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CASE REPORT

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Dominant outflow vein occlusion in the management of naturally occurring peripheral arteriovenous anomalies in cats and dogs

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Abstract

Two dogs and 1 cat were referred to a tertiary veterinary center for the consultation and treatment of limb edema, variable dermal sanguineous crusting lesions, and intermittent lameness. A peripheral arteriovenous anomaly (PAA) was diagnosed via computed tomographic angiography (CTA) in each case. Arteriography enabled further evaluation of the PAA with confirmation of a dominant outflow vein. Dominant outflow vein occlusion was achieved by direct ligation in 1 dog and retrograde transvenous glue embolization in the cat and other dog. Repeat arteriography demonstrated resolution of arteriovenous shunting. Presenting clinical signs resolved in all animals. The previously identified aberrant vessels in 1 dog were not identified after CTA 40 days postoperatively. No postoperative complications or recurrence was identified in any case during the 6- to 55-month follow-up period.

KEYWORDS
angiography, digital subtraction angiography, peripheral arteriovenous fistula, peripheral arteriovenous malformation

1 | INTRODUCTION

Arteriovenous malformations (AVMs) and fistulas are rare vascular anomalies that permit atypical left-to-right shunting of high-pressure arterial blood directly into low-pressure venous systems with local and systemic consequences.[1-3] In contrast to the multiple classification schemes and established treatment recommendations in human medicine,[4-8] veterinary literature concerning peripheral arteriovenous anomalies (PAAs) is limited to case reports. Surgical techniques in cats and dogs have traditionally targeted the central structure of anomalous vessels with successful treatment documented after ligation and excision,[9-21] sodium tetradecyl sulfate sclerotherapy,[22] resection after cyanoacrylate delineation,[23] embolization with cyanoacrylate,[24] ethylene-vinyl alcohol,[25] or coils[26] and ligation of the arterial supply feeding the anomaly.[27-29] Despite successful reports utilizing the above techniques, dog morbidity and other limitations are illustrated in the literature.[11,23] Nidus occlusion and extirpation are also widely accepted as primary interventions for many types of human AVMs.[5-7] Where a dominant outflow vein (DOV) is diagnosed, however, DOV occlusion is recognized as an effective treatment option.[4,6,30] DOV occlusion has been reported once in the veterinary literature where it was achieved inadvertently after surgical ligation was deemed unsafe at the time of surgery.[31] In that case, ligation of an arterialized cephalic vein just distal to the PAA was performed with subsequent resolution of all clinical signs and anomalous vessels. The objective of this study was to further

Abbreviations: AVM, arteriovenous malformation; CTA, computed tomographic angiography; DOV, dominant outflow vein; DSA, digital subtraction angiography; PAAs, peripheral arteriovenous anomalies.

evaluate the outcome of DOV occlusion in naturally occurring PAA in dogs and cats.

Three cases were identified with PAA that underwent DOV occlusion between 1 January 2017 and 1 January 2021.

2 | CASE 1

An 8-year 7-month-old, male neutered, 41 kg (90.2 lb) Pinscher was referred to the Animal Medical Center's Interventional Radiology Service for the surgical management of a previously diagnosed right antebrachial arteriovenous anomaly of 11 months duration. Comorbidities at the time of consultation included mitral valve regurgitation with mild left atrial dilatation, inflammatory bowel disease, von Willebrand's disease, and suspected cervical spondylomyelopathy. The dog first developed right antebrachial soft tissue swelling several weeks after an elective castration procedure. Physical examination revealed diffuse soft tissue swelling of the right antebrachium distal to the elbow joint (Figure 1A) with palpable fremitus deep to the musculature of the medial proximal antebrachium. No lameness, pain, or dermatological lesions were appreciated. Abnormalities detected with complete blood count and biochemistry analysis included abnormal alkaline phosphatase (180 U/L; reference range, 20-150 U/L), blood urea nitrogen (2.0 mmol/L; reference range, 2.5-8.9 mmol/L), leukocytosis (27.8 $\times$ 10^9/L; reference range, 6 $\times$ 10^9/L to 17 $\times$ 10^9/L), neutrophilia (25.5 $\times$ 10^9/L; reference range, 3 $\times$ 10^9/L to 12 $\times$ 10^9/L), and mean corpuscular hemoglobin concentration (30.2 g/dL; reference range, 31-34 g/dL). Right antebrachial ultrasonography confirmed arteriovenous shunting. Nonselective contrast-enhanced computed tomographic angiography (CTA) of the thoracic limbs identified a dense plexus of tortuous arteries at the level of the midradius likely originating from the transverse cubital artery and draining into the cephalic, median, and brachial veins. Arterial or venous embolization was subsequently scheduled based upon angiography results during the procedure. The dog was induced under general anesthesia, positioned in dorsal recumbency, and routinely prepared for surgery of the left pelvic and right thoracic limbs. Left femoral artery access was established via surgical cut-down with the placement of an introducer sheath (Prelude Sheath Introducer, Merit Maestro Microcatheter Inc, South Jordan, Utah) as previously described.[32] A 4Fr Berenstein (0.038″-100 cm) Catheter (Infiniti Medical, Menlo Park, California) was advanced into the right brachial artery with a 0.035″ angled hydrophilic guidewire (Weasel wire, Infiniti Medical) under fluoroscopic guidance and digital subtraction angiography (DSA) performed revealing a complex arteriovenous anomaly likely originating from the transverse cubital artery with 2 major feeding arteries ultimately draining into a DOV (Figure 2A). A microcatheter (Merit Maestro Microcatheter Inc) was positioned at the bifurcation of the 2 arteries supplying the nidus. Arterial embolization with 3 separate 0.1 mL increments of a 1.5 : 1 ethiodized oil (Lipidol, Recipharm Monts, Monts, France) : n-butyl-cyanoacrylate (TruFill Liquid Embolic System, Codman & Shurtleff Inc, Raynham, Massachusetts) mixture was administered into the nidus followed by 1 mL boluses of D5W to flush the glue through the catheter. Arterial shunting via the 2 major arteries were obstructed; however, additional nidus feeding vessels arising from the radial and median arteries were revealed (Figure 2B). Percutaneous retrograde access to the nidus via DOV puncture was achieved under DSA guidance. Care was taken to position the microcatheter proximal to the collateral venous drainage (Figure 2A,B). Four Complex Helical-18 (8 $\times$ 12 mm^2) pushable coils (Boston Scientific, Cork, Ireland) were deployed with markedly reduced yet persistent flow through the anomaly. Repeat DSA via the arterial microcatheter confirmed elimination of an estimated 90% of the previously observed arteriovenous shunting. At discharge, 1 day postoperatively, the owner was instructed to administer amoxicillin/clavulanate potassium (Clavamox, Zoetis, Kalamazoo, Michigan) at 15.2 mg/kg (6.9 mg/lb), PO q12h for 7 days in addition to ensuring activity restriction and the use of an Elizabethan collar for 14 days. All right antebrachial swelling was reported to resolve by 3 months postoperatively (Figure 1B). Fifty-five months postoperatively, the dog was reported to be ambulatory without lameness with no recurrence of right thoracic limb swelling.

3 | CASE 2

A 7-year 1-month-old, male neutered, 4.9 kg (10.8 lb) Tuxedo cat was referred to the Animal Medical Center's Interventional Radiology Service for further consultation of a suspected right pelvic limb

FIGURE 1 Dorsal thoracic limb photographs of a dog (case 1) diagnosed with a right antebrachial arteriovenous anomaly displaying diffuse soft tissue swelling of the right antebrachium distal to the elbow joint (A) and approximately 4 years postoperatively (B) displaying resolution of all soft tissue swelling (B)

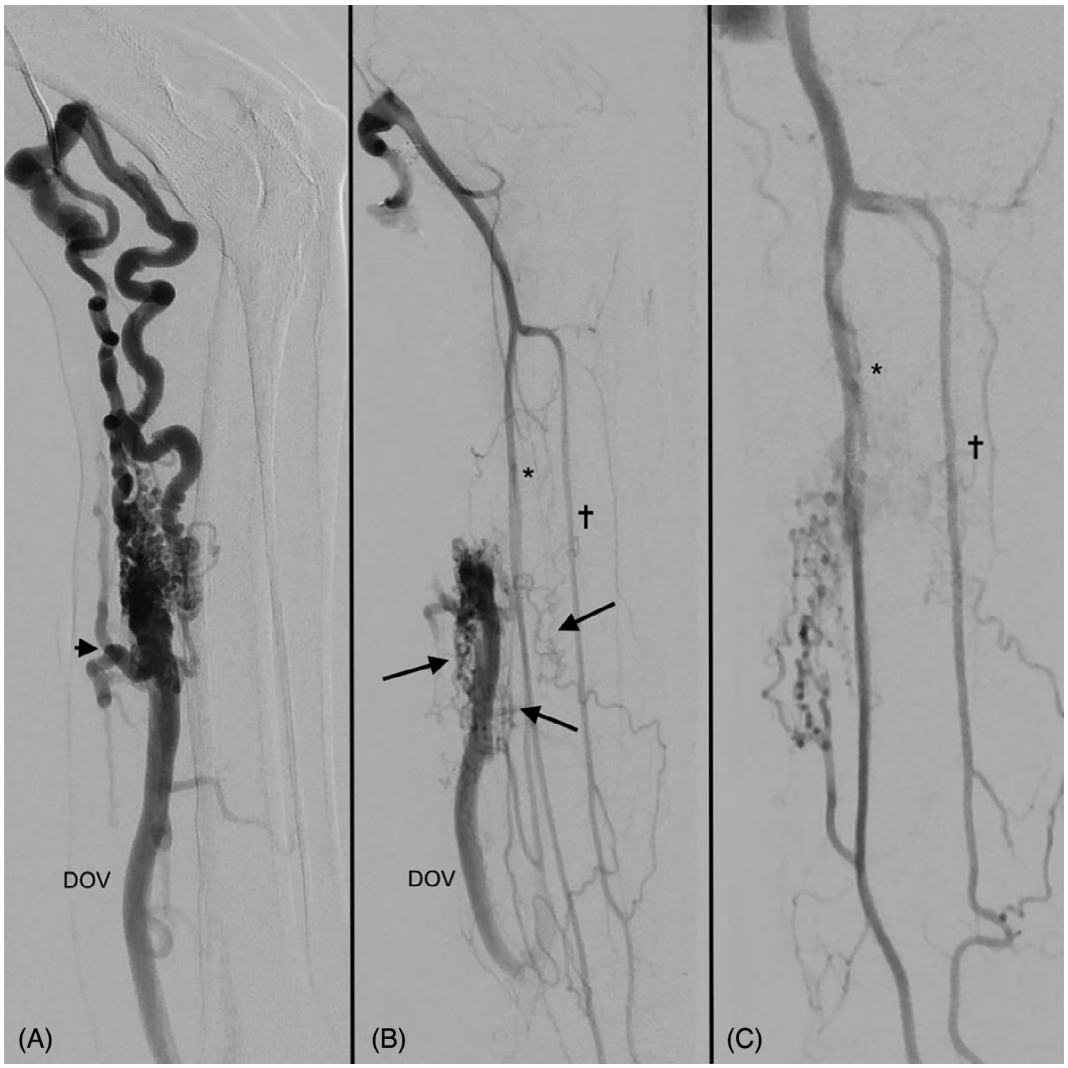

FIGURE 2 Serial lateral right antebrachial DSA of a dog (case 1) diagnosed with an arteriovenous anomaly arising from the transverse cubital artery and draining via a DOV. In each image, the dog is in dorsal recumbency with the distal and cranial surfaces of the antebrachium located at the bottom and left of each image, respectively. (A) The importance of angiography in understanding the vascular configuration is illustrated by the proximal DOV collateral venous drainage (arrowhead). (B) Repeat DSA postsuccessful arterial embolization with cyanoacrylate glue demonstrating additional nidus feeding vessels (arrows) arising from the radial (asterisk) and median (single dagger) arteries. (C) DSA post-DOV occlusion with no contrast identified within the dominant outflow vein or collateral venous system. DOV, dominant outflow vein; DSA, digital subtraction angiography

arteriovenous fistula. The cat was initially examined by the primary care veterinarian 7 months prior for a small lesion described as a blood blister. No historical trauma or comorbidities were reported. Progressive right pedal edema and superficial sanguineous crusting with associated lameness were observed. Skin biopsies of the right paw were consistent for necrotizing dermatitis. Blood chemistries were unremarkable. Culture of the skin identified light growth of coagulase-negative staphylococcus species with a wide antibacterial sensitivity profile. The cat was referred to a veterinary dermatologist where ultrasonographic evaluation with color Doppler diagnosed a tortuous right femoral vessel with turbulent blood flow. On examination with the Interventional Radiology Service, the right pelvic limb was assessed to be moderately swollen with multifocal dorsal pedal sanguineous crusts. A single severely dilated and tortuous vessel with palpable fremitus was identified on the medial aspect of the proximal limb. Nonselective CTA of the right pelvic limb was achieved with the administration of iodinated contrast medium at 673 mg iodine/kg (Omnipaque 300 mgI/mL, Amersham Health Inc, Princeton, New Jersey) by a power injector (Liebel-Flarshiem REF 902300 E, SN CI0709C042; Precise Biomedical Inc, Parma, Ohio) at 1 mL/s via a 20-gauge right cephalic catheter. A nest of tortuous vessels was identified arising from multiple branches of the femoral artery, which appeared to arterialize a dilated femoral vein. Medially, an aberrant vessel arising from the arterialized femoral vein coursed distally and superficially along the medial aspect of the distal limb with many smaller associated vessels. A metallic foreign body was identified in

the right caudoventral subcutis of the abdomen consistent with an air gun pellet. A combination arterial and venous treatment approach were planned depending upon arteriography confirmation of a DOV. After the induction of general anesthesia, the cat was positioned in dorsal recumbency and routinely prepared for surgery of the ventral cervical area and right pelvic limb. Right carotid artery access was established via cut-down and placement of a 4Fr introducer sheath (Prelude Sheath Introducer, Merit Maestro microcatheter Inc) as previously described.[32] A 4Fr Berenstein (0.038″-100 cm) Catheter (Infiniti Medical) was advanced into the right external iliac and then femoral artery with a 0.035″ angled hydrophilic guide wire (Weasel wire, Infiniti Medical) under fluoroscopic guidance and DSA performed (Figure 3A). A microcatheter (Merit Maestro Microcatheter Inc) was used to gain access into 1 of the many arterial branches supplying the nidus. Embolization with 0.1 mL increments of a 1.5 : 1 ethiodized oil (Lipidol, Recipharm Monts) : n-butyl-cyanoacrylate (TruFill Liquid Embolic System, Codman & Shurtleff Inc) mixture was administered into the nidus to determine if a solely arterial approach could achieve control of the vascular anomaly. Decreased yet persistent arterial and venous flow was observed through other contributing arterial branches (Figure 3B). Percutaneous retrograde access to the nidus via DOV puncture was achieved followed by placement of a microcatheter (Merit Maestro Microcatheter Inc). Direct manual compression of the DOV was performed distal to the opening of the microcatheter (Figure 3C) and a total of 0.4 mL of ethiodized oil (Lipidol, Recipharm Monts) : n-butyl-cyanoacrylate (TruFill Liquid

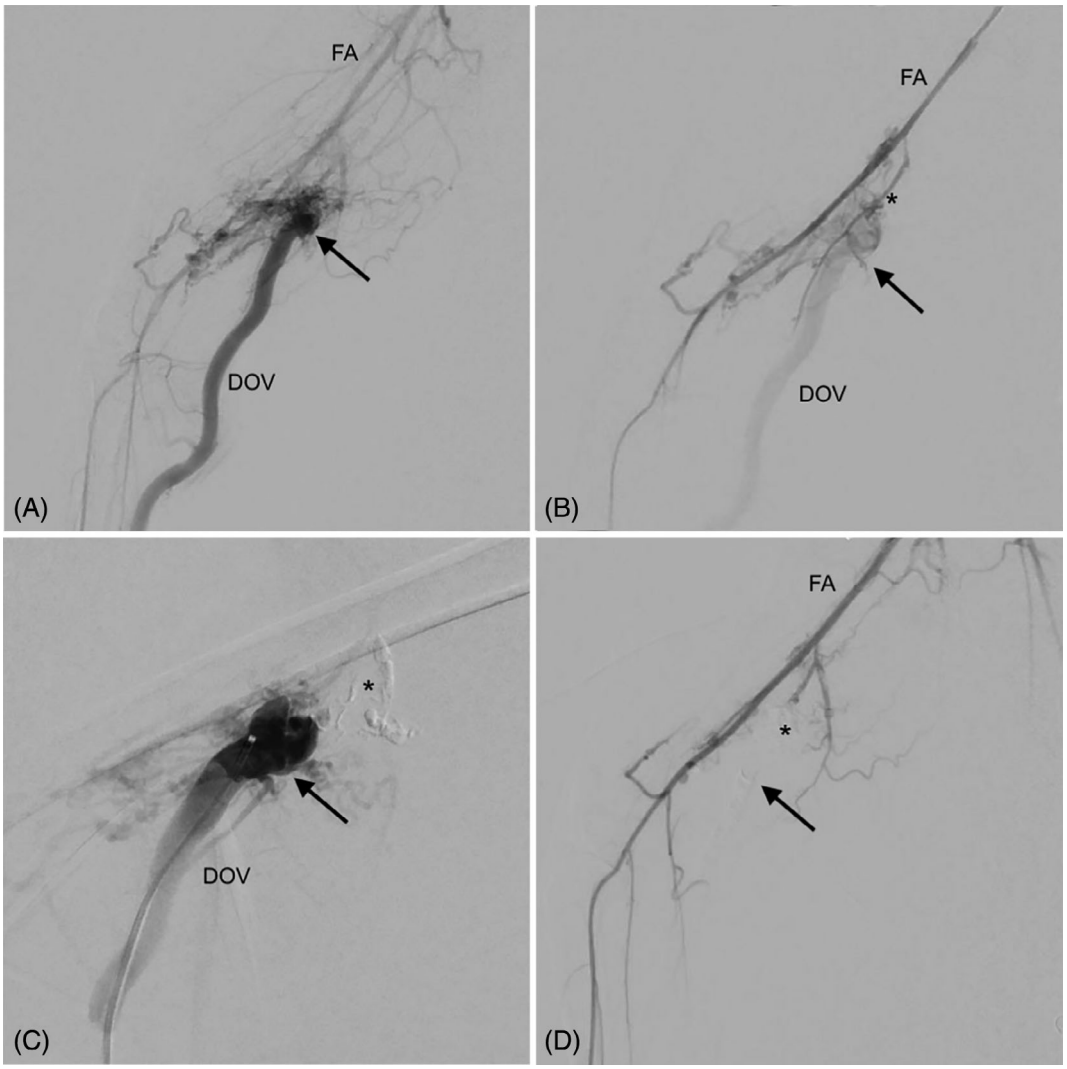

FIGURE 3 Serial lateral right pelvic limb DSA of a cat (case 2) diagnosed with an arteriovenous anomaly arising from the femoral artery (FA). In all images, the cat is in dorsal recumbency with the proximal pelvic limb located to the top and right of each image. (A) Initial DSA was performed to enable evaluation of the femoral artery, arteriovenous anomaly, DOV, and collateral circulation. (B) Repeat DSA postembolization with cyanoacrylate glue (asterisk) demonstrating reduced yet persistent venous drainage through the DOV. (C) Transvenous retrograde catheterization of the DOV with a microcatheter positioned just distal to the nidus before further glue embolization. (D) DSA post DOV occlusion with no contrast identified within the dominant outflow vein. The site of proposed and performed DOV occlusion is indicated with a black arrow in each image. DOV, dominant outflow vein; DSA, digital subtraction angiography

Embolic System, Codman & Shurtleff Inc) solution administered during vascular stasis followed by a 1 mL bolus of D5W to flush the mixture through the catheter. The microcatheter was withdrawn from the glue embolus. Compression was maintained for 1 minute. Repeat DSA (Figure 3D) confirmed elimination of arteriovenous shunting. A total of 636 mg iodine/kg (289 mg/lb) (Omnipaque 240 mgI/mL, Amersham Health Inc, 13 mL, 2.7 mL/kg [1.2 mL/lb]) was administered throughout the procedure. Other than minimal distal arterial reflux during embolization, no complications were noted. The previously palpated fremitus was not identified postoperatively. One day postoperatively, the cat was discharged with buprenorphine (Buprenex, Reckitt Benckiser Healthcare UK Ltd, Hull, England) at 0.01 mg/kg (0.005 mg/lb), trans-mucosal q8-12h pro re nata and amoxicillin tihydrate/clavulanate potassium (Clavamox, Zoetis) at 13.6 mg/kg (6.2 mg/lb), PO q12h for 7 days in addition to ensuring activity restriction and the use of an Elizabethan collar for 14 days. No new dermal lesions were documented during the cats recheck examination 11 days postoperatively. Six months postoperatively, the cat was reported to be ambulatory without lameness or discomfort with no recurrence of right pelvic limb swelling or dermal lesions.

4 | CASE 3

A 5-year 9-month-old, female spayed, 16.4 kg (36 lb) Airedale Terrier was evaluated by the Animal Medical Center's Emergency and Surgery

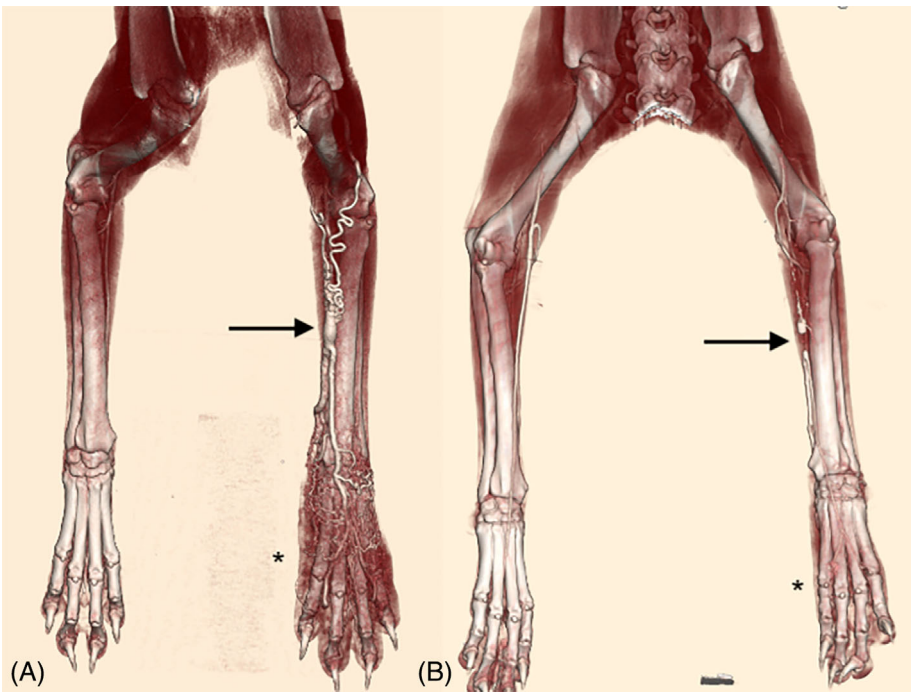

FIGURE 4 Three-dimensional color rendered nonselective CTA of the thoracic limbs in a dog diagnosed with a left antebrachial arteriovenous anomaly (case 3). Images of the thoracic limbs obtained preoperatively (A) and 40 days postvenous ligation (B) are displayed. The site of DOV ligation is indicated with a black arrow. The extensive distal arterialized venous system (asterisk) is not appreciated in the follow-up imaging. CTA, computed tomographic angiography; DOV, dominant outflow vein

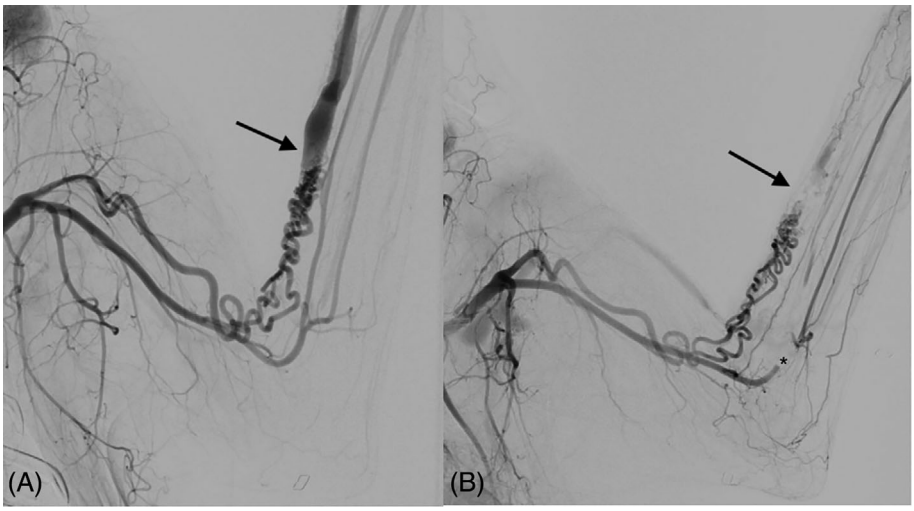

FIGURE 5 Left thoracic limb DSA in a dog (case 3) diagnosed with a proximal antebrachial arteriovenous anomaly (A). In both images, the dog was in left lateral recumbency with the head to the top of the image. (B) Repeat DSA after ligation of the proximal DOV with improved collateral circulation despite a small iatrogenic thrombus in the distal brachial vein (asterisk). The site of ligation is indicated with a black arrow. DOV, dominant outflow vein; DSA, digital subtraction angiography

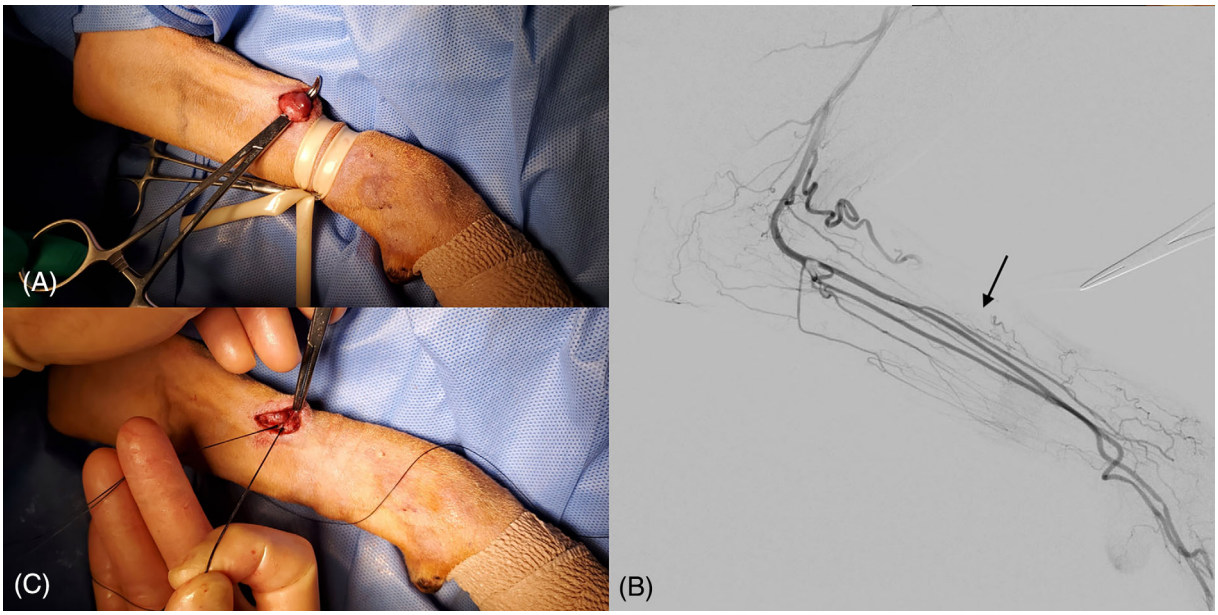

FIGURE 6 Intraoperative images of a dog (case 3) diagnosed with a left antebrachial arteriovenous anomaly. In each image, the dog was in left lateral recumbency with the head to the top and right of the image. (A) The proximal DOV was bluntly dissected from adjacent tissues with right-angled forceps after a 2.5 cm skin incision. The encircling tourniquet observed had been used to evaluate the effect of DOV occlusion; however, this technique was inferior to DOV Rummel tourniquet placement. (B) DSA after proximal DOV Rummel tourniquet placement (arrow) confirming the absence of arteriovenous shunting with improved arterial contrast to the distal antebrachium. (C) The proximal DOV was ligated at the location evaluated in (B) with 2 2-0 Silk simple interrupted sutures. DOV, dominant outflow vein; DSA, digital subtraction angiography

Services for persistent soft tissue swelling of the left thoracic limb. The dog was evaluated by the primary care veterinarian 9 months prior for purulent and hemorrhagic discharge associated with multifocal dermal sanguineous crusts of the carpus and digits. The dog had no known comorbidities or historical trauma but had been previously diagnosed with atopy and chronic borrelia burgdorferi exposure. Physical examination identified a mild left thoracic limb weight-bearing lameness, left carpal and metacarpal pitting edema, antebrachial vascular distension with a palpable pulse, dorsal metacarpal sanguineous crusts with discomfort on palpation, left superficial cervical lymphadenopathy, and a grade II/VI basilar systolic heart murmur. No palpable thrill, audible bruit, or Nicoladoni-Branham sign was appreciated. An echocardiogram revealed a physiologic heart murmur with no structural abnormalities. An incisional biopsy of the lateral aspect of the dorsal carpus was consistent with progressive angiomatosis with no aerobic or anaerobic bacteria cultured. No evidence of Bartonella infection was detected on blood polymerase chain reaction. Nonselective CTA of the thoracic limbs (Figure 4A) was achieved with the administration of iodinated contrast medium at 636 mg iodine/kg (omnipaque 300 mgI/mL, Amersham Health Inc) by a power injector (Liebel-Flarshiem REF 902300 E, SN CI0709C042; Precise Biomedical Inc) at 2 mL/s via a 20-gauge left lateral saphenous catheter. Two torturous and engorged aberrant arteries consistent with a cranial circumflex humeral artery and a superficial brachial (or transverse cubital) artery were identified to converge at the mid-antebrachium on several nests of smaller arteries which fed into a regionally enlarged antebrachial vein, arterializing the venous system distally. A purely transvenous treatment approach was anticipated after conclusive arteriography demonstrating a DOV. After the induction of general anesthesia, the dog was positioned in dorsal recumbency and routinely prepared for surgery of the left thoracic and left pelvic limbs. Left femoral artery access was established with the placement of a 5Fr introducer sheath (Prelude Sheath Introducer, Merit Maestro Microcatheter Inc) as previously described.[32] A 4Fr Berenstein (0.038″-100 cm) Catheter (Infiniti Medical) was advanced into the left axillary artery with a 0.035″ angled hydrophilic guide wire (Weasel wire, Infiniti Medical) under fluoroscopic guidance and DSA performed revealing the arteriovenous anomaly (Figure 5A). A 2.5 cm approach to the medial aspect of the arterialized left antebrachial vein distal to the suspected arteriovenous anomaly was performed (Figure 6A). The left antebrachial vein was localized and bluntly dissected to enable temporary occlusion with a Rummel tourniquet. Repeat DSA confirmed the absence of arteriovenous shunting with improved arterial contrast to the distal antebrachium followed by an improved venous phase (Figure 6B). The arterialized antebrachial vein was ligated with 2 2-0 Silk simple interrupted sutures (Figure 6C). Repeat DSA (Figure 5B) confirmed the elimination of arteriovenous shunting. After surgery, a pulse could no longer be palpated in association with the antebrachial vein. A total of 1018 mg iodine/kg (462 mg/lb) (omnipaque 240 mgI/mL, Amersham Health Inc, 70 mL, 4.2 mL/kg [1.9 mL/lb]) was administered throughout the procedure with no complications noted. At discharge, 1 day postoperatively, the owner was instructed to administer carprofen (Rimadyl, Zoetis) at 1.5 mg/kg [0.7 mg/lb], PO q12h and amoxicillin/clavulanate potassium

(Clavamox, Zoetis) at 15.2 mg/kg [6.9 mg/lb], PO q12h for 7 days in addition to ensuring activity restriction and the use of an Elizabethan collar for 14 days. Five days postoperatively, the client reported the dermal lesions and swelling to have progressively improved. Physical examination and nonselective CTA of the forelimbs were repeated 40 days postoperatively. No lameness, discomfort, swelling, dermal lesions, or antebrachial vein distension or pulse were detected. Additionally, a heart murmur was no longer audible. The previously identified aberrant vessels and nests associated were no longer appreciated (Figure 4B). Eight months postoperatively, the dog was reported to be ambulatory without lameness or discomfort. Although no dermal lesion or edema recurrence was noted, persistent mild limb asymmetry was suspected by the client.

5 | DISCUSSION

Successful management of naturally occurring PAAs via DOV occlusion is demonstrated in this retrospective study on 2 dogs and 1 cat. In all cases, complete resolution of clinical signs was achieved without recurrence during the follow-up period.

In addition to congenital AVMs and fistulas, acquired fistula secondary to vascular injury has been reported after catheterization,[33] barbiturate extravasation,[14,27] bite wounds,[9,14,23,31,34] neoplasia,[18,28,35] gunshot injuries,[21,28] surgery,[15] and blunt trauma.[13] Classically, AVMs structurally consist of nests of anomalous vessels connecting the arterial and venous systems, while fistula comprise singular or multiple vessels. No evidence or history of trauma was recounted by the owners in this report; however, a metallic foreign body (air-rifle pellet) was identified near the arteriovenous anomaly in the cat and 1 dog (case 1) had recently undergone general anesthesia with cephalic vein catheterization. The definitive etiology was not determined in any case, which is why the lesions were referred to as arteriovenous anomalies through this report, rather than AVM as they appeared angiographically. Although systemic cardiovascular consequences of left-to-right shunting are well recognized,[1,2] volume overload and high-output cardiac failure are rarely reported.[18,19,36] Localized clinical signs dependent on the structural characteristics and location of the anomaly most frequently reflect the manifestations of localized hypertension, impeded blood flow with venous congestion, and hypoxia.[9,23,25,26,31,33,34,36] As exemplified in this report, diagnostic evaluation can become misdirected due to such dermatological manifestations. In the cat, referral to a dermatologist was elected after skin biopsies were consistent for necrotizing dermatitis. In 1 dog (case 3), limb amputation was considered after progressive angiomatosis was diagnosed via incisional biopsy. It is plausible that PAA are underdiagnosed and at times misdiagnosed. An improved understanding of PAA within the wider veterinary community is required to appropriately diagnose, characterize, and treat these vascular anomalies and avoid needless amputation.

As previously demonstrated[31,34,37,38] and reinforced in this report, CTA and angiography are invaluable throughout diagnosis, treatment, and follow-up evaluation. In addition to reaching a diagnosis, CTA arterial and venous studies facilitate the interpretation of anomalous blood flow, while postprocessing 3-dimensional reconstruction supplements the anatomical "blue-print" for surgical planning. Intraoperatively, arteriography and venography advance the surgeon's understanding of blood flow with immediate feedback after temporary occlusion of contributing and draining vessels. Additionally, previously undiscovered vast collateral circulation typically not evident on CTA can be revealed and considered before definitive treatment. Arteriography provides further value after treatment with prompt confirmation of location and completeness of occlusion in addition to the resultant effects on collateral circulation.

Surgical techniques in cats and dogs have traditionally targeted the central structure of anomalous vessels relying on normal collateral circulation[1,23,28] which is typically bolstered with additional supply in chronic anomalies.[1] Despite many successful reports utilizing the established techniques, limitations are illustrated in the literature.[11,23] In addition to complicating safe ligation or excision, the complex arterial anatomy and superfluous collateral vascular supply are probable causes for incomplete resolution and treatment failure.[10,23,26-29,36,39] With advancements in veterinary interventional radiology, new treatment options have provided alternatives to amputation and wide excision. Importantly, the individual utilizing such technology should attain specialized training with many considerations fundamental to handling and administration of some of these substances, which can have severe deleterious effects if administered inappropriately.[24,38] This is exemplified in the use of n-butyl-cyanoacrylate which carries many potential risks for patient morbidity including nontarget embolization with necrosis, recurrent pyrexia, pain, persistent irritation, and self-trauma.[23-25] The cat in this report was monitored for such potential complications postembolization with no evidence of pyrexia or nontarget embolization observed. Where advanced intravascular techniques are not available or surgical excision is not feasible due to patient or owner factors, limb amputation has been deliberated[9,28,34] and performed.[33,36,37]

A nonconventional surgical approach is reported in 1 cat, whereby complete resolution of a thoracic limb arteriovenous fistula was achieved after ligation of an arterialized cephalic vein.[31] In that case, surgical dissection and ligation of the fistula were planned and initiated, however, could not be safely achieved. Ligation of the arterialized vein just distal to the fistula was elected to eliminate retrograde venous flow in an attempt to relieve distal venous congestion and hypertension. Complete resolution was unexpectedly achieved without recurrence. The surgical approach in that cat likely accomplished DOV occlusion resulting in thrombosis and closure of the arteriovenous fistula as the previously diagnosed anomalous vessels were not identified during follow-up CTA. Dominant outflow vein occlusion has also been successfully used more recently for hepatic AVMs in dogs and cats. Compared to hepatic lobectomy or arterial embolization, hepatic AVM DOV occlusion provides a relatively low-risk alternative while maintaining as much hepatic parenchyma and arterial blood supply as possible. In the third case of this report, after the diagnosis and localization of the DOV, ligation of the vein just distal to the arteriovenous anomaly was achieved via an open surgical approach. As observed in the previously reported cat,[31] resolution of the PAA proximal to the ligation was identified during follow-up CTA. In the first and second cases of this report, traditional arterial

embolization was unsuccessful with subsequent retrograde embolization of the proximal DOV. In all cases, clinical signs resolved without recurrence or evident complication. This alternative open surgical or interventional approach can provide a more durable treatment option as well as the prevention of unnecessary amputation or aggressive radical surgical excisions for cases with dominant venous outflow.

While nidus occlusion or extirpation are widely accepted as primary interventions for many types of human AVMs,[5-7] outflow vein occlusion is recognized as an effective treatment for certain lesions where dominant venous drainage is present.[4,6,30] In the retrospective evaluation of 19 human patients undergoing embolization, DOV occlusion was considered effective in all cases.[30] Consistent with the findings of other publications,[4,5,8] direct puncture and transvenous approaches offered effective and simplified access, serving as the preferred method for embolization of peripheral AVMs with dominant venous outflow. Contrasted to direct compression of venous outflow in the cat of this report, Cho et al describe the use of coil and core-removed guide wire embolization, intravascular occlusion balloons, and external pneumatic cuffs. Ugajin et al reported the atypical application of DOV occlusion in the successful management of a complex intrapelvic AVM after the patient experienced recurrence post transarterial embolization with n-butyl-cyanoacrylate.[40] That case differed from previous reports of DOV in the malformations large size with higher risk for nontarget embolization and nidus rupture, as well as the presence of multiple draining veins. The authors of that report emphasized the importance of embolization in a proximal location adjacent to the nidus to decrease the risk of collateral venous drainage. Importantly, the application of venous occlusion in the management of arteriovenous anomalies is only appropriate for those with a morphology that includes dominant venous outflow. The consequences of achieving venous occlusion in other morphologies could increase the risk of arteriovenous hypertension, rupture, and hemorrhage.[4]

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CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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