https://doi.org/10.17221/76/2019-VETMED

Tetralogy of Fallot with right ventricular outflow tract obstruction and patent ductus arteriosus in a dog

*Seungjo Park[1], Mary Jasmin C. Ang[2], Mark D. Kittleson[3], Kyoung-Oh Cho[2], Jihye Choi[1]**

[1]*Veterinary Medical Imaging, College of Veterinary Medicine and BK 21 Plus Project Team, Chonnam National University, Yongbong-ro, Buk-gu, Gwangju, Republic of Korea*
[2]*Laboratory of Veterinary Pathology, College of Veterinary Medicine and BK 21 Plus Project Team, College of Veterinary Medicine, Chonnam National University, Yongbong-ro, Buk-gu, Gwangju, Republic of Korea*
[3]*Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California Davis, Davis, CA*

**Corresponding author: imsono@jnu.ac.kr*

Citation: Park S, Ang MJC, Kittleson MD, Cho KO, Choi J (2020): Tetralogy of Fallot with right ventricular outflow tract obstruction and patent ductus arteriosus in a dog. Vet Med-Czech 65, 320–326.

Abstract: In this study we describe the echocardiographic features of a complex cardiac defect with a right to left shunt through tetralogy of Fallot and also a left to right shunt through a patent ductus arteriosus (PDA) in a 3-year-old dog. The echocardiography revealed a tetralogy of Fallot with a severely hypertrophied right ventricular outflow tract (RVOT), and a left to right shunting PDA. A contrast echocardiogram showed microbubbles moving from the right ventricle to the aorta through the ventricular septal defect. They then reached the main pulmonary artery through the PDA rather than through the RVOT. The necropsy confirmed tetralogy of Fallot with an RVOT obstruction and a PDA. This patient could have maintained the pulmonary circulation through the PDA in the spite of the right ventricular outflow tract obstruction and survive a long period. Not only the echocardiography, but also the contrast echocardiogram using agitated saline and trans-sectional images in CT enhanced the comprehensive understanding of the anatomic defects in this complex cardiac defect.

Keywords: canine; computed tomography; contrast echocardiogram

Tetralogy of Fallot (ToF) is characterised by a pulmonary outflow tract obstruction, a large ventricular septal defect (VSD), an overriding (dextroposed) aorta, and right ventricle (RV) concentric hypertrophy (van Praagh 2009; Bussadori and Pradelli 2015). In ToF, the infundibular septum forms too far cranially. This results in a defect in the upper septum (VSD), the aorta being malpositioned (dextroposed), and the right ventricular outflow tract (RVOT) being narrowed. In children, infundibular pulmonary stenosis is the most common form of pulmonary stenosis identified (Karl and Stocker

Supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2018R1A2B6006775).

https://doi.org/10.17221/76/2019-VETMED

2016). In a few patients, the RVOT is occluded, as seen in the case described here. Presumably, most dogs born with ToF with an RVOT obstruction die at birth or soon after from a lack of pulmonary blood flow, once oxygenation is no longer provided by the maternal blood flow through the umbilical cord and once the *ductus arteriosus* and *foramen ovale* close. We report on a rare dog with ToF and an RVOT obstruction that survived because the *ductus arteriosus* remained patent, which allowed blood to flow through the pulmonary vasculature.

Case description

A 3-year-old female Maltese dog weighing 1.8 kg was presented with a heart murmur. The dog had no clinical signs of heart disease. The systolic blood pressure was 163 mmHg and the heart rate was 84 beats/minute.

A grade 5/6 systolic heart murmur was heard at the left heart base and a continuous heart murmur was heard at the left cranial sternal border. There were no abnormalities on the routine blood tests.

The thoracic radiographs revealed cardiomegaly (vertebral heart scale, 11.5), a large bulge in the aorta, and a proximal descending aorta bulge typical of a ductal aneurysm (Figure 1). A tentative diagnosis of a patent ductus arteriosus (PDA) was made.

On the echocardiography, a large VSD (9 mm) was seen along with an overriding aorta (Figure 2). The RV free wall was severely thickened (maximum of 9.5 mm), particularly in the RVOT. The pulmonary valve cusps appeared normal, but the echocardiographic window was limited for visualising the valve cusps clearly. The pulmonary valve annulus appeared normal and the ratio of the main pulmonary artery (MPA) to the aorta was in the reference range. The PDA was also visualised. On a colour flow Doppler, the blood flow shunted across the VSD from the RV to the left ventricle and aorta. The colour signal was not observed in the RVOT, however, a continuous aliased flow was observed in the MPA. In addition, mild mitral regurgitation, tricuspid regurgitation, and pulmonary valve insufficiency were identified.

A contrast echocardiography using a systemic venous injection of agitated saline was performed to determine the flow pattern and to improve the assessment of the RVOT. After the rapid injection of the agitated saline into the cephalic vein, the microbubbles flowed from the RV to the aorta through the VSD and then appeared in the PDA and MPA. The flow was not seen in most of the RVOT. Only a small number of microbubbles was regurgitated through the pulmonary valve from the MPA into a small distal section of the RVOT in diastole (Figure 3).

For a more detailed characterisation of the structural abnormalities, a cardiac computed tomography

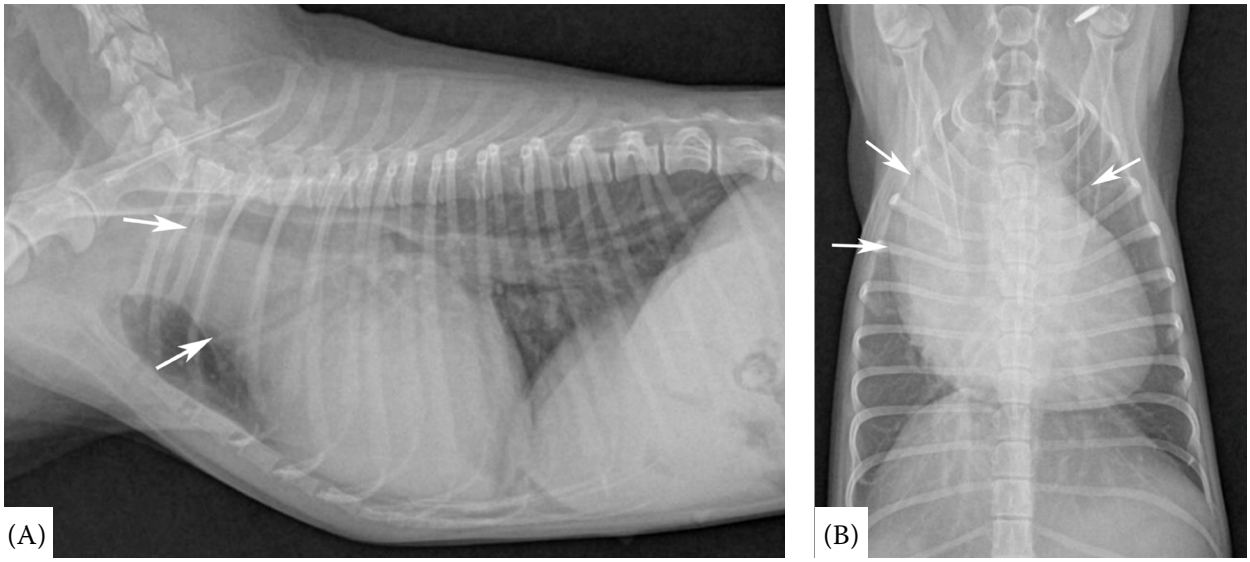

Figure 1. The right lateral (A) and ventrodorsal (B) thoracic radiographs of the dog. Note the cardiomegaly (vertebral heart scale 11.5 on the lateral view), and marked aortic bulging (arrows)

https://doi.org/10.17221/76/2019-VETMED

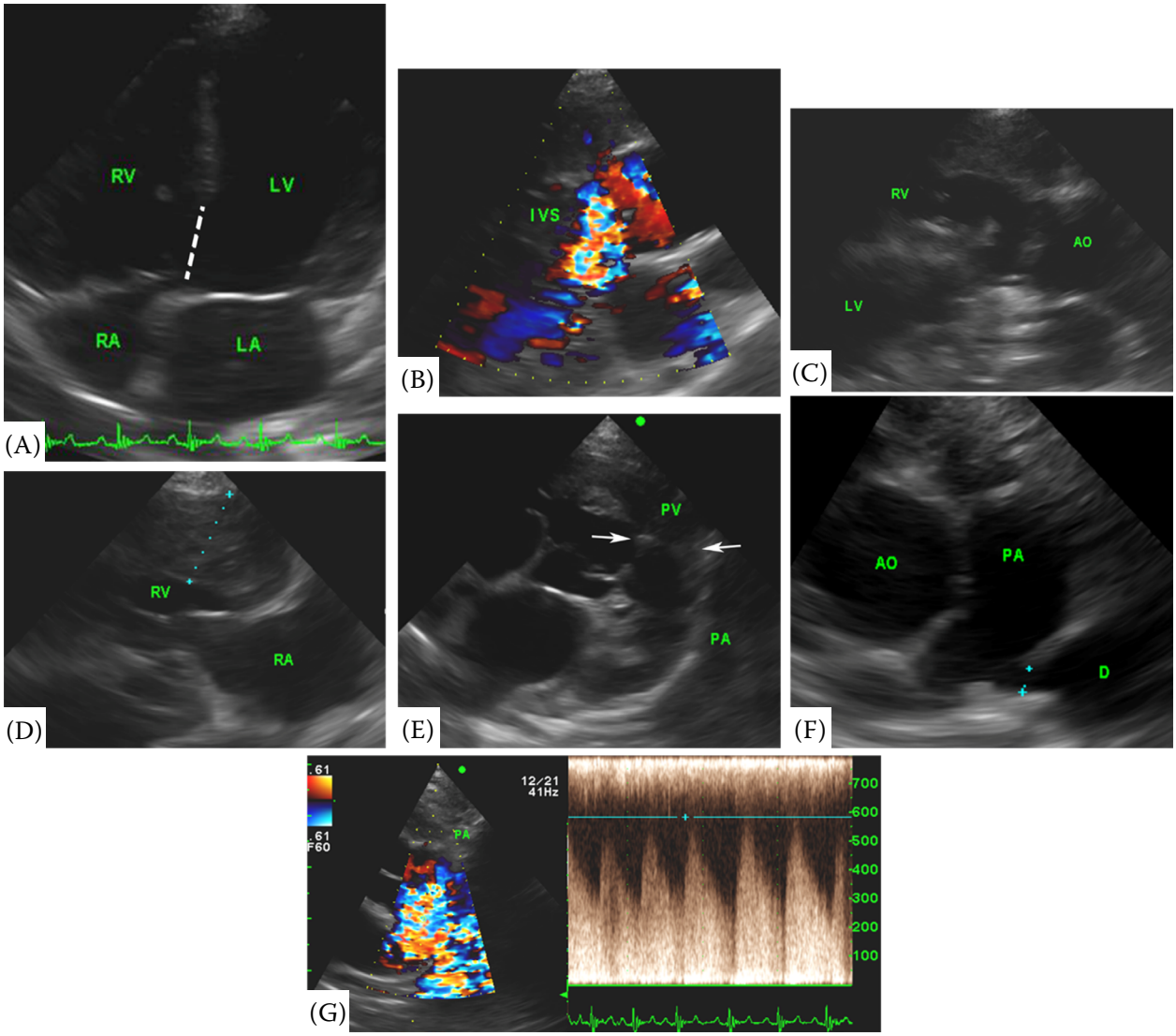

Figure 2. The echocardiogram of the dog. On the left apical 4 chamber view (A), a ventricular septal defect (dotted line) is seen about 9 mm in size. The right parasternal oblique 4 chamber view (B), a mosaic pattern of right to left shunting blood flow is observed through the septal defect on the colour flow Doppler mode. On the right parasternal oblique left ventricular outflow tract view (C), the aorta overrides the ventricular septum. On the left parasternal short axis view (D), the right ventricular free wall is severely thickened (9.5 mm) in diastole. The pulmonary valve cusps (arrows) appear normal (E). The ratio of the main pulmonary artery to the aorta (0.8) is in the normal reference range (F). The ductus (3.8 mm) connecting the main pulmonary artery to the aorta is seen on the short axis view (F). The turbulent flow within the main pulmonary artery shows a continuous flow pattern on the spectral Doppler (G)
AO = aorta; D = ductus; IVS = interventricular septum; LA = left atrium; LV = left ventricle; PA = main pulmonary artery; PV = pulmonary valve; RA = right atrium

(CT) was performed under general anaesthesia using a 16-slice CT scanner (Somatom Emotion, Siemens, Germany). An intravenous bolus of 400 mg iodine/kg of iohexol (Omnihexol 300; Korea United Pharm Co, Seoul, Republic of Korea) diluted in normal saline (1 : 2) was administered (Kim et al. 2015). Besides, the VSD, the overriding aorta, and the RV hypertrophy, a conical PDA (ostium = 3.8 mm diameter) was identified (Figure 4). Most of the RVOT, except for the distal section of it, was not filled with the contrast medium, which was consistent with an RVOT obstruction. The dog was diagnosed with tetralogy of Fallot (ToF) with an RVOT obstruction and a PDA. Because the dog had no clini-

https://doi.org/10.17221/76/2019-VETMED

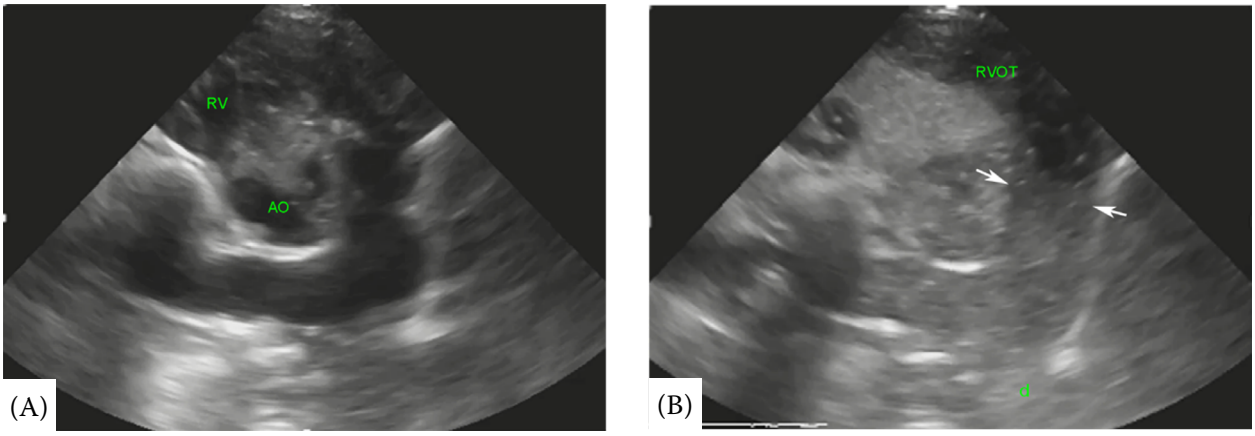

Figure 3. The contrast echocardiogram using agitated saline. The right parasternal short axis view. The microbubbles moved from the right ventricle to the aorta through the ventricular septal defect (A) and then appeared in the main pulmonary artery (arrows) via the patent ductus arteriosus (B). The right ventricular outflow tract was not filled with bubbles (B). Instead, the bubbles flowed from the ductus (d) to the main pulmonary artery and were then regurgitated into the small distal section of the right ventricular outflow tract at diastole

AO = aorta; RV = right ventricle; RVOT = right ventricular outflow tract

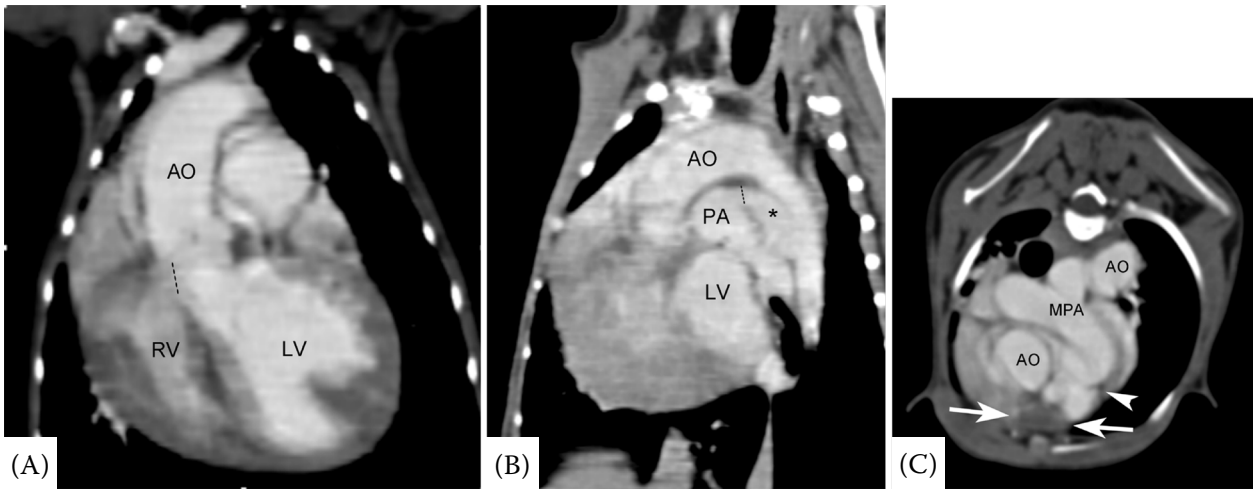

Figure 4. The contrast cardiac CT. (A) In the dorsal reformatted image, a ventricular septal defect (dotted line), overriding aorta, and right ventricular hypertrophy can be detected. (B) The conical patent ductus arteriosus (asterisk) is seen and the ductal ostium diameter is 3.8 mm (dotted line). (C) The transverse image shows a region not filled with contrast medium within the right ventricular outflow tract (arrows) immediately below the pulmonary valve (arrow head)

AO = aorta; LV = left ventricle; MPA = main pulmonary artery; PA = pulmonary artery; RV = right ventricle

cal signs and there were no surgical options, only regular re-examinations were planned for the dog. On day 945 after the initial examination, the dog was still clinically normal although the respiratory rate (44 breaths/min) was slightly increased. The dog was given no medications. On the repeated radiography and echocardiography performed every 4 to 5 months, there was no specific change although the right side of the cardiac silhouette looked more prominent compared with the previous radiographs. A syncope occurred on day 1 072 followed by another on day 1 117. The owner did not seek medical attention and the dog died suddenly on day 1 174. A necropsy confirmed the VSD, overriding aorta, mildly dilated MPA with a PDA, and a uniform hypertrophy of RV. The lumen of most of the RVOT was not formed and obstructed by the myocardium except for a small distal section (Figure 5).

https://doi.org/10.17221/76/2019-VETMED

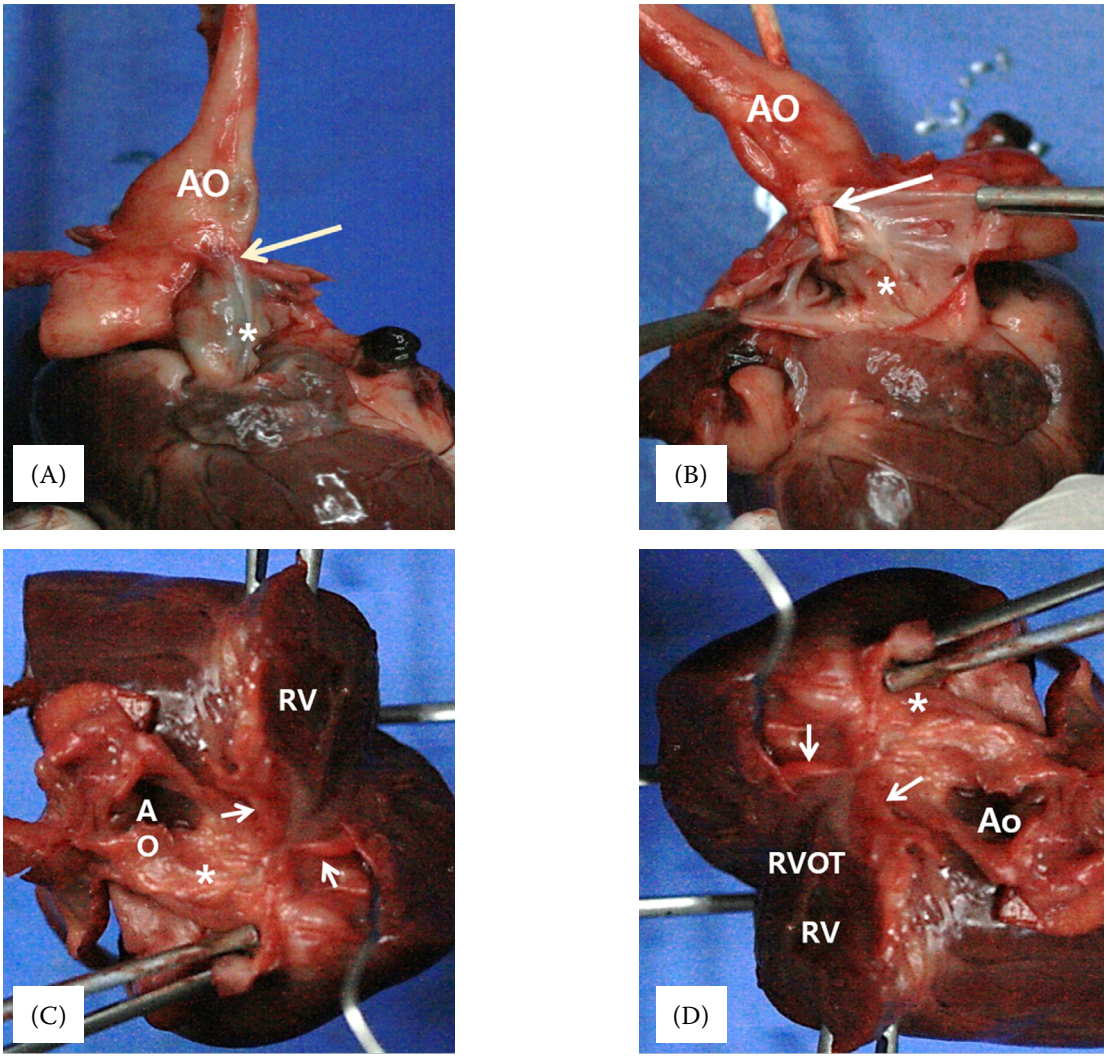

Figure 5. The gross post-mortem specimen. (A) The patent ductus arteriosus (long arrow) is seen between the main pulmonary artery and the aorta. (B) The lumen of the pulmonary artery has been opened. The stick has been passed through the ostium of the patent ductus arteriosus (long arrow). (C, D) The right ventricle has been opened and the area of the right ventricular outflow tract has been cut across. The pulmonary valve cusps (short arrows) are identified. The atretic region lies between the right ventricle and the valve cusps. Asterisk, the main pulmonary artery
AO = aorta; RV = right ventricle; RVOT = right ventricular outflow tract

The pulmonary valve cusps looked short and not fully formed, consistent with hypoplasia. The *tunica intima* of the aorta, pulmonary artery, and coronary vessels were thickened, and the neovascularisation of the RV myocardium was observed on the microscopic examination. The dog was diagnosed with ToF with an RVOT obstruction and a PDA.

DISCUSSION AND CONCLUSIONS

This study described the echocardiographic and CT findings of a dog with ToF with an RVOT obstruction concurrent with a PDA. The right cardiac outflow was completely or extremely restricted going into the pulmonary circulation due to the RVOT obstruction, however, the dog was free from clinical signs for a long time. The longer survival of the dog in this report could be explained by the concurrent PDA, which allowed the blood to flow through the pulmonary vasculature. While this may appear to be serendipitous, in a study about the colony of Keeshond dogs with conotruncal malformations such as ToF, pulmonary atresia with VSD, a double-outlet right ventricle, a double-outlet left ventricle, *truncus arteriosus*, and a trans-

https://doi.org/10.17221/76/2019-VETMED

position of the great arteries, 19 of the 352 (5%) also had a PDA (Patterson et al. 1974).

In human medicine, ToF with an RVOT obstruction can be diagnosed by means of echocardiography (Murthy et al. 2010). The RVOT obstruction can occur at the infundibular, valvular or pulmonary artery level. A careful scanning technique and combining the two-dimensional and colour flow Doppler modes are needed for demonstrating the lesion. However, there is an echocardiography limitation in order to demonstrate all kinds of cardiac defects and blood flow in some cases. In the previous two dogs reported with VSD with an RVOT obstruction, the VSD, overriding aorta, and RV hypertrophy were identified on the echocardiography, but the atretic lesion could not be diagnosed with a transthoracic echocardiography (Tou et al. 2011; Fukushima et al. 2013). Moreover, these cases must have a route, such as aortopulmonary collateral arteries, for the blood to reach the pulmonary circulation by some other means, since blood cannot flow from the RV to the pulmonary artery in the cases of ToF with an outflow obstruction (Park and Kim 1992; Murthy et al. 2010). Consequently, angiography and/or transoesophageal echocardiography was needed to confirm a VSD with an outflow obstruction and aortopulmonary collateral circulation or a PDA (Neches et al. 1990; Park and Kim 1992; Murthy et al. 2010).

The echocardiography, in our case, revealed the VSD, the overriding aorta, the RV hypertrophy, and the PDA. The RVOT could not be adequately evaluated due to the limited echocardiographic window. At first, a pulmonary stenosis was thought to be present because a fibrous valvular tissue was observed and there was a normal MPA. The complete obstruction of the RVOT was not suspected because there was a colour signal in the distal section of the RVOT. The RVOT obstruction and the direction of the blood flow could be demonstrated with a contrast echocardiography. Using a frame-by-frame video analysis, microbubbles were observed to move from the RV to the aorta through the VSD and then appeared in the PDA and the MPA. The bubbles then entered the distal section of the RVOT via the pulmonary insufficiency in diastole. A cardiac CT is helpful for determining the anatomy of complex congenital cardiac abnormalities in humans, including ToF with an outflow obstruction (Shiraishi et al. 2003). The obstruction of the RVOT, in our case, was observed as a lack of contrast filling in the RVOT and seeing the RVOT replaced by a hypoattenuating myocardium on the cardiac CT.

The severity of the clinical signs and prognosis of ToF with an outflow obstruction depends primarily on the magnitude of the aorta to the pulmonary artery shunt through the major aortopulmonary arteries or the PDA (van Praagh 2009; Bussadori and Pradelli 2015). In human medicine, approximately half of the patients with VSD accompanying an outflow obstruction survive until one year of age and only 8% survive to age 10 (Bertranou et al. 1978). A 4-month-old Labrador Retriever and a 2-year-old Terrier mix, which had the same cardiac malformation, survived more than 3 months and more than 30 months (the exact survival times were not presented in the reports), respectively, although they had clinical signs such as exercise intolerance, cyanosis, cough, tachypnoea, and/or pelvic limb collapse (Tou et al. 2011; Fukushima et al. 2013). The present case was subclinical at presentation and did not have any clinical signs until day 945 (31 months). Although the magnitude ratio of the aorta to the pulmonary artery was not quantified, the dog could have obtained a sufficient quantity of pulmonary blood supply through the PDA. The dog died suddenly, presumably from ventricular fibrillation of the massively hypertrophied RV.

This study described the two-dimensional echocardiographic, contrast echocardiographic, and cardiac CT features of a dog with a complex cardiac malformation – ToF with an RVOT obstruction and a PDA. To the authors' knowledge, this is the first report of echocardiographic and CT findings of these complex cardiac malformations in a dog. The echocardiography visualised the VSD, overriding aorta, RV hypertrophy, and PDA, but the RVOT obstruction could not be identified. An echocardiographic contrast study clarified the blood flow between the chambers and large vessels and identified the complementary blood circulations – a right to left shunting VSD and a left to right shunting PDA. The cardiac CT confirmed the RVOT obstruction. A contrast echocardiography and cardiac CT can be useful in evaluating ToF with an RVOT obstruction in order to demonstrate the cardiac lumen and blood flow through the cardiac defects.

Conflict of interest

The authors declare no conflict of interest.

https://doi.org/10.17221/76/2019-VETMED

REFERENCES

Bertranou EG, Blackstone EH, Hazelrig JB, Turner ME, Kirklin JW. Life expectancy without surgery in tetralogy of Fallot. Am J Cardiol. 1978 Sep;42(3):458-66.

Bussadori C, Pradelli D. Congenital cardiopathies. In: de Madron E, Bussadori C, Chetboul V, editors. Clinical echocardiography of the dog and cat. Saint Louis, Mo: Elsevier; 2015. p. 285-322.

Fukushima R, Yoshiyuki R, Machida N, Matsumoto H, Kim S, Hamabe L, Huai-Che H, Fukayama T, Suzuki S, Aytemiz D, Tanaka R, Yamane Y. Extreme tetralogy of Fallot in a dog. J Vet Med Sci. 2013;75(8):1111-4.

Karl TR, Stocker C. Tetralogy of Fallot and its variants. Pediatr Crit Care Med. 2016 Aug;17(8 Suppl 1):S330-6.

Kim J, Bae Y, Lee G, Jeon S, Choi J. Dynamic computed tomographic determination of scan delay for use in performing cardiac angiography in clinically normal dogs. Am J Vet Res. 2015 Aug;76(8):694-701.

Murthy K, Reddy KP, Nagarajan R, Goutami V, Cherian K. Management of ventricular septal defect with pulmonary atresia and major aorto pulmonary collateral arteries: Challenges and controversies. Ann Pediatr Cardiol. 2010 Jul;3(2):127-35.

Neches WH, Park SC, Ettedgui JA. Tetralogy of Fallot and tetralogy of Fallot with pulmonary atresia. In: Garson A, Bricker JT, McNamara DG, editors. The science and practice of pediatric cardiology. Philadelphia: Lea & Febiger; 1990. p. 1073-100.

Park KS, Kim DY. The major aortopulmonary collateral arteries in pulmonary atresia with ventricular septal defect: Chest radiologic findings. Korean J Radiol. 1992 Nov; 28(6):875-80.

Patterson DF, Pyle RL, Van Mierop L, Melbin J, Olson M. Hereditary defects of the conotruncal septum in Keeshond dogs: Pathologic and genetic studies. Am J Cardiol. 1974 Aug;34(2):187-205.

Shiraishi I, Yamamoto Y, Ozawa S, Kawakita A, Toiyama K, Tanaka T, Sakata K, Hayano T, Itoi T, Yamagishi M, Hamaoka K. Application of helical computed tomographic angiography with differential color imaging three-dimensional reconstruction in the diagnosis of complicated congenital heart diseases. J Thorac Cardiovasc Surg. 2003 Jan;125(1):36-9.

Tou SP, Keene BW, Barker PC. Pulmonary atresia and ventricular septal defect with aortopulmonary collaterals in an adult dog. J Vet Cardiol. 2011 Dec;13(4):271-5.

van Praagh R. The first Stella van Praagh memorial lecture: The history and anatomy of tetralogy of Fallot. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu. 2009:19-38.

Received: June 21, 2019
Accepted: May 24, 2020