NOTE *Surgery*

Evaluation of the Efficacy and Safety of Coil Occlusion for Patent Ductus Arteriosus in Dogs

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ABSTRACT. We performed a retrospective study of 56 dogs with Patent Ductus Arteriosus (PDA) to evaluate the indications for and efficacy of transarterial PDA coil embolization. Transarterial PDA coil embolization was conducted in 37 cases (66.1%) and surgical ligation was conducted in 16 cases (28.6%). Three cases (5.4%) were diagnosed as pulmonary hypertension and were excluded from surgical intervention. Although coil dislodgement was observed in the pulmonary artery in one case, no death occurred during coil embolization or surgical ligation. Echocardiography showed that fractional shortening decreased from 35.4 ± 6.8% to 30.2 ± 5.9% ($P<0.05$) after transarterial PDA coil embolization. Although slight residual shunts were observed in 18 cases, transarterial PDA coil embolization was effective treatment of PDA.

KEY WORDS: canine, interventional cardiology, patent ductus arteriosus (PDA).

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Treatment of patent ductus arteriosus (PDA) in dogs has changed dramatically in the last several years. Historically, surgical ligation has been the standard method of correction, however, transarterial PDA coil embolization is offered by many specialty centers for PDA occlusion as a safe, cost effective, and less invasive alternative. There are many case reports of transarterial PDA coil embolization [4–7], and we reported the first Japanese case of transarterial PDA coil embolization in a dog in 2001 [13]. In the early days, dislodgement of the coil in the pulmonary artery was frequently reported because of use of a "push-out" type of device. On the other hand, a detachable coil is now widely used for PDA closure that is superior because it can be reinstalled if it is not in a favorable location.

Human PDA is classified into five forms (types A-D) [8], and canine PDA is clinically classified into several forms (megaphone, tubular, and window type). Most cases of PDA in dogs are reported to be the megaphone type, and this type is suitable for coil embolization because it has a narrow segment that can firmly retain a coil. However, the tubular type of PDA dose not posses a narrow segment, and placement of the coil can be unstable.

Unlike human medicine, veterinarians must treat a wide variety of sizes of dog with coils designed for another species (humans). Therefore, coil selection seems to be very important in order to achieve an appropriate occlusion. Currently, Cook® products (detachable coils for PDA closure) consist of four sizes (3, 5, 6.5 and 8 mm in diameter) and three loop varieties (1, 3, and 5 loops), and selection of the appropriate size is very difficult. If the coil is too small, residual shunts or coil dislodgement occur.

The present, a retrospective study was performed on 56 dogs with PDA in order to evaluate the indications for and efficacy of transarterial PDA coil embolization, postoperative cardiac function, and postoperative complications.

The dogs were admitted to the Veterinary Teaching Hospital at Tokyo University of Agriculture and Technology and the Animal Clinical Research Foundation for evaluation of a previously detected heart murmur between 1999 and 2005. Hyperdynamic precordium and a grade III-IV/VI left-sided basal systolo-diastolic murmur were documented for each dog. Left atrial and ventricular enlargement were identified on thoracic radiographs. Using pulsed-wave Doppler echocardiography, turbulent retrograde continuous flow was detected in the main pulmonary artery, indicating left-to-right shunting. Colorflow Doppler mapping was used to visualize the vascular shunt. Angiography was conducted in order to determine the form and diameter of the ductus. Transarterial PDA coil embolization was conducted if the patient was considered to be a candidate for transarterial PDA coil embolization Transarterial PDA coil embolization was conducted as reported previously. Briefly, the angiographic catheter was replaced by a delivery catheter (Multipurpose catheter, 5 F; Cook, Bloomington, U.S.A.), which was passed through the ductus into the pulmonary artery. An embolization coil (detachable coil for PDA closure; Cook, Bjaeverskov, Denmark) attached to a delivery wire (Flipper PDA closure TFE-coated delivery system, Cook, Bjaeverskov, Denmark, Fig. 1) was then introduced. The coil was advanced to the tip of the catheter, and 1.5 loops of the coil were pushed out of the catheter tip into the pulmonary artery. The rest of the loops were then pushed out of the catheter into the ductus. After confirming correct

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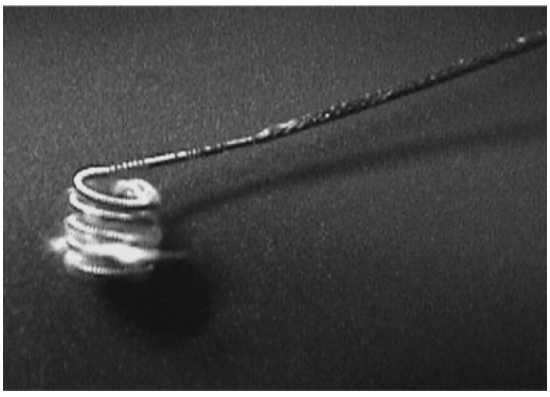

Fig. 1. An embolization coil (detachable coil for PDA closure; Cook, Bjaeverskov, Denmark) attached to a delivery wire (Flipper PDA closure TFE-coated delivery system, Cook, Bjaeverskov, Denmark, Fig. 1).

placement of the coil and the effectiveness of the occlusion, the delivery wire was rotated to detach it from the coil.

Surgical ligation was planned for another day if the patient was not considered to be a candidate for transarterial PDA coil embolization. Surgical ligation was conducted using a modified Jackson's method under intercostal thoracotomy. Surgical intervention was not undertaken if a reversed shunt and/or pulmonary hypertension was observed by angiography; instead, the animal was treated medically and was therefore not included in the following postoperative assessment.

Postoperative assessment of transarterial PDA coil embolization patients consisted of echocardiographic evaluation and observation for postoperative complications. Residual shunting was evaluated using colored Doppler ultrasound imaging of the pulmonary artery. Cardiac function (fractional shortening, FS; stroke volume index, SVI) was evaluated using M-mode echocardiography. Postoperative complications were evaluated by close observation of the patient and clinical laboratory tests, such as blood tests and/or urine analysis, were conducted as needed.

All calculations were performed using statistical software. Unpaired *t*-tests (2-way) for parametric data were used for continuous variables to identify differences between groups of dogs. Values are shown as the median and range or as the mean ± standard deviation (SD). A P value of <0.05 was considered to be significant.

The patients consisted of 15 Dachshunds, 9 Welsh Corgi Pembrokes, 5 Maltese, 4 Shetland Sheepdogs, 3 Cavalier King Charles Spanielss, 3 Toy Poodles, 3 Papillons, 3 Yorkshire Terriers, 2 Chihuahuas, 2 Pomeranians, 1 Shiba Inu, 1 German Shepherd, 1 Standard Poodle, 1 Bernese Mountain Dog, 1 Beagle, 1 Miniature pinscher and 1 mixed breed dog. There were 21males and 35 females, and their mean age was 13.6 ± 13.9 months. Of the 56 patients diagnosed with PDA, 3 cases (5.4%) were diagnosed with pulmonary hypertension and were excluded from surgical intervention. Angiography was conducted for 51 patients; five patients for which it could not be conducted were treated with surgical ligation. As shown in Table 1, transarterial PDA coil embolization was conducted for 37 cases (66.1%) and surgical ligation was conducted for 16 cases (28.6%). The form of the duct was classified as the megaphone type for 44 cases and as the tubular type in 7 cases. None of the patients with tubular type ducts were considered to be candidates for coil embolization. The minimum diameter of the ductus was 4.5 ± 2.6 mm for all patients. In patients that underwent coil embolization, the minimum diameter of the ductus was 3.7 ± 1.5 mm, whereas it was 6.4 ± 1.3 in the patients that underwent surgical ligation. Only one coil was used for each patient when PDA coil embolization was conducted. The coil variation (in diameter) and number of loops used in these patients were 8 mm and 5 loops in 19 cases, 6.5 mm and 5 loops in 10 cases, 5 mm and 5 loops in 3 cases, and 5 mm and 3 loops in one case (Fig. 2), respectively.

No deaths during occurred coil embolization or surgical ligation. Coil dislodgement in the pulmonary artery (perioperateive complication) was observed in one case. This coil was not retrieved and was left in the pulmonary artery. No complication were observed in relation to this coil, and the patient was subsequently treated by surgical ligation. Hemolysis and related hematuria were observed as postoperative complications in 18 cases (48.6% of the coil cases). Arthritis pyogenes was observed in one dog; however, no relationship to coil implantation was demonstrated. Residual shunts were observed in 18 cases (48.6% of the coil cases), no residual shunts were observed in the patients treated with surgical ligation.

M-mode echocardiography of the patients that underwent transarterial PDA coil embolization showed that FS decreased from 35.4 ± 6.8% to 30.2 ± 5.9% ($P<0.05$, Fig. 3). There was no difference between the pre (88.9 ± 51.5) and post-operative SVIs (75.5 ± 58.6, Fig. 3).

Although surgical ligation has been recommended for all cases of left-to-right shunting PDA [1, 2], the alternative method of transcatheter coil occlusion has been used in the veterinary field [4, 6, 7, 10, 11, 13]. Transcatheter coil

Table 1. Minimum ductal diameter, PDA form, and treatment method

Treatment method	Number of dogs	Mean minimum ductal diameter (mm)	Type of PDA Megaphone	Tubular
Transarterial coil occlusion	37	3.7 ± 1.5	37	0
Surgical ligation	16	6.4 ± 1.3	7	4
Inadequate for treatment	3	9.5 ± 1.5	0	3
Total	56	4.5 ± 2.6	44	7

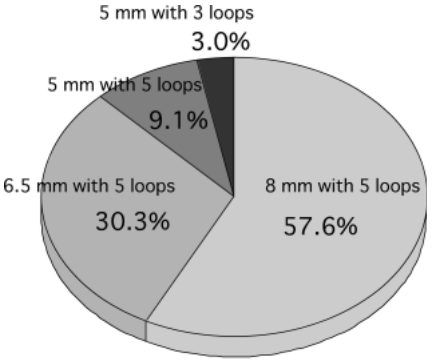

Fig. 2. Coil variation in the patients.

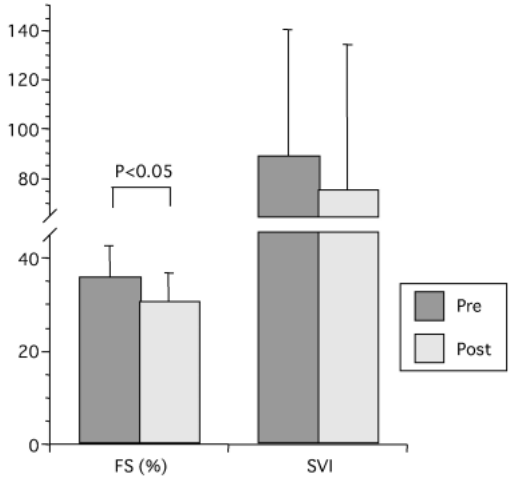

Fig. 3. M-mode echocardiography for the transarterial PDA coil embolization patients.

occlusion is superior in terms of invasiveness and is widely accepted by owners. In the present study, the indications, effects, and complications of coil occlusion were analyzed, and the results of this analysis were very useful for obtaining informed consent from owners when deciding which treatment to choose.

Complications reported for transcatheter coil embolization include hemorrhaging at the vascular access site, systemic or pulmonary embolization by coils, residual shunts, hemolysis, and stenosis of the left pulmonary artery [7, 9, 12, 14]. Residual shunts are often observed in animals that undergo transarterial PDA coil embolization; however, most of these animals do not experience adverse clinical effects, and the residual shunts disappear spontaneously [3, 13]. In addition, high percentage of mild hemolysis occurs in relation to residual shunts, but this is spontaneously resolved within a few days. Occurrence of these complications in the present study may have resulted from use of only one coil for each dog. If multiple coils are implanted, the rate of residual shunting may decrease. However, implantation of multiple coils will cause an increase in the cost of treatment because the unit price of coils is very high. Furthermore, it will also increase a risk of pulmonary embolization. This procedure can cause hemodynamic effects even though it also cause a high percentage of residual shunts, as shown by the significant decrease in FS observed after transarterial PDA coil embolization in the present study. We previously reported that supplemental coil insertion can produce successful occlusion when a residual shunt is severe [12]. However, the residual shunts in the other cases were slight, and no other cases required supplemental coil implantation.

Recently, septicemia was reported in a young dog following treatment of patent ductus arteriosus via coil occlusion, and it was assumed that the PDA occlusion coils were infected [15]. Arthritis pyogenes was observed in one case in the present study, although no relationship with coil implantation was demonstrated. Veterinarians should be more prepared to aggressively treat implant infections after coil implantation.

Transarterial PDA coil embolization for PDA is now a commonly conducted procedure in many specialty centers. However, there are no guidelines in terms of the number to use and method of use of coils for patients with PDA. We prefer to use one coil based on cost, while other institutions prefer multiple coil occulusion [4]. The present study proved that our method can achieve good results. Further investigation is necessary to clarify which method is best for PDA embolization with coils.

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