CASE STUDIES in CARDIOTHORACIC MEDICINE

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Foreword by
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VIDEOS INCLUDED

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CASE 18. TETRALOGY OF FALLOT

SIGNALMENT

Breed: French Bulldog
Age: 8 months old
Sex: Male, intact
Presenting complaint: Exercise intolerance, cyanosis, heavy breathing episodes, and loud heart murmur

CLINICAL EXAMINATION

On presentation, the patient could not walk more than a few steps without severe dyspnoea. His respiratory rate was variable but increased to 60 breaths per minute with exertion. The mucous membranes were dull pink, with a prolonged capillary refill time (3 seconds). The patient weighed 10.1 kg and had a subnormal body condition score (4/9). Auscultation revealed a loud grade IV/VI systolic heart murmur at the left base and a heart rate of 132 bpm. Abdominal palpation was unremarkable.

DIAGNOSTIC INVESTIGATION

A limited biochemical profile was performed and revealed no significant abnormalities. The total protein concentration was 68 g/l. A packed cell volume (PCV) of 84 % was measured (reference 35–55 %), which indicated severe polycythaemia.

ELECTROCARDIOGRAPHY

Sinus rhythm was present, with a right axis deviation (deep S waves in lead II and positive QRS complexes in aVR), suggestive of right ventricular enlargement (Fig. 1).

ECHOCARDIOGRAPHY

Severe right ventricular hypertrophy and right atrial dilation were detected (Fig. 2, Videos 1 and 2). A large subaortic ventricular septal defect (VSD) was present, with malposition of the aorta to the right side of the septum. Flow through the VSD was present from the right to the left side, which explained the polycythaemia. The pulmonary artery was hypoplastic. Doppler imaging defined a severe pulmonic stenosis and a narrowing of the pulmonary trunk at the valvular and supravalvular levels (Fig. 3, Video 3).

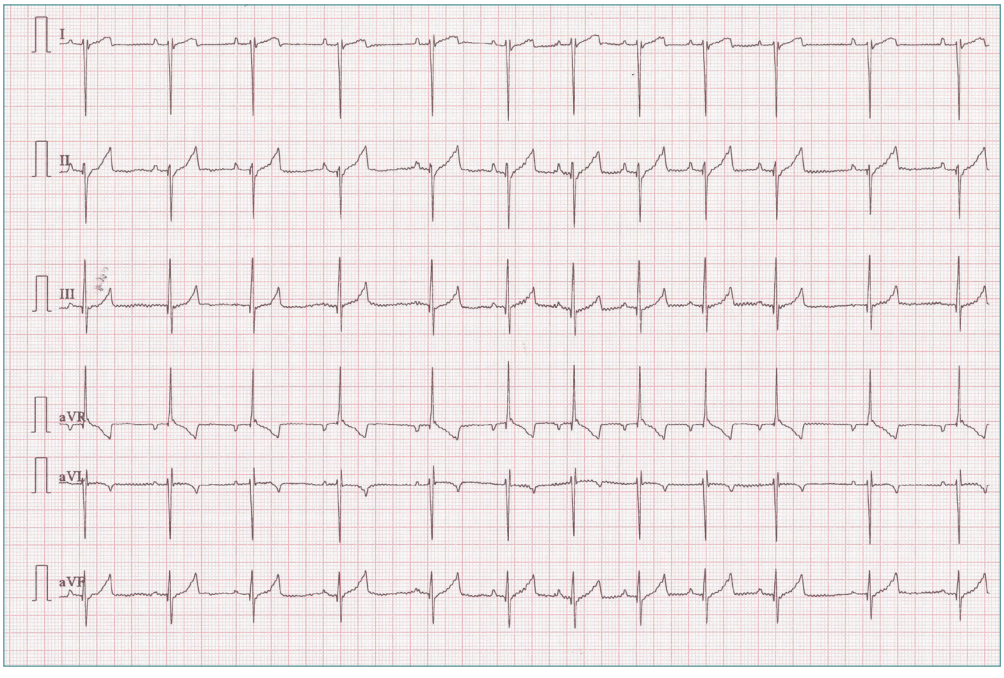

FIGURE 1. Electrocardiogram showing sinus rhythm with a marked right axis deviation. [50 mm/s, 10 mm/mV].

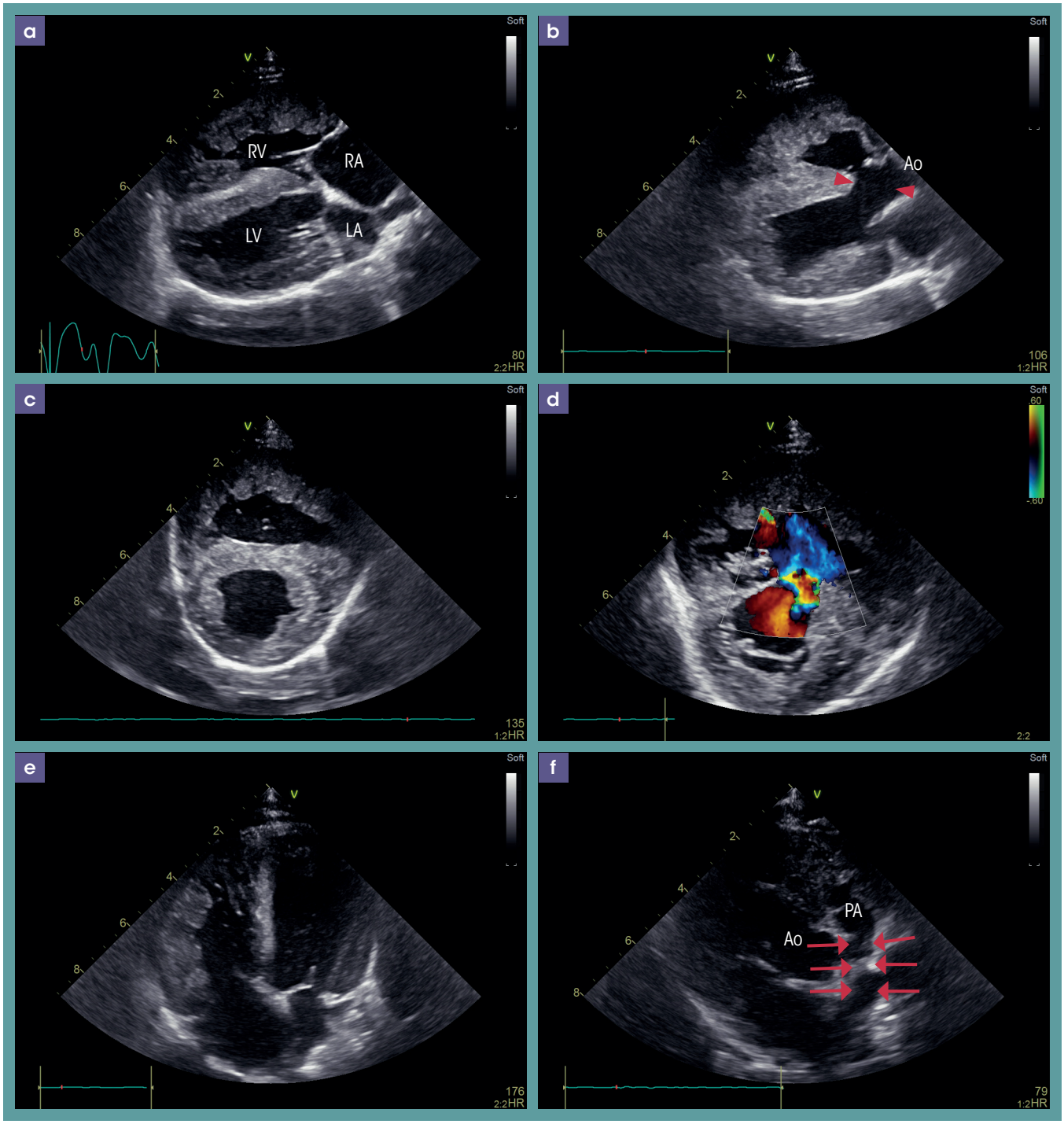

FIGURE 2. Echocardiographic images showing major abnormalities in the heart. Severe right ventricular hypertrophy and dilation can be seen in the right parasternal long-axis view (a) and short-axis view (c) and in the left apical four-chamber view (e). A large ventricular septal defect (VSD) can be identified in the long-axis view (b)—the VSD is indicated by arrowheads below a dextropositioned aortic root—and in the short-axis colour flow Doppler scan (d). In image f, note the hypoplastic region in the pulmonary artery (delineated by arrows). Ao, aortic root; LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle.

Video 1
Right parasternal long-axis echocardiographic view showing severe right ventricular hypertrophy in this case of tetralogy of Fallot.

Video 2
Colour flow Doppler echocardiogram showing a large inlet ventricular septal defect below the aortic annulus with bidirectional flow.

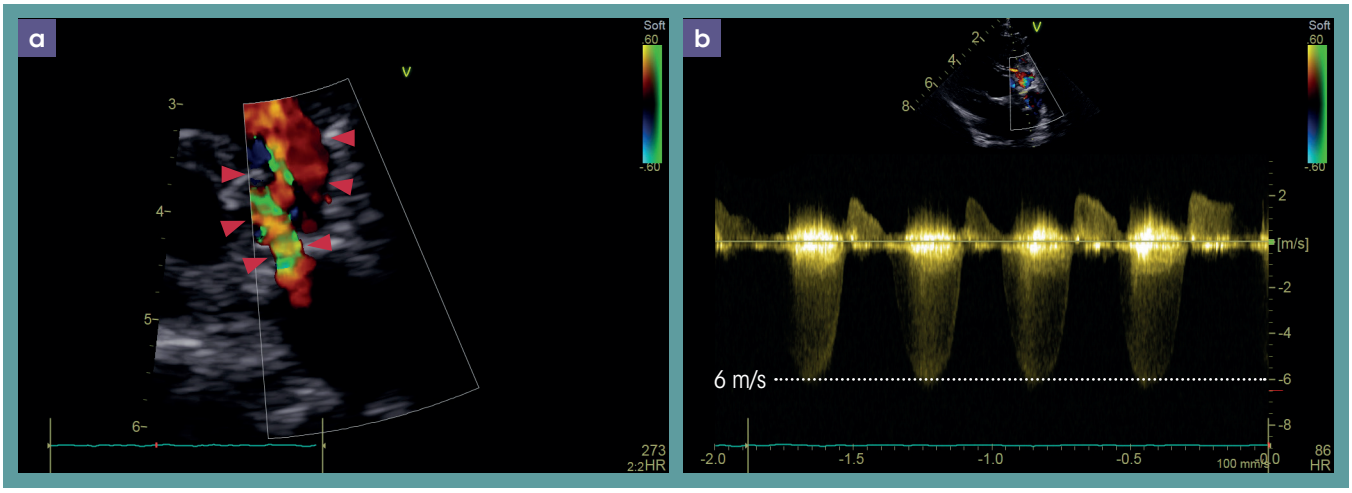

FIGURE 3. Doppler assessment of the hypoplastic, stenotic pulmonary artery. Colour flow Doppler mapping over the pulmonary valve (a) shows a tortuous, narrow route for blood flow and two apparent regions of stenosis (arrowheads). Continuous wave Doppler interrogation of flow across the hypoplastic region (b) identifies a maximum velocity of over 6 m/s, which is consistent with a very severe stenosis and a systolic right ventricular pressure of at least 169 mmHg (normal 25 mmHg).

Video 3
Right parasternal short-axis echocardiographic view showing a hypoplastic pulmonary annulus with components of annular and artery hypoplasia. Pulmonic stenosis and insufficiency can be identified on colour flow Doppler.

The diagnosis was tetralogy of Fallot (TOF), based on the presence of a VSD, a dextropositioned aorta, pulmonary hypoplasia, and right ventricular hypertrophy.

TREATMENT

Phlebotomy was performed to lower the PCV (target approximately 65 %) and thereby reduce the risk of complications associated with hyperviscosity syndrome such as tissue ischaemia. According to the formula below, a volume of 183 ml of blood was drawn from the left jugular vein with a butterfly needle and an extension set. A replacement volume of crystalloids was administered over a similar time frame, and then 4 ml/kg/h intravenous crystalloids followed for 12 hours.

Propranolol was prescribed (0.5 mg/kg every 8 h, up-titrated to reduce the heart rate) as a mixed-efficacy β-blocker to reduce right-to-left shunt flow and myocardial work at exertion. Given the risk associated with a primary repair surgery under cardiopulmonary bypass, a minimally invasive stenting procedure was elected for this patient.

Minimally invasive pulmonary artery stenting or primary surgical solutions are a more definitive treatment for tetralogy of Fallot than medical therapy.

Under general anaesthesia, the right femoral vein was surgically exposed and isolated. After securing vascular access, a pigtail angiographic catheter was passed through the caudal vena cava and into the right ventricle. The angiogram identified the position of the hypoplastic pulmonary trunk and showed concurrent opacification of the aorta, which confirmed the right-to-left shunt (Fig. 4a, Video 4). The angiographic catheter was then removed, and a rigid guidewire was positioned across the pulmonic stenosis, in a branch pulmonary artery.

Formula to calculate the volume of blood to be removed by phlebotomy in a patient with polycythaemia

$$\text{Blood to be withdrawn (ml)} = (\text{Body weight [kg]} \times 0.08) \times 1000 \times \frac{(\text{Actual PCV} - \text{Desired PCV})}{\text{Actual PCV}}$$

A delivery sheath was advanced over the guidewire, and a balloon-expandable metallic vascular stent was positioned to cover the stenotic region. After withdrawing the delivery sheath, the balloon was inflated to expand the stent in position (Fig. 4b, Video 5). Inflation at 8 atm of pressure was held for 3 seconds, and then the balloon was deflated and withdrawn. A repeat right ventricular contrast injection revealed that flow through the pulmonary trunk had improved and that the right-to-left shunt had resolved (Fig. 4c, Video 6). Following catheter removal, the femoral vein was ligated.

Video 4

Angiogram performed from a femoral vein approach with a pigtail catheter located in the right ventricle. Contrast can be seen opacifying the pulmonary artery first (hypoplastic) followed by simultaneous opacification of the aorta, confirming a right-to-left shunting ventricular septal defect.

Video 5

Fluoroscopic video showing inflation of a high-pressure balloon to deploy a transvalvular pulmonic stent across the stenotic lesion.

Video 6

Repeated injection of contrast in the right ventricle after stenting, showing good flow across the transvalvular pulmonic stent with no visible right-to-left shunt flow across the ventricular septal defect.

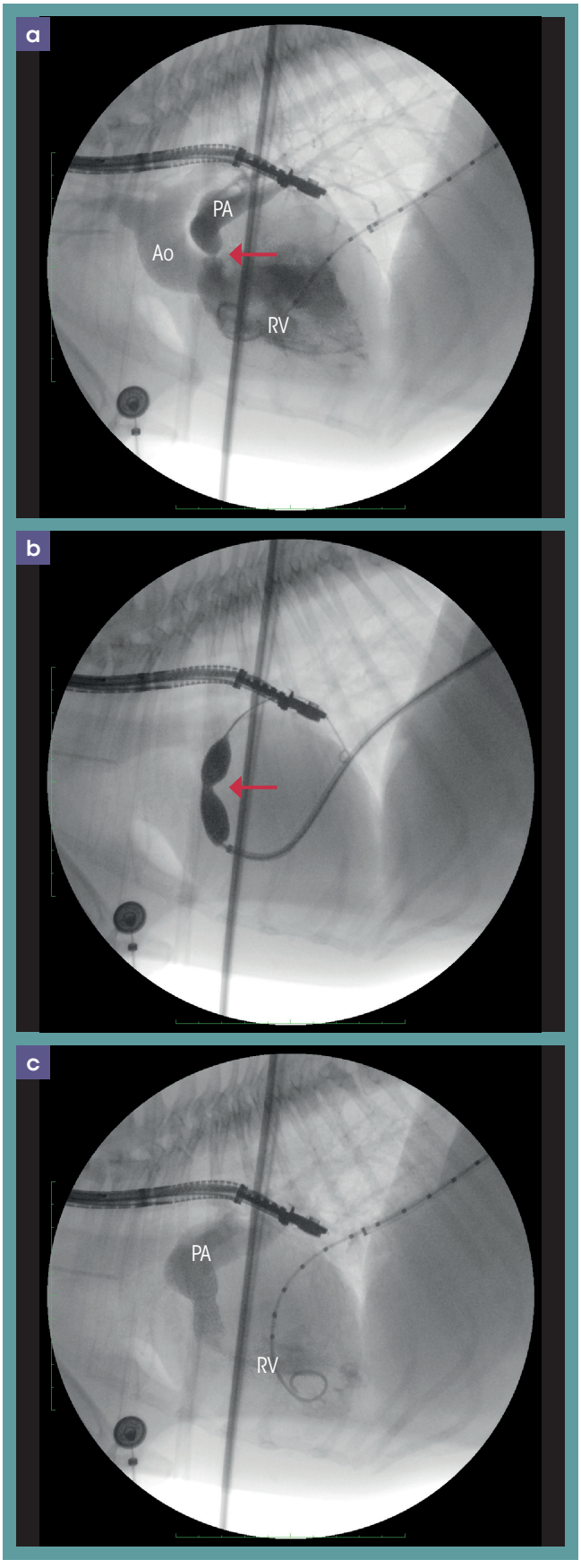

FIGURE 4. Fluoroscopic images illustrating the deployment of the transvalvular pulmonic stent. A transoesophageal echocardiography probe is visible dorsal to the heart in all images. Contrast injection in the right ventricle (RV) (a) showed simultaneous opacification of the pulmonary artery (PA) and aorta (Ao), a characteristic sign of a right-to-left intracardiac shunt; the pulmonary artery is very small in comparison to the aorta and a marked stenosis is visible just beyond the pulmonic valve (arrows). The balloon was inflated to deploy the metallic stent (b). An angiogram performed after the procedure (c) showed resolution of the stenosis and no further evidence of shunt flow.

The patient recovered well and was discharged 24 hours later with instructions for 10 days of lead rest. Clopidogrel was prescribed (18.75 mg every 24 h) to reduce the risk of stent thrombosis and subsequent occlusion. At 4 and 6 months after the procedure, the dog was clinically much improved. Exercise tolerance had greatly improved and polycythaemia had resolved (PCV 44 %).

DISCUSSION

TOF is a complex conotruncal malformation that occurs due to a failure in the process of spiral septation of the embryonic structures of the cardiac conus and truncus arteriosus, which fail to develop normally into the basilar interventricular septum, aorta, and pulmonary artery. Dogs with TOF experience high right ventricular systolic pressure because of pulmonary artery hypoplasia and exposure of the ventricle to systemic pressures by malpositioning of the aorta over a large VSD. This leads to a right-to-left intracardiac shunt. A range of patient presentations exist for TOF, but exertional dyspnoea and cyanosis are the most common. The key findings which should raise concern of TOF are a loud left basilar murmur (from the pulmonic stenosis), a prominent right-sided apical impulse (from the right ventricular hypertrophy), and polycythaemia.

Dogs with tetralogy of Fallot commonly present with exertional dyspnoea, cyanosis, and polycythaemia.

Polycythaemia secondary to the release of erythropoietin is an appropriate physiological response of the body to systemic hypoxaemia associated with TOF. Hyperviscosity syndrome, caused by an excessively high PCV (typically >75 %), can cause exercise intolerance owing to poor muscle perfusion, tachypnoea owing to poor pulmonary perfusion, and neurological signs caused by poor brain perfusion. When this syndrome is present, treatment is urgent. In the case presented here, the PCV of 84 % was considered an emergency. Phlebotomy, followed by appropriate fluid therapy, is the fastest way to relieve the clinical signs.

In the longer term, the signs may be controlled using a mixed β-blocker such as propranolol: β_1-receptor blockade reduces myocardial oxygen demand and has a cardioprotective effect, and β_2-receptor blockade reduces the degree of systemic vasodilation that occurs at exertion and thereby limits the right-to-left shunt at exercise. However, such β-blocker therapy to control the shunt direction is unlikely to be effective alone in the medium- to long-term. A more definitive solution may be to reduce right ventricular afterload and thereby promote more balanced or even left-to-right flow.

In the case described here, pulmonary artery stenting was performed to abolish the right-to-left shunt. The PCV normalised within weeks, and the owners reported a great improvement in the dog's quality of life. If stenting fails or is not an option, pulmonary flow may be surgically increased either by using a modified Blalock–Taussig–Thomas shunt or by operating directly on the right ventricular outflow tract to overcome the pulmonary artery hypoplasia. Other techniques, such as using a conduit or a patch graft, have also been reported. As a last resort and when surgery is not possible, hydroxyurea may be administered to control the clinical signs. This drug is a bone marrow suppressant which reduces erythropoiesis and therefore PCV. Titration to effect is necessary (target PCV of 50–60 %). Adverse effects are possible, including gastrointestinal signs, skin and hair coat changes, and damage or loss of the claws. Despite these considerations, hydroxyurea can be an effective drug that maximises the quality of life in dogs with TOF.

Medical treatment of tetralogy of Fallot includes propranolol to reduce vasodilation associated with exertion and phlebotomy or bone marrow suppressants, such as hydroxyurea, to control the packed cell volume.

CASE 28. PARASITIC PNEUMONIA. *ANGIOSTRONGYLUS VASORUM*

SIGNALMENT

Breed: Crossbred dog
Age: 3 years old
Sex: Female, neutered
Presenting complaint: Ten-day history of anaemia, lethargy, tachypnoea, and dyspnoea

CLINICAL EXAMINATION

The dog was quiet, alert, and responsive. The mucous membranes were pale, with a prolonged capillary refill time. The peripheral pulses were weak. The heart rate was 90 bpm and the respiratory rate was 60 breaths per minute. Thoracic auscultation revealed increased lung sounds. Abdominal palpation and the patient's body temperature were normal. There was marked bilateral scleral haemorrhage, multiple petechiae in the mucosa, and large, ill-defined bruising and haematomas under the skin surface (Figs. 1 and 2).

DIAGNOSTIC INVESTIGATION

A routine complete blood cell count and biochemistry profile revealed a moderate regenerative anaemia (PCV 15 %), marked thrombocytopaenia (7×10^9/l) and mild leucocytosis (18.3×10^9/l, reference $6.0–15.0 \times 10^9$/l).

Blood coagulation tests revealed increased activated partial thromboplastin time (APTT) and prothrombin time (PT) with a markedly increased buccal mucosal bleeding time (BMBT), suggesting a consumptive coagulopathy.

ABDOMINAL ULTRASONOGRAPHY

A conscious abdominal ultrasound was performed and showed a moderate amount of echogenic retroperitoneal effusion. The fluid was sampled under ultrasound guidance and was consistent with blood (Fig. 3).

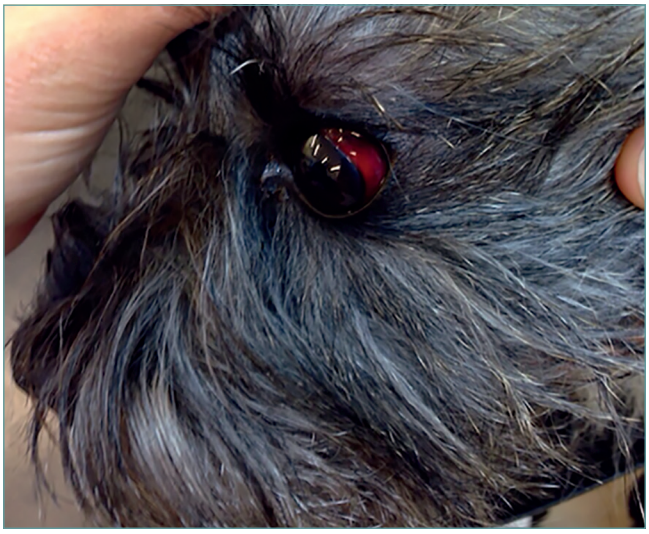

FIGURE 1. Image of the patient with marked scleral haemorrhage.

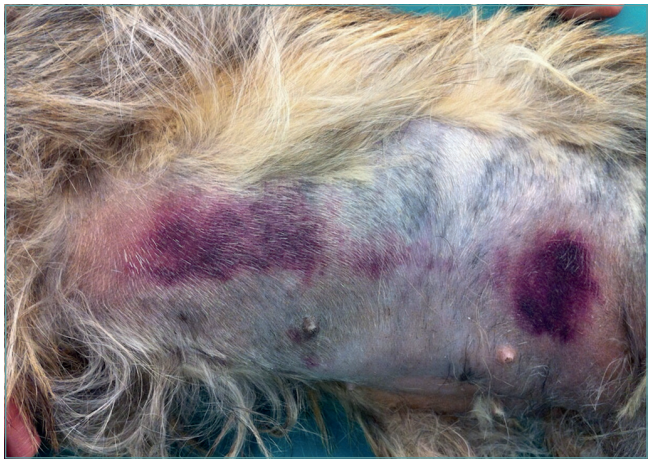

FIGURE 2. Image of the thorax and abdomen prior to the ultrasound examination showing extensive skin haemorrhages.

THORACIC RADIOGRAPHY

The thoracic radiographs taken by the referring veterinary surgeon were reviewed at the time of presentation. They showed a moderate interstitial pattern with a peripheral and mainly caudodorsal distribution and decreased vascular outline. The cardiac silhouette and pulmonary vessels were normal (Fig. 4).

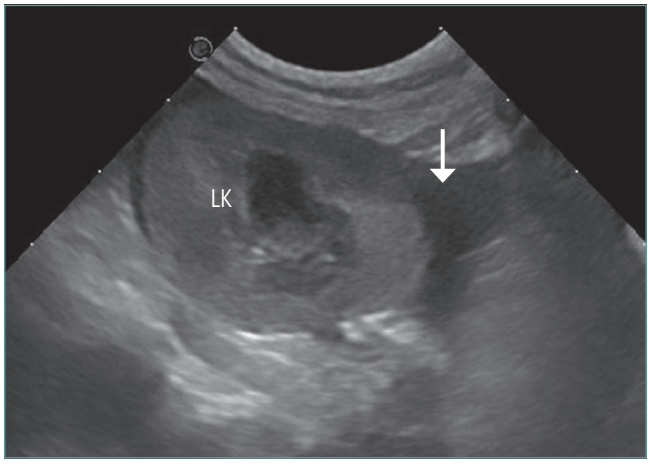

FIGURE 3. Transverse ultrasound image of the left kidney (LK) surrounded by echogenic fluid (arrow).

COMPUTED TOMOGRAPHY

A CT scan of the thorax was performed under general anaesthesia to further assess the pulmonary parenchyma and identify any possible underlying pathology. It revealed increased lung changes compared to those seen on the previous radiographs, including marked, generalised interstitial infiltrate with a ground-glass appearance, and patchy areas of alveolar consolidation that mainly involved the peripheral aspects of the caudal lobes (Fig. 5).

BRONCHOALVEOLAR LAVAGE

A bronchoscope-guided bronchoalveolar lavage (BAL) was performed after the CT scan under the same general anaesthesia. The cytological examination of the sample revealed a background of clumped eosinophilic material and dispersed fresh blood with mixed inflammatory cells including macrophages, mature neutrophils, eosinophils, and reactive lymphocytes. The presence of coiled parasitic larvae embedded within the mucoid clumps was also detected (Fig. 6).

The final diagnosis was parasitic bronchopneumonia due to *Angiostrongylus vasorum*.

Identification of first-stage larvae in the lungs or faeces is needed to diagnose the infection.

TREATMENT

The patient was hospitalised to receive intravenous fluid therapy. Antimicrobial (amoxicillin–clavulanic acid at 15 mg/kg every 24 h for 7 days) and anthelmintic therapy (fenbendazole at 50 mg/kg every 24 h for 14 days) was also initiated in hospital and continued after discharge.

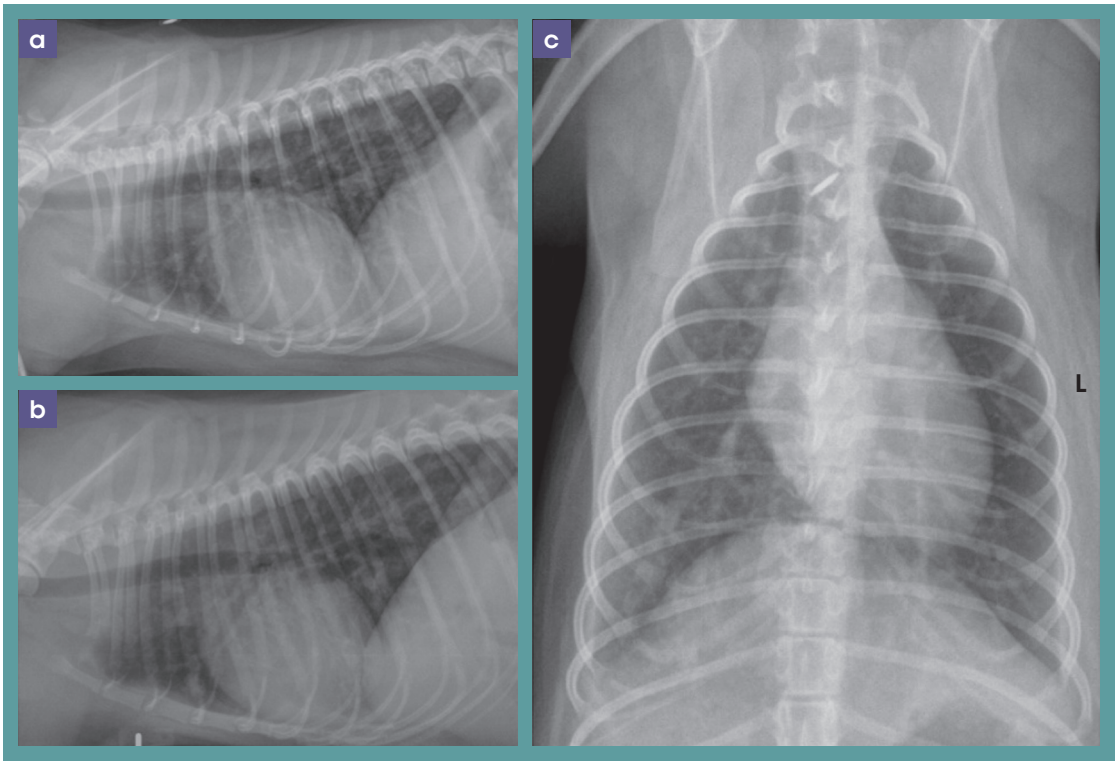

FIGURE 4. Thoracic radiographs. Right lateral (a), left lateral (b), and dorsoventral (c) projections showing patchy and mainly peripheral areas of increased opacity and a diffuse bronchointerstitial pattern.

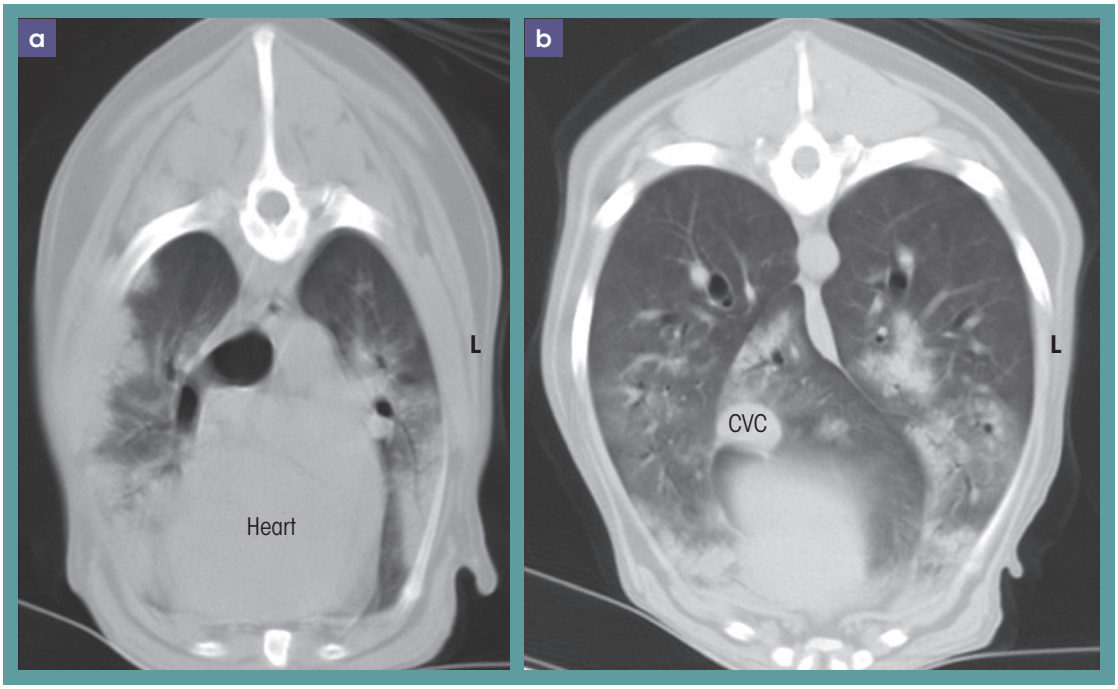

FIGURE 5. Transverse CT reconstructions in lung window at the level of the carina (a) and caudal vena cava (CVC) (b). Note the ill-defined, multifocal, peripheral and mainly ventral interstitial-alveolar infiltrates.

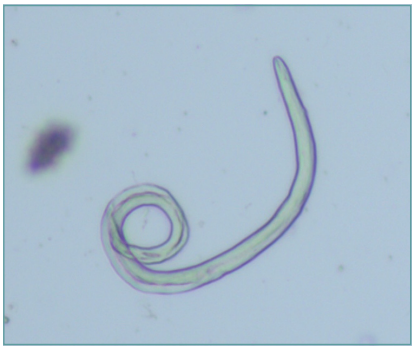

FIGURE 6. Typical image of a curled first-stage larva of *Angiostrongylus vasorum*.

The dog showed marked improvement in both clinical and laboratory parameters 3 days after starting the treatment. The BMBT was measured to confirm adequate primary haemostasis and was normal, so the patient was discharged.

Re-examination 3 weeks after the initial consultation revealed no clinical signs and unremarkable blood work results. Lungworms were not observed in three consecutive faecal analyses.

DISCUSSION

Angiostrongylus vasorum, also called lungworm or "French heartworm", is a metastrongyloid nematode that affects dogs and other species of *Canidae*, including foxes, via an indirect cycle that involves slugs, snails, and frogs. The adult worms accumulate in the pulmonary artery and its branches, where they lay eggs. The eggs remain in the pulmonary capillaries, where they hatch into first-stage larvae (L1). These larvae then penetrate into the alveoli, causing interstitial pneumonia, or even pulmonary thrombosis and an inflammatory reaction leading to pulmonary hypertension. From there, aided by the animal's cough, they migrate to the pharynx and are swallowed and excreted in the faeces. Erratic locations of L1 in the brain and other organs have also been described.

The free L1 in the soil are ingested by the intermediate host and reach infective stage (L3). The life cycle is completed when the definitive host (dog) swallows the infected intermediate host and the L3 moult into L4 and L5, which migrate through the circulatory or lymphatic system to the heart and pulmonary arteries, where they mature.

Geographically, *A. vasorum* has a worldwide distribution. However, this parasite generally lives in wet and moderate climates in Europe, Africa, and America.

Angiostrongylus vasorum infection is an uncommon disease that can cause respiratory, neurological, or systemic signs.

There is no breed or sex predisposition, but young to middle-aged dogs are predisposed, which is thought to be due to the scavenging and playful behaviour typical of younger ages. Some articles report that working dogs are more predisposed to this disease during their training.

The clinical signs and severity of the disease are very variable, from subclinical patients to sudden death. Respiratory involvement is most common, with signs due to interstitial pneumonia such as cough (productive or unproductive), exercise intolerance, tachypnoea, dyspnoea, or cyanosis. In a minority of dogs (estimated 5 % in general practice, but up to 33 % in referral clinics), pulmonary hypertension develops secondary to *A. vasorum* infection and may cause clinical signs of syncope or right-sided heart failure.

It is also frequent for affected dogs to suffer from bleeding abnormalities, which are manifested as ecchymoses, petechiae, haematomas, or abdominal/thoracic bleeding. Neurological signs due to larvae and haemorrhage in the brain or the spinal cord can cause seizures, paresis, and other neurological signs. Other nonspecific signs such as uveitis, depression, weight loss, anorexia, and vomiting and diarrhoea may also be observed.

Imaging of the thorax shows a multifocal, mainly peripheral, bronchointerstitial pattern with alveolar patches, due to granulomas and bleeding caused by the migration of L1. In chronic cases, an interstitial pattern occurs secondary to pulmonary consolidation and lung fibrosis. Other changes include right-sided heart enlargement, dilation of the main pulmonary artery, pleural or mediastinal haemorrhage, and rarely pneumothorax. After resolution of the infection, a mild interstitial pattern can remain visible.

Thoracic radiographs usually reveal a multifocal, mainly peripheral, bronchointerstitial pattern with patchy areas of alveolar consolidation.

Doppler echocardiography is useful to estimate pulmonary arterial pressure and assess effects on the right heart. Dogs with moderate to severe pulmonary hypertension tend to have concentric hypertrophy and right ventricular dilation, with a distended pulmonary artery and potentially right atrial dilation. Detection of peak pulmonic insufficiency over 2.2 m/s (mean pulmonary artery pressure >20 mmHg) or tricuspid regurgitation over 3 m/s (systolic pulmonary artery pressure >36 mmHg) is consistent with pulmonary hypertension.

Even though a neurological presentation is less frequent, neurological signs can occur from bleeding in or around the central nervous system. In these cases, advanced imaging techniques such as computed tomography and magnetic resonance imaging are necessary for the diagnosis.

The clinical presentation, blood analyses, and imaging findings are helpful in the diagnosis, but the detection of L1 in the respiratory tract or faeces or of antigens in the blood is needed for a definitive diagnosis. A BAL may be performed, but it should be done with caution as these patients may present with severe respiratory distress and a bleeding tendency. Submitting faeces for a Baermann test is recommended. This test can be insensitive owing to intermittent shedding of L1 in faeces. As such, it may need to be carried out on faecal samples from three consecutive days. Performing one test only detects half of infected dogs. In urgent cases, point-of-care microscopy of direct faecal smears can detect the larvae with a sensitivity of 54–61 %.

Since the Baermann test can be insensitive, faecal samples from three consecutive days may maximize the diagnostic capability.

Treatment is based on a combination of anthelmintic therapy (fenbendazole [25–50 mg/kg for 5–21 days], milbemycin oxime–praziquantel [weekly oral administration for 4 weeks], and imidacloprid–moxidectin [monthly spot-on administration]) and supportive care, which depends on the patient's clinical signs. The bleeding tendency resolves approximately 24 hours after starting the anthelmintic treatment in most dogs.

The prognosis depends on the severity of the clinical signs, but it is usually good if the diagnosis is made at an early stage of the disease. Respiratory signs generally disappear within 1–2 weeks after treatment. However, approximately 40 % of severe cases have residual signs such as cough and exercise intolerance after resolution of the infection. If mortality occurs, it is due to severe bleeding or respiratory failure.

Noncomplicated cases have an excellent prognosis with anthelmintic therapy.

Prophylactic treatment with imidacloprid 10 % combined with moxidectin 2.5 % is currently effective against *A. vasorum*.