An 8-year-old male red kangaroo (*Macropus rufus*) from a small private zoo was evaluated because of vomiting and anorexia. Clinical signs had been noticed for at least 2 weeks prior, with a reported initial frequency of vomiting 1 to 4 times/d. The severity and frequency of the vomiting had increased over the 4 days prior to initial evaluation to 6 to 10 times/d. The kangaroo’s clinical signs had become refractory to treatment for at least 2 weeks prior, with a reported initial frequency of vomiting 1 to 4 times/d. The kangaroo’s clinical signs had become refractory to treatment with flunixin meglumine and sucralfate administered.

**Case Description**—An 8-year-old male red kangaroo (*Macropus rufus*) was evaluated with a 2-week history of vomiting and anorexia. Four days prior, the patient became refractory to medical management. The kangaroo was admitted for diagnostic testing and treatment including whole body CT, blood work, and emergency laparotomy.

**Clinical Findings**—CT findings of a severely enlarged stomach, splenic displacement, and a whirl sign were indicative of mesenteric volvulus with gastric dilatation-volvulus (GDV). Contrast enhancement of abdominal viscera suggested intact arterial blood supply; however, compression of the caudal vena cava and portal vein indicated venous obstruction. Results of preoperative blood work suggested biliary stasis without evidence of inflammation. Additionally, a tooth root abscess was diagnosed on the basis of results of CT.

**Treatment and Outcome**—Exploratory laparotomy confirmed the diagnosis of mesenteric volvulus and GDV. The volvuli were corrected by clockwise derotation, and a gastropexy was performed. Tissue samples were obtained from the spleen and liver for evaluation. The kangaroo recovered from surgery, and the abscessed tooth was extracted 6 days later. Eight days after initial evaluation, the kangaroo was discharged.

**Clinical Relevance**—In the present report, the CT whirl sign was used to diagnose volvulus of the abdominal viscera, which suggests that this diagnostic indicator has utility in veterinary patients. Mesenteric volvulus with GDV was successfully treated in a nondomestic species. The tooth root abscess, a common condition in macropods, may explain the historic episodes of anorexia reported by the owner and may have contributed to the development of mesenteric volvulus and GDV in this kangaroo. (J Am Vet Med Assoc 2014;244:844–850)

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**Diagnosis and treatment of mesenteric volvulus in a red kangaroo (*Macropus rufus*)**


**Case Description**—An 8-year-old male red kangaroo (*Macropus rufus*) was evaluated with a 2-week history of vomiting and anorexia. Four days prior, the patient became refractory to medical management. The kangaroo was admitted for diagnostic testing and treatment including whole body CT, blood work, and emergency laparotomy.

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**Treatment and Outcome**—Exploratory laparotomy confirmed the diagnosis of mesenteric volvulus and GDV. The volvuli were corrected by clockwise derotation, and a gastropexy was performed. Tissue samples were obtained from the spleen and liver for evaluation. The kangaroo recovered from surgery, and the abscessed tooth was extracted 6 days later. Eight days after initial evaluation, the kangaroo was discharged.

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General anesthesia was induced and maintained with isoflurane in oxygen administered by facemask. Once the kangaroo was anesthetized, an IV catheter was placed in the left lateral saphenous vein. Given the extent of abdominal distention, large patient size, shorter examination times versus radiography or ultrasonography, and excellent cross-sectional and multiplanar detail with image reconstruction, it was determined that CT was the most suitable imaging modality. With the patient positioned in dorsal recumbency, whole body CT scans before and after contrast media administration (iohexol, 700 mg/kg [318.2 mg/lb] IV, once) were performed. CT images were acquired in a volumetric fashion with contiguous transverse slices, and reconstructed in 1- to 4-mm transverse, sagittal and dorsal plane images, and volume-rendered maximum-intensity projection. The images were displayed in soft tissue, bone, lung, and soft tissue postcontrast windows, and viewed on a commercial picture archiving and communication system.

Evaluation of the results of CT revealed that the abdominal cavity was distended by a very large, sacculated, gas- and fluid-distended stomach (Figure 1). A moderately enlarged, gas- and fluid-filled esophagus was diagnosed as generalized megaesophagus. The dilated esophagus could be traced into the midcranial abdomen, where it tapered, and coursed slightly to the right into a whirl-like structure composed of swirling strands of alternating mesenteric soft tissue– and fat-attenuating tissue (whirl sign) around the celiac and cranial mesenteric arteries, with the esophagus at the center (Figure 2). The prehepatic caudal vena cava and portal vein were severely narrowed, particularly through the region of the whirl. The spleen was moderately to severely enlarged, had increased contrast enhancement in a speckled pattern, and was abnormally located in the right dorsal abdomen (Figure 3). The small and large intestinal segments were diffusely, mildly distended (up to 1.5 cm in diameter) with gas, fluid, and feces, with normal wall contrast enhancement. Unusually, the small intestine was divided into separate portions, with 1 part located in the left craniodorsal abdomen and the remainder in the caudal and right dorsal abdomen. The tributaries and branches of the portal vein and cranial mesenteric and celiac arteries, originating at the whirl at the root of the mesentery, were subsequently distributed throughout the abdomen toward these displaced viscera. The gallbladder was moderately enlarged and fluid distended. The bile duct was also enlarged and could be traced into the whirl, where it tapered until it was no longer visible. A small amount of fluid was dispersed throughout the peritoneal cavity. The liver was confined to the right cranial abdomen. No evidence of a tumor, foreign body, or other cause of gastrointestinal obstruction was observed. A tooth root abscess of the right lower first incisor was diagnosed on the basis of severe expansion and thinning of the alveolar bone surrounding this tooth with a large amount of periapical lucency.

From these CT findings, the kangaroo was suspected to have an anticlockwise mesenteric volvulus, a GDV ≥ 180° with associated splenomegaly and 45° to 90° splenic displacement, and secondary megaesophagus. An underlying cause for these pathologic-
cal changes was not detected. Even though contrast enhancement of the abdominal viscera indicated adequate arterial blood supply, venous obstruction was evident. Biliary obstruction was also considered as a differential diagnosis because of the presence of icteric plasma and elevated serum bilirubin concentration. At the time of the CT scan, not all imaging findings had been thoroughly evaluated. Therefore, the kangaroo was recovered from anesthesia pending a complete review of all diagnostic tests. On the basis of the imaging results, combined with hematologic and clinical findings, surgical exploration of the abdomen was elected.

The kangaroo was again anesthetized approximately 4 hours later with midazolam (0.2 mg/kg, IV, once) and dexmedetomidine (0.1 mg/kg [0.045 mg/lb], IV, once), an endotracheal tube was placed, and inhalation anesthesia was maintained with sevoflurane in oxygen. The kangaroo was positioned in dorsal recumbency, and the abdomen was clipped of hair and prepared for surgery by means of standard aseptic technique. A routine ventral midline incision was made, and upon entry of the abdomen, the stomach was confirmed to be severely gas distended with omentum covering the ventral portion, similar to what is typically found in dogs affected with GDV. The proximal loops of small intestine were discolored (ie, dusky purple), appeared to be in an abnormal location, and at that time, were markedly distended (Figure 4). The spleen was not immediately identified upon entering the abdomen because it was dorsal to the distended stomach and small intestine. Once located, the spleen was an abnormal bluish-gray color and displaced to the right dorsal abdomen. A small volume of serosanguinous fluid was present in the abdomen. The root of the mesentery was palpated and found to be thick and firm. The bowel was examined, and no perforations, foreign bodies, or masses were detected. The gallbladder was observed and found to be full and patent, although expressed with some difficulty. Neither a 1- nor 0.75-cm-diameter orogastric tube could be passed into the stomach because of firm resistance at the cardia. The spleen was gently passed dorsally to the distended small bowel loops from right to left into its normal position. This movement was achieved with some resistance and tension, and it was observed that the remainder of the bowel began to change to a similar purple color as the more proximal small bowel loops. A 16-gauge catheter was placed into the stomach to allow gas decompression. Two liters of warm sterile saline (0.9% NaCl) solution was then poured into the abdomen, and the abdominal contents were allowed to float freely to aid in manipulation. Initial attempts to rotate the viscera counterclockwise only added tension to the attachments and exacerbated the dark discoloration of the bowel. Therefore, the intestines, spleen, and stomach were subsequently rotated (from the ventral aspect) in a clockwise direction. The gastrointestinal tract was assessed as viable, and therefore, resection was not indicated. The root of the mesentery was palpated again and found to

Figure 3—Dorsal plane CT reconstruction (slice thickness, 2 mm; soft tissue window images obtained after contrast administration) of the patient in Figure 1. The spleen, which is enlarged and has increased contrast enhancement in a speckled pattern, is abnormally located in the right side of the abdomen (arrows). See Figures 1 and 2 for remainder of key.

Figure 4—Intraoperative photograph of the patient in Figure 1, during emergency laparotomy via a ventral midline approach. A—Notice the distended, twisted stomach with tightly wrapped omentum ventrally (large arrow) and distended, twisted loops of small intestines (small arrow). The spleen is not visible. B—Following repositioning of the viscera, the decompressed, normally located stomach (large arrow), relaxed loops of small intestines (small arrow), and the spleen are visible in the left side of the abdomen (arrowhead). See Figures 1 and 2 for remainder of key.
be relaxed with no suggestion of twisting within the tissue as observed previously. Biopsy samples were obtained from the spleen and liver to help identify any underlying disease that could have contributed to the clinical signs. A gastropexy was performed by scarification along a taenia band of the stomach. A 5-cm incision was made in the right ventrolateral aspect of the body wall, and scarification was performed adjacent to this site. Several simple interrupted No. 1 polypropylene sutures were placed between the sites of scarification, fixing the stomach to the body wall. A 0.75-cm orogastric tube could be passed successfully at this time. Closure of the incision and recovery from anesthesia were normal. Vitamin E (40 U/kg [18 U/lb], SC, once) was administered to help prevent stress or capture myopathy in this animal in light of recent confinement, travel, surgery, and hospitalization. Results of histologic evaluation of the spleen were normal; however, the liver showed evidence of biliary obstruction of undetermined chronicity.

The kangaroo was treated with crystalloid fluids (3 mL/kg/h, [1.4 mL/lb/h], IV, continuous rate infusion) supplemented with 2.5% dextrose and potassium chloride (15 mEq/L), buprenorphine (0.01 mg/kg [0.005 mg/lb], IV, q 8 h), flunixin meglumine (0.5 mg/kg [0.23 mg/lb], IV, q 12 h), famotidine (0.5 mg/kg, IV, q 24 h), and penicillin G procaine (20,000 U/kg [9,000 U/lb], SC, q 24 h). The first day after surgery, the kangaroo was quiet and alert but had not shown any interdental mobility. During the 3 weeks following discharge from the hospital, the owners reported that the kangaroo’s appetite and fecal output steadily returned to normal. The kangaroo subsequently developed progressive anemia secondary to presumed gastric ulceration and was euthanized at home by the primary veterinarian 3 months after discharge. No necropsy was performed.

Discussion

Kangaroos are macropod marsupials in the order Diprotodontia. The red kangaroo is a large macropod with a reported mean male weight of 66 kg (145.2 lb). They have unique gastrointestinal anatomy, being foregut fermenters with a complex, composite, spiral stomach consisting of succular and tubular regions with a small hind stomach aborally. Compared with cats and dogs, the esophagus opens into a more caudally located cardiac, near the border of the 2 forestomach regions. Digestive system diseases, including dental disease, cecal ileus, bacterial overgrowth, parasitism, toxoplasmosis, and intestinal neoplasia, are all commonly reported. Mesenteric and gastrointestinal volvulus has been reported as the cause of death in a few captive kangaroos, diagnosed at necropsy, with disease of the gastrointestinal tract described as the leading cause of death in 1 population (31% of deaths). However, abdominal volvulus, defined as the acquired twisting of the gastrointestinal tract, mesentry, omentum, and other abdominal organs, is not common. In particular, mesenteric volvulus has been infrequently reported in the veterinary literature in any species. It has been reported rarely in cats and in a dog, but is more commonly seen in horses, cattle, rabbits, pigs, and dogs. In veterinary patients, these diseases have historically been diagnosed on the basis of results of
radiography, ultrasonography, and surgical exploration, whereas contrast-enhanced multidetector CT is the current modality of choice for evaluating acute abdominal pain and gastrointestinal symptoms in people.18–23 The use of contrast-enhanced CT to evaluate abdominal disease in canine patients is increasingly accessible, with safe, fast examinations facilitating rapid and accurate diagnosis.39,40

The CT whirl sign, first described by Fisher3 as a distinctive whirl-like pattern of collapsed small-bowel loops encircling the superior mesenteric artery in a case of small intestinal volvulus in a human patient, is an important characteristic of gastrointestinal volvulus.4 It may be seen when an organ (usually intestine) rotates around its mesentery, with the appearance of a whirlpool or hurricane formed by a mass with an internal architecture of swirling strands of soft tissue created by the branching mesenteric vessels against a background of mesenteric fat.17 Various forms of volvulus in humans have since been diagnosed with the aid of the CT whirl sign, including stomach, small bowel, large bowel, and splenic volvulus.36,37 This sign is best appreciated when the imaging plane is perpendicular to the axis of rotation; therefore, multiplanar reconstructions (ie, in transverse, dorsal, and sagittal planes) may be necessary for identification of the whirl.9,28 Modern multiple detector array CT scanners enable acquisition of images with a notable decrease in slice thickness versus older technology, thus improving spatial resolution so that it is nearly isotropic; high-resolution multiplanar reconstructions are therefore readily produced.38

In our patient, the axis of rotation ran in a dorsoventral direction; thus, the whirl was most clearly visible on dorsal plane images (Figure 2).

The CT whirl sign is a moderately sensitive but highly specific marker for gastrointestinal volvulus, with a high positive predictive value and an OR of 259 in predicting the presence of small bowel obstruction necessitating surgery in people.18,28,30,36,41 The sign is highly suggestive of, but not pathognomonic for, gastrointestinal volvulus, as any situation that produces rotation or twisting of the mesentery and its contents may produce a whirl composed of bowel loops, mesentery, or blood vessels. Examples in human patients include adhesions, prior abdominopelvic surgery, or comorbidities such as cancer.9,36,37 Experience in human medicine suggests that it is a highly relevant predictor of appropriate clinical management,30 with early detection of the sign being crucial to improve prognosis and patient survival.39

In dogs, mesenteric volvulus occurs when intestines rotate around the root of the mesentery causing occlusion of the cranial mesenteric artery and its branches.43 Blood flow to the duodenum, jejunum, ileum, cecum, ascending colon, and proximal descending colon is compromised when these vessels are occluded.77 The degree of vascular obstruction and resulting ischemia can vary depending on the degree of rotation, which can be estimated from the tightness of the whirl, and therefore, severity of clinical signs and prognosis can also vary. Mesenteric volvulus is well described in humans.15 Survival rates in human patients improved with the advent of surgical intervention, and 1 retrospective study40 of 182 patients reported a survival rate of 92%, even when up to 50% of the bowel was necrotic. Survival rates in animals vary between studies and species, with horses having the highest reported postoperative survival rate (80%).12 This relatively high survival rate in horses is likely due to rapid surgical intervention as well as improvements in anesthesia and perioperative care, as reported in horses with small intestinal strangulations in general (not limited to mesenteric volvulus).43 Studies7,47 in dogs have found survival rates of 0%, 10%, and 42%. The generally poor prognosis and high variability in survival rates in dogs are likely due to the difficulty in achieving a quick diagnosis, considering that the clinical signs can be nonspecific and the condition of the animal can decline rapidly. Recognition of the severity of the disease and swift surgical intervention if possible are necessary to provide the best chance of survival.

Typically, clinical signs of mesenteric volvulus in dogs, including vomiting, diarrhea, hematochezia, shock, tachycardia, circulatory collapse, and death, are acute and severe.17 However, chronic mesenteric volvulus has been reported in 1 dog with intermittent clinical signs for 4 months.47 The clinical signs of the dog described in that report47 were quite similar to those of the kangaroo, although the chronic volvulus was attributed to adhesions from prior surgery, which was not a confounding factor in this kangaroo. In both cases, by the time a referral was made for a more thorough diagnostic workup, the long duration of illness allowed considerable weight loss to occur. Systemically, both animals had mild dehydration but were not in shock and had only moderate signs of abdominal discomfort. Interestingly, the dog described in the previous report47 also had elevated cholestatic and hepatocellular leakage enzymes. Biopsy samples taken at surgery in that dog indicated a chronic obstruction of hepatic venous outflow, as demonstrated histologically. The kangaroo of this report had evidence of obstruction of biliary outflow, but the extent of obstruction and chronicity remained unclear on histologic evaluation. The biliary obstruction in this kangaroo, like that in the dog described in the prior report,47 was likely secondary to mechanical obstruction and ischemia from the volvulus. Portal hypoperfusion with resulting ischemic hepatopathy as can occur in GDV,9,46–51 might also be associated with mesenteric volvulus.47,52

Gastric volvulus involves abnormal rotation of the stomach along 1 or both of its axes. Abnormal gastric distension can predispose to volvulus, and a wandering (displaced) spleen is frequently associated with the condition.3,34,51 Gastric volvulus may be acute or chronic (or intermittent)53,54 and can be lethal. Most dogs with chronic GDV have weight loss, chronic vomiting, lethargy, and abdominal pain; the most common finding at exploratory celiotomy is a 45° to 90° rotation in a clockwise direction.9,55 In comparison, patients with acute GDV have been reported20 to commonly involve clockwise rotations ≥ 180°, often with concurrent splenic congestion. Although unfamiliar gastric anatomy particular to this species, combined with severe gas distension, made interpretation of CT images of the stomach somewhat difficult, imaging and surgical find-
ings in this patient as well as the inability to pass an orogastric tube prior to derotation were felt to be most consistent with an acute GDV ≥ 180°.

Considering the relatively stable medical status of the kangaroo when it was first evaluated, the decision to perform an exploratory laparotomy was not immediately clear. The gastrointestinal tract, although gas distended, did not feel particularly thick or turgid on abdominal palpation. Hematologic evaluation also suggested mild dehydration and electrolyte imbalances, but given the frequency of vomiting, this was expected and likely could be quickly addressed with fluids and electrolyte replacement. However, the information obtained from CT, specifically demonstration of the whirl sign, was a critical factor in the decision-making process, resulting in surgery being performed the same day rather than pursuing medical management overnight.

This case demonstrates the possibility of mesenteric volvulus as a chronic condition and suggests that it can be successfully treated and managed in a kangaroo. In this patient, the mesenteric volvulus may have occurred secondary to pain and anorexia from a primary tooth root abscess, resulting in aerophagia, altered gastrointestinal flora, and subsequent gas distension of the gastrointestinal tract and ileus. The ensuing mesenteric volvulus was loose enough to preserve arterial supply but still caused venous obstruction. We hypothesize that GDV occurred more acutely, secondary to vomiting and ileus caused by the other gastrointestinal pathologic changes. The volvuli in turn caused hepatic hypoperfusion and biliary stasis identified histologically. The sequence of events underscores the importance of proper diet, dental care, and husbandry for captive marsupials. Furthermore, this case demonstrates the successful diagnosis, treatment, and management of mesenteric volvulus in a nondomestic species. Although 1 report of canine splenic torsion describes a whirled or corkscrew-like soft tissue mass containing vessels as representing a rotated splenic pedicle on contrast-enhanced CT, to our knowledge, this is the first documented use of the CT whirl sign to provide critical diagnostic information used to direct case management in veterinary medicine. In cases of suspected abdominal volvulus in small animals, use of contrast-enhanced helical CT could be considered to aid diagnosis, with careful evaluation for a whirl sign as an indicator of volvulus.

References

From this month's AJVR

Effects of ultraviolet radiation produced from artificial lights on serum 25-hydroxyvitamin D concentration in captive domestic rabbits (Oryctolagus cuniculi)

Jessica A. Emerson et al

Objective—To determine the effects of UVB radiation produced by artificial lights on serum 25-hydroxyvitamin D concentrations in domestic rabbits (Oryctolagus cuniculi).

Animals—9 juvenile domestic rabbits.

Procedures—After an acclimation period, rabbits were anesthetized with isoflurane, and an initial blood sample was collected for determination of serum 25-hydroxyvitamin D concentration. Rabbits were randomly assigned to receive 12-hour exposure to UVB radiation produced by 2 compact fluorescent lights daily (n = 5) or no UVB supplementation (4) commencing on day 1. The UVB radiation emitted into the cage was measured at 9 points approximately 34 cm from the surface of the UVB light sources during the acclimation period, after exposure for a total of 14 days. The UVB radiation level was 8.3 to 58.1 μW/cm² for the exposed rabbits and consistently < 0.001 μW/cm² for the control rabbits. Mean ± SD serum 25-hydroxyvitamin D concentrations in the rabbits that were or were not provided supplemental UVB radiation for 14 days differed significantly (66.4 ± 14.3 nmol/L and 31.7 ± 9.9 nmol/L, respectively).

Conclusions and Clinical Relevance—Exposure to UVB radiation produced by artificial light significantly increased circulating serum 25-hydroxyvitamin D concentration in juvenile rabbits. Because vitamin D is an essential hormone in vertebrates, these findings suggested that the provision of supplemental UVB radiation to captive rabbits may be important. (Am J Vet Res 2014;75:380–384)