Case Report

Surgical Ligation of Patent Ductus Arteriosus in an Adult Pomeranian

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Received: 16 August 2021; Revised: 10 November 2021; Accepted: 11 November 2021

Abstract

Patent ductus arteriosus (PDA) is the most common congenital heart disease in dogs. The ductus arteriosus extends from the main pulmonary artery to the descending aorta, shunting blood away from the nonfunctional lungs in neonates. When it fails to constrict after birth, oxygenated blood can flow from the aorta to the pulmonary artery. Most of untreated patients develop congestive heart failure at one year of age. The treatment options include both minimally invasive and open surgical techniques. It is recommended that PDA be promptly closed after diagnosis as immature dogs are the best candidates for surgery. An adult Pomeranian with PDA was referred to Prasu-Arthorn Animal Hospital, Faculty of Veterinary Science, Mahidol University. An open surgical ligation was performed at the animal hospital with the cooperation of a diplomate of the Thai Board of Thoracic Surgery from the Faculty of Medicine Ramathibodi Hospital, Mahidol University. No intraoperative complications occurred. Postoperative echocardiograms showed no residual flow, and there was a gradual decrease in heart size three days to two months after surgery. The dog was more energetic and healthier.

Keywords: PDA, Pomeranian, open surgical ligation

การผ่าตัดแก้ไขโรคหลอดเลือดหัวใจคงค้างในสุนัขปอมเมอราเนียนเต็มวัย

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Received: 16 August 2021; Revised: 10 November 2021; Accepted: 11 November 2021

บทคัดย่อ

โรคหลอดเลือดหัวใจคงค้าง (Patent ductus arteriosus: PDA) เป็นโรคหัวใจพิการแต่กำเนิดที่พบได้บ่อยในสุนัข เส้นเลือดนี้เชื่อมต่อระหว่างเส้นเลือดพัลโมนารีอาร์เตอรีกับเส้นเลือดเอออร์ตาส่วนลง ทำหน้าที่เป็นทางผ่านของเลือดไม่ให้ไปยังปอดที่ยังไม่ทำงานในลูกสัตว์ หากเส้นเลือดนี้ยังคงค้างอยู่หลังจากคลอด เลือดที่มีออกซิเจนจะสามารถไหลจากเส้นเลือดเอออร์ตาส่วนลงไปสู่เส้นเลือดพัลโมนารีอาร์เตอรี ส่วนมากสัตว์ป่วยที่ไม่ได้รับการรักษาจะมีภาวะหัวใจล้มเหลวเมื่ออายุ 1 ปี ทางเลือกในการผ่าตัดมีทั้งแบบไม่เปิด และเปิดช่องอก การผ่าตัดเพื่อปิดเส้นเลือด PDA นั้น ควรทำให้เร็วที่สุด เนื่องจากการผ่าตัดได้ผลดีในลูกสัตว์ที่ยังไม่โตเต็มวัย สุนัขปอมเมอราเนียนโตเต็มวัยที่มีภาวะ PDA ถูกส่งตัวมาที่โรงพยาบาลสัตว์ประศุอาทร มหาวิทยาลัยมหิดล และได้รับการผ่าตัดเปิดช่องอกเพื่อผูกปิดเส้นเลือด โดยได้รับความร่วมมือจากอาจารย์แพทย์สาขาศัลยศาสตร์ทรวงอก คณะแพทยศาสตร์โรงพยาบาลรามาธิบดี มหาวิทยาลัยมหิดล ทั้งนี้ ไม่พบข้อแทรกซ้อนระหว่างการผ่าตัด จากการบันทึกภาพหัวใจด้วยคลื่นเสียงความถี่สูงหลังผ่าตัด 3 วันจนถึง 2 เดือน พบว่าหัวใจมีขนาดเล็กลง และไม่พบการไหลของเลือดผ่านหลอดเลือดดังกล่าวเหลืออยู่อีก สุนัขแข็งแรงมากขึ้นหลังการผ่าตัด

คำสำคัญ : โรคหลอดเลือดหัวใจคงค้าง ปอมเมอราเนียน ผ่าตัดเปิดช่องอกผูกเส้นเลือด

Introduction

Patent ductus arteriosus (PDA) occurs when the ductus arteriosus muscle fails to constrict after birth, leaving a persistent opening between the aorta and pulmonary artery. It is the most common congenital heart disease in dogs and is overrepresented in female purebred dogs, including Poodles, Keeshonds, Maltese, Bichons, Yorkshire Terriers, Cocker Spaniels, Pekinese, Collies, Shelties, Welsh corgis, and Pomeranians. It can also occur in cats but not as frequent as dogs (Orton et al., 2018).

Young dogs with PDA may have no clinical signs. PDA is commonly identified at the time of routine vaccinations. Simple thoracic auscultation can reveal a characteristic continuous machinery murmur at the high left heart base. On the other hand, the patient can present with coughing, dyspnea, exercise intolerance, and stunted growth. Further diagnostic evaluations include thoracic radiography and echocardiography. Treating PDA requires medical management or occlusion of the duct or both. If left untreated, the mortality rate of an animal with PDA aged one year is 70% (Fossum 2013).

PDA allows blood to continuously flow from the systemic circulation to the pulmonary circulation (left-to-right shunting) (Figure 1). Chronic volume overload causes left-sided heart enlargement and, eventually, left-sided congestive heart failure. If the pulmonary hypertension is so severe that the pressure in the pulmonary artery exceeds that in the aorta, blood will reversely flow from the pulmonary artery into the aorta (right to left shunting), causing nonoxygenated blood to mix with oxygenated blood. Only a small percentage of dogs with PDA will develop this "reversal." The characteristic sign of reverse PDA is differential cyanosis most obvious in the caudal mucous membranes. The heart murmur will disappear, and the dogs may have intermittent hind limb weakness and seizures.

PDA can be treated using medical management or occlusion of the ductus arteriosus or both. Prostaglandin synthase inhibitors can stimulate ductus closure. Unfortunately, ductal smooth muscle hypoplasia is common in dogs, and the time of diagnosis is often weeks to months after birth. These factors make prostaglandin synthase inhibitors ineffective. As a supportive treatment, furosemide can improve pulmonary edema. Digoxin can control the ventricular response rate in dogs with atrial fibrillation.

PDA is mainly treated with physical occlusion of the ductus arteriosus, performed using minimally invasive techniques or open surgical management. Minimally invasive techniques include transvenous catheterization and thoracoscopic PDA occlusion. Thrombogenic coils and Amplatz canine duct occluder (ACDO) are the two main devices used in transvenous catheterization. Angiography is an essential and accurate measurement of the PDA, and device sizing is required.

In the retrospective study by Goodrich et al. (2007), using a thrombogenic coil had a reduced risk of major complications compared with surgical ligation, but it was associated with a lower initial success rate and the same mortality rate. Dogs with nontapering ductus are contraindicated for the thrombogenic coil because the device could slip into the pulmonary artery.

ACDO is a self-expanding plug made of nitinol wire. The dense wire mesh of the device obstructs the blood flow through a PDA. The device can be securely positioned in the ostium of PDA. In thoracoscopic PDA occlusion, titanium vascular clips are used to occlude a PDA. Accurately measuring PDA size and choosing the proper vascular clip size are crucial.

Minimally invasive techniques are recommended, if available, because of the reduced operative pain and

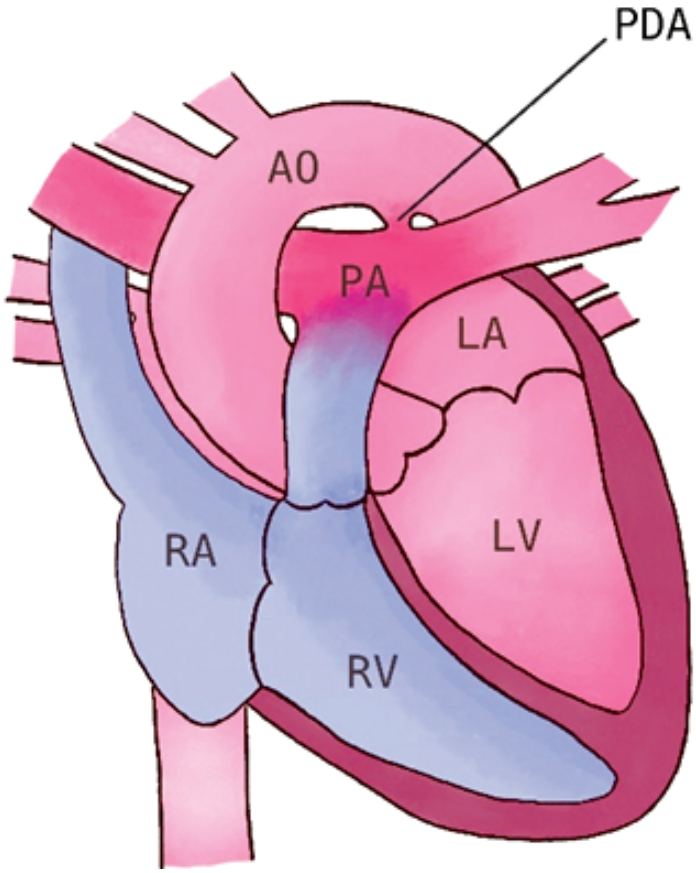


Figure 1. Diagram showing flow from systemic circulation to pulmonary circulation. PDA: patent ductus arteriosus; AO: aorta; PA: pulmonary artery; RA: right atrium; RV: right ventricle; LA: left atrium; LV: left ventricle.

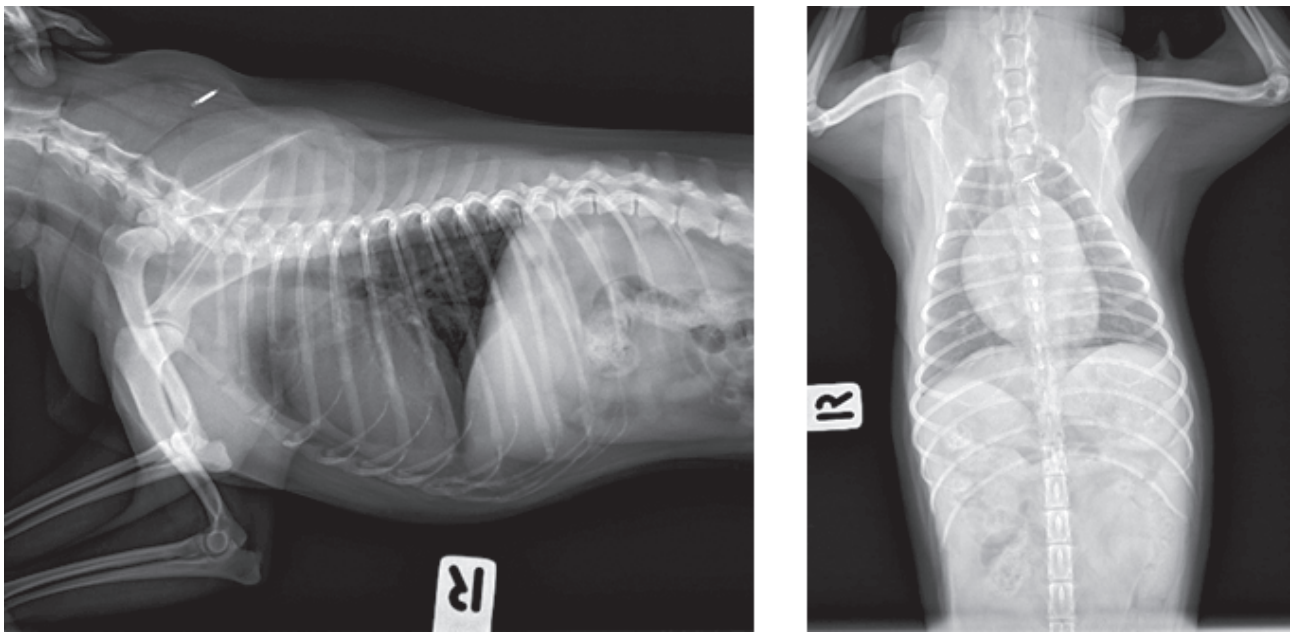


Figure 2. Thoracic radiograph of the lateral (left) and ventrodorsal (right) views showing pulmonary artery and vein dilation.

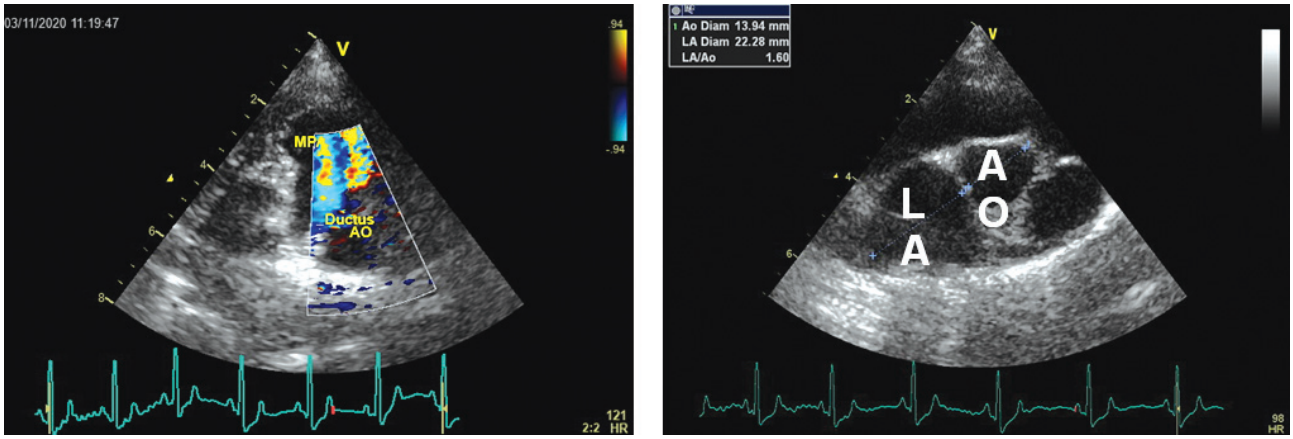


Figure 3. Echocardiography on the left parasternal cranial right outflow tract (left) view and right parasternal short axis (right) views showing turbulence flow through the pulmonary artery. Left atrial and ventricular enlargement. MPA: main pulmonary artery; LA: left atrium; AO: aorta.

recovery time. However, investment in a high-cost instrument and expertise in minimally invasive surgery are required.

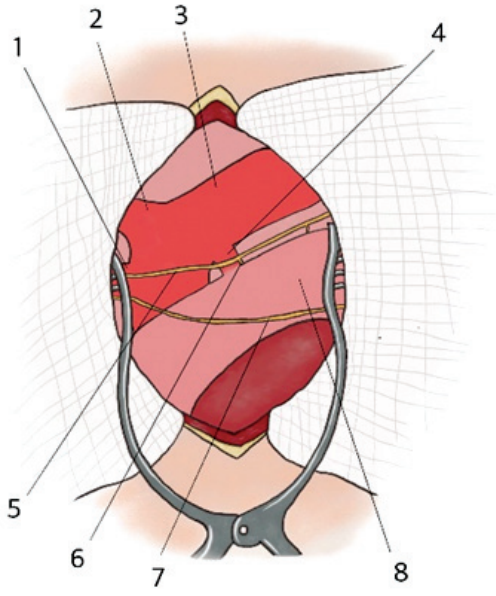
The ligation of the ductus is an open surgical technique, which is considered curative. Very-low-birth-weight, premature puppies are ideal candidates for surgery. Surgery should be promptly performed after the diagnosis. Broaddus and Tillson (2010) described the open surgical technique and reported the outcome of the surgery. An invited instructor, who is a diplomate of the Thai board of Thoracic Surgery from the Faculty of Medicine Ramathibodi Hospital, Mahidol University, performed the surgery at the Prasu-Arthorn Animal Hospital, Mahidol University. A veterinary clinician from Prasu-Arthorn Animal Hospital assisted the surgeon.

Case Descriptions

A three-year-old male Pomeranian was referred to Prasu-Arthorn Animal Hospital for further investigations of his cardiac murmur. On physical examination, the dog was healthy despite his grade IV/VI systolic murmur auscultated from the left chest wall at the level of the heart base. His body condition score was 4/9. Hematology and serum biochemical profiles were within normal limits. Thoracic radiographs showed pulmonary artery and vein dilation (Figure 2). There was no evidence of pulmonary edema. The vertebral heart score was 11.5. On echocardiogram, continuous turbulent flow was found through the pulmonary artery. PDA with an eight-millimeter diameter was identified. Color-flow Doppler revealed a blood flow velocity of 3.9 m/sec across the PDA, which indicated a pressure gradient at approximately 60 mmHg. There was a slight increase in the left atrium to the aorta (LA: AO) ratio and left ventricular internal dimension normalized by body weight (NLVIDd) at 1.6 and 1.9, respectively. No mitral or tricuspid regurgitation was found (Figure 3). To prepare for surgery, pimobendan at 0.25 mg/kg was prescribed twice daily to improve ventricular contractility. As there was no evidence of pulmonary edema and heart failure, diuretics and angiotensin-converting enzyme inhibitor were not required. Surgery for PDA ligation was then scheduled.

Preoperatively, the dog was premedicated with 0.3 mg/kg morphine and 0.3 mg/kg midazolam IM. General

anesthesia was induced with 2 mg/kg etomidate IV given titrated to effect. 25 mg/kg cefazolin was given IV. Acetate solution was administered intravenously at a rate of 5 ml/kg/h. Anesthesia was maintained with isoflurane in oxygen. As a mechanical ventilator was unavailable at the time of surgery, positive ventilation was applied manually after opening the thoracic cavity. Positive ventilation was necessary to aid the lung expansion since, during thoracotomy, normal negative pressure in the thoracic cavity was disrupted. The dog was placed in right lateral recumbency with a rolled towel tucked under the cranial thorax. The entire left side of the thorax was clipped and prepared. The surgeon stood on the patient's dorsal side. Thoracotomy was performed at the left fourth intercostal space. The underlying cutaneous trunci and latissimus dorsi muscles were incised. Intercostal spaces were recounted from the first rib before further incision. Scalenus muscle was incised at the fourth intercostal space. External and internal intercostal muscles were incised in the middle between the ribs, and then, the pleura was penetrated. Moistened gauze sponges were placed along the cranial and caudal rim of the ribs. Weitlaner retractor was placed and retracted to achieve sufficient exposure. The cranial lung lobe was packed caudally to expose the aorta, pulmonary artery, and phrenic and vagus nerves (Figure 4a). The vagus nerve was isolated and retracted ventrally. Care was taken to keep the left recurrent laryngeal nerve intact as it leaves the vagus nerve caudally to the PDA (Figure 4a). Usually, associated thrill can be palpated at the site of the PDA. However, in this patient, the thrill was palpated slightly cranial and ventral to the PDA. The PDA location was carefully verified using anatomical landmarks including the aortic arch and left subclavian artery. The ductus was



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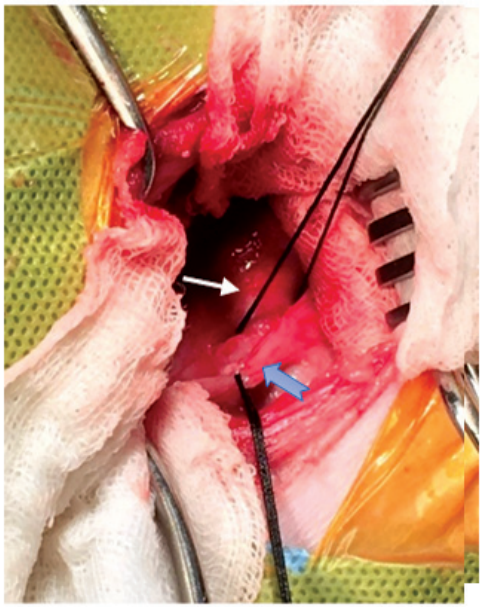

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Figure 4a. Diagram showing important landmarks at the left heart base. (1) Brachiocephalic trunk; (2) left subclavian artery; (3) aorta; (4) patent ductus arteriosus; (5) left vagus nerve; (6) left recurrent laryngeal nerve; (7) phrenic nerve; (8) pulmonary trunk.

Figure 4b. Photograph showing intraoperative appearance. The vagus nerve was retracted ventrally using one strand of silk (notched arrow). The suture was passed around the PDA one by one (arrow).

bluntly dissected using right-angle forceps from cranial to caudal aspect. Two separate strands of USP size 1 silk were passed behind the ductus one by one (Figure 4b). Recurrent laryngeal nerve was observed, and care was taken to avoid the nerve during suturing. The suture close to the aorta was ligated first to stop blood flowing through the ductus, followed by the one close to the pulmonary artery. Heart rate and blood pressure at the time of ligation were closely monitored and were in significantly variable. The PDA area was then palpated again, and the thrill disappeared. A chest drain was placed using a feeding tube and three-way stop clock system. The thoracotomy closure was routinely performed. Air and fluid were aspirated until a negative pressure was achieved. The patient recovered well and was stable after surgery.

Postoperatively, the patient was administered with fentanyl, 3 μg/kg/hr CRI, to control the pain. It was tapered and then changed to tramadol injection, 4 mg/kg TID, on the second day after surgery. Carprofen, 4.4 mg/kg SID, was given for three days. Three days after the operation, the patient was comfortable and eating. Fluid from the chest drain at this time was minimal (mean production of 0.35 ml/kg/day), and thus, the chest drain was removed. When the pain score was 1/4 according to the Colorado State University pain scales, the patient was discharged after three days of hospitalization. There was no further need for intravenous fluid, medication injections, or oxygen therapy. On discharge, cephalexin, 25 mg/kg BID for seven days, was prescribed for the patient. An echocardiogram was performed before discharge. The size of the left side of the heart returned to normal. The ductus had a 7.9 mm diameter. However, no ductal flow through the pulmonary artery was detected. The skin suture was removed 14 days after the operation. Pimobendan was discontinued at this time. At one- and two-month follow-up, the echocardiogram showed that the left atrium reduced in size compared with before surgery. The LA: AO ratio was 1.3. No ductal recanalization was found (Figure 5). Echocardiographic parameters before and after surgery are shown in Table 1.

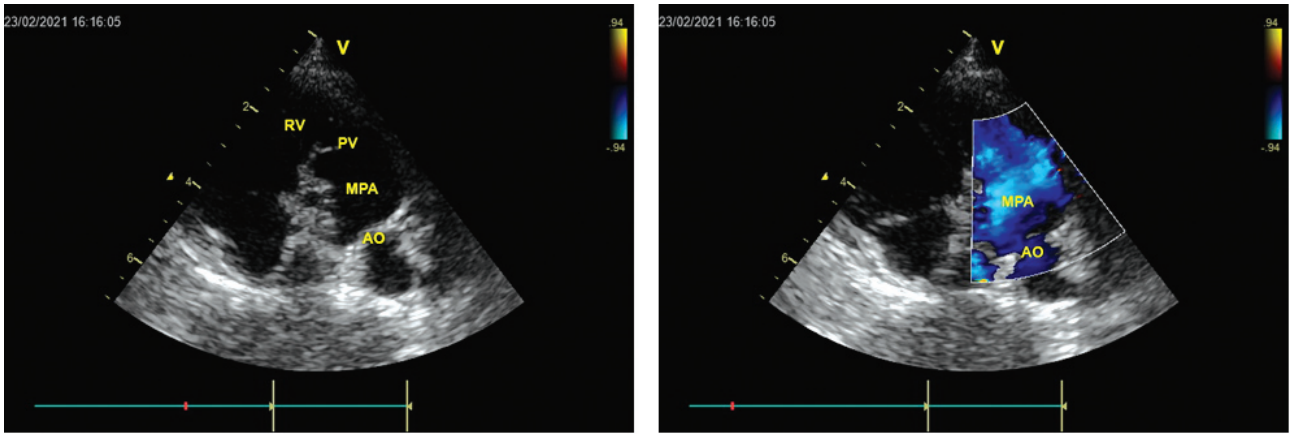

Figure 5. Echocardiography at two months after surgery on left parasternal cranial right outflow tract views showing no residual flow. RV: right ventricle; PV pulmonic valve; MPA: pulmonary artery; LA: left atrium; AO: aorta.

Table 1. Echocardiographic values before and after surgery.

Parameter	Before	3 days PO	30 days PO	60 days PO
AO diameter (cm)	1.4	1.6	1.3	1.3
LA diameter (cm)	2.2	2.0	1.6	1.6
LA/AO ratio	1.6	1.2	1.3	1.3
%FS	39	33	27	24
NLVIDd (cm/kg)	1.9	1.6	1.7	1.7
AVmax (m/s)	1.5	1.2	1.3	N/A
PVmax (m/s)	1.2	N/A	1.0	N/A

AO: aorta; LA: left atrium; FS: fractional shortening; NLVIDd: normalized left ventricular internal diameter in diastole; AVmax: aortic flow; PVmax: pulmonary artery flow.

Discussion

PDA is the most common congenital heart disease in dogs. Most dogs with PDA undergo surgery at a young age (Saunders et al., 2013). However, our patient presented with no clinical signs at three years of age. This conforms to the study by Israël et al. (2003), that stated that left-to-right shunt PDA is more common in older dogs than broadly recognized. They recommended the occlusion of the PDA regardless of age because it can relieve the clinical signs and should be promptly performed to avoid mechanical stress on the mitral valve, which can then develop to mitral valve endocardiosis. The risk of residual flow and complication rates are not greater in the adult population (Boutet et al., 2017).

Moreover, another report showed that increasing age was negatively associated with survival rate (Bureau et al., 2005). The authors further discussed that age may not directly increase the risk of death caused by PDA, but, in older animals, the duct could be more friable and could have more surrounding fibrous tissues. Thus, the risk of intraoperative hemorrhage and subsequent death may increase.

In our patient, the echocardiograms showed improvement in the size of the left atrium and ventricle after surgery. This contrasts with the results in the previously mentioned study by Israël et al. (2003), which mentioned that, in most older animals, cardiomegaly was irreversible. Our patient may represent the minor incidence that cardiac size was improved after occlusion. Although cardiomegaly persisted after occlusion, it may not affect the lifespan.

The study showed that the ductal diameters varied in size from 3.5 mm to 20 mm. An 8 mm ductus (like the one in our study) or wider was not always associated with congestive heart failure or poor survival. There was no correlation between ductal size and clinical signs.

Regarding the occlusion techniques, although both minimally invasive techniques and open surgical techniques have been described for a long time in the veterinary literature, the first case report of tranveneous catheterization technique using ACDO to close the PDA was in 2015 in Thailand (Buranakarl et al., 2015). The

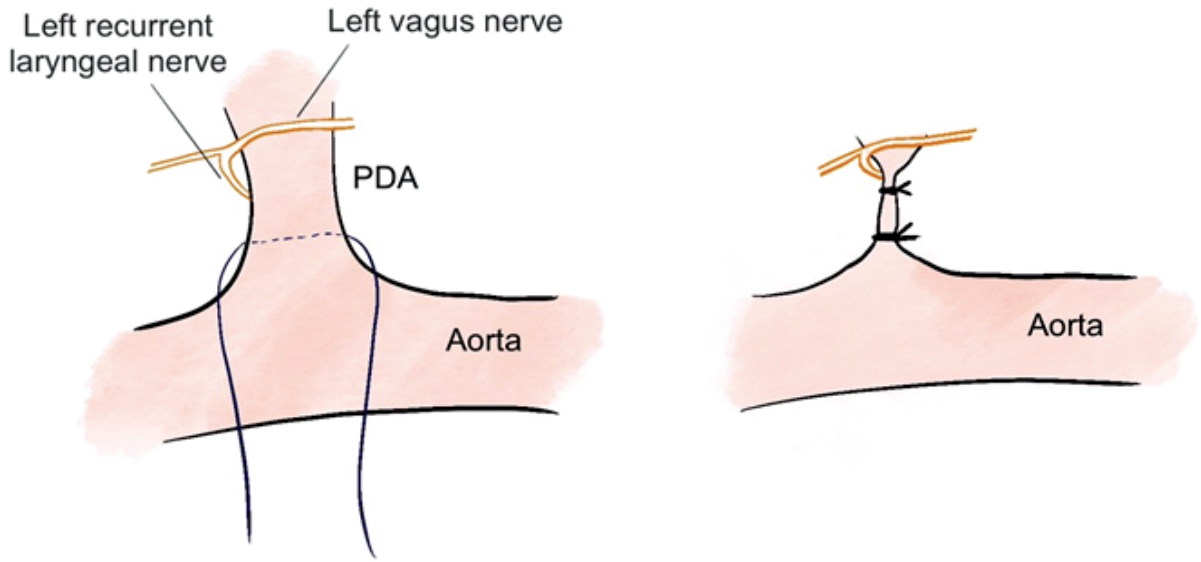

Figure 6. Diagram showing anatomical landmark from the standing position of the surgeon.

operation was successful. The dog had improved cardiac function and size. Thoracoscopic PDA occlusion was not reported in Thailand. Minimally invasive techniques are significantly less accessible than open surgical techniques because of device availability and high cost. The device must be compatible with the PDA in terms of size and shape. Also, the surgeon should be highly experienced in minimally invasive procedures. Although angiography is needed to determine the shape and the minimal internal diameter of the ductus, because of our patient's size, occlusion using transvascular catheterization technique may be possible. However, this option was unavailable at the authors' practice. Treatment options were already discussed with the owner before a decision was made for surgical ligation.

A standard technique and many variations were described for open surgery. The major goals of these techniques are to avoid damage to the ductus during dissection and suture passage (Broaddus and Tillson 2010). Attention should be paid to the medial side of the ductus, which is usually fragile and tearing it can cause catastrophic hemorrhage. In the study by Parchman (2008), the suture was tied and then the knot was grabbed while passing behind the duct to avoid closing the forceps during passage. Another goal is to avoid recanalization on the long term. Brockman et al. (2018), recommended that one strand of 5-0 polypropylene suture be placed between the silk sutures to prevent recanalization.

The technique performed in this report was similar to the standard technique. The differences were the position of the surgeon, the direction of dissection, and the suture passage. Although, in the veterinary field, the standing position of the surgeon is on the patientís ventral side, the surgeon in our report was standing on the patient's dorsal side. This standing position is common in surgical PDA ligation for infants. Thus, the surgeon was familiar with anatomical landmarks viewed in this position (Figure 6) rather than the ventral side position.

Before dissection around the ductus, the vagus nerve was retracted ventrally. Ventral retraction is described in both veterinary and human surgery for PDA (Mandhan et al., 2006; Valentik et al., 2007; Brockman et al., 2018).

Because the surgeon was standing on the dorsal side of the patient, retracting the vagus nerve ventrally toward the assistant, away from the surgeon, can give an advantage in terms of the working space.

The dissection of PDA was performed from the right to the left direction according to the surgeon's position. From his experience, since there is more space caudal to the ductus, it is easier to pass the tip of the right-angle forceps in that direction. Moreover, it is convenient to introduce the suture into the jaws of forceps when there is more room. Also, dissection from the right to the left might be more convenient for a right-handed surgeon. However, in this report, the direction of dissection and suture passage (although used in human surgery) is the opposite direction of the usual direction recommended in the veterinary field. The experienced surgeon contributed to successful ligation of the ductus without intraoperative complications. Authors encourage using methods that are well described and studied in small animals. Nevertheless, in older animals where the ductal surrounding tissue could be more fibrous, opening the cranial plane of the PDA is difficult. After creating a caudal dissection plane, changing the standing position can be beneficial to right-handed surgeons during the opening of the cranial plane since it aids with the hand direction during dissection.

Other methods to ligate PDA have been described and studied in small animals, including Jackson-Henderson and intrapericardial technique. Jackson-Henderson method avoids direct dissection of the PDA by passing the suture around the descending aorta on either side of the ductus. However, the incidence of residual flow was reported to be higher than that in the standard technique (Stanley et al., 2003).

Selmic et al. (2013), thoroughly described an intrapericardial technique. This technique provides a lower rate of residual flow than the others. In this technique, an incision is made into the pericardium and mediastinal pleura perpendicular to the ductus and immediately ventral to the insertion of fibrous pericardium. The location of the incision is limited because the fibrous pericardium is inseparable from the adventitia of the aorta at the level of the brachiocephalic trunk and from the adventitia of the pulmonary artery proximal to the bifurcation. This fibrous pericardium in the aorta and pulmonary artery adventitia was also noticed during surgery in our patient. The intrapericardial technique, when applicable, provides better visualization of the ventral aorta, pulmonary artery, and margins of the ductus. Blind dissection on the medial side of the ductus can be avoided. Moreover, less periductal tissue is included in the ligature. Thanks to these advantages, the rate of perioperative hemorrhage and echocardiographic residual flow are low.

In conclusion, our patient, a fully grown Pomeranian with left-to-right shunt PDA, underwent open surgical ligation. The surgical technique used in this study was similar to the human surgical PDA ligation technique (the details are mentioned in this report). Thanks to experience and skill of the surgeon, there were no intraoperative complications. Recovery was smooth, and the patient was discharged after three days of hospitalization. Cardiomegaly was improved after surgery. The long-term outcomes are to be monitored through clinical examination, thoracic radiography, echocardiography, and electrocardiography. Long-term outcome is expected to be good. A possible but rare, long-term complication is recanalization. It is 1%-3% for extrapericardial ligation and can develop six weeks to 37 months after surgery.

The overall result of the surgery was satisfactory up to the publication date.

Acknowledgments

The authors would like to express sincere appreciation to Dr. Piya Cherntanomwong for his kind and foremost cooperation. The authors would also like to thank Asst. Prof. Dr. Rungrote Osathanon for his valuable advice and the medical team at Prasu-Arthorn Animal Hospital for their great work in both pre- and postoperative medical management.

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