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Persistent ductus arteriosus in an elderly dog

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ABSTRACT

Patent ductus arteriosus (PDA) is characterized by the failure of complete closure of the communication between the aorta and the pulmonary trunk during the early stages of life and is frequently observed in young animals. This vascular connection originates from pulmonary non-functionality during the fetal period and should close shortly after birth. In the absence of complete closure, the patient becomes a carrier of PDA, often with hemodynamic consequences. The aim of the present case report is to describe a case of PDA in an elderly mixed-breed dog. A mixed-breed dog, approximately 12 years old, was referred for cardiological evaluation due to a history of excessive fatigue reported over the previous 60 days. Clinical and laboratory examinations revealed a continuous murmur localized over the pulmonary area. Additional diagnostic tests were requested for further investigation. On Doppler echocardiographic examination, the following findings were observed: continuous turbulent flow at the site of the ductus arteriosus in the pulmonary trunk (left-to-right shunting); a minimal ductal diameter ranging from approximately 4.3 to 5.7 mm; and no abnormalities in other cardiac structures. These findings confirmed the diagnosis of PDA. Given the presence of flow reversal, routine clinical monitoring was recommended.

Keywords: congenital heart disease, congenital defect, hemodynamics, ductal patency.

Persistência do canal arterial em cão idoso

RESUMO

A persistência do ducto arterioso (PDA) é caracterizada pela falha no fechamento completo da comunicação entre a artéria aorta e o tronco pulmonar durante os estágios iniciais de vida, sendo frequentemente observada em animais jovens. A ligação entre os vasos é derivada da afuncionalidade pulmonar no período fetal, que deveria ser ocluída logo após o nascimento e, na ausência de oclusão completa, o paciente se torna portador de PDA,

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geralmente com repercussão hemodinâmica. O objetivo do presente relato é descrever um caso de PDA em paciente sem raça definida idoso. Um cão, sem raça definida, com aproximadamente 12 anos de idade, foi encaminhado para avaliação cardiológica mediante histórico de cansaço excessivo, identificado há 60 dias. Ao exame clínico-laboratorial, constatou-se sopro contínuo em foco pulmonar. Exames complementares foram solicitados para maiores investigações. Ao exame ecodopplercardiográfico, notou-se: fluxo turbulento e contínuo em topografia do canal arterial no tronco pulmonar (direção esquerda-direita); diâmetro ductal mínimo de aproximadamente 4,3 – 5,7mm; demais estruturas sem alterações. Os achados foram conclusivos de PDA, e mediante a presença de reversão de fluxo, foi indicado apenas o monitoramento clínico rotineiro.
Palavras-chave: cardiopatia congênita, defeito congênito, hemodinâmica, patência ductal.

Introduction

Patent ductus arteriosus (PDA) is a congenital defect characterized by the failure of closure of the ductus arteriosus (Toom *et al.*, 2016). It is among the most common congenital heart diseases, with a worldwide prevalence ranging from 10% to 32% (Argenta *et al.*, 2018; Piantedosi *et al.*, 2019; Brambilla *et al.*, 2020). From an embryological perspective, the origin of the ductus arteriosus is partly explained by the absence of effective pulmonary function during fetal life, which facilitates blood circulation prior to birth (Toom *et al.*, 2016). In this context, pulmonary arterial pressure is higher than aortic pressure, resulting in blood flow from the pulmonary artery to the aorta (Toom *et al.*, 2016). After birth, with the establishment and development of pulmonary function, a reversal of the pressure gradient occurs, wherein aortic pressure exceeds pulmonary pressure. This change redirects blood flow from the aorta to the pulmonary artery, leading to the closure of the ductus arteriosus within the first week of life and the formation of the fibrous ligamentum arteriosum, a remnant of the ductus (Toom *et al.*, 2016).

In cases where the ductus fails to close or closes incompletely, the animal is considered to have a congenital condition and becomes susceptible to hemodynamic alterations. However, the extent of pulmonary communication determines the presence and severity of clinical signs. The most evident alterations include congestive heart failure (CHF) and signs such as pulmonary edema and congestion, concentric hypertrophy of the right ventricle, eccentric hypertrophy of the left ventricle, dilation of the atrioventricular and aortic trunks, and increased pulmonary blood flow (Toom *et al.*, 2016). In cases of flow reversal, animals may develop polycythemia and blood hyperviscosity (Toom *et al.*, 2016). The aim of the present case report is to describe the occurrence of PDA in an elderly mixed-breed dog.

Case description

A 12-year-old, 14 kg, neutered, dewormed, and vaccinated male mixed-breed dog was presented to a veterinary clinic in the metropolitan area of Belo Horizonte, Minas Gerais, Brazil, with a two-month history of progressive fatigue and lethargy. The animal was referred for a Doppler echocardiographic evaluation

under suspicion that the symptoms might be related to cardiovascular dysfunction. Physical examination revealed a heart rate (HR) of 132 bpm, a respiratory rate of 36 bpm, moist and normally pigmented mucous membranes, a rectal temperature of 38.1 °C, a muscle condition score of 3, and a body condition score of 6/9, according to the World Small Animal Veterinary Association (WSAVA) guidelines. Lymph nodes were normal in size, morphology, and dimension. The animal was clinically hydrated, with a negative jugular pulse, unremarkable abdominal palpation, and clear pulmonary auscultation, with no abnormalities detected in other examined regions. However, cardiac auscultation identified a continuous holosystolic murmur localized to the pulmonary area. Blood pressure measured by Doppler was 130 mmHg. Hematology, serum biochemistry (including urea, creatinine, alanine aminotransferase, aspartate aminotransferase, total proteins, and fractions), and urinalysis revealed no significant abnormalities. To complement the clinical evaluation and obtain a detailed cardiovascular morpho-functional analysis, electrocardiographic and Doppler echocardiographic examinations were recommended.

Electrocardiography showed sinus arrhythmia with a migrating pacemaker as the basal rhythm. The P-wave duration exceeded normal limits (0.46 ms), suggesting possible left atrial overload. Additionally, a T-wave amplitude exceeding 25% of the R-wave amplitude was observed, which may indicate nonspecific repolarization disturbances, potentially resulting from subtle myocardial oxygenation alterations and/or electrolyte or metabolic imbalances.

On echocardiographic evaluation, the animal, experiencing mild stress, had a heart rate (HR) of 100 bpm. Cardiac situs solitus with normal atrioventricular and ventriculoarterial concordance was confirmed. The left ventricle exhibited mild to moderate dilation, with a left ventricular diastolic internal diameter (LVIDd) of 42.0 mm and a normalized LVIDd of 1.9. Color Doppler imaging detected systolic mitral regurgitation. Aortic flow was laminar, though mild diastolic regurgitation was present, with a maximum velocity (Vmax) of 1.31 m/s and a pressure gradient (PG) of 6.83 mmHg, without apparent hemodynamic compromise. Pulmonary flow was laminar with mild diastolic regurgitation (Vmax = 1.12 m/s; PG = 5.02 mmHg), with minimal hemodynamic impact. The pulmonary artery trunk bifurcated normally but was dilated (pulmonary artery diameter: 19.6 mm; aorta: 16.0 mm; pulmonary-to-aortic ratio: 1.23) (figure 1).

Color doppler further revealed a continuous, turbulent flow within the pulmonary trunk, cranial to the pulmonary valve, predominantly directed left-to-right (aorta to pulmonary artery). The estimated Vmax of the turbulent flow was 4.82 m/s, with an approximate pressure gradient between the aorta and pulmonary artery of 93 mmHg. The minimum observed ductal diameter ranged from 4.3 to 5.7 mm, classified as medium to large according to Kittleson and Kienle (1998), although the sole clinical sign noted was fatigue.

The final echocardiographic diagnosis was a patent ductus arteriosus (PDA) with mild to moderate left ventricular overload. However, systolic and diastolic functional indices of the left ventricle remained within species-specific reference ranges. Therefore, the animal was diagnosed with PDA at 12 years of age based on echocardiographic

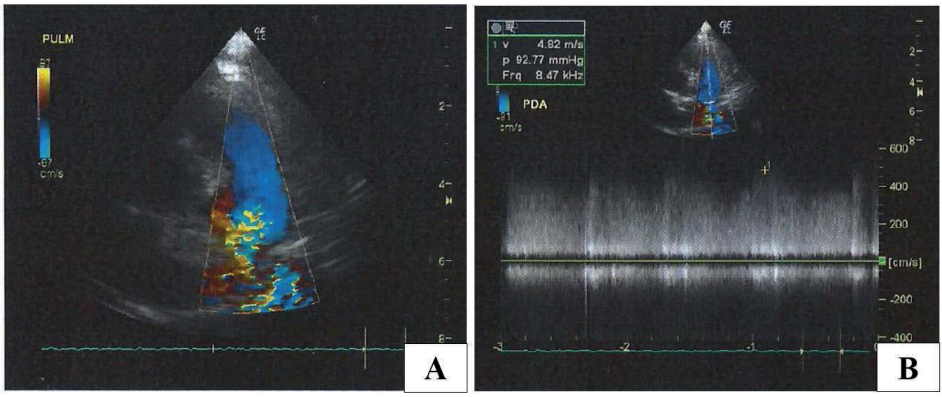

FIGURE 1. (A/B) Echocardiographic findings demonstrate the presence of a patent ductus arteriosus (PDA). Turbulent, continuous flow within the pulmonary trunk is observed, along with dilation of the pulmonary trunk and a continuous flow pattern characteristic of ductal patency.

Source: Own elaboration.

findings combined with clinical presentation (figure 1). Periodic follow-up examinations every 3-6 months were recommended. The attending clinicians informed the owner about the condition, emphasizing that surgical correction was not feasible due to flow reversal. Consequently, the owner was advised to continue monitoring the animal every 3-6 months, with a recommended reevaluation five days after the initial assessment to adjust pharmacological management if needed. However, the owner did not return for follow-up.

Discussion

The persistence of communication between the aorta and the pulmonary trunk is considered a congenital defect, primarily observed in young animals, and results from absent or incomplete closure between these vessels. According to Buchanan and Patterson (2003), normal closure of the ductus arteriosus requires the timely interaction of various morphological, biochemical, molecular, and environmental factors, many of which are influenced by gestational age and the consequent maturation of the ductus arteriosus and preparatory angiomalacia. Prior to the occlusion of the patent ductus arteriosus (PDA), blood flow occurs from the aorta to the pulmonary artery (left-to-right shunting) due to higher aortic pressure and the temporary non-functionality of the lungs (Toom et al., 2016). According to Greet et al. (2021), the direction of blood flow is influenced by factors associated with pulmonary and systemic resistance, favoring predominantly left-to-right shunting. In cases where patients present with concurrent pulmonary hypertension and PDA, blood flow may reverse from the pulmonary artery to the aorta (right-to-left shunting), leading to blood mixing and tissue oxygenation deficits (Toom *et al.,* 2016). The hemodynamic reasons for flow reversal are associated with increased pulmonary arterial pressure, changes in vascular resistance, and diversion of blood flow. Thus, in cases of PDA, either unidirectional or bidirectional flow may be observed, depending on the presence of

additional comorbidities (Toom et al., 2016). In the present case report, the patient was diagnosed with PDA via echocardiography following episodes of sudden fatigue and, at the time of evaluation, exhibited left-to-right flow (aorta to pulmonary artery).

PDA can be diagnosed at any age; however, it is most frequently identified in young animals (Toom *et al.*, 2016). Detection of PDA in older animals is less common compared to younger dogs (Toom *et al.*, 2016; Ro *et al.*, 2022), potentially due to the organism's compensatory capacity and the absence of classical clinical signs such as cyanosis and cough. The lack of evident clinical signs of PDA may be related to factors such as hemodynamic compensation, the size of the ductus, the animal's age, and overall health status, which could explain the absence of significant symptoms. Toom *et al.* (2016), in a study aimed at assessing the incidence, clinical presentation, and histopathology of PDA in dogs, reported that most diagnoses occurred in puppies, although a small proportion (n = 4) involved adult animals, indicating that late presentations are rare. In contrast to these findings, the animal in the present report was elderly at the time of diagnosis, which diverges from the data reported by Toom *et al.* (2016) and Ro *et al.* (2022), who primarily observed PDA in young animals. In this case, the defect was diagnosed at 12 years of age, and the delayed diagnosis may have resulted from the absence of adequate clinical evaluation during the animal's early life and the lack of obvious clinical signs.

Certain breeds, such as the Maltese, Chihuahua, and Pomeranian, are described as predisposed to PDA, although the defect may occur in any breed (Brambilla *et al.*, 2020; Grimes & Thieman Mankin, 2022). Congenital heart defects, particularly PDA, may be more frequently observed in mixed-breed dogs due to the blending of racial characteristics, potentially explaining its occurrence in non-pedigree dogs (Brambilla *et al.*, 2020). Data suggest that females are more commonly affected than males (Brambilla *et al.*, 2020; Grimes & Thieman Mankin, 2022), although the reason for this sex predilection remains unclear. Some studies have not reported significant sex-based differences in the occurrence of PDA (Toom *et al.*, 2016); however, in the present case, the affected patient was male, which contrasts with the findings of Brambilla *et al.* (2020) and Grimes and Thieman Mankin (2022). Furthermore, the animal was not from a breed traditionally predisposed to PDA, which aligns with Brambilla *et al.* (2020), who reported that approximately 43% of affected dogs were mixed breed.

According to Buchanan and Patterson (2003), changes observed in the wall of the ductus arteriosus in dogs with PDA may be a potential causal factor for the failure of ductal closure after birth. They noted that dogs may exhibit PDA sporadically, with morphological characteristics similar to those observed in hereditary cases, such as ductal hypoplasia, muscular asymmetry, and the presence of elastic tissue resembling that of the aorta within the ductus wall, which confers continued patency. The authors suggest that supposedly sporadic PDA may result from a genetic alteration of the ductal structure, partially resembling the presentation seen in Poodle breeds.

Ductus arteriosus occlusion is currently considered one of the most appropriate surgical procedures for the resolution of PDA, particularly to prevent complications such as congestion or cardiac insufficiency. However, there is a specific window during which occlusion should

be performed—namely, while the shunting remains left-to-right (Grimes & Thieman Mankin, 2022) and before any flow reversal occurs. If pressure overload leads to right-to-left shunting, occlusion should not be pursued; instead, the animal should undergo periodic monitoring and receive supportive medical management as needed. Cases of reversed PDA (right-to-left shunting) are not surgically manageable due to the high risk of cardiac failure and sudden death (Scurtu *et al.*, 2016). Although ductal occlusion remains the most frequently adopted approach, procedural complications such as ligature loosening or ductal rupture can occur (Grimes & Thieman Mankin, 2022). The use of more advanced therapeutic tools, such as Amplatzer vascular plugs and percutaneous closure (Bagardi *et al.*, 2022; Papa *et al.*, 2023; Wesselowski & Saunders, 2019), is not yet widely available in most veterinary centers in Brazil.

In the present case, the patient was not subjected to ductal occlusion due to the occurrence of flow reversal, although the procedure and its implications were thoroughly discussed. The decision to surgically intervene in PDA cases depends on multiple factors, including the patient's age, ductal size, and the presence of flow reversal; closure is contraindicated once right-to-left shunting has developed due to the associated elevated pulmonary pressure. Each case must therefore be evaluated individually. There is a hypothesis that the use of sildenafil may aid in the management of reversed PDA, although its efficacy remains controversial (Nakamura *et al.*, 2011; Greet *et al.*, 2021). Other pharmacological agents, such as prostacyclin analogs and endothelin receptor antagonists, have also been proposed, but their application remains poorly characterized in veterinary medicine. Given the delayed diagnosis, the clinical presentation (notably excessive fatigue over approximately 60 days), and the presence of flow reversal, periodic monitoring combined with supportive therapy, if necessary, was deemed the most appropriate management strategy.

The complications associated with PDA are highly variable and depend on numerous factors, including patient-specific characteristics, ductal diameter, hemodynamic status, and compensatory capacity. Some animals with PDA exhibit a range of clinical signs (Ro *et al.*, 2022), such as excessive fatigue, syncope, and coughing; however, asymptomatic cases are not uncommon, complicating early detection. Clinical manifestations associated with PDA vary based on intrinsic and extrinsic factors, including ventricular hypertrophy, aortic and pulmonary artery dilation, and cyanosis, among others (Toom *et al.*, 2016).

In the present report, the patient was referred for cardiological evaluation with a two-month history of excessive fatigue and a continuous murmur localized to the pulmonary area. More classical signs, such as coughing, cyanosis, and syncope, were not reported by the owner. The absence of overt cardiopulmonary symptoms may have delayed the suspicion and investigation of an underlying cardiovascular disorder, as owners typically seek veterinary evaluation only when noticeable clinical changes occur.

The echocardiographic findings reported herein are characteristic of PDA. In a case report by Ro *et al.* (2022), a 9-year-old Maltese female diagnosed with PDA exhibited severe left atrioventricular dilation, increased diastolic diameter, an elevated left atrium-to-aorta ratio, reduced fractional shortening, mitral regurgitation, pulmonary artery dilation, elevated aortic,

pulmonary, and transmitral flows, and severe diastolic dysfunction. The echocardiographic findings described by Ro *et al.* (2022) partially align with those in the present case. A notable difference was observed in the ductal diameter: Ro *et al.* (2022) reported a ductus diameter of 5.15 mm, whereas in the present case, measurements ranged from 4.3 to 5.7 mm. Based on these measurements and associated clinical findings, the ductus in this patient was classified as medium to large; however, it did not produce marked clinical repercussions. The right heart chambers in this patient maintained a pressure regime of approximately one-third to one-quarter that of the left ventricle.

The diameter of the ductus arteriosus partially explains why some animals maintain ductal patency into adulthood; hemodynamic complications are proportional to the volume of blood diverted from the physiological flow pathway (Pugliesi *et al.*, 2021). In the present case, the 12-year-old patient exhibited only mild clinical symptoms, suggesting that the persistent ductal diameter may have been relatively small or that incomplete closure occurred, which could account for the relatively mild clinical status despite the advanced age. However, these hypotheses remain speculative, as definitive imaging techniques, such as fluoroscopy, were not performed to precisely characterize the ductal morphology.

Routine clinical evaluation of puppies should be strongly encouraged, as it represents their first opportunity for assessment by trained professionals capable of detecting deviations from physiological norms. According to Pugliesi *et al.* (2021), presumptive diagnosis of PDA can often be made based on the auscultation of a strong, continuous "machinery" murmur, known as a Gibson murmur, especially in the left axillary region. Therefore, systematic clinical evaluation of puppies—ideally before initiating vaccination protocols (Vos & Szatmári, 2022)—is critical to detect and manage conditions that could adversely affect adult life. Furthermore, it is essential to inform prospective owners about the possibility of congenital defects when acquiring animals from certified breeders or adopting from shelters, including associated risks and available management options (Vos & Szatmári, 2022).

In the present case, suspicion of PDA could have arisen earlier through thorough veterinary examinations during routine auscultations, such as those performed at the time of primary vaccination. In such cases, early surgical correction might have been feasible following confirmation through Doppler echocardiography.

Conclusion

Patent ductus arteriosus (PDA) is a congenital condition characterized by persistent communication between the pulmonary trunk and the aorta. In the present case, the patient was diagnosed incidentally during an echocardiographic examination prompted by the onset of sudden fatigue. Due to the presence of flow reversal, surgical correction was deemed unfeasible, and routine monitoring was recommended instead. To date, the patient has not returned for follow-up clinical evaluations; however, at the time of the last assessment, the patient remained clinically stable.

An earlier diagnosis could have been achieved, for instance during the primary vaccination phase, had a thorough clinical evaluation been conducted. It is crucial that puppies undergo Doppler echocardiographic assessment whenever abnormal sounds are detected during

cardiopulmonary auscultation, to identify potential vascular communications. Early diagnosis may allow for timely and safe surgical intervention, ultimately promoting improved well-being and quality of life.

Conflict of interest

The authors declare no conflicts of interest.

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Use of artificial intelligence

No artificial intelligence tools were employed during the diagnostic or treatment processes, nor in the preparation of this manuscript.

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