensitive to radiation and have a longer time ahead during which to develop malignancy. Moreover, a larger body area of children is exposed to radiation during the procedure as compared to adults. Thus, an infant or child patient has a longer lifetime risk of developing radiation-induced cancers than an adult patient.[4,6] While exposed dose increases, cancer development risk also increases, even to as low as 0.4%.[7] The probability of a fatal cancer is about 0.07% per fluoroscopically guided cardiac procedure.[5] However, in a recent study done with a new biomarker, the median lifetime attributable risk of cancer mortality was reported to be 0.404% (1/248).[4] In the end, the authors comment as follows: since there is a high level of risk, ionized radiation should be given only for necessary procedures, and magnetic resonance or ECHO must be chosen if possible.[4] In the literature, mean fluoroscopy time

during PDA closure ranges between 7.1 and 34 min and increases as age increases.[6,18-24] While dose area product values range between 8 and 110 cmGy/cm^2, they also increase as age and weight increase.[21,23,24] The ideal method for children is to calculate this value via body mass index; this was done only by Chida et al.,[6] and the mean dose area product was found to be 65.5 cmGy/cm^2/kg. In the literature, although fluoroscopy duration is still given when closure is performed with an ADO; there are no studies of radiation dose. [24] In our study, we calculated the amount of total radiation patients were exposed to during PDA closure with various devices, and the mean dose area product was found to be 28.1 cmGy/cm^2/kg.

Study limitations

First of all, the findings of this study should be carefully evaluated due to the small number of the sample. Secondly, procedure time, total radiation dosage and total contrast volume were all higher in patients with ADO-II and AVP. This may have been caused by small patient numbers, or be an outcome of clinicians' use of more contrast and fluoroscopy, compared to other devices, during the learning curve with these devices . Finally, we excluded those patients who needed more than one device or device change, and those who developed a complication during the procedure. This may have interfered with the results and make it difficult to compare the findings with those of other similar studies.

Although this is a limited study, our results indicate that echocardiographic evaluation after transcatheter PDA closure, instead of control aortography, would provide less exposure to radiation and contrast material in the patients for whom the appropriate device was selected before the procedure. Considering the follow-ups performed via ECHO and the increased cancer risk due to radiation, we believe that decreasing radiation exposure is important in pediatric cases.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national guidelines on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008, and has been approved by the Hospitals' Institutional Committees.

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Key words: Cardiac catheterization/adverse effects; child; ductus arteriosus, patent; heart defects, congenital/radiography; radiation injuries/epidemiology; risk factors.

Anahtar sözcükler: Kalp kateterizasyonu/yan etkiler; çocuk; duktus arteriyozus, açıklık; kalp defektleri, doğuştan/radyografi; radyasyon yaralanması/epidemiyoloji; risk faktörleri.