Case Report
J Vet Intern Med 2014;28:656–660

Transarterial Coil Embolization of an Abdominal Aortocaval Fistula in a Dog

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Key words: Angiography; Arteriovenous fistula; Endovascular repair.

A 3-year-old, 5 kg, male Toy Poodle with a mast cell tumor on the left pelvic limb was referred to Tokyo University of Agriculture and Technology Animal Hospital for an oncologic evaluation. On physical examination, a continuous bruit was auscultated over the left inguinal region with a palpable thrill. Cardiac auscultation identified a grade II/VI systolic and a grade I/VI diastolic murmur over the mitral and the aortic valves, respectively. No signs of peripheral cyanosis or congestion were noted. On thoracic radiographs, moderate, generalized enlargement of the cardiac silhouette was observed without evidence of pulmonary edema or pleural effusion. Color Doppler echocardiography identified mild pulmonic, mitral, and aortic valve regurgitation. Measurements of the left ventricle (LV) indicated an increased internal diameter with normal LV wall and septal thicknesses, normal fractional shortening and mild left atrial (LA) enlargement, with normal sinus rhythm. Normal mean arterial blood pressure was obtained on the thoracic limb using the oscillometric method.

Laboratory test results (complete blood count, serum biochemistry profile, electrolytes, coagulation profile) were within the normal reference ranges.

Ultrasonography of the caudal abdomen showed a caudal vena cava (CVC) with a diameter of 24.6 mm (dog <10 kg, reference values 0.65 ± 0.12 mm)[1] at the site of shunt. Color Doppler with simultaneous electrocardiogram showed turbulent flow in the CVC during the arterial phase. Continuous-wave Doppler interrogation showed continuous low-velocity flow with a pulsatile pattern and spectral broadening of Doppler waveform and peak flow velocity of 3 m/s across the aortocaval shunt (Fig 1).

Contrast-enhanced computed tomography[a] (CT) was performed under general anesthesia for anatomic evaluation of the arteriovenous shunt. The contrast timing bolus method was used to synchronize image acquisition. Iodinated contrast medium[b] (2 mL/kg of iodine) was injected into the cephalic vein at flow rate of 1 mL/s. After a 20-second delay, the entire abdomen was scanned with a dual-slice spiral CT scanner. Reconstruction was carried out using contiguous images with a slice thickness of 1.0 mm (total of 149 slices). Post imaging processing showed an aortocaval connection by an anomalous vessel (shunt) located caudal to the renal arteries and a saccular dilatation of the CVC elongating in the caudal direction. The major dilatation was observed caudal to the fistula, 2.6-fold greater than the dilatation observed cranial to the fistula (Fig 2A,B).

Endovascular repair was performed under general anesthesia that was maintained with isoflurane. The dog was positioned in right lateral recumbency for a cervical left lateral approach and a small incision in the skin was made to access the left common carotid artery. A 4-Fr multipurpose catheter[c] was inserted through a puncture in the artery and advanced over a guide wire. The catheter tip was positioned in the abdominal aorta, cranial to the fistula to perform aortography. A 5-mL bolus injection of iodinated contrast medium[b] showed the contrast medium being diverted from the aorta into the CVC (Fig 3A). Blood flow in the renal arteries was preserved as observed by contrast filling of the arteries and renal excretion. The tip of the catheter then was repositioned into the AVF over a guide wire to deliver the embolization coil, because contrast injection showed that adequate coil deployment could be achieved through the aorta. An embolization coil of 6.5 mm diameter, 5 loops, and 10 cm in length[d] was deployed along the fistula lumen under fluoroscopic guidance. Aortography a few minutes after coil deployment identified residual flow through the fistula (Fig 3B). Residual flow was also observed on Doppler ultrasonography, but the shunt flow velocity had decreased to 1.5 m/s.

Recovery from the anesthesia was uneventful. Postoperative mean arterial blood pressure ranged from

Abbreviations:

AVF	arteriovenous fistula
CT	computed tomography
CVC	caudal vena cava
LA	left atrium
LV	left ventricle

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Submitted May 17, 2013; Revised November 19, 2013; Accepted December 16, 2013.

10.1111/jvim.12308

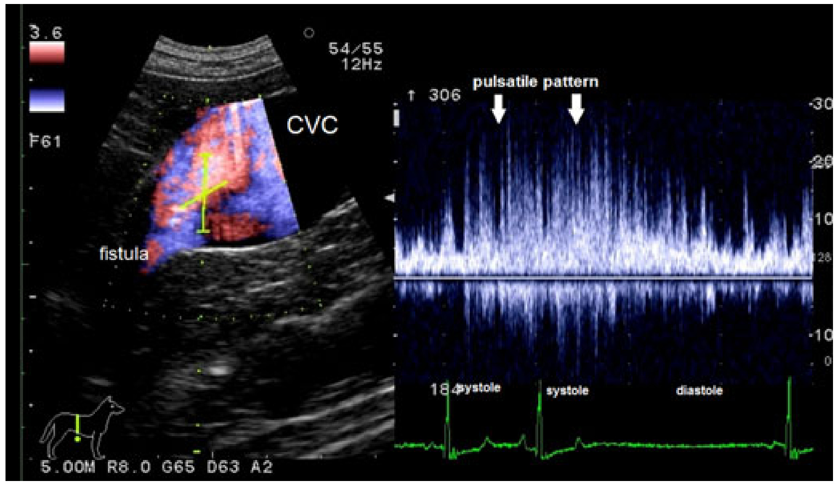

Fig 1. Doppler ultrasound image of the caudal vena cava (CVC) obtained from caudal abdomen. Continuous Doppler image showing an arterialized flow or pulsatile pattern (arrows) across the fistula entering the CVC.

130 to 135 mmHg, and 2 hours after a single application of 2 cm 2% nitroglycerin ointment cutaneously to the pinna, blood pressure was normal. Eight hours after surgery, a decrease in hematocrit from 52 to 38% was detected, with concomitant hemoglobinemia and hemoglobinuria. The hematocrit gradually decreased to 18% on the second day, and a blood transfusion was administered in the following hours. After a single transfusion, blood test results returned to within the normal reference range, and no signs of hemolysis were noted on the third day. The dog was discharged 12 days after surgery without additional treatment. During the following weeks, the dog was rechecked by a local veterinarian, and when examined 2 months after the surgery, no residual shunting was detected on Doppler ultrasonography (Fig 4). Echocardiography showed substantial reductions in LV dimensions (to normal size). Mild pulmonic, mitral, and aortic regurgitation flows, however, were still visible on color Doppler.

Cases of abdominal aortocaval fistula are rarely diagnosed in veterinary medicine. An unsuccessful attempt of abdominal aortocaval fistula occlusion using conventional surgery was reported in a cat.[2] In humans, arteriovenous communications are most commonly associated with trauma, invasive procedures, ruptured aneurysms, or arteriovenous malformations.[2,3] Persistent communication between an artery and vein related to incomplete embryologic development of the local capillary bed may result in congenital arteriovenous fistulas. In humans, fistulas connecting the abdominal aorta and the inferior vena cava are rare and frequently acquired.[2] In this case, localization could indicate possible origin from the testicular artery, but the history and clinical evaluation alone did not provide any information that allowed identification of the origin of the fistula. Typically, the clinical presentation (including signs of high-output cardiac failure and an asymptomatic pulsatile abdominal mass) has been reported in 20–50% of human patients diagnosed with AVF.[3–5] Origin, size, localization, and evolution time of the fistula determine the degree of hemodynamic disturbances. The hemodynamic disturbances observed depend on arterial pressure at the site of arteriovenous connection and the velocity of shunting flow.[6–8] Arteriovenous fistulas deviate blood flow from high-resistance arterial to low-resistance venous systems and decrease peripheral vascular resistance and pressure inside the aorta, caudal to the fistula.[5,9] In addition, changes in blood volume are associated with relatively small changes in venous pressure attributable to the large systemic venous capacitance.[10]

Decreased peripheral vascular resistance evokes physiologic responses resulting in volume overload and hyperdynamic circulation.[3] In addition, the increased venous return from the fistula increases RV volume, which then is transmitted through the lungs, resulting in increased LV preload and LV volume. Therefore, a substantial reduction in LV end-diastolic diameter was observed 2 months after surgery. This observation has been reported in patients after arteriovenous shunt occlusion, and it is related to decreases in right ventricular preload and consequently in LV preload and volume.[11,12] Systemic arterial hypertension related to fluid overload immediately after fistula occlusion is a common complication and results from a sudden increase in intravascular volume and total peripheral resistance.

Doppler ultrasonography is frequently used for evaluation of vascular anomalies, although it may not accurately measure hemodynamic parameters because of dependency on Doppler beam alignment with jet flow, multidirectional flow, and the presence of turbulent flow.[13] Turbulent flow at the site of the fistula appears as spectral broadening in the Doppler waveform and mosaic of colors.[13] In this case, assessment of shunt flow, using Doppler ultrasonography performed at the initial presentation, did not demonstrate the typical Doppler waveform with continuous high-velocity flow throughout diastole, commonly observed in cases of aortocaval fistula.[14] Lower shunt flow

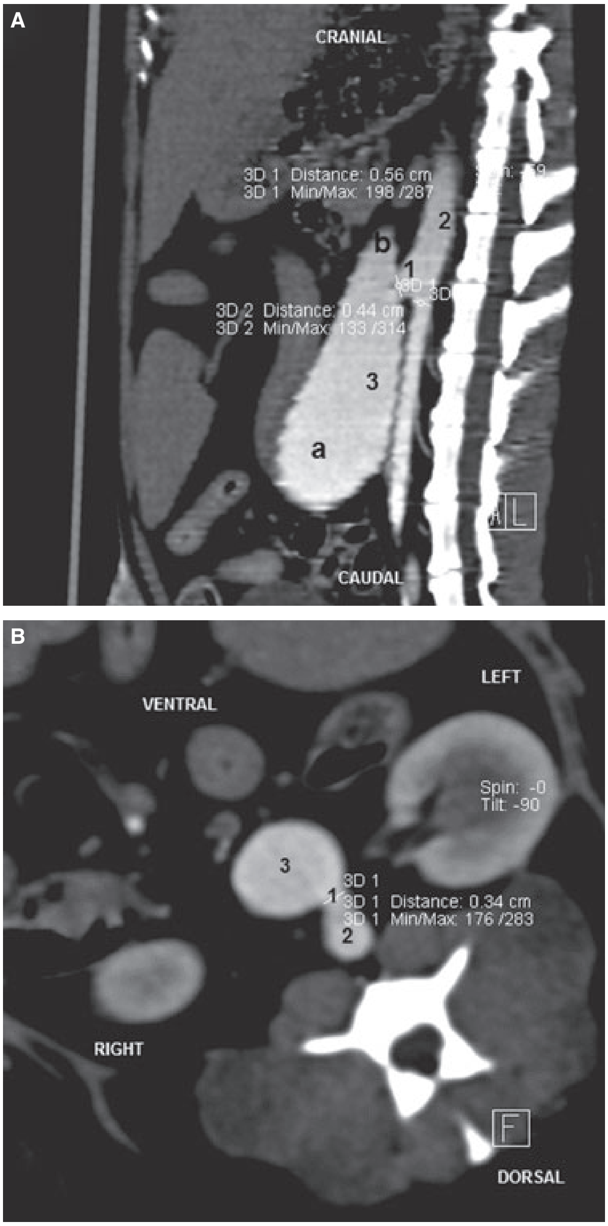

Fig 2. Contrast computed tomography. (**A**) Parasagital and (**B**) transversal images showing the connection (1) between the abdominal aorta (2) and the dilated caudal vena cava (3). (A) The dilatation caudal to the shunt was 2.6-fold greater than (B) the dilatation cranial to the shunt

velocities of 1.1 m/s in an aortocaval fistula in a human patient and 2.42 m/s in an aorticopulmonary fistula in a dog were reported previously.[5,14]

Selective angiography is the gold-standard method used for the assessment of vascular anomalies before surgical intervention.[15,16] Computerized tomographic scan techniques have been developed to provide a noninvasive diagnostic method with 3-dimensional perspective that permits complete preoperative evaluation of the fistula.[16]

Attempts to occlude AVFs using conventional methods are performed by transperitoneal surgery.

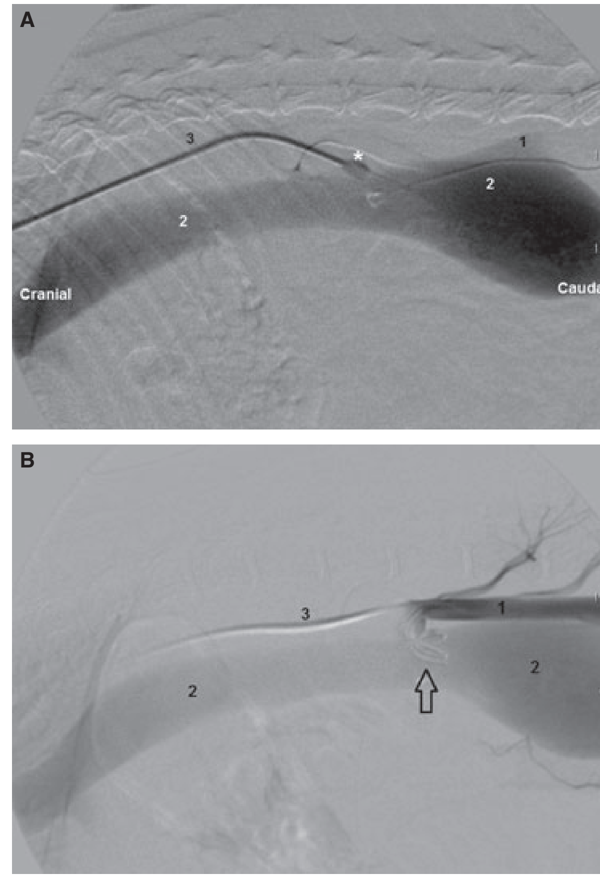

Fig 3. Selective aortography. (**A**) Flow diverting from aorta (1) to the caudal vena cava (2) attributable to the presence of an arteriovenous fistula (asterisk) shown by contrast injected into the abdominal aorta through the catheter (3); (**B**) second contrast injection (3) after coil deployment showing normalized aortic flow (1) caudal to the site of coil occlusion (arrow) and residual flow in the caudal vena cava (2).

However, previous reports described an increased risk of rupture of the dilated vessel, and surgery is associated with high mortality and morbidity rates caused by hemorrhage, thrombi, or air or debris embolization.[2,17] Recurrence of the fistula caused by conventional surgery for fistula repair has also been reported in humans, and must be considered in patients presented with a fistula of unknown origin, as in the present case.[3] Therapeutic intervention in humans has been recommended for symptomatic patients and those with fistulas ≥3 mm in width.[18] A main advantage reported for endovascular repair is only minor tissue damage. Several techniques and devices are available for transarterial occlusion, including Amplatzer vascular plugs, detachable balloons, Gianturco coils, and coils combined with cyanoacrylate glue.[17–20] According to presurgical evaluation of fistulas (including dimensions, CVC dilatation, patient weight, and small-diameter catheter required for coil deployment compared with the catheters required for the described devices), transarterial embolization using a coil was hypothesized to be the most appropriate technique. Requirements for

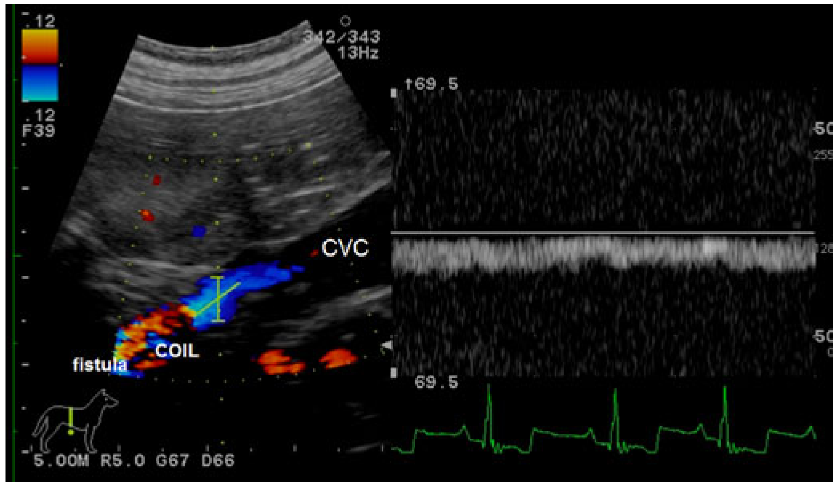

Fig 4. Postoperative Doppler image of the caudal vena cava. Spectral Doppler taken after 2 months indicated no arterial inflow in the CVC.

coil implantation include a lumen of sufficient length for coil deployment without protruding into the lumen of the feeding artery and the draining vein, and adequate width to permit safe anchoring on both the arterial and venous sides. The coil diameter must be larger than the width of the fistula, and a previous study demonstrated that an appropriate coil diameter/fistula ratio is between 1.25 and 1.3.[19]

An incidence rate of 0.9% for intravascular hemolysis after coil implantation has been reported in humans, and this is likely because of mechanical injury of the erythrocytes passing through the coil in the presence of residual shunting.[21,22] Residual shunting for a short period after coil embolization is reported in 30% of human patients with AV fistulas.[23] Patients with persistent hemolysis require a second intervention to occlude the shunt completely, but in most cases of residual shunting, these episodes gradually cease without further intervention.[23–25] Complications reported after endovascular repair of pulmonary arteriovenous malformation include recanalization, embolization of intraluminal debris, or embolization of the coil, whereupon long-term follow-up is recommended.[14]

Limitations of the present report include the lack of an arteriovenous gradient measurement at the fistula site during the catheterization, which could have confirmed the pressure gradient measured by Doppler ultrasound. This could be complementary information correlated with clinical and hemodynamic disturbances caused by the shunting flow. In addition, the coil is a device that fits less tightly to the vascular walls compared with the Amplatzer vascular plug, the second option for treatment; and, in addition to the catheter size needed to deploy it, a single Amplatzer vascular plug could occlude the fistula. However, complications reported after fistula occlusion are similar for the Amplatzer vascular plug and embolization with a coil (eg, residual shunting present at short-term follow-up, device embolization, protrusion into the arterial or venous side, hemolysis).[19] Despite the risk of rupture and hemorrhage, occlusion by transperitoneal surgery could also have been performed because only 1 branch was present connecting the aorta and the CVC. However, recurrence after a transperitoneal approach was considered possible because of the unknown origin of the fistula. The onset of hemolysis a few hours after the surgery was thought to be caused by persistent shunting, but other differential diagnoses could have been considered and evaluated by immunohematologic tests (eg, Coombs test, tick-borne disease serology). Although a short hospitalization period is considered an advantage of this technique, hemolysis in this case delayed discharge of the dog from the hospital.

In summary, small aortocaval fistulas result in mild hemodynamic disturbance and the patient may present with an asymptomatic pulsatile mass in the early stages. Clinical suspicion of AVF may lead to early diagnosis and surgical intervention, which is essential for successful treatment. Presurgical evaluation of fistula morphology using multiple imaging techniques optimized outcome in the dog reported here. The aim of transarterial coil embolization is fistula occlusion with minimal tissue injury. However, the presence of residual flow and its consequences required intensive care for a short period and follow-up. Several techniques and occlusion devices are available for endovascular repair. Nonetheless, additional studies are warranted to evaluate the efficacy of the coil embolization compared with newer devices.

Footnotes

[a] Somatom Emotion Duo, Siemens Medical Solutions, Erlangen, Germany

[b] Oypalomin 150, Fuji Pharma Co, Tokyo, Japan

[c] Technowood, Tonokura, Tokyo, Japan

[d] Flipper PDA Closure Detachable Coil, William Cook Europe, Bjaeverskov, Denmark

Acknowledgments

We thank Professor Hutz R.J. for his contribution to the final review.

Conflict of Interest: Authors disclose no conflict of interest.

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