Evaluation of ameroid ring constrictors for the management of single extrahepatic portosystemic shunts in cats: 23 cases (1996–2001)

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Objective—To document the signalment; history; clinical signs; clinicopathologic, diagnostic imaging, and surgical findings; perioperative complications; and long-term clinical results of ameroid ring constrictor (ARC) placement on single extrahepatic portosystemic shunts (PSS) in cats.

Design—Retrospective study.

Animals—23 cats treated with an ARC on a single extrahepatic PSS.

Procedure—An ARC was placed surgically around the PSS. Portal pressure was measured prior to ARC placement, with complete temporary PSS occlusion, and after ARC placement. Cats were scheduled for recheck transcolonic portal scintigraphy 8 to 10 weeks after surgery. Follow-up information was obtained by telephone interview with the owners.

Results—An ARC was successfully placed in 22 of 23 cats. Intraoperative complications, consisting of PSS hemorrhage, occurred in 2 cats. Mean (± SD) portal pressure (n = 15) was 6.7 ± 2.9 mm Hg before PSS manipulation, 18.6 ± 7.7 mm Hg with complete temporary PSS occlusion, and 6.9 ± 2.7 mm Hg after ARC placement. Postoperative complications developed in 77% (17 of 22) of cats after ARC placement, and included central blindness, hyperthermia, frantic behavior, and generalized motor seizures. Perioperative mortality rate was 4.3% (1 of 23). Persistent shunting was identified in 8 of 14 cats. Overall, 75% (15 of 20) of cats had an excellent long-term outcome.

Conclusions and Clinical Relevance—Placement of an ARC on single extrahepatic PSS in cats resulted in low surgical complication and perioperative mortality rates, but most cats did have substantial postoperative complications. Persistent shunting was common, although many cats with persistent shunting were clinically normal. (*J Am Vet Med Assoc* 2002;220:1341–1347)

Portosystemic shunts (PSS) are vascular anomalies that divert portal blood away from the liver and into a systemic vein. The reported incidence of PSS is higher in dogs than other companion animal species.[1] Portosystemic shunts are rarely diagnosed in cats, occurring at a rate of 2.5/10,000 cats examined at North American veterinary schools.[2] There are sporadic reports and case series of PSS in cats in the veterinary literature.[3-18] Single extrahepatic portocaval shunts are reported to be the most common type of PSS in cats.[19] In a review of 11 clinical studies reporting a total of 40 cats with PSS, all had single PSS, and most (79%) were extrahepatic.[19]

The **ameroid ring constrictor (ARC)** is a device designed to produce gradual vascular occlusion. The ARC is a cylindrical device with a slot to allow placement around a vessel. A key is placed in the slot to prevent dislodgement. The ARC consists of an inner ring of ameroid, a hygroscopic, compressed casein that expands when immersed in water. An outer ring of stainless steel prevents the outward expansion of the ameroid so that as the ameroid expands, the inner diameter of the cylinder is gradually reduced. The ARC produces an early rapid expansion followed by a period of slower expansion.[20] The ARC was originally developed for experimental use and has been used to create canine models of coronary artery stenosis, esophageal varices, and endophlebitis hepatica obliterans-like syndrome.[21-24] In dogs and cats with PSS, gradual occlusion of the PSS with an ARC should allow development of hepatic architecture in response to the increased vascular supply and avoid the development of fatal portal hypertension.[15] The use of an ARC for the surgical management of a single extrahepatic PSS has been reported in 2 cats.[15] One cat had complete shunt occlusion, demonstrated by use of technetium Tc 99m pertechnetate portal scintigraphy, 30 days after surgery, and a second cat developed multiple extrahepatic PSS, demonstrated by mesenteric portography 90 days after surgery.[15] Both cats were reported to be improved on the basis of clinical assessment, shunt fraction, and serum bile acid concentration.[15] To the authors' knowledge, the long-term results of ARC placement on single extrahepatic PSS in cats have not been reported.

The purpose of the study reported here was to report the signalment, history, clinical signs, and clinicopathologic, diagnostic imaging, and surgical findings in cats with single extrahepatic PSS. Additionally, the perioperative complications and long-term clinical results of ARC placement on single extrahepatic PSS in cats were documented.

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Criteria for Selection of Cases

Medical records of all cats that had transcolonic technetium Tc 99m pertechnetate portal scintigraphy performed for the diagnosis of a PSS and all cats that had a PSS surgically operated at the Veterinary Medical Teaching Hospitals of the **University of California, Davis (UCD)** and **North Carolina State University (NCSU)** between January 1996 and January 2001 were reviewed. All cats with a single extrahepatic PSS that the surgeon intended to treat with an ARC were included. Exclusion criteria included a negative portal scintigraphic scan, intrahepatic PSS, multiple extrahepatic PSS, portal atresia, portal vein thrombosis, and cats with a single extrahepatic PSS where the surgeon decided prior to surgery to treat by suture ligation.

Procedures

Presurgical evaluation—Data obtained from the medical record included age at surgery, sex, breed, weight, pertinent medical history, medical and dietary treatment, and prior surgical procedures. All cats were treated, using a similar diagnostic and therapeutic protocol. Complete blood counts and serum biochemical analyses were performed, and 12-hour fasting and 2-hour postprandial serum bile acid concentrations were obtained for each cat. Urine was collected by cystocentesis, and urinalyses were performed. Abdominal ultrasonography and transcolonic technetium Tc 99m pertechnetate portal scintigraphy[25] were also performed.

Surgical procedure—A midline exploratory laparotomy was performed, and the anatomic location of the PSS was recorded. The extrahepatic PSS was dissected with right-angled forceps as it entered the caudal vena cava (portocaval PSS) or just caudal to the diaphragm (portoazygous PSS). A length of size 2-0 silk suture was passed around the PSS. A 23-gauge catheter was placed in a jejunal vein, and the resting portal pressure was measured with a pressure transducer (UCD) or water manometer (NCSU). The suture around the PSS was temporarily tightened to occlude the PSS and the portal pressure measured. Cats were allocated into 2 groups: those in which portal pressure increased by less than 7.6 mm Hg (10 cm H_20), which could have been acutely completely occluded with a ligature in accordance with accepted criteria in dogs,[26] and those in which portal pressure increased by greater than 7.6 mm Hg, which would have been partially occluded with a ligature. An ARC was placed around the PSS, the silk suture was removed, and the portal pressure after ARC placement was measured. The size of the ARC was chosen to sit snugly around the PSS without producing any degree of initial constriction. The amount of dissection was limited, and care was taken with ARC placement to prevent kinking of the PSS. The ARC size, appearance of the splanchnic viscera after ARC placement, intraoperative complications, and perioperative antibiotic use were recorded. A liver biopsy specimen was obtained. The urinary bladder was palpated for the presence of cystic calculi. The abdominal incision was routinely closed.

Postoperative care and evaluation—After surgery, each cat was monitored for heart rate, indirect arterial blood pressure by use of Doppler sphygmomanometry on a forelimb, PCV, serum total protein, glucose, electrolyte, and creatinine concentrations, colloid osmotic pressure (UCD cases only), rectal temperature, and activated clotting time. Urine output and specific gravity were monitored, though a urinary catheter was not placed. Postoperative medical treatments, postoperative complications, and the length of hospitalization were recorded. The medical and dietary management instituted prior to surgery to control the clinical signs of the PSS were continued until cats were rechecked 8 to 10 weeks after surgery.

All cats were scheduled for a recheck examination and transcolonic portal scintigraphy at 8 to 10 weeks after surgery. If scintigraphy revealed continued portosystemic shunting, abdominal ultrasonography, portography, or exploratory laparotomy was recommended. Follow-up information was collected via telephone interview with the owner. A questionnaire was filled out, which included current medical and dietary treatments, signs of urinary tract disease (calculi, polyuria, or polydipsia), neurologic signs (circling, staring into space, tremors, seizures, administration of anticonvulsant medication), gastrointestinal signs (hypersalivation, vomiting, diarrhea), and nonspecific signs (lethargy, weight loss). Each owner was asked whether they considered their cat to be normal. Clinical outcomes were classified as excellent (complete resolution of clinical signs), fair (improved clinical signs), or poor (no improvement or worsening of clinical signs) at the final follow-up examination.

Results

Selection of cases—During the 5-year study period, 51 cats had transcolonic portal scintigraphy performed for the diagnosis of a PSS or underwent surgery for PSS (41 at UCD and 10 at NCSU). Results from 38 of 51 scans were positive. Surgical treatment was declined by 3 owners because of cost and by 1 owner based on the diagnosis of a portal vein thrombus on a preoperative ultrasound scan. Thirty-four cats underwent surgery (26 at UCD and 8 at NCSU). Eleven cats were excluded because of the presence of 1 of the following conditions: multiple extrahepatic PSS (4 cats), portal atresia (1), or surgeon preference for suture ligation (6). In the remaining 23 cats, ARC placement was attempted, and these cats were included in the study. No cats with an intrahepatic PSS were identified.

Presurgical evaluation—Median age of cats at time of surgery was 12 months (range, 5 to 72 months; age not known in 2 cats). Seven cats were spayed females, 5 were sexually intact females, 8 were castrated males, and 3 were sexually intact males. Breeds included domestic shorthair (13 cats), Siamese (4), domestic longhair (2), Himalayan (2), and Siamese-crossbreeds (2). Body weight at surgery ranged from 1.1 to 6.2 kg (2.42 to 13.64 lb; mean ± SD, 3.3 ± 1.3 kg [7.26 ± 2.86 lb]).

Clinical signs included hypersalivation (16 cats), weight loss or underweight (13), encephalopathic episodes (10), anorexia (9), dysuria and hematuria (9), episodic central blindness (7), ataxia (7), signs of depression and lethargy (7), seizures (5), intention tremors (5), yellow irises (3), aggression (2), polyuria and polydipsia (2), slow recovery from general anesthesia (2), recurrent upper respiratory infection (2), urethral obstruction (2), vomiting (1), and icterus (1). Concurrent medical conditions included progressive retinal degeneration (1 cat), feline asthma (1), mitral stenosis (1), and left renal hypoplasia (1). Medical treatment included a low protein diet (20 cats), lactulose (15), anticonvulsant medication (19) consisting of either potassium bromide (12 cats) or phenobarbital (7), and antibiotic treatment (14) consisting of neomycin (6 cats), metronidazole (4), amoxicillin (3), enrofloxacin (1), ampicillin and clavulanic acid (1), cephalexin (1), or clindamycin (1); 2 cats were not on medical treatment prior to surgery. Nine cats had previous surgery: 6 cats had a cystotomy performed to remove cystic urinary calculi, 2 cats had persistent clinical signs after partial PSS ligation, and 1 cat had a perineal urethrostomy for urinary obstruction secondary to urethral calculi.

Results of the serum biochemical analyses, pre- and postprandial bile acid concentrations, CBC, and urinalysis obtained during the initial visit were compared. All cats had at least 1 variable (excluding electrolyte concentrations) on the serum biochemistry panel outside the reference range. The most common biochemical abnormalities included panhypoproteinemia (74% of cats [17 of 23]), and decreased BUN (61 [14 of 23]) and serum creatinine (52% [12 of 23]) concentrations. Moderate increases in liver enzyme activities were evident in 52% (12 of 23) of cats; 48% had high alkaline phosphatase activity, 35% had high alanine aminotransferase activity, and 33% had high aspartate transaminase activity. Hypocalcemia was evident in 43% (10 of 23) of cats. Preprandial bile acid concentration was high in 94% (17 of 18) of cats, and 2-hour postprandial bile acid concentration was high in 100% (18 of 18) of cats. The most common abnormalities on the CBC included decreased mean cell volume (52% [12 of 23]) and mean cell hemoglobin (35% [8 of 23]), and increased RBC (22% [7 of 23]) and WBC (30% [7 of 23]) concentrations. Ammonium biurate or uric acid crystals were present in 31% (5 of 16) of cats. Calculus analysis had previously been performed on 4 of 6 cats after retrieval of cystoliths; in 3 of 4 cats the calculi were 100% uric acid, and 1 cat had mixed uric acid and struvite calculi.

Transcolonic technetium Tc 99m pertechnetate portal scintigraphy was performed in 21 of 23 cats, and results for portosystemic shunting were positive in all 21 cats scanned. Abdominal ultrasound was performed in 17 cats; the PSS was identified in 47% (8 of 17) of cats , though in 2 of 8 cats with an ultrasonographically identifiable PSS, it was believed that the PSS was intrahepatic.

Surgical procedure—There was a single extrahepatic PSS identified during surgery in all 23 cats. The PSS drained into the caudal vena cava in 9 cats, through the diaphragm adjacent to the esophagus and presumably into the azygous vein in 8 cats, into the phrenicoabdominal vein in 1 cat, into the left renal vein in 1 cat, and from the colonic vein into the caudal vena cava dorsal to the urinary bladder in 1 cat; in 3 cats the precise location of the PSS was not recorded. An ARC was successfully placed in 22 of 23 cats; in 1 cat, the back wall of the PSS was lacerated during dissection, and the PSS was subsequently ligated completely. Portal pressures were recorded in 15 of 23 cats. Mean (± SD) portal pressure was 6.7 ± 2.9 mm Hg before PSS manipulation and 18.6 ± 7.7 mm Hg with complete temporary PSS occlusion (if suture ligation had been performed, 5 of 15 cats would have undergone complete ligation, and 10 would have undergone partial ligation). Internal diameter of the ARC was 5 mm in 14 cats, 3.5 mm in 3 cats, and 6.5 mm in 2 cats; the size was not recorded in 3 cats. Mean portal pressure after ARC placement was 6.9 ± 2.7 mm Hg (n = 14; 1 cat had the ruptured PSS ligated), and subjective assessment of the splanchnic viscera did not identify intestinal blanching or hypermotility or pancreatic cyanosis in any cat. Intraoperative complications occurred in 2 of 23 cats; both cats had hemorrhage associated with PSS ligation, 1 of which was controlled with digital pressure and the second required PSS ligation. In 2 cats, the liver was considered to be grossly abnormal, consistent with hepatic lipidosis; in 1 cat, a gastrostomy tube was surgically placed to allow for postoperative enteral nutrition. A liver biopsy specimen was obtained in 18 of 23 cats. Histologic findings were consistent with a PSS in all 18 cats, reported as moderate to severe lobular atrophy with portal arteriolar duplication and inconspicuous or absent portal veins. Concurrent hepatic lipidosis was present in 3 of 18 liver biopsy specimens, including the 2 cats with grossly apparent hepatic lipidosis. No cat had evidence of cystic urinary calculi, and no cystotomies were performed. Prophylactic antibiotic treatment consisted of cefazolin (22 mg/kg [10 mg/lb], q 2 h, IV) in 12 cats, cefotetan (30 mg/kg [13.6 mg/lb], q 2 h, IV) in 8 cats, and ampicillin (20 mg/kg [9.09 mg/lb], q 2 h, IV) in 3 cats.

Postoperative care and evaluation—Complications developed during postoperative hospitalization in 77% (17 of 22) of cats after ARC placement. Ten cats developed central blindness (loss of menace reflex, with intact papillary light and palpebral reflexes) within 48 hours of surgery; all 10 were considered to be visual prior to surgery. Seven of 10 were still blind at discharge. Six cats became hyperthermic (rectal temperature > 39 C [102.2 F]); 3 hyperthermic cats were considered to have frantic behavior after surgery. Five cats had frantic postoperative behavior, and 5 cats had encephalopathic episodes or obtundation after surgery. Generalized motor seizures occurred on the first (1 cat) or second (2 cats) day after surgery; all 3 of these cats were given perioperative anticonvulsant treatment (potassium bromide in 2 cats and phenobarbital in 1 cat) and none had a history of seizures. One of these 3 cats was treated with phenobarbital (administered IV), developed status epilepticus, and died; 1 cat was treated with phenobarbital (administered IV) and recovered with no neurologic impairment; and 1 cat did not receive additional anticonvulsant medication and recovered with no neurologic impairment. One cat developed a coagulopathy 12 hours after surgery, characterized by a PCV of 12.5%, an activated clotting time > 999 seconds, prothrombin time of 16.7 seconds (reference range, 9.0 to 15.9), and a partial thromboplastin time of 29.0 seconds (reference range, 10.0 to 17.4). This cat had increased respiratory effort and a generalized alveolar pattern radiographically. The cat was treated with a fresh whole blood transfusion and vitamin K, and clotting variables returned to normal 36 hours after surgery. Other postoperative complications included twitching, which was considered to represent focal seizures (1 cat), tremors (1), incisional seroma (1), and transfusion reaction (1).

In addition to medical and dietary treatment instituted prior to surgery, postoperative treatment after ARC placement in 22 cats included administration of analgesic drugs (22 cats), additional antibiotics (19), and intravenous fluid therapy (17). Postoperative analgesia consisted of administration of oxymorphone (17 cats), butorphanol (3), or buprenorphine (2). Additional antibiotic treatment consisted of cefotetan (5 cats), ampicillin (4), cephazolin (3), enrofloxacin (3), ampicillin and clavulanic acid (2), metronidazole (1), amoxicillin (1), or clindamycin (1). Intravenous fluid therapy consisted of crystalloid solutions (15 cats), synthetic colloid solutions (4), fresh frozen plasma (3), and fresh whole blood (2). Additional medical treatment administered to cats that did not develop a seizure included dextrose (2 cats), famotidine (1), ranitidine (1), diazepam (1 cat with focal seizures and 1 with central blindness), and diphenhydramine (1 cat with a transfusion reaction).

Twenty-one cats with an ARC survived to discharge; mean (± SD) time of hospitalization was 5.0 ± 3.6 days (range, 1 to 17 days). Nineteen of 21 cats were prescribed a low-protein diet at discharge. Medical treatment at discharge included anticonvulsant medication (16 cats), consisting of either potassium bromide (9) or phenobarbital (7); lactulose (13); and antibiotics (19), consisting of neomycin (6), metronidazole (4), ampicillin and clavulanic acid (4), cephalexin (3), amoxicillin (3), or enrofloxacin (2); 1 cat was not on medical treatment at discharge.

Fourteen of 21 cats with an ARC were examined 8 to 10 weeks after surgery. Ten of 14 cats were still receiving the medical and dietary management regimens prescribed at discharge. Thirteen of 14 cats were clinically normal; 1 cat was persistently dull and had occasional seizures. All 7 cats with postoperative central blindness that were reexamined had vision 8 to 10 weeks after surgery. Portal scintigraphy revealed that 57% (8 of 14) of cats had persistent portosystemic shunting. Further evaluation of 3 cats with persistent portosystemic shunting on scintigraphy, by abdominal ultrasonography (2 cats), or exploratory laparotomy (1), revealed multiple extrahepatic PSS. Six of 7 cats with a portocaval PSS and 2 of 6 cats with a portoazygous PSS had persistent shunting. When cats were grouped on the basis of increased portal pressure with temporary PSS occlusion, 1 of 3 cats in which the PSS could have been completely ligated and 4 of 7 cats in which the PSS would have been partially ligated had persistent shunting. Mean (± SD) increase in portal pressure with temporary PSS occlusion was 12.6 ± 5.5 (range, 6 to 18) mm Hg in cats with negative scan results and 18.4 ± 8.3 (range, 7 to 30) mm Hg in cats with positive scan results.

Follow-up information from the owners was available in 20 of 21 cats with an ARC, with a mean (± SD) follow-up period of 26 ± 17 months (range, 3 to 51 months). Clinical outcome was classified as excellent in 75% (15 of 20) of cats. Scintigraphy had been performed in 11 cats that had an excellent clinical outcome; 6 had negative results, and 5 had persistent shunting. Of the 15 cats with an excellent outcome, none were on continued medical treatment, and 13 were being fed a diet with a normal protein content; 2 cats were still being fed a low-protein diet (1 cat at 3 months that had negative scan results, and 1 at 46 months in which a follow-up scan was not performed). Clinical outcome was classified as fair in 2 cats (41- and 42-month follow-up periods); both cats were clinically normal with positive scan results 8 to 10 weeks after surgery and subsequently had occasional lethargy and episodes of staring into space. One of these cats was still being treated with lactulose and a low-protein diet. Three cats had a poor clinical outcome, developing seizures, lethargy, and failure to gain weight after surgery, despite continued medical management. One cat died in status epilepticus 6 months after surgery, and the other 2 cats were euthanatized 12 and 44 months after surgery. Only 1 of these 3 cats was examined 8 to 10 weeks after surgery; this cat was persistently dull with seizure episodes and had persistent portosystemic shunting. Five cats had less than excellent outcomes; 3 had been scanned at 8 to 10 weeks, and all 3 had persistent shunting.

Discussion

This study was designed to include all consecutively treated cats with a single extrahepatic PSS on the basis of an intention-to-treat with an ARC. Hence, we included 1 cat that had the PSS ligated after inadvertent PSS rupture but did not include 6 cats for which the surgeon decided prior to surgery to ligate the PSS. The follow-up, however, was limited to cats treated with an ARC, excluding the cat with the ligated PSS. Intrahepatic PSS, multiple extrahepatic PSS, and portal atresia have been reported in cats[2,10,12,16,27]; therefore, cats with these conditions were excluded.

Single extrahepatic PSS are generally considered to be congenital, with the onset of clinical signs variously reported in 75% of cats by 6 months of age[2] and in 78% by 1 year of age.[19] In this series, only 35% of cats were < 1 year of age, indicating an older patient population, compared with previous reports. Persian and Himalayan cats are reported to represent the majority of affected purebred cats,[2] although in our study 26% of cats were Siamese or Siamese crosses. Male cats are reported to be more commonly affected,[2,19,28] but there was no apparent sex predilection in our study (12 females vs 11 males). The clinical signs observed were similar to those reported previously,[2,9,12,13,19,28] and included hypersalivation (70%) and episodic central blindness (30%), which are rarely described in dogs with this condition.

Biochemical changes have been reported in approximately 40% of cats tested[28]; in our study all 23 cats had at least 1 serum biochemical abnormality (excluding electrolyte and serum bile acid concentrations). Similar to dogs with PSS,[29] commonly observed biochemical abnormalities included panhypoproteinemia, decreased BUN concentration, and moderately increased liver enzyme activity. Hypocalcemia, detected in 43% of cats, was most likely related to the low serum albumen concentration.[30] The low serum creatinine concentration, observed in 52% of cats, may have been related to low muscle mass. Pre- and postprandial serum bile acid concentrations were the most sensitive test for PSS, with sensitivities of 94 and 100%, compared with reported sensitivities of 58 and 100%,[31] respectively. The most common abnormality on the CBC was microcytosis without associated anemia (52%).

Transcolonic portal scintigraphy is a highly sensitive test for macroscopic PSS in dogs and cats[25] and was used as the primary preoperative imaging modality in cats with biochemical changes consistent with PSS. The sensitivity and specificity of abdominal ultrasound for detecting extrahepatic PSS is reported as 80 and 67%, respectively, in dogs and cats.[32] In another study, ultrasonography revealed an anomalous vessel in 14 of 14 cats and correctly differentiated intra- versus extrahepatic PSS in 13 of 14 cats.[33] A third study, however, reported that the anomalous vessel was located in only half of cases examined.[2] Similarly, in our study, an anomalous vessel was detected in only 8 of 17 cats, and in 2 cats the vessel was incorrectly identified as intrahepatic.

The location of the extrahepatic PSS in the cats of this study was similar to that reported previously.[2] Levy et al[2] reported that the shunt vessel most commonly originates from the portal vein, left gastric vein, or splenic vein, and less commonly the mesenteric, colic, or right gastric vein, and joins the caudal vena cava in more than half of all cases, transverses the diaphragm to enter a thoracic vein in another quarter, and occasionally enters the renal or phrenicoabdominal vein. In the cats of this study, portoazygous PSS were more common than previously reported (47%) and were more common in older cats (mean age, 24.5 months vs 13.8 months for portocaval PSS). Guidelines for the amount of PSS occlusion that can be safely achieved are lacking in cats; thus, most surgeons use the guidelines for increase in portal pressure reported for dogs.[2, 26] Similar to previous reports,[19] 33% of cats in our series could have been completely ligated. Intraoperative complications were not common (9% of cats) and consisted of hemorrhage from the PSS during shunt dissection in 2 cats. In 1 cat, the hemorrhage was controlled with digital pressure, whereas the second cat required PSS ligation. Although the amount of dissection required to place an ARC is greater than for a ligature, careful surgical technique should limit this complication. Liver biopsies revealed histologic evidence of hepatic lipidosis in 17% (3 of 18) of cats, indicating the importance of meeting postoperative nutritional requirements.

The use of an ARC should limit postoperative portal hypertension.[15] In 1 study, 14% (2 of 14) of animals developed portal hypertension after ARC placement, which led the authors to recommend that the size of the ARC is chosen to avoid initial vessel constriction.[15] In this study, portal hypertension was not evident in any cat, but there was a high prevalence of postoperative complications, with 77% of cats developing complications during postoperative hospitalization. Central blindness was the most common postoperative complication, recognized in 45% of cats after surgery. Blindness appears to be temporary, with a return of sight in 3 of 10 cats by the time of discharge and in all cats reexamined 8 to 10 weeks after surgery. Postoperative generalized motor seizures have been reported in dogs and cats after PSS surgery,[2,34-37] and in 1 dog 1 day after ARC placement.[38] Levy et al[2] reported 4 of 73 (5%) cats that underwent surgery developed postoperative seizures, compared with 14% of cats in our study. This prevalence occurred despite the fact that 83% of cats had anticonvulsant therapy initiated prior to surgery. The prognosis in dogs and cats that develop postsurgical seizures is guarded.[34-37] Heldmann et al[2] reported on 4 cats treated with propofol; all survived to time of discharge, but 1 was subsequently euthanatized, a second was "severely retarded," a third had occasional seizures, and the fourth was neurologically normal. Similarly, in our study, 1 cat died in status epilepticus, and 2 recovered with normal neurologic function. Additional postoperative complications included hyperthermia, frantic behavior, encephalopathic episodes or obtundation, coagulopathy, twitching, tremors, incisional seroma, and transfusion reaction.

Despite the high complication rate, the perioperative mortality rate was low, with 1 (4.5%) cat dying because of status epilepticus. The reported mortality rates after ligation of a single extrahepatic PSS in cats are 11% (7 of 62 cats), caused by portal hypertension and worsening neurologic status,[2] and 20% (3 of 15) after gauged PSS attenuation.[18] This compares with a reported mortality rate of 14 to 21% after PSS ligation in dogs.[39-42] In 2 clinical series, the mortality rate after ARC placement on a single extrahepatic PSS was 14% (2 of 14) of dogs and cats[15] and 6% (1 of 18) of dogs.[38]

The outcome of PSS surgery can be evaluated by biochemical indices such as serum bile acid concentration, clinical outcome, and nuclear scintigraphy. Postoperative serum bile acid concentrations have been shown to correlate poorly with clinical outcome in dogs[15,42-44] and were not included in the study protocol. Transcolonic portal scintigraphy is a sensitive and specific method for determining the presence or absence of portosystemic shunting.[25,45] Shunt fraction can be calculated from the nuclear scan, and comparison of pre- and postoperative shunt fraction has been used as a method of evaluating the outcome of surgery in cats with PSS.[46] However, there is poor reproducibility in shunt fraction determination between operators.[45] Long-term clinical outcome is the principal method for evaluating the outcome of PSS surgery. In our study, two thirds of cats (14 of 21) had portal scintigraphy 8 to 10 weeks after surgery, and 57% (8 of 14) had persistent portosystemic shunting. Only 1 of 8 cats with persistent shunting had clinical signs, though most cats were still on dietary and medical management. The long-term clinical outcome in cats that survived was excellent in 75% (15 of 20) of cats, fair in 10%, and poor in 15%. Using similar outcome criteria and a compilation of previous case series, Birchard et al[19] reported that 59% of cats had an excellent, 18% a fair, and 23% a poor outcome after PSS ligation in cats (n = 22). The long-term clinical outcome is poorer in cats compared to dogs.[18,19]

Interestingly, of the 8 cats with persistent shunting 8 to 10 weeks after surgery, 3 had a fair or poor outcome, and 5 had an excellent outcome. Studies documenting the gradual occlusion of blood flow after placement of an ARC on a vein have been limited to the angiographic demonstration of the time to complete occlusion in dogs. In 1 study, the ARC was placed around the splenic vein in 3 dogs; complete occlusion developed by 4 weeks in 2 dogs and by 5 weeks in the third dog.[15] In another study, the ARC was placed around the femoral vein in 5 dogs; complete occlusion developed by 2 weeks in 4 dogs and by 3 weeks in the fifth dog.[47] Hence, by 8 to 10 weeks after surgery, we would expect the vessel within the ARC to be completely occluded. Vogt et al[15] reported that 1 of 2 cats and 1 of 10 dogs developed multiple extrahepatic PSS (diagnosed at repeat surgery) after ARC placement on a single extrahepatic PSS. The most likely explanation for multiple extrahepatic PSS is that as the ameroid closed, the hepatic portal vasculature was unable to compensate for the increased blood flow, and multiple portosystemic venous communications opened as a result of subclinical portal hypertension. A similar effect was observed after placement of an ARC on the portal vein of research cats.[48] Evaluation of cats with persistent shunting is difficult. Ideally, the cats should be surgically explored, but the owners of only 1 of 6 cats with persistent shunting permitted surgical exploration at UCD; this cat had multiple extrahepatic PSS. Ultrasound examination was performed in both cats with persistent shunting at NCSU, and both cats were found to have multiple extrahepatic PSS. However, the reliability of ultrasonography for the diagnosis of multiple extrahepatic PSS remains to be established. Ultrasound-guided transsplenic portography has been described in dogs but is not feasible in small animals such as cats.[49] Although it is most likely that cats with persistent shunting developed multiple extrahepatic PSS, other explanations are possible, such as misdiagnosis of the location of the PSS at initial surgery, the presence of a second PSS or portal branches joining the PSS below the level of ARC placement, failure of the ARC to close the PSS, or recanalization of the PSS. The clinical data indicate that some cats with persistent shunting have excellent outcomes and some have fair or poor outcomes. This may reflect the degree of residual shunting, portal vascular supply, and hepatic development after surgery.

There are limited reports available on the long-term results of surgical management of extrahepatic PSS with ARC. Vogt et al[15] reported on 10 dogs and 2 cats (1 dog and 1 cat had persistent shunting); all animals improved, based on clinical assessment, shunt fraction, and serum bile acid concentrations; however, the follow-up period was limited to 60 days. Swalec Tobias et al[38] reported a series of 18 consecutive canine cases; 16 of 17 surviving dogs were clinically normal, with a median follow-up time of 6 months. Murphy et al[50] reported on 10 dogs treated with an ARC and 12 dogs treated by ligation; ARC placement reduced the surgical time and intra- and postoperative complication rate. Clinical follow-up revealed 7 of 9 dogs were normal and 2 of 9 dogs were improved, with a mean follow-up period of 16.5 months; scintigraphy revealed that 3 of 5 dogs had persistent shunting.

The major limitation of this study was its retrospective nature. Although the diagnostic and therapeutic protocol was fairly consistent, complete data were not available for each cat. Most suture ligations were performed early in the study period, perhaps indicating that certain surgeons were not initially comfortable with the surgical technique. There were no obvious differences in clinical or clinicopathologic findings between the 6 cats treated by suture ligation and the 23 cats for which ARC placement was planned. Ideally, a randomized study would compare ligation and ARC placement, but the limited number of cases in cats would make such a study difficult.

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