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Choledochal stenting for treatment of extrahepatic biliary obstruction in cats

Maureen A. Griffin[1] | William T. N. Culp[1] | Michelle A. Giuffrida[1] | Laura E. Selmic[2] | Jordan C. Denitz[1] | James A. Perry[3] | Alexander C. Schoelkopf[3] | Milan Milovancev[4] | Heidi Phillips[5] | Mandy L. Wallace[6] | Michele A. Steffey[1] | Ingrid M. Balsa[1] | Philipp D. Mayhew[1]

[1]University of California-Davis, School of Veterinary Medicine, Davis, California

[2]Ohio State University, College of Veterinary Medicine, Columbus, Ohio

[3]Veterinary Cancer & Surgery Specialists, Milwaukie, Oregon

[4]Oregon State University, Carlson College of Veterinary Medicine, Corvallis, Oregon

[5]University of Illinois, College of Veterinary Medicine, Champaign, Illinois

[6]University of Georgia, College of Veterinary Medicine, Athens, Georgia

Correspondence
William T. N. Culp, University of California-Davis, School of Veterinary Medicine, One Garrod Drive, Davis, CA 95616.
Email: wculp@ucdavis.edu

Abstract

Background: Limited information currently exists regarding the clinical progression and outcomes of cats that undergo choledochal stenting as a treatment for extrahepatic biliary obstruction (EHBO).

Hypothesis/Objectives: Describe clinical characteristics, indications for choledochal stent placement, procedure, and outcomes in a cohort of cats undergoing choledochal stenting and evaluate risk factors associated with survival as well as recurrence of EHBO in affected cats.

Animals: Twenty-three client-owned cats undergoing choledochal stent placement.

Methods: Retrospective study. Medical records from 6 academic institutions were reviewed, and data were extracted and analyzed statistically.

Results: Median age of cats was 10.1 years (range, 2-16), and all cats had at least 2 clinical signs. Most common clinical signs were vomiting in 20/22 (90.9%), inappetence in 19/22 (86.4%), and lethargy in 19/23 (82.6%). Procedural complications were uncommon and rarely related to the stenting procedure. Clinical signs improved postoperatively in 15/20 (75.0%) cats and serum total bilirubin concentration decreased postoperatively in 13/19 (68.4%) cats. Eighteen (78.3%) cats survived to discharge. Recurrence of EHBO was documented in 7/18 (38.9%) cats that survived to discharge. Cholelithiasis was associated with recurrence of EHBO. Median survival time for cats that survived to discharge was 931 days (range, 19-3034). Absence of peritoneal effusion was associated with survival to discharge.

Conclusions and Clinical Importance: Choledochal stenting was an effective treatment modality in cats with EHBO with few procedural complications and potential for prolonged survival, but substantial risk for recurrence of EHBO was identified.

Abbreviation: EHBO, extrahepatic biliary tract obstruction.

KEYWORDS
bilirubin, common bile duct, gallbladder, icterus, stent

1 | INTRODUCTION

Extrahepatic biliary tract obstruction (EHBO), or obstruction of bile flow from the liver or gallbladder to the duodenum, is a life-threatening condition that occurs uncommonly in cats.[1-3] Reported causes of EHBO in cats include bile sludge, cholelithiasis, cholangitis and cholecystitis, pancreatitis, neoplasia, foreign material, biliary mucoceles or cysts, and gastrointestinal disease including sphincter of Oddi pathology.[1,4,5] Clinical signs of EHBO in cats generally are non-specific, and diagnosis is made based on increased liver enzyme activity (particularly alkaline phosphatase [ALP]) and sometimes hyperbilirubinemia as well as imaging findings.[1,6,7] Documented pathophysiologic consequences associated with EHBO include hypotension, acute kidney injury, impaired myocardial function, coagulopathy, gastrointestinal hemorrhage, and delayed wound healing.[8-17] Hypotension and impaired response to vasopressors have been identified in cats with EHBO.[3,15] Treatment and prognosis of EHBO in cats are variable and depend on the underlying cause of the obstruction. Most surgical procedures for treatment of EHBO aim to bypass the common bile duct and provide a conduit for bile from the gallbladder to enter the gastrointestinal tract or involve placement of temporary or permanent choledochal stents.[2]

Information regarding clinical characteristics and outcomes of choledochal stent placement in cats is very limited. The largest case series included 7 cats that underwent choledochal stent placement, and all cats were treated for pancreatitis-associated EHBO.[3] In that study, red rubber latex catheters or IV catheters were used to form choledochal stents that were fixed in place within the common bile duct in a temporary fashion using polydioxanone (3/7) or poliglecaprone sutures (2/7) or in a permanent fashion using nylon sutures (1/7); fixation was not reported for 1 cat.[3] Complications were common and included recurrent biliary obstruction within 1 week of surgery (2/7), chronic intermittent vomiting (2/7), intermittent ascending cholecystitis (1/7), and pulmonary thrombosis and pneumonia (1/7).[3] One of 2 cats with recurrent biliary obstruction underwent revision surgery and the other was euthanized.[3] Five cats survived to discharge.[3] Another retrospective study that described surgical treatment of 8 cats with severe acute pancreatitis included only 1 cat that underwent choledochotomy with stent placement.[18] No postoperative complications were identified in this cat, and the cat was alive 4 months postoperatively.[18] In a case series of 6 cats with pathology of the sphincter of Oddi, all cats underwent surgical treatment with Foley catheter placement (with 2 catheters exiting through an intestinal stoma percutaneously left in place for 24 hours postoperatively), sphincterotomy, or both.[4] Both cats with catheter placement were clinically healthy for at least 5 and 8 months postoperatively.[4] An additional case report described a cat with a common bile duct cyst that underwent choledochal stent placement using a silicone catheter and absorbable sutures as well as temporary cholecystostomy tube placement; the cat had a good long-term outcome (7 months at last follow-up).[5] No other reports have described choledochal stent placement or outcomes of this procedure in client-owned cats.

Information on the clinical findings, complications, and short- and long-term outcomes in cats that undergo choledochal stenting for decompression of the extrahepatic biliary tract is lacking. Our primary objective was to describe the clinical characteristics and outcomes of choledochal stent placement in cats with EHBO. A secondary objective of our study was to evaluate potential risk factors for survival as well as recurrence of EHBO in these cats. We hypothesized that choledochal stenting would be an effective method of extrahepatic biliary decompression in cats, the number of cats surviving to discharge after choledochal stenting would be high, and the frequency of recurrent EHBO would be low.

2 | MATERIALS AND METHODS

The medical record databases of 6 academic teaching hospitals were retrospectively searched to identify cats that underwent choledochal stenting (using red rubber latex catheters or catheters composed of other forms of synthetic material placed within the common bile duct) for decompression of the extrahepatic biliary tract. All cats that had choledochal stents placed were included in the study. Information obtained from the medical records included signalment, history of hepatobiliary disease, type and duration of clinical signs, physical examination findings, results of pre- and postoperative laboratory diagnostic testing and diagnostic imaging, results of the choledochal stenting procedure and additional treatments performed, complications, results of histopathology and bacterial culture and sensitivity, progression of disease in hospital, survival to discharge, recurrence of EHBO, documentation of stent passage, and timing and cause of death.

Descriptive statistics were calculated for all measured variables. Continuous variables were reported as mean (SD) or median (range) and categorical variables were reported as number (percentage). Multiple variables were evaluated for association with survival to discharge. These variables included duration of clinical signs, icterus on initial physical examination, preoperative serum total bilirubin, cholesterol, and creatinine concentrations, prothrombin time (PT), partial thromboplastin time (PTT), cholelithiasis, pancreatic changes on abdominal ultrasonography, preoperative peritoneal effusion, preoperative maximal common bile duct diameter on abdominal ultrasonography, septic peritonitis, positive bacterial bile culture, bile peritonitis, cholecystectomy, and pancreatic biopsy or surgery. Wilcoxon rank sum tests were used to compare presurgical variables in cats that did and did not survive to discharge. Several variables were assessed for

possible association with recurrence of EHBO, including preoperative pancreatic abnormality on abdominal ultrasonographic examination, cholelithiasis, cholecystectomy, stent size <5 Fr (Fisher's exact test), and maximal preoperative common bile duct diameter (Wilcoxon rank sum test). The Kaplan-Meier method was used to estimate recurrence rate of biliary obstruction among cats that survived beyond hospital discharge after the initial choledochal stenting procedure, and overall survival time among cats that survived to hospital discharge. Overall postdischarge survival time was compared between cats with and without recurrent EHBO after the stent procedure. Cats that did not experience the outcome event were censored in analyses at their last known date alive for cats living or lost or follow-up, as well as at date of death in the analysis of recurrence. All tests were 2-sided and $P < .05$ was considered statistically significant. Analyses were performed using computer software (Stata Statistical Software: Release 14, College Station, Texas: StataCorp LP, 2015).

3 | RESULTS

3.1 | Animals

Between 2006 and 2020, 23 cats from 6 institutions satisfied the inclusion criteria. These included 7 cats that underwent stent placement between 2006-2010, 11 cats between 2011-2015, and 5 cats between 2016-2020. The median age of cats was 10.1 years (range, 2-16). Cats consisted of 13/23 (56.5%) female spayed and 10/23 (43.5%) male neutered cats. Breeds included 15/23 (65.2%) domestic shorthair, 2/23 (8.7%) domestic medium hair, 2/23 (8.7%) domestic long hair, and 1/23 (4.3%) each of Maine coon, Somali, Singapura, and unknown breeds. Important findings for each cat are summarized in Table 1.

3.2 | Medical history and clinical signs

History of hepatobiliary disease (ie, clinical signs that occurred at a different time than when the cats were presented for choledochal stenting) was reported in 12/19 (63.2%) cats with available data. The median time between prior disease and presentation for choledochal stenting was 86 days (range, 4-1638). Of these 12 cats, 9 underwent treatment, including 2 cats that had surgery. One cat (cat 17) underwent exploratory celiotomy by its primary veterinarian for collection of multiple biopsy and culture samples 803 days before presentation; the cat was diagnosed with small intestinal lymphoma, bacterial cholangitis, choledochitis, and pancreatitis and was treated medically. The other cat (cat 18) that had prior surgical intervention underwent exploratory celiotomy by its primary veterinarian for excision of a liver mass (biliary cystadenoma) and concurrent cholecystectomy 4 days before presentation. Before presentation to the referral hospital,

TABLE 1 Risk factors for survival to discharge

	Survived (N = 18)	Did not survive (N = 5)	*P* value
Duration of clinical signs[a]	7 (0-56)	14 (2-126)	.33
Jaundice on initial physical examination	12 (66.7)	3 (60.0)	>.99
Presurgical total bilirubin[b,c]	9.0 (0.1–29.4)	12.5 (6.8-20.6)	.61
Presurgical cholesterol[b]	177 (92-602)	260 (220-432)	.09
Presurgical creatinine[a,d]	0.9 (0.3-1.7)	1.7 (0.8-2.7)	.42
Presurgical PT[b,d]	10.2 (9.3-24.0)	12.9 (10.0-17.7)	.22
Presurgical PTT[b,d]	17.1 (10.3-112.0)	14.3 (9.1-40.2)	.3
Cholelithiasis[e]	9 (40.0)	2 (40.0)	>.99
Pancreatic disease on ultrasound[f]	11 (68.8)	5 (100.0)	.28
Presurgical peritoneal effusion[b]	7 (41.2)	5 (100.0)	.04[g]
Presurgical maximum common bile duct diameter, mm[d]	9.5 (6.8-20.0)	6.2 (4.2-22.0)	.49
Positive bile culture	7 (38.9)	1 (20.0)	.62
Septic peritonitis[b]	1 (5.8)	1 (20.0)	.41
Cholecystectomy	4 (22.2)	3 (60.0)	.14
Pancreatic biopsy or surgery	8 (44.4)	3 (60.0)	.64

Notes: Data are reported as number (%) or median (range).
[a]Missing data for 4 cats that survived.
[b]Missing data for 1 cat that survived.
[c]Reference ranges for total bilirubin in mg/dL (Clinic 1: 0.0-0.1, Clinic 2 and 3: 0.0-0.5, Clinic 4: 0.0-0.11, Clinic 5: 0.0-0.2, Clinic 6: 0.1-0.5).
[d]Missing data for 1 cat that died.
[e]Missing data for 3 cats that survived.
[f]Missing data for 2 cat that survived.
[g]Statistically significant.

20/23 (87.0%) cats were seen previously by the primary veterinarian for the presenting complaint.

The frequency of clinical signs as described by owners in cats with available data was: vomiting in 20/22 (90.9%), inappetence in 19/22 (86.4%), lethargy in 19/23 (82.6%), weight loss in 14/20 (70.0%), icterus in 15/23 (65.2%), abdominal pain in 3/21 (14.3%), and polyuria and polydipsia in 1/20 (5.0%). All 23 cats hat at least 2 clinical signs, and 16/23 (70.0%) cats had clinical signs that included vomiting, inappetence, and lethargy as well as possible additional clinical signs.

3.3 | Physical examination

At the time of initial physical examination at the referral hospital, cats had a mean body weight of 4.4 ± 1.3 kg and median body condition score of 4/9 (range, 2-9/9). Hydration status was reported as good or fair in 12/22 (54.5%) cats and poor in 10/22 (45.5%) cats. Median temperature was 38.8°C (range, 37-39.7°C) with 5/20 (25.0%) cats having a temperature >39.2°C. Median pulse was 190 beats/minute (range, 100-240), and median respiratory rate was 40 breaths/minute (range, 18-112). Icterus was noted on physical examination in 17/23 (73.9%) cats, and abdominal palpation was noted to be abnormal in 10/23 (43.5%) cats.

3.4 | Clinical laboratory diagnostic testing

A CBC was performed before surgery in 21/23 (91.3%) cats, and serum biochemistry panels were performed before surgery in 22/23 (95.7%) cats. The preoperative CBC was performed a median of 1 day (range, 0-4) before surgery, and the preoperative biochemistry panel was performed a median of 1 day (range, 0-2) before surgery. Median preoperative serum total thyroxine concentration for 5 cats was 1.9 μg/dL (range, 0.7-14.5). Coagulation panels were performed preoperatively in 20 cats and showed a median PT of 10.3 seconds (range, 9.3-24.0) and median PTT of 16.4 seconds (range, 9.1-112.0). Median preoperative serum lactate concentration for 9 cats was 1.1 mmol/L (range, 0.4-5.9). Median preoperative serum total bilirubin concentration closest to the date of surgery was 10.6 mg/dL (range, 0.1-29.4). Median feline pancreatic lipase immunoreactivity (fPLI) for 3 cats was 1.3 μg/L (range, 2.8-18.2). Eleven cats had a preoperative urinalysis with median urine specific gravity of 1.027 (range, 1.005-1.047). No cat with a preoperative urinalysis had bacteriuria, and of 4 urine cultures performed preoperatively, none showed bacterial growth.

3.5 | Diagnostic imaging

Preoperative diagnostic imaging included abdominal ultrasonography in 22/23 (95.7%) cats and abdominal radiography in 5/23 (21.7%) cats. Abdominal ultrasonography identified distension of the common bile duct in 21/22 (95.5%) cats, and median maximal common bile duct diameter was 8.5 mm (range, 3.5-22.0) in reported cases. Ultrasonography also showed cystic duct distension in 14/21 (66.7%) cats, and median maximal cystic duct diameter was 6.5 mm (range, 1.3-15.0) in reported cases. Intrahepatic biliary duct distension was reported in 12/21 (57.1%) cats, and median maximal intrahepatic biliary duct diameter was 4.0 mm (range, 1.4-8.6) in reported cases. Distension of the gallbladder was noted in 8/22 (36.4%) cats. Biliary wall thickening was documented in 16/21 (76.2%) cats. Cholelithiasis was documented in 12/20 (60.0%) cats. Echogenic biliary debris or sludge was noted in 13/22 (59.1%) cats. Abnormal appearance of the pancreas or evidence of pancreatitis was detected in 16/21 (76.2%) cats. Hepatic abnormalities were reported in 14/22 (63.6%) cats. Abnormalities of the duodenal wall were reported in 5/22 (22.7%) cats. Peritoneal effusion was identified before surgery in 12 cats with scant effusion in 7/12, mild effusion in 4/12, and moderate effusion in 1/12. The results of cytology from a preoperative sample of peritoneal effusion in 1 cat (cat 8) were consistent with mild neutrophilic inflammation.

3.6 | Surgery

The median duration of time from presentation at the referral hospital until surgery for alleviation of EBHO was 1 day (range, 0-8). At the time of surgery, 1 cat (cat 1) was diagnosed with septic peritonitis (based on cytology and culture results of effusion samples obtained intraoperatively).

All 23 cats underwent celiotomy, and multiple surgeons performed these procedures. Median surgical time was 120 minutes (range, 70-210). Patency of the common bile duct was confirmed by catheterization in all cats. Method of access to the common bile duct was reported in 20 cats and included duodenotomy in 13/20 (65.0%), duodenotomy and cholecystotomy in 4/20 (20.0%), duodenotomy and choledochotomy in 2/20 (10.0%), and cholecystotomy alone in 1/20 (5.0%). The type of stent placed was a red rubber catheter in 21 (91.3%) cats, silastic tubing in 1 (4.4%) cat, and a Cotton-Huibregtse biliary stent (Cook Medical; Bloomington, Indiana) in 1 (4.4%) cat. Stent size, reported in 21 cats, was 5 Fr in 14/21 (66.7%) cats, 3 or 3.5 Fr in 4/21 (19.0%) cats, 7 Fr in 1/21 (4.8%) cats, and 14 Fr in 1 cat. All but the Cotton-Huibregtse biliary stent were fixed in place by suturing of the catheter to the duodenum, and the suture type used was reported in 21/22 cats: polydioxanone (absorbable suture with 50% tensile strength at 5-6 weeks) in 9/21 (42.9%), poliglecaprone (absorbable suture with 50% tensile strength at 1-2 weeks) in 8/21 (38.1%), chromic gut (absorbable suture with 0% tensile strength at 2-3 weeks) in 2/21 (9.5%), and polypropylene (nonabsorbable suture) in 2/21 (9.5%).[19] Number of sutures placed to fix the stent to the duodenal wall was reported in 6 cats: 1 suture was placed in 5/6 cats and 2 sutures were placed in 1/6 cat. Intraoperative complications were reported in 14/23 (60.9%) cats and included hypotension in 12/23 (52.2%) cats, hemorrhage requiring blood transfusion in 1 cat, arrhythmias in 1 cat, and inadvertent biliary system rupture that required surgical closure in 1 cat.

3.7 | Postoperative diagnostic testing and outcomes

Postoperatively, serum biochemistry panels were performed in 21 cats. Median serum total bilirubin concentration postoperatively (closest to the date of discharge or death) was 5.6 mg/dL (range, 0.1-20.6).

After the stenting procedure, 18 cats were treated with broad-spectrum antibiotics and all cats received supportive care as indicated; because of the retrospective design of the study, explanations for antimicrobial decisions often were lacking.

Postoperative complications were reported in 15 cats and included hypoglycemia (5), hypotension (4), cardiopulmonary arrest (3), gastrointestinal signs (2), oxygen dependence (2), progressive anemia requiring blood transfusion (1), and aspiration pneumonia (1). After the surgical procedure, clinical signs of disease were noted to improve in 15/20 (75.0%) cats and were not noted to improve in 5/20 (25.0%) cats; data were not available in the remaining 3 cats. Of the 5 cats that did not experience improvement in clinical signs, 3 died shortly after surgery during hospitalization, and data regarding persistence or progression of clinical signs for the other 2 was lacking, but long-term survival was achieved (alive at 551 and 642 days postoperatively). After the surgical procedure, serum total bilirubin concentration (mg/dL) decreased in 13/19 (68.4%) cats for which both pre- and postoperative measurements were available. In 4 cats, serum total bilirubin concentration increased postoperatively, and in 2 cats the pre- and postoperative measurements were identical. Three of 4 (75.0%) cats with preoperative serum total bilirubin concentrations ≤1.0 mg/dL at the time of surgery also had documented postoperative serum total bilirubin concentrations ≤1.0 mg/dL. Only 2/15 (13.3%) cats with preoperative serum total bilirubin concentrations >1.0 mg/dL had documented postoperative serum total bilirubin concentrations ≤1.0 mg/dL.

Of the 23 cats in the study, 18 (78.3%) survived to discharge. Of the 5 cats that did not survive to discharge, 3 cats died within 24 hours of surgery, 1 cat died 5 days postoperatively, and 1 cat died 7 days postoperatively. None of the cats that died before discharge was noted to have recurrent EHBO. The only variable that was significantly associated with survival to discharge was absence of preoperative peritoneal effusion ($P = .04$); cats with peritoneal effusion identified before surgery were significantly less likely to survive to discharge than those without effusion (Table 1).

Of the 18 cats that survived to discharge, stents were recorded to have passed in 8 cats and passage was unknown in the other 10 cats; no cat had a surgical or endoscopic procedure performed to remove the stent. In the cats that had documented passage of the stent, 6 were determined based on the absence of a stent on abdominal ultrasonography, 1 was determined at the time of necropsy, and 1 was determined based on the absence of a stent on radiography; no stent was observed to have passed in the feces. For cats that had documented passage of the stent, the median time after surgery when stent passage was first documented was 43.5 days (range, 7-447). The cat (cat 19) with the Cotton-Huibregtse biliary stent had the earliest known time of stent passage (7 days postoperatively). Of the 2 cats with nonabsorbable sutures used to secure the stent in position, 1 cat (cat 17) had documented stent passage 147 days postoperatively and the other cat (cat 22) was not known to have had stent passage at the time of euthanasia for nonhepatobiliary disease 74 days after discharge.

Recurrent EHBO was not diagnosed in any cat that died or was euthanized before hospital discharge. Among the 18 cats that survived to discharge, recurrent EHBO was identified in 7 (38.9%) cats. The estimated recurrence rate was 21.7% (95% confidence interval [CI], 10.3 to 45.5) per 365 cat-days. Recurrence of EHBO was detected at 4, 6, 7, 24, 146, 268, and 563 days postoperatively. For the 2 cats that had recurrent EHBO identified 4 and 6 days postoperatively, the cats were still in hospital at the time of EHBO recurrence. The cause of recurrent EHBO was determined to be recurrence or progression of the initial EHBO disease in 2 cats (pancreatic cyst, pancreatitis, and cholangitis in 1 cat and cholelithiasis in the other cat), a different disease process in 1 cat (pancreatitis and systemic fungal disease with prior cholangitis), and undetermined in 4 cats. The only factor that was significantly associated with recurrence of EHBO after choledochal stenting was choleliths as the cause of EHBO (Table 2). Of the 7 cats with recurrent EHBO, stents were known to have passed in 5 cats, the stent was still in place in 1 cat, and stent position was unknown in 1 cat.

At the time of study completion, 15/23 (65.2%) cats were known to be dead. Euthanasia was performed in 11 cats; the reason was unknown in 4 cats, euthanasia was associated with nonhepatobiliary disease in 4 cats, and it was associated with hepatobiliary disease in 3 cats. Four cats died, of which 3 cats had unknown cause of death and 1 cat died secondary to hepatobiliary disease. In cases with described cause of death or euthanasia, nonhepatobiliary causes included pulmonary disease (2/15), cardiovascular disease (1/15), and coagulopathy with hemoperitoneum (1/15); hepatobiliary causes included severe cholangitis, hepatitis, and choledochitis (1/15). The overall estimated median survival time for the 18 cats that were discharged was 931 days (95% CI, 166 to >3034). The median survival time was 231 days (95% CI, 19 to >931) for 7 cats with documented recurrent EHBO and 2031 days (95% CI, 74 to >3034) for cats without documented recurrent EHBO, but these differences were not significant ($P = .34$).

4 | DISCUSSION

Most of the cats in our study showed improvement in clinical signs postoperatively and survived to discharge. Recurrent EHBO was detected in more than 1/3 of cats that survived to discharge, and cats experienced long-term survival postoperatively. Affected cats were primarily middle-aged to older with a prior history of hepatobiliary disease, with previous disease occurring approximately 3 months before presentation to the referral hospital for choledochal stenting. All cats had clinical signs of hepatobiliary disease at presentation, and the majority of cats had several clinical signs. Most cats had icterus on physical examination. Therefore, cats with a history of hepatobiliary

TABLE 2 Risk factors for EHBO recurrence

	Recurred	Recurrence not documented	*P* value
Pre-op pancreatic abnormality on US	4/5 (80.0)	7/11 (63.6)	>.99
Choleliths pre-op	1/6 (16.7)	8/9 (88.9)	.01[b]
Cholecystectomy	2/7 (28.6)	2/11 (18.2)	>.99
Stent size <5Fr	1/7 (14.3)	3/10 (30.0)	.6
Maximum pre-op common bile duct diameter (mm)[a]	11.9 (3.5-20)	9.5 (4.6-15.8)	.67

Notes: Data are presented as number of cats with risk factor/number of cats assessed for risk factor (%), except as indicated.
[a]Data presented as median (range). Data available for 4 cats with recurrence and 10 cats with no documented recurrence.
[b]Statistically significant.

disease that present with icterus and gastrointestinal signs should be thoroughly evaluated for EHBO, and both medical and surgical treatment options should be considered if EHBO is detected.

Hyperbilirubinemia and distension of the biliary system on ultrasonography were common in this cohort of cats with EHBO. Although all cats with icterus had marked hyperbilirubinemia (≥3 mg/dL), not all cats with marked hyperbilirubinemia were noted to be icteric preoperatively, indicating the subjective nature of this relatively insensitive clinical finding. Therefore, monitoring of serum total bilirubin concentration is valuable in cats with suspected EHBO. Pancreatic abnormalities or findings consistent with pancreatitis also were noted (based on imaging assessment) in most affected cats. Similar to cats that underwent choledochal stent placement,[3] pancreatitis was a common contributor to EHBO in cats of our study.

Biliary stenting (in combination with other procedures) was performed to relieve the biliary obstruction in cats of our study. The most common size and type of stent placed was a 5 Fr red rubber catheter, and the majority of stents were secured using absorbable sutures. However, for 1 of 2 cats (cat 17) in which nonabsorbable sutures were used to fix the stent in position, the stent passed within 146 days postoperatively, which indicates that use of nonabsorbable sutures does not necessarily render the stent permanent. The stent that passed at the earliest time point postoperatively (7 days) was the 7 Fr Cotton-Huibregtse biliary stent, which was placed without suture fixation. Statistical analysis of stent or suture type and risk of EHBO recurrence was not possible because of small sample size. Our study provides information regarding the general timeframe for stent passage after placement in cats, which appears to be highly variable. Because the stent passage data reflect date of documentation rather than date of actual stent passage, and given that all stent passages were documented by imaging and not observation in the feces, the actual time for passage of the stent likely was shorter. Although stent passage was documented in 8 cats without observation of the stent in the feces by the owners, it is assumed that all instances of stent passage occurred via the fecal route because none of the stents were removed and all were nonbiodegradable. Based on these findings, choledochal stent placement in cats should be considered a temporary form of relief of biliary obstruction, because the stents ultimately are anticipated to pass in the feces (although the timeframe for stent passage is widely variable), and even stents fixed to the duodenum using nonabsorbable sutures may pass. Abdominal ultrasonography appears to be a more reliable form of detection of stent passage as compared with detection of the stent in feces. Although no stents required removal in our study, indications for stent removal include ascending infection and stent occlusion with recurrent EHBO.

Regarding clinical outcome, most cats in our study experienced improvement in clinical signs and had evidence of relief of EHBO with decreased postoperative serum total bilirubin concentrations. Survival to discharge was not associated with evaluated factors of EHBO (ie, preoperative serum total bilirubin concentration, presence or absence of icterus, or preoperative maximal common bile duct diameter), pancreatic abnormalities or pancreatic surgery, concurrent cholecystectomy, cholelithiasis, or positive bile culture, and these findings should not be considered associated with prognosis in affected cats based on these results. The only variable associated with survival to discharge was peritoneal effusion, and cats with peritoneal effusion preoperatively were more likely to die or be euthanized before discharge. Although peritoneal effusion was associated with outcome, 7/12 (58%) cats with peritoneal effusion did survive to discharge. Also, no significant differences were identified with respect to severity of effusion (survival to discharge occurred in 4/7 cats with scant effusion, in 2/4 cats with mild effusion, and in 1cat with moderate effusion). Of the approximately 22% of cats that did not survive to discharge, the underlying cause of death generally was related to severe systemic illness and not stent placement or recurrence of EHBO. In addition, the intraoperative and postoperative complications reported predominantly were associated with anesthesia or systemic illness rather than the stent placement procedure itself. In general, the underlying diseases in these cats as well as the surgical interventions performed were variable, and all cats underwent multiple surgical procedures at the time of choledochal stent placement. Therefore, outcomes of these cats must be viewed with regard to the cats' overall systemic conditions as well as the multiple surgical and medical interventions utilized, and the effects of choledochal stent placement alone cannot be conclusively established.

Another important finding is that recurrence of EHBO, as determined by progressive hyperbilirubinemia as well as distension of the biliary system on abdominal ultrasonography, appears to be common in cats that undergo choledochal stent placement. Although recurrence of EHBO appears to be more likely after choledochal stent

passage, 1 cat (cat 3) with suspected recurrence had evidence of obstruction despite the stent remaining in place. Recurrence occurred 6 days postoperatively, and the cat subsequently improved and survived long-term without further surgical intervention. This cat may have experienced transient persistence or progression rather than recurrence of EHBO with the stent in place, and the underlying cause of the cat's progressive hyperbilirubinemia postoperatively is not known. However, recurrence with the stent in place cannot be ruled out in this cat and theoretically could have occurred because of stent occlusion. Regardless, although the risk of recurrent EHBO likely is higher after stent passage, progression or recurrence of EHBO is possible with a choledochal stent still in place, and additional surgical intervention may not always be indicated to alleviate this obstruction.

Cholelithiasis as the cause of EHBO was positively associated with recurrence of EHBO. Because choleliths have the potential to fill the lumen of the common bile duct, we speculate that stricture secondary to cholelith obstruction may have been responsible for increased risk of recurrent obstruction. Considering ureteral strictures associated with stents, any stricture generally remains after stent removal and passive dilatation of the ureter at the site of the stricture does not occur.[20] A similar situation may occur with choledochal stent placement in the setting of choledocholiths and possible stricture, given that recurrent obstruction is common after stent placement. This hypothesis requires further investigation to understand the cause of increased EHBO recurrence after stenting to treat cholelith obstruction, and further investigation will be important to determine if alternative methods of EHBO relief are indicated in cases of obstruction associated with cholelithiasis. Another important consideration in cases of EHBO secondary to cholelithiasis is cholecystectomy as a component of surgical management, because cholecystectomy generally is recommended to minimize recurrence of cholelith formation and subsequent EHBO.[14,21]

Many of the cats that developed recurrent EHBO did well clinically either with or without additional surgery. Because we did not find a significant difference in median survival times between cats that survived to discharge and developed recurrent EHBO and those that survived to discharge and did not develop recurrent EHBO, development of recurrent EHBO can be manageable and may not affect long-term outcome, but additional studies with larger case numbers are needed to support this conclusion.

Overall, cats in our study had prolonged survival after choledochal stent placement, and the population generally consisted of older cats with a variety of concurrent systemic diseases. For cats that died, the cause of death often was unknown or not associated with hepatobiliary disease.

Our study had several limitations. The study was retrospective in design and complete clinical information was lacking for some patients. The study was performed to assess the outcomes of cats that underwent choledochal stent placement for treatment of EHBO and did not include all cats with EHBO. Therefore, the prevalence of EHBO in cats and percentage of cats with EHBO that required choledochal stenting is not known. Because of the retrospective design of the study, it is not possible to determine factors that resulted in the decision to pursue surgical treatment in these cats. Also, we were unable to assess certain risk factors (eg, stent passage) for survival or recurrent disease because of missing data as well as bias or confounding for cats in which these data were known. Several patients were lost to follow-up, and the long-term outcomes of many stents could not be determined. Also, sample size was relatively small and type II error may have occurred in the statistical analysis. Moreover, the population varied with regard to disease, management, and follow-up, such that cause and effect were difficult to determine. In addition, selection bias may have occurred because all cases were contributed by academic institutions, such that cats with more severe disease may be overrepresented in this cohort presented for care to tertiary referral institutions.

In conclusion, cats that present for EHBO with an underlying disease that is amenable to surgical treatment should be considered possible candidates for choledochal stenting. In general, if the stent is not likely to be required permanently, temporary stent placement should be considered because of the potential for risks associated with long-term stenting, particularly across the sphincter of Oddi with risk of ascending infection, but owners should be advised of the potential for recurrent EHBO.[22] Cats that survive to discharge typically have long survival times (even if recurrence of EHBO occurs), and death in this population rarely is related to the biliary surgery itself.

Overall, choledochal stenting can provide successful reestablishment of choledochal bile flow in cats with few complications associated with the procedure itself and the potential for prolonged survival, although recurrence of EHBO can occur. These findings may inform clinicians and owners about clinical presentation, disease progression, surgical intervention, and outcome, including survival and recurrence of EHBO, in cats that undergo this treatment. Additional studies with larger numbers of cats undergoing choledochal stent placement are needed to gain more information and to compare the benefits and disadvantages of this procedure to other forms of extrahepatic biliary tract decompression, such as biliary rerouting procedures.

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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.

ORCID

William T. N. Culp https://orcid.org/0000-0001-6132-156X
Heidi Phillips https://orcid.org/0000-0002-3291-0266

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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