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Case Report

Surgical Correction of an Arteriovenous Fistula in a Ring-Tailed Lemur (*Lemur catta*)

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A 10-y-old ovariohysterectomized ring-tailed lemur (*Lemur catta*) was presented for exacerbation of respiratory signs. The lemur had a history of multiple examinations for various problems, including traumatic lacerations and recurrent perivulvar dermatitis. Examination revealed abnormal lung sounds and a femoral arteriovenous fistula with a palpable thrill and auscultable bruit in the right inguinal area. A diagnosis of congestive heart failure was made on the basis of exam findings, radiography, abdominal ultrasonography, and echocardiography. The lemur was maintained on furosemide until surgical ligation of the fistula was performed. Postoperative examination confirmed successful closure of the fistula and resolution of the signs of heart failure. Arteriovenous fistulas are abnormal connections between an artery and a vein that bypass the capillary bed. Large arteriovenous fistulas may result in decreased peripheral resistance and an increase in cardiac output with consequent cardiomegaly and high output heart failure. This lemur's high-flow arteriovenous fistula with secondary heart failure may have been iatrogenically induced during blood collection by prior femoral venipuncture. To our knowledge, this report is the first description of an arteriovenous fistula in a prosimian. Successful surgical correction of suspected iatrogenic femoral arteriovenous fistulas in a cynomolgus monkey (*Macaca fascicularis*) and a rhesus macaque (*Macaca mulatta*) have been reported previously. Arteriovenous fistula formation should be considered as a rare potential complication of venipuncture and as a treatable cause of congestive heart failure in lemurs.

Arteriovenous fistulas are abnormal connections between an artery and a vein which bypass the capillary bed. An arteriovenous fistula is a distinct vascular pathology from an aneurysm, pseudoaneurysm, or arterial dissection. An aneurysm is a localized dilation of an artery involving all layers of its wall, whereas an arterial dissection is a separation of the layers of the wall. Aneurysms and dissections generally result from congenital or acquired (as can occur with atherosclerosis) deficiency of the arterial wall. A pseudoaneurysm is a hematoma formed from leakage into adjacent tissue from a defect in the arterial wall and typically is due to iatrogenic or enzymatic (as can occur with pancreatitis) trauma. Communication between artery and vein is only present in an arteriovenous fistula.

Arteriovenous fistulas in humans can be acquired or congenital. Acquired arteriovenous fistulas may be created surgically for vascular access for hemodialysis or may result from a pathologic process such as trauma to the involved vessels or, rarely, rupture of an arterial aneurysm into an adjacent vein. The usual presentation in an acquired arteriovenous fistula is a pulsatile mass with a palpable thrill and an audible bruit in an extremity with previous penetrating trauma. If the flow through the arteriovenous fistula exceeds 20% of cardiac output, the patient may have signs of high-output congestive heart failure. Patients with greater than 20% of the cardiac output going through the arteriovenous fistula usually have a positive Nicoladani–Branham sign: the heart rate decreases and the blood pressure increases from baseline when the arteriovenous fistula is occluded temporarily by direct pressure.[3] This phenomenon is due to increased peripheral resistance and decreased cardiac output with occlusion of the arteriovenous fistula. Standard treatment of an acquired arteriovenous fistula is surgical ligation or division of the involved vessels. It is important to obtain proximal and distal control of both the artery and the vein before approaching the fistula.

Congenital arteriovenous fistulas in humans may (or may not) be obvious at birth and can be located anywhere, including in the brain and liver. When the fistula is large and the percentage of cardiac output that flows through the arteriovenous fistula is greater than 20%, early congestive heart failure may develop.[12] In extremity lesions, the arteriovenous fistula may not be obvious until years after birth and usually congestive heart failure is not present. An unusual feature of extremity arteriovenous fistulas—whether they are acquired or congenital—is the propensity for the involved extremity to become hypertrophied, not just edematous, when the patient is young enough to have significant growth potential and especially when the lower extremity is involved.[6] Because congenital arteriovenous fistulas have multiple niduses and because surgical ligation or extirpation has a high recurrence rate, transarterial embolization of a congenital arteriovenous fistula is the procedure of choice for correction.[4]

Arteriovenous fistulas have been reported infrequently in veterinary medicine, in species including dogs, cats, horses, and laboratory animals.[1,15,19,20] Many of the reported cases are iatrogenic due to blunt trauma or surgery, and some have been reported as being secondary to infiltrative neoplasia.[8] Arteriovenous fistulas in animals typically affect the peripheral vasculature but can also be located within the cardiac chambers and great vessels secondary to congenital defects.[18] As in humans, the long-term effects of arteriovenous fistulas in animals are secondary to increased venous return, increased cardiac

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output, and decreased peripheral vascular resistance, which together eventually can lead to clinical signs of congestive heart failure.[13] The most common treatment in veterinary medicine has been surgical ligation of the contributing arteries and drainage of the dilated veins; embolization with coils, balloons, or cyanoacrylate has also been reported.[10,19] The prognosis for occlusion of the fistulous vessels is very good, as long as pulmonary hypertension is absent.[8]

Case Report

A 10-y-old, 3.4-kg, ovariohysterectomized ring-tailed lemur (*Lemur catta*) presented for exacerbation of respiratory signs, including pronounced tachypnea and possible dyspnea during periods of physical stimulation. The lemur had been housed for 5.5 y as part of a social group with conspecifics at the Smithsonian's National Zoological Park (Washington, DC). The lemurs were housed in a facility with indoor and outdoor access and maintained on standard diets for this species. The animal's relevant medical history included perivulvar and perineal dermatitis and overgrooming that showed minimal response to treatment with antibiotics, antihistamines, steroids, controlled weight loss, and ovariohysterectomy during the 15 mo prior to presentation. The lemur was examined under anesthesia repeatedly for diagnostic and therapeutic procedures related to these conditions as well as for laceration repair and routine preventive care. Blood collection by femoral venipuncture was performed as part of each examination. Fourteen months prior to presentation for increased respiratory rate, the lemur was ovariohysterectomized due to persistent vulvar swelling, ovarian cysts, follicular mineralization, cystic endometrial hyperplasia, and endometritis. A sizeable hematoma formed at the femoral venipuncture site at the time of the ovariohysterectomy.

When presented for respiratory signs, the lemur was examined under anesthesia by using butorphanol (0.4 mg/kg IM), medetomidine (0.04 mg/kg IM), and midazolam (0.2 mg/kg IM) followed by maintenance with isoflurane (1% to 5%) delivered in oxygen by endotracheal tube. Thoracic auscultation revealed bilaterally muffled pulmonary sounds, and the respiratory rate was mildly elevated. The heart rate was 148 bpm, with a regular cardiac rhythm, and a soft (2/6) systolic flow murmur was detected over the left base with a bilateral systolic ejection click. An abnormal, continuous bidirectional vibration (a palpable thrill) was noted in the area of the femoral vasculature of the right inguinal region, along with a bounding femoral pulse and an auscultable bruit. Compression of this region resulted in a decline in the heart rate, consistent with a positive Nicoladani–Branham sign. The distal portion of the right hindlimb was cool to the touch. The lemur had a doughy abdomen with possible fluid distension. Abdominal ultrasonography confirmed ascites.

Additional cardiac diagnostic testing performed during this examination included thoracic radiography and echocardiography. The radiographs revealed the presence of pleural effusion and right ventricular enlargement (Figure 1). Mild enlargement of all 4 cardiac chambers, along with mild tricuspid valve regurgitation, was noted during transthoracic echocardiography. The velocity of the tricuspid regurgitation was low and therefore suggested a normal pulmonary arterial systolic pressure. Abdominal and thoracic effusions were noted on ultrasonography, although no hepatic congestion was found. Inspection of the right inguinal region by using ultrasonography revealed a dilated femoral vein, with turbulent continuous flow to the femoral vein (Figure 2). The exam findings were consistent with a diagnosis of congestive heart failure and an arteriovenous fistula of the right femoral artery.

Figure 1. Ventrodorsal radiograph of the thorax showing cardiac enlargement and pleural effusion consistent with congestive heart failure.

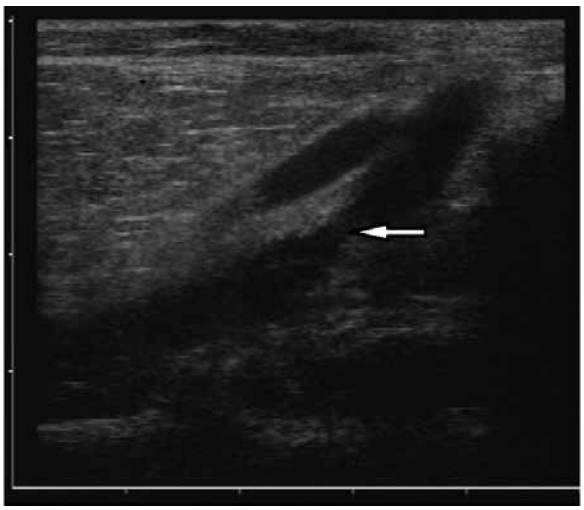

Figure 2. Ultrasound image of the arteriovenous fistula in the right inguinal region. A single connection (arrow) between the femoral artery and vein was identified. Continuous flow was identified in the enlarged femoral vein by using color Doppler (not shown).

Treatment with furosemide (0.5 mg/kg PO daily) was initiated and resulted in rapid resolution of the lemur's intermittent episodes of tachypnea, dyspnea, and exercise intolerance. The lemur continued receiving oral furosemide therapy until surgical repair of the arteriovenous fistula (3 mo after diagnosis).

Anesthesia for the surgery was induced with ketamine (10 mg/kg IM) and midazolam (0.3 mg/kg IM) and maintained with isoflurane (2% to 3%) in oxygen administered via endotracheal tube, with intermittent positive-pressure ventilation. Recovery from anesthesia was rapid and uncomplicated. A 22-gauge IV catheter was placed in the right cephalic vein for administration of a total of 75 mL 0.45% NaCl throughout the procedure. The surgical site in the right inguinal area was clipped, surgically prepped, and draped.

Preoperative medications included cefazolin (20 mg/kg IV), ketoprofen (2 mg/kg IM), furosemide (4 mg/kg IV), and long-acting ceftiofur formulation (ceftiofur crystalline free acid; 6 mg/kg SC). Injectable bupivacaine (1 mg/kg) was applied topically to the incision site intraoperatively prior to skin closure. Additional furosemide (2 mg/kg IM) was administered during recovery.

An oblique incision (approximate length, 2 cm) was made over the area with the palpable thrill. The relevant anatomy of lemurs is similar to that of humans, with the exception that the vessels in lemurs are relatively slightly deeper due to the upright posture of humans stretching the inguinal ligaments. The femoral artery and vein were identified, and the fistula was located between the common femoral artery and a vein deep to it, probably the profunda femoris vein (Figure 3). The fistula was ligated with 2 ligatures of 4-0 silk suture, and the vein and artery were separated. The wound was closed by using 4-0 polyglactin 910 suture for the subcutaneous layer and 4-0 poliglecaprone 25 suture for the subcuticular layer. The skin then was closed with cyanoacrylate tissue adhesive. A paste was prepared by crushing a 250-mg metronidazole tablet and mixing with a small volume of 0.9% saline. A thin layer of this paste was placed topically on the incision site to deter postoperative licking.

After surgery, the lemur recovered in an incubator, with supplemental oxygen provided overnight. The animal was tapered off oxygen without complication and returned to the indoor holding area of the lemur enclosure the next day. The lemur was continued on oral furosemide as prescribed preoperatively. Ibuprofen (9 mg/kg PO BID) was prescribed for 10 d postoperatively for analgesic and antiinflammatory effects. The surgical incision healed without apparent complication. Mild overgrooming and small superficial erosions and dermatitis of the perivulvar region were noted, but these lesions had resolved completely by 3.5 mo postoperatively. Two months postoperatively, multiple alopecic and superficial erosive lesions appeared on the medial aspect of the right leg. (Figure 4). Overgrooming due to postoperative hyperesthesia was suspected. Skin biopsy and culture of these lesions revealed a *Staphylococcus aureus* pyoderma. The lesions responded favorably to treatment with cefdinir (14 mg/kg PO daily for 5 wk) and resolved.

At a recheck examination under anesthesia performed 2.5 mo postoperatively, the lemur's cardiomegaly and signs of congestive heart failure had resolved. Cardiac auscultation was normal, with no murmur or systolic click identified. The heart rate was 144 bpm with a regular cardiac rhythm, with a normal respiratory rate and sounds. The pulse in the right inguinal region was bounding, but no bruit was ausculted and no thrill palpated. Radiographs did not show right ventricular enlargement or pleural or abdominal effusion. A bronchial pattern of the right middle lung lobe noted on the radiographs was attributed to atelectasis secondary to anesthesia without intubation. Abdominal ultrasonography was unremarkable, with no ascites detected. Follow-up echocardiography revealed normal cardiac dimensions and function with an absence of pleural effusion, indicating resolution of congestive heart failure. Treatment with furosemide was tapered over 2 wk and then discontinued. Radiographic films taken 10 mo later without anesthesia, with the lemur confined in an acrylic box, suggested normal lung fields with resolution of the bronchial pattern in the right middle lung lobe. Other than occasional episodes of mild alopecia and associated superficial erosions and overgrooming of the right medial thigh and right perivulvar region, the lemur remains clinically normal 4.5 y after the surgical repair of the femoral arteriovenous fistula. These mild recurrent skin lesions have resolved without treatment within weeks to months and occur with decreasing duration and frequency over time.

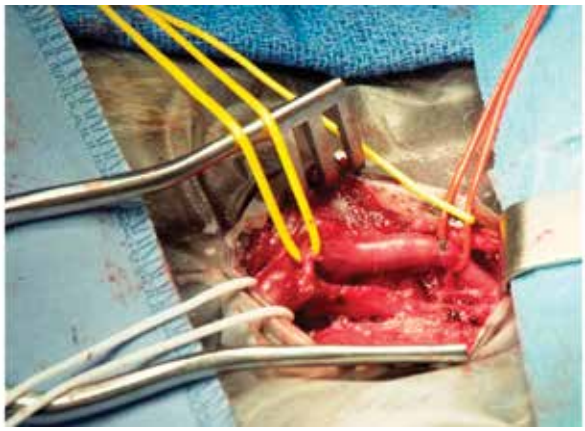

Figure 3. Intraoperative view of the right inguinal arteriovenous fistula prior to ligation. The red cord isolates the femoral artery, the white cord isolates the femoral vein, and the yellow cord isolates the fistula.

Figure 4. Alopecia and dermal erosions of the medial aspect of the right leg first appeared 2 mo after surgical repair of the right femoral arteriovenous fistula.

Discussion

Arteriovenous fistulas are not commonly reported in nondomestic species; the majority of cases are described in macaques and suspected to be iatrogenic. An arteriogram in a cynomolgus macaque (*Macaca fascicularis*) with cardiomegaly confirmed a femoral arteriovenous fistula suspected to be iatrogenic (secondary to venipuncture) that was surgically repaired with subsequent resolution of signs of heart failure.[17] A femoral arteriovenous fistula was also diagnosed and successfully surgically ablated in a rhesus monkey (*Macaca mulatta*).[17] A femoral artery pseudoaneurysm and associated arteriovenous fistula suspected to have occurred secondary to venipuncture were diagnosed in a cynomolgus macaque by using duplex Doppler ultrasound imaging. The pseudoaneurysm was treated successfully with ultrasound-guided compression repair, whereas the fistula was left untreated.[5] A femoral artery pseudoaneurysm associated with

venipuncture was reported in a white colobus monkey (*Colobus guereza caudatus*) and treated by vein patch angioplasty.[16] A grizzly bear (*Ursus arctos horribilis*) was diagnosed with a perineal arteriovenous fistula according to the histopathology of excised vascular tissue from a hemorrhaging nonhealing wound. The surgical excision was apparently curative, and the fistula was suspected to have been acquired secondary to trauma from a conspecific.[21] To our knowledge, the current case is the first arteriovenous fistula diagnosed and successfully treated in a prosimian.

In this case, the recognition of a palpable thrill over the right femoral artery was highly suggestive of an abnormal, permanent connection between the artery and a vein. The thrill and associated bruit had not been noticed during numerous previous veterinary interventions in this 10-y-old lemur, making congenital malformation highly unlikely and suggesting that the fistula developed later in life, although a timeline is impossible to reconstruct. Perhaps this animal's historic perivulvar dermatitis developed secondary to overgrooming stimulated by abnormal sensations associated with the fistula. The size and clinical manifestations of arteriovenous fistulas can increase over time when left untreated[9] and, in the case we present, resulted in congestive heart failure and associated respiratory signs. Some cases of arteriovenous fistulas in primates may go undiagnosed, particularly when signs of congestive heart failure are not apparent. During examination of this patient, the difference in temperature when palpating the right and left feet, distal to the abnormal region, suggested decreased blood flow to the affected foot. Ultrasonography and Doppler flow evaluation of the region confirmed the patent communication between the artery and vein and indicated that surgical correction was an option. Arteriovenous fistulas should be considered a treatable cause of congestive heart failure in lemurs.

An iatrogenic etiology for the arteriovenous fistula is highly suspected—although not proven—in this case. The femoral vein is a common site for blood collection in primates, including lemurs. This lemur had undergone repeated venipuncture as part of multiple health assessments, and there had been a prior history of hematoma formation at the site of venipuncture. The location of the femoral artery and vein, which parallel each other, make the possible inadvertent puncture of both structures a distinct risk when advancing and withdrawing a needle for blood collection. The femoral crease is an unreliable landmark for femoral puncture in humans, often resulting in an excessively distal puncture site past the bifurcation of the common femoral vessels or where the common femoral vein is more lateral and posterior (rather than medial) to the common femoral artery, making arteriovenous fistula and pseudoaneurysm formation more likely.[11,14] In light of these findings, the use of the inguinal ligament or femoral head as landmarks instead has been recommended.[14] Additional study of the vascular anatomy of lemurs either by using angiography or opportunistically at necropsy may support this recommendation in these species as well. Using ultrasound guidance for venous cannulation is increasingly common in human medicine and could prove useful in increasing the precision and decreasing the complications associated with venipuncture in nonhuman primates.[2,7] Arteriovenous fistula formation should be considered a potential risk of femoral venipuncture in lemurs and probably all primates.

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