Received: 20 December 2023 | Revised: 24 April 2024 | Accepted: 26 May 2024

DOI: 10.1111/vsu.14125

CLINICAL RESEARCH

WILEY

Linear and discrete foreign body small intestinal obstruction outcomes, complication risk factors, and single incision red rubber catheter technique success in cats

Annellie Kaitlin Miller DVM, MPH[1] | **Penny Jean Regier DVM, MS, DACVS (Small Animal)**[1] | **Kathleen Marie Ham DVM MS, DACVS (Small Animal)**[1] | **Joseph Bradly Case DVM, MS, DACVS (Small Animal)**[1] | **Kristina Janine Fisher BS**[1] | **Jessika Mary Rogers BS**[1] | **Edward James Daly BS**[1] | **James Christopher Colee PhD**[2]

[1]Department of Small Animal Clinical Sciences, University of Florida, Gainesville, Florida, USA

[2]Institute of Farm and Agricultural Sciences, Statistics Consulting Unit, University of Florida, Gainesville, Florida, USA

Correspondence
Penny Jean Regier, Department of Small Animal Clinical Sciences—University of Florida, PO Box 100126, 2015 SW 16th Avenue, Gainesville, Florida 32610, USA.
Email: pregier@ufl.edu

Abstract

Objective: To compare survival and report perioperative complications in cats undergoing surgery for small intestinal (SI) linear (LFBO) and discrete (DFBO) foreign body obstructions (FBO). To report success of a red rubber catheter technique (RRCT) to remove LFBOs.

Study design: Retrospective study.

Animals: Client-owned cats ($n = 169$).

Methods: Medical records of cats undergoing surgery for SI FBO from a veterinary teaching hospital between February 2012 and January 2023 were classified as LFBO, DFBO, or both linear and discrete FBO (BFBO). Signalment and perioperative data were collected.

Results: Preoperative hypoalbuminemia (LFBO: $n = 1/6$; DFBO: $n = 5/6$) and septic peritonitis (LFBO: $n = 2/4$; DFBO: $n = 0/4$; BFBO: $n = 2/4$) were rare. Intraoperative hypotension did not differ between LFBOs and DFBOs ($p = .4756$). RRCT was successful in 20/24 attempts of LFBO removal. Three cats were euthanized intraoperatively (LFBO: 1; DFBO: 1; BFBO: 1). Postoperatively, two cats (DFBO) experienced intestinal dehiscence and two cats (DFBO) died or were euthanized. Survival to discharge ($p = 1.0000$) and postoperative complications ($p = .1386$) did not differ between LFBOs and DFBOs.

Conclusions: Postoperative complications and survival did not differ between cats with LFBOs and DFBOs. Intestinal dehiscence secondary to FBO in cats is rare. A RRCT can be successful in many cats with LFBOs.

Clinical significance: Cats with LFBOs and DFBOs have similar postoperative complication rates and survival to discharge when preoperative septic peritonitis is not present. Intestinal dehiscence is rare, which is important when discussing surgical prognosis with owners. A RRCT can be considered to remove LFBOs when there is concern for multiple enterotomies.

1 | INTRODUCTION

Small intestine (SI) foreign body obstruction (FBO) is a common surgical emergency in cats and dogs and may be caused by a linear foreign body obstruction (LFBO), a discrete or nonlinear foreign body obstruction (DFBO), or both linear and discrete FBOs (BFBO). LFBOs often cause partial obstruction and may present acutely or chronically,[1] with one case report describing an obstruction of one-month duration.[2] LFBOs often anchor within the gastrointestinal tract, and as peristalsis continues, intestines plicate, and traction of the foreign body (FB) along the mesenteric surface increases the risk of intestinal perforation.[1,3] In contrast, DFBOs, especially of larger size, often cause complete obstruction and present more acutely. Accumulation of fluid and gas orad to the foreign body causes intestinal distention. With worsening distension, intraluminal pressures increase and potentially cause capillary bed congestion and edema of the intestinal wall, followed by thinning, barrier compromise, and/or necrosis.[1] As a result of these pathophysiological changes, increased morbidity and mortality with the possibility of septic peritonitis and/or death can occur regardless of FB type.[1,4]

Traditionally, if a linear foreign body was unable to be removed through a gastrotomy or single enterotomy, multiple enterotomies or a large resection and anastomosis would be commonly performed. However, multiple intestinal incisions have been associated with increased mortality and resection and anastomosis has been reported in some studies to have higher intestinal dehiscence rates.[5–8] A red rubber catheter technique (RRCT) with a single enterotomy has been evaluated in a cadaveric model and in three feline cases as a method to remove LFBOs while decreasing the number of enterotomies and aforementioned risks.[5,6,9] One case report[10] depicted failure of this technique due to embedment of the LFBO within the small intestinal wall; however, to the authors' knowledge, no studies have reports of RRCT success or failure amongst a large cohort of cats.

In contrast to canine studies, there is a paucity of literature on cats with FBOs. In the past 14 years, FBOs in both dogs and cats have been evaluated; however, species conclusions were combined,[5,11] and feline FBOs were included amongst other indications for intestinal surgery so that conclusions specific to FBOs could not be made.[11,12] Additionally, sample sizes amongst feline FBO literature have been limited to less than 30 cats, except for a recent study that included 56 cats.[13] The study by Gollnick et al. currently represents the largest feline study in the last 10 years comparing linear and discrete FBOs.[13] Two larger feline FBO studies exist; however, these were performed more than 35 years ago and only reported LFBOs.[14,15] Therefore, a continued lack of recent feline literature with large sample sizes and comparisons between linear and discrete FBOs still exists.

The first objective of this study was to compare survival to discharge between cats with LFBOs and DFBOs. The second objective was to compare duration of clinical signs before surgery between cats with LFBOs and DFBOs. The third objective was to report a success rate of a red rubber catheter technique (RRCT) to remove LFBOs in cats. The fourth objective was to report perioperative complications in LFBOs and DFBOs. Our first hypothesis was that feline LFBOs would have decreased survival to discharge than DFBOs. Our second hypothesis was that feline LFBOs would have a longer duration of clinical signs before surgery than DFBOs.

2 | MATERIALS AND METHODS

The surgical database at the University of Florida Small Animal Hospital was searched for feline medical records between February 2012 and January 2023 using the terms “exploratory”, “explore”, “laparotomy”, “foreign body”, “removal”, “linear”, “gastrotomy”, “enterotomy”, “resection and anastomosis”, “intestinal”, “intestine”, “perforation”, “sepsis”, and “septic peritonitis”. Cats were included if a gastrointestinal FBO was diagnosed or suspected on abdominal imaging and if they underwent surgery. Cats were excluded if the medical record was incomplete, the sole FB was located in the colon, the FB was not found during surgery, and/or the FB location within the SI was not specified in the operative report.

Cats with FBOs were classified into LFBO, DFBO, or BFBO categories. LFBOs were obstructions defined by the surgeon or radiologist if linear material and/or plication of the intestinal tract was recorded in the abdominal imaging report, operative report, and/or discharge paperwork. DFBOs were obstructions defined as nonlinear FBs without plication. BFBO were defined as having both LFBOs and DFBOs present. Medical records were reviewed for signalment, weight, medical history, diagnostic imaging, preoperative hypoalbuminemia and septic peritonitis, and intra-, postoperative, and recheck findings.

Preoperative data included the albumin measurement closest to surgical start time, and hypoalbuminemia was defined as an albumin value below the reference range of the specific analyzer. Reference range lower limits of different analyzers ranged from 2.2–2.7 g/dL. Preoperative septic peritonitis was defined as the presence of intracellular bacteria on abdominal fluid cytology or growth on culture or if noniatrogenic perforations were identified on immediate abdominal explore.[12]

Intraoperative data included date of surgery, FB type, types of intestinal procedure(s) performed (e.g., enterotomy, gastrotomy, resection and anastomosis, RRCT, surgical stapler use, etc.), hypotension, surgical time, presence of adhesions, location of obstruction, linear material anchor point, RRCT use, and presence of perforations. Either a faculty board certified surgeon, a surgical resident, or a surgical intern performed all surgeries.

Hypotension was defined as blood pressure <90 mmHg systolic and/or <60 mmHg mean arterial pressure. Surgical time was from the time of incision to completion of closure for the FBO surgery. Anchor point was defined as the most proximal location of the linear material. The RRCT was defined as use of a red rubber catheter with the goal of advancing the LFBO through the intestine for removal through the anus, gastrotomy incision, and/or one or more enterotomies while minimizing the number of anticipated enterotomies and avoiding intestinal resection and anastomosis. RRCT failure was defined as inability to advance the LFBO due to embedment of the LFBO within the intestinal wall or if intestine was unable to be preserved (i.e., euthanasia or resection and anastomosis was deemed necessary due to perforations or intestinal nonviability after FB removal with the RRCT). Perforations were categorized as perforations observed before FB removal and after FB removal (i.e., no perforations were observed on initial exploration but only observed after FB removal).

Postoperative data included hospitalization duration, complications, and survival to discharge. Postoperative surgical complications were categorized as minor and major. Minor complications occurred when cats did not require additional surgery and/or did not lead to death or euthanasia within 2 weeks of surgery. Hypothermia was defined as <99 degrees Fahrenheit. Hyperthermia or fever was defined as temperature >103 degrees Fahrenheit and/or specification of fever in the medical record. Major complications occurred when cats required additional surgery and/or death or euthanasia occurred within 2 weeks of surgery. Postoperative intestinal dehiscence was defined as the presence of abdominal intracellular bacteria on cytology or visualization of dehiscence during a reoperation.

Short-term follow-up occurred within 30 days of discharge and included date of examination, clinical signs, and physical examination findings. If follow-up was not performed at the institution, referring veterinarians and owners were contacted by phone at the time of data collection for interview, and a cat was included if either the owner or the veterinarian provided follow-up information. Dates of recheck examination were only obtained from in-hospital records or referring veterinarian information. If both the owners and veterinarians could not be contacted or did not respond to voicemails by the time of data analysis, cats were considered lost to follow-up.

2.1 | Statistical analysis

Descriptive statistics were calculated with JMP Pro 16 and reported for characteristics of cats undergoing surgery for a LFBO, DFBO, or BFBO. All continuous variables were visually inspected for normality, and none appeared to be normally distributed; therefore, median (interquartile range [IQR]) was reported. Range is reported for follow-up duration. Frequencies ± percentages are reported for categorical variables. Total sample size was adjusted to reflect the number of cats with available data for each variable category. Standard error is reported for RRCT and duration of clinical signs.

All statistical analyses amongst FB types were performed between LFBO and DFBO due to a small sample size of the BFBO category. To test for association between categorical variables, a Fisher's exact test was used for all 2×2 tables, otherwise, a likelihood chi-square ratio was used. A chi-square test of equal proportions was used to test for differences in proportions amongst five different groups of LFBO anchor locations. To estimate which of the five groups were different, the exact method was used to calculate the 95% confidence interval for each percentage, and different groups were determined if their 95% confidence intervals did not overlap. In the case where one of the variables was continuous, the nonparametric Kruskal-Wallis test was used to test for differences. p-values $< .05$ were considered statistically significant.

3 | RESULTS

A total of 379 cases were consistent with the search terms and operative reports reviewed. A total of 184 records met the inclusion criteria and 15 were excluded due to incomplete operative reports ($n = 7$), colonic FB only (5), FB unidentified during surgery (2), and unspecified FB location (1). Medical records of the remaining 169 cats were reviewed and classified as LFBOs (55), DFBOs (101), or BFBOs (13). Breeds included 94 domestic short hairs (LFBO: 43; DFBO: 45; BFBO: 6), 24 domestic long hairs (LFBO: 3; DFBO: 20; BFBO: 1), 22 domestic medium hairs (LFBO: 7; DFBO: 12; BFBO: 3), and 29 other cats (LFBO: 2; DFBO: 24; BFBO: 3). Reproductive status ($p = .4327$) and weight ($p = .8499$) did not differ between cats with linear and discrete FBOs (Tables 1 and 2). Cats with LFBOs were younger ($p = .0321$) and had shorter durations of clinical signs before surgery ($p < .0001$) than cats with DFBOs (Table 2). Owners were aware of FB

TABLE 1 Reproductive status of cats undergoing surgery for removal of LFBOs, DFBOs, or BFBOs.

	LFBOs ($N = 55$)	DFBOs ($N = 101$)	BFBOs ($N = 13$)	Total ($N = 169$)
Reproductive status ($p = 0.4327$)				
Female intact	2	6	1	9
Female spayed	25	38	5	68
Male intact	0	2	0	2
Male castrated	28	55	7	90

Note: A *p*-value is reported for comparison between LFBOs and DFBOs.
Abbreviations: BFBOs, both linear and discrete foreign body obstructions; DFBOs, discrete foreign body obstructions; LFBOs, linear foreign body obstructions.

TABLE 2 Clinical parameters of cats undergoing surgery for removal of LFBOs, DFBOs, or BFBOs.

Clinical Parameter	LFBOs	DFBOs	BFBOs	*p*-value
Weight (kilograms)				
(LFBO: 55; DFBO: 101; BFBO: 13)	4.5 (3.7–5.5)	4.7 (4.0–5.4)	4.4 (2.8–4.8)	.8499
Age (years)				
(LFBO: 55; DFBO: 101; BFBO: 13)	2.1 (1.0–6)	4.0 (1.7–7.5)	1.0 (0.6–1.8)	.0321*
Duration of clinical signs (days)				
(LFBO: 55; DFBO: 100; BFBO: 13)	2.0 (2.0–3.0)	4.0 (2.3–6.0)	2.0 (1.0–3.5)	<.0001*
Surgical time (minutes)				
(LFBO: 48; DFBO: 70; BFBO: 12)	77.0 (59.3–99.3)	58.0 (46.0–79.3)	87.0 (67.8–115.5)	.0018*
Hospitalization (days)				
(LFBO: 54; DFBO: 98; BFBO: 12)	1.0 (1.0–2.0)	2.0 (1.0–2.0)	1.0 (1.0–1.8)	.3660
Postoperative follow-up (days)				
(LFBO: 22; DFBO: 54; BFBO: 8)	11.0 (10.0–14.0)	11.5 (10.0–14.0)	10.5 (9.0–13.5)	…

Note: Median (IQR) is reported. An asterisk (*) denotes significant values ($p < .05$) between LFBOs and DFBOs.
Abbreviations: …, not applicable; BFBOs, both linear and discrete foreign body obstructions; DFBOs, discrete foreign body obstructions; IQR, interquartile range; LFBOs, linear foreign body obstructions.

TABLE 3 Preoperative imaging modalities performed in cats undergoing surgery for removal of LFBOs, DFBOs, or BFBOs.

Imaging modality	LFBOs ($N = 55$)	DFBOs ($N = 101$)	BFBOs ($N = 13$)	Total ($N = 169$)
Radiographs only	39	43	5	87
Ultrasound only	2	7	1	10
Radiographs and ultrasound	14	49	7	70
CT only	0	1	0	1
CT and radiographs	0	1	0	1

Abbreviations: BFBOs, both linear and discrete foreign body obstructions; CT, computed tomography; DFBOs, discrete foreign body obstructions; LFBOs, linear foreign body obstructions.

ingestion (42) and had increased awareness ($p = .0011$) for linear FB ingestion compared to discrete FB ingestion (LFBO: 21; DFBO: 14; BFBO: 7). All cats underwent at least one abdominal imaging modality (Table 3). Albumin was measured in 98 cats (LFBO: 23; DFBO: 72; BFBO: 3) and preoperative hypoalbuminemia occurred in six cats (LFBO: 1; DFBO: 5; BFBO: 0). PSP was reported in four cats (LFBO: 2; DFBO: 0; BFBO: 2).

Various procedures were performed (Table 4). Resection and anastomoses were performed in eight cats (LFBO: 4; DFBO: 3; BFBO: 1) and did not differ ($p = .2434$) between cats with linear and discrete FBOs. Two cats underwent resection and anastomoses using gastrointestinal anastomosis and thoracic-abdominal staplers (BFBO) and endovascular gastrointestinal anastomosis and thoracic-abdominal staplers (DFBO); the

TABLE 4 Surgical procedures or maneuvers performed in cats for removal of LFBOs, DFBOs, or BFBOs.

Surgical procedure(s)	LFBOs ($N = 55$)	DFBOs ($N = 101$)	BFBOs ($N = 13$)	Total ($N = 169$)
Milked to stomach	1	0	0	1
Milked to colon/rectum	1	5	1	7
Gastrotomy only	16	46	1	63
Single enterotomy	4	40	0	44
Three enterotomies	0	0	1	1
Gastrotomy and single enterotomy	5	6	5	16
Gastrotomy and two enterotomies	4	0	1	5
Gastrotomy and three enterotomies	1	0	0	1
Resection and anastomosis only	0	3	0	3
Resection and anastomosis and gastrotomy	1	0	0	1
RRCT and gastrotomy	2	0	0	2
RRCT with single enterotomy	1	0	0	1
RRCT with two enterotomies	2	0	0	2
RRCT with gastrotomy and single enterotomy	7	0	0	7
RRCT with gastrotomy and two enterotomies	2	0	1	3
RRCT with gastrotomy and three enterotomies	1	0	0	1
RRCT with gastrotomy and R&A	3	0	1	4
RRCT to colon with gastrotomy	2	0	0	2
RRCT to colon, gastrotomy, and enterotomy	1	0	0	1
Needle punctured through intestine	0	0	1	1
Euthanasia	1	1	1	3

Abbreviations: BFBOs, both linear and discrete foreign body obstructions; DFBOs, discrete foreign body obstructions; LFBOs, linear foreign body obstructions; RRCT, red rubber catheter technique.

TABLE 5 Comparison of linear material anchor point locations using 95% confidence intervals.

Anchor location ($N = 68$)	Upper 95% confidence interval	Lower 95% confidence interval	Probability
Tongue ($N = 17$)	0.377579	0.17082	.26154
Stomach ($N = 32$)	0.581668	0.348027	.46154
Duodenum ($N = 7$)	0.204826	0.054556	.10769
Jejunum ($N = 10$)	0.260421	0.085998	.15385
Ileum ($N = 1$)	0.081071	0.003873	.01538
Unknown ($N = 1$)	N/A	N/A	N/A

Abbreviation: N/A, not applicable.

remaining six cats underwent handsewn anastomosis. Intraoperative blood pressure was available in 167 cats (LFBO: 55; DFBO: 99; BFBO: 13) and hypotension occurred in 59 cats (LFBO: 20; DFBO: 30; BFBO: 9) with no difference ($p = .4756$) between cats with linear and discrete FBOs. Cats with LFBOs had longer surgical times ($p = .0018$) than cats with DFBOs (Table 2).

Adhesions ($n = 10$) were rare (LFBO: 1; DFBO: 9; BFBO: 0). Any cat with linear material (68) was evaluated for anchor point location and use of the RRCT (LFBO: 55; BFBO: 13). Anchor points included tongue ($n = 17$), stomach (32), duodenum (7), jejunum (10), ileum (1), and unknown (1). Anchor point location in the stomach was more frequent compared to duodenum, jejunum, and ileum, but not different from tongue (Table 5). Additionally, tongue was increased compared to ileum, but not different from any other location (Table 5). Cats undergoing the RRCT ($n = 24$) were categorized as successful (20) and unsuccessful (4) attempts. Although all unsuccessful attempts of the RRCT occurred in cats with perforations, the causes for unsuccessful attempts were inability to advance the LFBO due to tissue engagement (1) and inability to preserve intestine due to the presence of perforations or nonviability leading to a resection and anastomosis (3). Cats with RRCT failure had a higher median duration of clinical signs prior to surgery than cats with RRCT successes (success: median = 2.0 days, IQR = 1.8, standard error = 0.2; failure: median = 6.5 days, IQR = 10.0, standard error = 2.7).

Intestinal perforations identified before FB removal were observed in four cats (LFBO: 2; DFBO: 0; BFBO: 2) and occurred in one out of the four RRCT failures. One cat had one perforation with a needle puncturing the jejunum (BFBO) and the other cats had nine (LFBO), 10 (BFBO), or more than 15 (LFBO) perforations. The second cat's (LFBO) nine perforations throughout the jejunum and part of the ileum were repaired and interrogated with leak testing. The linear material in the third cat (BFBO) with 10 perforations along the mesenteric border could not be moved using the RRCT due to firm engagement within the intestinal wall, resulting in approximately 75% of the jejunum being resected; however, after anastomosis, leak testing revealed another perforation extending aborad, and the cat was euthanized intraoperatively. This was considered failure of the RRCT. The fourth cat (LFBO) had preoperative septic peritonitis, more than 15 perforations extending from the proximal duodenum to the distal jejunum and was euthanized due to being inoperable.

Five cats (LFBO: 3; DFBO: 1; BFBO: 1) with no perforations on initial exploration had perforations observed after FB removal. This led to four of eight resection and anastomoses and three of four RRCT failures. One cat (DFBO) had a nearly perforated region observed before FB removal but was only observed as a true perforation after FB removal during leak testing. This perforation was repaired using 4–0 Monocryl. A second cat (LFBO) with several distal jejunal perforations observed after the RRCT was used to remove the linear material underwent resection and anastomosis of this region. This was considered failure of the RRCT. A third cat (LFBO) underwent the RRCT for FB removal which revealed two mesenteric perforations and one antimesenteric perforation that underwent repair using 4–0 PDS. After part of the linear material was removed from the stomach, the previously repaired regions of intestine were deemed nonviable and underwent resection and anastomosis. This was considered failure of the RRCT. Another perforation was observed on the antimesenteric border after leak testing, resulting in revision of the resection and anastomosis and no further leaking. The fourth cat (LFBO) underwent external manipulation of the linear material to break down the plication and milk it to the stomach; however, this revealed eight perforations along the mesenteric border, and a resection and anastomosis was performed. The fifth cat (BFBO) had multiple perforations along the mesenteric border between the middle and distal jejunum after a RRCT failed to disengage the linear material from the intestinal wall, and a resection and anastomosis was performed. This was considered failure of the RRCT.

A leak test was performed in 61 cats (LFBO: 16; DFBO: 41; BFBO: 4). An omental patch was performed in 65 cats (LFBO: 21; DFBO: 35; BFBO: 9). Three cats were euthanized intraoperatively (LFBO: 1: DFBO: 1: BFBO: 1): two cats due to perforations (LFBO and BFBO) and one cat (DFBO) with severe concurrent esophageal trauma and incidental gastric FBs.

Of the 166 cats surviving surgery, 40 (LFBO: 17; DFBO: 21; BFBO: 2) were lost to follow-up with no difference ($p = .1725$) in follow-up between cats with linear and discrete FBOs. Of 126 cats with follow-up information, all cats were reported to be alive 2 weeks after surgery, and 84 cats (LFBO: 22; DFBO: 54; BFBO: 8) had a recheck appointment date obtained from in-hospital records or referring veterinarian calls. The median and range of follow-up days for each FB classification group was 11 days (5–16) for cats with LFBOs, 11.5 days (3–22) for cats with DFBOs, and 10.5 days (2–14) for cats with BFBO. Of 126 cats with follow-up information, 38 cats (30.2%) had postoperative complications (LFBO: 15; DFBO: 21; BFBO: 2) with no difference ($p = .1386$) between cats with linear and discrete FBOs. Minor complications occurred in 34 cats and included fever or hyperthermia (25), hypothermia (14), surgical site infection (4), regurgitation (2), aspiration pneumonia (3), and vomiting (1). When body temperature was excluded, only 7.9% of cats with follow-up had minor complications reported.

Major complications occurred in four cats with DFBOs due to euthanasia (1), arrest (1), and intestinal dehiscence requiring reoperation (2). Both deaths occurred in cats presenting several days after clinical signs and had similar problem lists prior to death or euthanasia. One cat presented after 5 days of clinical signs (lethargy, inappetence, vomiting, and decreased thirst), and postoperatively experienced vasopressor-dependent hypotension, acute kidney injury, and pleural effusion. Systemic inflammatory response syndrome was suspected and he arrested. Another cat presented after 14 days of clinical signs (lateral recumbency, lethargy, inappetence, and bilateral ocular/nasal discharge) and postoperatively experienced vasopressor-dependent hypotension, acute kidney injury, and pleural/pericardial effusion. This cat was euthanized. Dehiscence occurred in two cats with DFBOs 3 and 4 days after surgery, but this did not differ ($p = .5416$) between cats with linear and discrete FBOs. A total of 164 cats (LFBO: 54 [98.2%]; DFBO: 98 [97%]; BFBO: 12 [92.3%]) survived to discharge for an overall 97% survival rate. Survival to discharge did not differ ($p = 1.0000$) between cats with linear and discrete FBOs. Of the 164 cats that survived to discharge, hospitalization duration did not differ ($p = .3660$) between cats with linear and discrete FBOs (Table 2).

4 | DISCUSSION

To the authors' knowledge, our study represents the largest study to date comparing FBOs in cats with 59.8% DFBOs, 32.5% LFBOs, and 7.7% BFBOs. In our population, intestinal dehiscence was rare, and while both cats had DFBOs, dehiscence did not differ between cats with linear and discrete FBOs. Although cats with LFBOs had longer surgical times, the incidence of intraoperative hypotension, intraoperative euthanasia, postoperative complications, and survival to discharge did not differ between cats with linear and discrete FBOs. A RRCT was successful in removing LFBOs in most cats.

To our knowledge, intestinal incisional dehiscence after surgery for FBO in cats has not been previously reported in the literature. Historically, 0% dehiscence[6,7,11,13,16] has been reported in cats after enterotomy or resection and anastomosis; however, all sample sizes were limited to less than 25 cats, except one study that included 56 cats with FBOs. A recent study included 126 cats undergoing gastrointestinal surgery for a variety of indications; however, only 29 cats had FBOs with 7 LFBOs and 22 DFBOs.[12] One cat had intestinal dehiscence; however, this occurred secondary to a jejunal adenocarcinoma in a cat without preoperative septic peritonitis, and euthanasia was elected before reoperation.[12] The sample size of patients experiencing dehiscence prevented identification of dehiscence risk factors; however, the question of why cats have a low incidence of intestinal dehiscence is still unanswered for this species. Dogs have higher rates of intestinal dehiscence ranging from 0% to 16%[7,8,11,17–21] with risk factors including preoperative peritonitis,[7,8,18,19] preoperative hypoalbuminemia <2.5 g/dL,[7] intraoperative peritonitis,[8] intraoperative hypotension,[19] location of anastomosis,[19] and possibly preoperative inflammatory bowel disease.[19] In our study, we also could not determine risk factors for dehiscence due to having a limited sample size (2 cats); however, intraoperative hypotension did not differ between cats with linear or discrete FBOs. In addition, only six cats had hypoalbuminemia (3.6%); therefore, statistical analyses were not performed between FB classifications due to small sample size. Hiebert et al. reported risk factors for increased mortality.[12] Preoperative septic peritonitis, diagnosed in 13.5% of cats, was reported to have 6.7 times higher odds of mortality than cats without preoperative septic peritonitis, whereas intraoperative hypotension and preoperative hypoalbuminemia did not achieve significance as a risk factor for mortality.[12] While the specific mortality rate in cats with preoperative septic peritonitis was not specified in that study,[12] preoperative septic peritonitis has also been identified in dogs as a risk factor for mortality with a 68% mortality rate.[4,22] In this study, half of dogs died or were euthanized within one day of diagnosis and never underwent surgery, while the remaining half of dogs were euthanized postoperatively.[4] Hiebert et al. defined preoperative septic peritonitis as the presence of intracellular bacteria or positive culture within abdominal fluid or the presence of a noniatrogenic intestinal perforation on abdominal explore.[12] In our study, four cats (2.4%) with linear material, two with LFBOs and two with BFBOs, had preoperative septic peritonitis using this same definition. Preoperative septic peritonitis was a rare finding in our study and could be due to population differences between our study and the aforementioned study[12] and/or because all our cases involved FBOs. Future multi-institutional studies of cats with intestinal dehiscence may include enough cases to identify potential risk factors; however, small sample sizes may continue to be a limitation. Previously, it was unknown if cats were truly at a lower risk of intestinal dehiscence after foreign body obstruction or if sample sizes were not large enough to identify this outcome. Our study's results provide additional information from a large cohort of cats with the first report of intestinal dehiscence after foreign body obstruction in cats. Therefore, when discussing prognosis with owners of cats with FBOs undergoing surgery, dehiscence appears to be a lower risk factor than dogs and may help owners be more comfortable with the risks of surgery.

Survival to discharge was not different between cats with linear (98.2%) or discrete (97%) FBOs. Therefore, we rejected our first hypothesis. Our LFBOs survival to discharge was slightly higher than previous reports of survival in 84%[15] and 92%[14] of cats, but similar to a report in 100%[13] of cats. Our DFBO survival to discharge was similar to two previous reports of survival in 100% of cats.[6,13] It is possible that surgeon experience could have influenced these survival rates; however, it could not be determined from medical records whether the faculty or surgical resident/intern primarily performed the surgery. However, all these studies are either limited by sample size or a lack of follow-up. Although the first two studies[14,15] were performed in over 100 cats, publishing occurred in the

1980s and did not report follow-up information or did not specify a timeframe for follow-up. The most recent study included 56 cats, but did not include follow-up information beyond discharge.[13] Although the study by Hayes et al. included follow-up information for 10 days postoperatively, they only included 24 cats.[6] In addition, a significantly lower survival rate in cats with LFBOs (63%) was reported with higher rates of mortality associated with longer durations of clinical signs, presence of linear foreign bodies, and multiple intestinal procedures.[6] In contrast, cats in our study with LFBOs had a shorter duration of clinical signs than cats with DFBOs. Therefore, we rejected our second hypothesis. It is possible that differences in owner populations and earlier recognition of clinical signs in our study could be the reason for this difference between studies. In the aforementioned study, owners were aware of FB ingestion in 25% of FB cases when grouping dogs and cats together; however, this was not separated by species.[6] In our study, owners were also aware of FB ingestion in 24.9% of all cats; however, owners were aware of FB ingestion in 38.2% of cats with LFBOs alone. This could have led to an earlier presentation and treatment for these cats. Therefore, in our study, the low frequency of preoperative septic peritonitis, shorter duration of clinical signs, over one-third of owners being aware of LFBO ingestion, and the potential differences in surgeon decisions during surgery (i.e., resection and anastomosis vs. RRCT vs. euthanasia) could have influenced our high LFBO survival to discharge rate. It is the authors' opinion that earlier recognition of foreign body ingestion and earlier treatment may help with improved survival to discharge in cats with LFBOs.

Intraoperative euthanasia was similar between cats with linear or discrete FBOs. Euthanasia was performed in one cat with incidental gastric FBs due to severe concurrent trauma and in two cats due to extensive perforations. Short-term follow-up was available in about three quarters of the cases, and all of these cats were reported to be alive at a minimum of 2 weeks after surgery. The presence or absence of postoperative complications did not differ between cats with linear and discrete FBOs. Postoperatively, two cats with DFBOs died: one was euthanized and one arrested. Systemic inflammatory response syndrome was suspected in one of these cases and both of the cats who died were also affected by vasopressor-dependent hypotension, acute kidney injury, and pleural effusion. While specific postoperative risk factors for mortality could not be compared due to our low sample size of postoperative deaths, future prospective randomized multi-institutional studies may determine if these pathologies are potential risk factors for increased mortality amongst a larger cohort of cats that died after surgery for FBOs.

A RRCT through a single enterotomy has been reported to aid in the removal of LFBOs.[9] The goal of this technique is to decrease the number of intestinal incisions because multiple incisions have been associated with increased mortality in cats.[5,6] In our study, we used a RRCT through manipulation to a gastrotomy, anus, or through another enterotomy(ies) to decrease the number of enterotomies performed. A limitation of the RRCT is the potential for iatrogenic perforations due to manipulation of the red rubber catheter, which has been reported in a cat with a LFBO.[10] If this occurs, a resection and anastomosis may be necessary or an attempt at the RRCT may be beneficial before condemning the intestine. In the case report of the cat with iatrogenic perforations after RRCT use, clinical signs were apparent for 9 days before surgery, which may suggest that a longer duration of clinical signs could increase the risk of LFBOs becoming embedded within tissue.[10] Statistical analysis was not performed to compare duration of clinical signs amongst successful and failed RRCT attempts due to higher standard error amongst only 24 cases; however, the median of 2 days in successful RRCT versus 6.5 days in failed RRCT could represent clinical significance. Future prospective, randomized studies comparing risk factors for a RRCT are recommended. Regardless, the RRCT technique described in our study was successful in a majority (83.3%) of LFBOs in this population and may continue to be a useful option in a majority of feline surgeries for LFBO.

The main limitation of this study was its retrospective nature and reliance on reports in the medical record. Due to the nature of our record's system, it could not be differentiated whether a surgery was primarily performed by the faculty or surgery resident/intern. In addition, short-term follow-up included owner opinion and duration of recall could have varied over the 10-year period of the study. Owner recall bias could have influenced our postoperative outcomes, and our study could have over- or underestimated complications. Prospective randomized studies between LFBOs and DFBOs in cats undergoing surgery should be performed to compare postoperative complications in the future.

In conclusion, intestinal dehiscence is possible, but rare and did not differ between cats with linear and discrete FBOs. Future multi-institutional studies of cats with intestinal dehiscence would be necessary to determine risk factors; however, sample size may continue to be a limitation due to a low incidence of intestinal dehiscence in cats. Postoperative complications and survival to discharge did not differ between cats with linear and discrete FBOs. Our study reported a high survival rate for cats with LFBOs and DFBOs, although the rare incidence of preoperative septic peritonitis and earlier recognition of clinical signs could have influenced these findings in our population. The RRCT described in our study was successful in the majority of cats undergoing the technique. Future randomized prospective studies of a RRCT between cats with linear and discrete FBOs are indicated to determine risk factors for failure.

AUTHOR CONTRIBUTIONS

Miller AK, DVM, MPH: Substantial contribution to the conception and design of this study, data acquisition, data analysis, data interpretation, drafting and revision of work, in-line specific manuscript editing, and final approval of manuscript. Regier PJ, DVM, MS, DACVS (Small Animal): Substantial contribution to the conception and design of this study, data interpretation, revision of work, in-line specific manuscript editing, and final approval of manuscript. Ham KM, DVM, MS, DACVS (Small Animal): Substantial contribution to the acquisition of data, data interpretation, revision of work, in-line specific manuscript editing, and final approval of manuscript. Case JB, DVM, MS, DACVS (Small Animal): Substantial contribution to the acquisition of data, data interpretation, revision of work, in-line specific manuscript editing, and final approval of manuscript. Fisher KJ, BS: substantial data acquisition, owner and primary care veterinarian interview for follow-up, drafting and revision of work, and final approval of manuscript. Rogers JM, BS: Substantial data acquisition, owner and primary care veterinarian interview for follow-up, drafting and revision of work, and final approval of manuscript. Daly EJ, BS: Substantial data acquisition, owner and primary care veterinarian interview for follow-up, drafting and revision of work, and final approval of manuscript. Colee JC, PhD: Statistician with substantial contribution to data analysis, data interpretation, in-line specific manuscript editing regarding statistical data, and final approval of manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest related to this report.

ORCID

Annellie Kaitlin Miller https://orcid.org/0000-0002-3844-0170

REFERENCES

1. Papazoglou LG, Patsikas MN, Rallis T. Intestinal foreign bodies in dogs and cats. *Compend Contin Educ Vet*. 2003;25(11):830-844. doi:10.1111/j.1751-0813.1939.tb04295.x
2. Willis SE, Farrow CS. Partial gastrointestinal obstruction for one month due to a linear foreign body in a cat. *Can Vet J*. 1991;32(11):689-691.
3. MacPhail C. Gastro-intestinal obstruction. *Clin Tech Small Anim Pract*. 2002;17(4):178-183. doi:10.1097/00007611-195808000-00042
4. Hosgood G, Salisbury SK. Generalized peritonitis in dogs: 50 cases (1975-1986). *J Am Vet Med Assoc*. 1988;193(11):1448-1450.
5. Wylie K, Hosgood G. Mortality and morbidity of small and large intestinal surgery in dogs and cats: 74 cases (1980-1992). *J Am Anim Hosp Assoc*. 1994;30:469-474.
6. Hayes G. Gastrointestinal foreign bodies in dogs and cats: a retrospective study of 208 cases. *J Small Anim Pract*. 2009;50(11):576-583. doi:10.1111/j.1748-5827.2009.00783.x
7. Ralphs CC, Jessen CR, Lipowitz AJ. Risk factors for leakage following intestinal anastomosis in dogs and cats: 115 cases (1991-2000). *J Am Vet Med Assoc*. 2003;223(1):73-77. doi:10.2460/javma.2003.223.73
8. Allen D, Smeak D, Schertel E. Prevalence of small intestinal dehiscence and associated clinical factors: a retrospective study of 121 dogs. *J Am Anim Hosp Assoc*. 1992;28(1):70-76.
9. Anderson S, Lippincott C, Gill P. Single Enterotomy removal of gastrointestinal linear foreign bodies. *J Am Anim Hosp Assoc*. 1992;28(6):487-490.
10. Muir P, Rosin E. Failure of the single enterotomy technique to remove a linear intestinal foreign body from a cat. *Vet Rec*. 1995;136:75.
11. Weisman DL, Smeak DD, Birchard SJ, Zweigart SL. Comparison of a continuous suture pattern with a simple interrupted pattern for enteric closure in dogs and cats: 83 cases (1991-1997). *J Am Vet Med Assoc*. 1999;214(10):1507-1510.
12. Hiebert EC, Barry SL, Sawyere DM, DeMonaco SM, Muro NM. Intestinal dehiscence and mortality in cats undergoing gastrointestinal surgery. *J Feline Med Surg*. 2022;24(8):779-786. doi:10.1177/1098612X211048454
13. Gollnick HR, Schmiedt CW, Wallace ML, Sutherland BJ, Grimes JA. Retrospective evaluation of surgical treatment of linear and discrete gastrointestinal foreign bodies in cats: 2009-2021. *J Feline Med Surg*. 2023;25(6):1098612X231178140. doi:10.1177/1098612X231178140
14. Basher AW, Fowler D. Conservative versus surgical management of gastrointestinal linear foreign bodies in the cat. *Vet Surg*. 1987;16(2):135-138.
15. Felts J, Fox P, Burk R. Thread and sewing needles as gastrointestinal foreign bodies in the cat: a review of 64 cases. *J Am Vet Med Assoc*. 1984;184(1):56-59.
16. Gorman SC, Freeman LM, Mitchell SL, Chan DL. Extensive small bowel resection in dogs and cats: 20 cases (1998-2004). *J Am Vet Med Assoc*. 2006;228(3):403-407. doi:10.2460/javma.228.3.403
17. Boag AK, Coe RJ, Martinez TA, Hughes D. Acid-Base and electrolyte abnormalities in dogs with gastrointestinal foreign bodies. *J Vet Intern Med*. 2005;19(6):816-821. doi:10.1111/j.1939-1676.2005.tb02770.x
18. Ullman SL, Pavletic MM, Clark GN. Open intestinal anastomosis with surgical stapling equipment in 24 dogs and cats. *Vet Surg*. 1991;20(6):385-391. doi:10.1111/j.1532-950x.1991.tb00344.x
19. Snowdon KA, Smeak DD, Chiang S. Risk factors for dehiscence of stapled functional end-to-end intestinal anastomoses in dogs: 53 cases (2001-2012). *Vet Surg*. 2016;45(1):91-99. doi:10.1111/vsu.12413

20. White RN. Modified functional end-to-end stapled intestinal anastomosis: technique and clinical results in 15 dogs. *J Small Anim Pract*. 2008;49(6):274-281. doi:10.1111/j.1748-5827.2007.00499.x
21. Jardel N, Hidalgo A, Leperlier D, et al. One stage functional end-to-end stapled intestinal anastomosis and resection performed by nonexpert surgeons for the treatment of small intestinal obstruction in 30 dogs. *Vet Surg*. 2011;40(2):216-222. doi:10.1111/j.1532-950X.2010.00784.x
22. Culp WTN, Holt DE. Septic peritonitis. *Compend Contin Educ Vet*. 2010;32(10):E1-E14. quiz E15.

How to cite this article: Miller AK, Regier PJ, Ham KM, et al. Linear and discrete foreign body small intestinal obstruction outcomes, complication risk factors, and single incision red rubber catheter technique success in cats. *Veterinary Surgery*. 2024;53(7):1256-1265. doi:10.1111/vsu.14125