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Prognostic indicators for survival in surgically managed small intestinal obstruction in pet rabbits: 141 presentations (2011–2021)

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OBJECTIVE
To determine prognostic relevance of various patient factors and intraoperative variables associated with surgical management of small intestinal obstruction in pet rabbits.

ANIMALS
114 pet rabbits with 141 presentations of small intestinal obstruction treated surgically between June 2011 and December 2021.

METHODS
In a retrospective observational study design, medical records were reviewed for rabbits with small intestinal obstruction that had undergone surgical intervention. Data were collected on variables of interest and outcome (survival to hospital discharge). Univariable and multivariable logistic regression analyses were performed to identify variables associated with survival.

RESULTS
Overall survival was 75.2% (106/141). Specifically, 95.7% (22/23) of presentations involving rabbits < 25 months survived. The odds of survival on univariable modeling were significantly lower in presentations of rabbits > 72 months compared with those < 25 months (OR, 0.05; 95% CI, 0.01 to 0.40; P = .005). Rectal temperature, clinicopathologic findings, etiology of obstruction, presence of full-thickness gastrointestinal wall injury, and previous small intestinal obstruction surgery did not show significant effects on survival. In a multivariable model that controlled for plasma potassium and calculated plasma osmolarity and tonicity, the odds of survival in presentations of rabbits > 72 months were 95% lower than those < 25 months (OR, 0.05; 95% CI, 0.01 to 0.50; P = .012).

CLINICAL RELEVANCE
Surgical intervention should be considered a suitable treatment option for small intestinal obstruction in rabbits < 72 months and carried a good prognosis. The most common etiology was consistent with a compressed hair pellet, and extraluminal digital manipulation into the cecum was a successful surgical technique in most presentations.

Keywords: rabbit, small intestinal obstruction, gastrointestinal, age, soft tissue surgery

Small intestinal obstruction in rabbits is a common, potentially life-threatening condition. It is often associated with significant hypovolemic and obstructive shock, acid-base and electrolyte derangements, hyperglycemia, and pain.[1–9] Affected rabbits generally require prompt diagnosis and treatment to prevent further decline in clinical status and support recovery.[1,3–6,8] Typical clinicopathologic and diagnostic imaging findings associated with rabbit small intestinal obstruction have been established and should be used to differentiate this condition from other causes of rabbit gastrointestinal syndrome.[2,4,8–11] Treatment of small intestinal obstruction can be broadly classified as either medical or surgical, with varying outcomes reported for each modality.[1–6,12] Surgical intervention has often been thought to be associated with a poorer prognosis, with less than half the rabbits recovering to hospital discharge in 1 study.[1] However, while medical

management alone may offer a favorable outcome in many rabbits,[4,12] surgical intervention remains the treatment of choice in those that demonstrate a continual decline in clinical status or show minimal response to medical management.[3–6]

A compressed hair pellet (CHP) located in the proximal duodenum is considered the most common cause and site of small intestinal obstruction in rabbits.[1,8,12] However, foreign bodies and extraluminal conditions such as neoplasia and abdominal adhesions have also been reported.[1] The well-developed cardiac sphincter in rabbits limits emesis or eructation. Marked and rapid dilation of the gastrointestinal tract therefore occurs orad to the site of obstruction due to fluid and gas accumulation, with the stomach usually most significantly affected.[3,8] In addition, significant pain, fluid sequestration into the gastrointestinal tract, and impaired venous return from pressure of the dilated stomach on the caudal vena cava contribute to hypovolemic and obstructive shock.[3,8] Disturbances in acid-base and electrolyte homeostasis are also frequently observed due to sequestration into various body compartments and from respiratory compromise caused by increased pressure of the dilated stomach on the diaphragm.[3,8,9]

Fluid resuscitation and appropriate analgesia following current emergency and critical care guidelines form the cornerstones of initial management in rabbit small intestinal obstruction.[11,13,14] Active warming should be provided for hypothermic rabbits.[11,13] In conjunction with clinical markers denoting resuscitation end points, changes in intestinal gas pattern and gastric size on serial abdominal radiography can be used to assess response to initial medical therapy.[3,6,10,11] A reduction in gastric size together with the appearance of small intestinal gas dilation that was not previously present, followed later by cecal gas dilation, can be suggestive of aboral passage of an obstruction along the small intestines into the cecocolic complex.[10,11] Use of radiographic intestinal contrast studies to confirm small intestinal luminal patency has also been suggested, but this can be difficult to interpret and administration of any products PO in intestinal obstruction can be controversial.[15–18]

While there is a consensus that surgical intervention is not generally indicated in rabbits that demonstrate a presence of cecal gas pattern on diagnostic imaging,[1,5,6,8] opinions vary regarding selection criteria and time points for surgical intervention.[1,3,4,6,8] These may include lack of positive response to initial medical therapy and a declining clinical status, but clinician and client preferences may also influence judgment. Prompt surgical intervention may reduce risk of tissue devitalization and potential perforation orad to or at the site of obstruction and resultant septic peritonitis. It may also enable immediate resolution of the underlying cause without risking further decline in the rabbit's clinical status.[6,8] However, delaying surgical intervention may enable correction of hemodynamic, electrolyte, and acid-base derangements and thus reduce associated anesthetic risks. This can also offer an opportunity for spontaneous passage of the obstruction following medical therapy and may eliminate the need for surgical intervention.[3,4,12] Orogastric decompression at the time of diagnosis in rabbits that were in critical condition with signs of shock and a severely distended stomach on palpation has also been suggested to favor the resolution of obstruction without surgical intervention.[4]

Two main surgical techniques have been described for small intestinal obstruction in rabbits. A CHP or foreign body may be manipulated extraluminally along the small intestine aborally into the cecocolic complex. Alternatively, enterotomy or enterectomy can be performed.[3,6,8] It is considered by some authors that extraluminal manipulation where possible is preferable, due to the increased challenge associated with repair of the thin-walled rabbit small intestine and reduced risk of postoperative peritonitis and stricture formation.[3,6,8,19] It is thought that a CHP or mobile foreign body will pass spontaneously and uneventfully once it is in the cecocolic complex.[8,19] However, immediate as well as delayed postoperative complications may be caused by increased intestinal handling during digital manipulation, such as altered intestinal motility, hypothermia, and abdominal adhesion formation.[8]

This was a retrospective study of 141 presentations of small intestinal obstruction in rabbits managed surgically across 2 specialist exotic animal veterinary services in Sydney, Australia, between June 2011 and December 2021. We aimed to review the outcomes associated with surgical intervention and its relationship to patient factors, clinicopathologic findings, and perioperative variables.

Methods

Electronic medical records between June 2011 and December 2021 from 2 specialist exotic animal veterinary services were searched using the keywords "rabbit" together with "intestinal obstruction," "gut obstruction," "gastrointestinal obstruction," and "laparotomy." The inclusion criteria were met in rabbits that had small intestinal obstruction confirmed on exploratory laparotomy.

Records that met the inclusion criteria were reviewed for signalment, rectal temperature, and clinicopathologic findings (BUN, plasma glucose, sodium, and potassium) on presentation; intraoperative findings (etiology and location of obstruction); surgical technique(s) used; and outcome. Some rabbits over their lifetime had multiple presentations of small intestinal obstruction that required surgical intervention. The number of previous obstruction surgeries on presentation was also recorded.

Rectal temperatures between 38.0 and 39.9 °C were considered normal on the basis of a previous study describing the prognostic value of rectal temperatures in rabbits; similarly, hypothermia was defined as ≤ 37.9 °C.[20]

Plasma biochemistry and electrolytes were performed using in-house analyzers (VetScan Comprehensive Diagnostic Profile, Abaxis Inc; i-STAT handheld

analyzer and Chem8+ or EC8+ cartridges, Abaxis Inc; or IDEXX Catalyst One chemistry analyzer, IDEXX Laboratories). Reference ranges were based on published values for each method or analyzer used.[7,21,22] For statistical analysis, extreme hyperglycemia beyond the maximal limit of the analytical method used was interpreted as the maximal numerical glycemic index for the method used.

Plasma osmolarity and tonicity were calculated using the following formulas[23,24]:

Plasma osmolarity (mOsm/L) = 2 X sodium(mmol/L) + glucose(mmol/L) + BUN(mmol/L)

Plasma tonicity (mOsm/L) = 2 X sodium(mmol/L) + glucose(mmol/L)

Normal calculated plasma osmolarity was considered to be 284 to 312 mOsm/L and tonicity 78 to 302 mOsm/L.[24]

Initial medical management strategies

Rabbits showing radiographic findings consistent with small intestinal obstruction as per current published parameters[10] received immediate medical intervention. These parameters included a summed gastric silhouette length and width greater or equal to the length between the first lumbar vertebra and the coxofemoral joint, extension of the gastric silhouette beyond the caudal edge of the second lumbar vertebra (both assessed on lateral abdominal radiographic views), homogenous gastric contents of soft tissue radiopacity together with a gas "cap," and absence of significant gas accumulation within the cecocolic complex.[10]

Although there was variability between medical therapies offered by different clinicians, therapy primarily incorporated the following: (i) IV fluid resuscitation (typically isotonic crystalloid fluids with or without the addition of colloids) following current emergency and critical care guidelines,[11,14] (ii) opioid analgesia (buprenorphine, 0.03 mg/kg, IV or SC, or fentanyl constant rate infusion, 2 mg/kg/h), and (iii) active warming measures as necessary based on current published guidelines.[14] Gastrointestinal promotility agents, assist feeding, and oral products were never administered at this stage.

Rabbits were monitored for demeanor and vital signs at regular intervals. Depending on the perceived clinical status, serial abdominal radiography with orthogonal views were obtained at approximately 2-hour intervals to aid assessment of response to medical therapy. A positive response was typically defined as achieving resuscitation end points such as normothermia, normotension, and reduced signs of pain, as well as evidence demonstrating passage of the obstruction including reduced gastric size on palpation and corresponding radiographic signs as described previously.

Decision for surgery

There were variabilities in individual case management by different clinicians across each institution. Factors such as prolonged duration of clinical signs before presentation, poor clinical status such as significant hypothermia or hypotension, and willingness of the client to pursue surgery may encourage the clinician to recommend early surgical intervention. Lack of positive response to medical management using parameters as described above after several hours may also prompt the clinician to pursue surgery. Practical factors such as time of day of presentation, hospital scheduling conflicts, and availability of veterinary surgeons may also influence the decision to pursue a particular management modality initially.

Surgical intervention

All rabbits were anesthetized and intubated. This was followed by orogastric decompression using a premeasured, lubricated 16 to 20 Fr orogastric tube passed into the stomach while the rabbit was in sternal recumbency. The gastric contents were aspirated using gentle negative suction applied via a catheter-tipped syringe. If the orogastric tube became obstructed by any fibrous gastric contents or if negative suction ceased to aspirate any further material and the stomach was palpably smaller in size, the tube was removed to minimize risk of mucosal damage through repeated placement and suction.

Rabbits were then placed in a reverse Trendelenburg position and aseptically prepared for exploratory laparotomy. A ventral midline incision into the abdominal cavity was performed, typically extending from the xiphoid process to the umbilicus, and may be lengthened further caudally as deemed necessary by the clinician. Inspection of the abdominal cavity followed, and the site of the small intestinal obstruction was located. This area was then explored to identify the underlying cause of obstruction.

The small intestinal wall in most rabbits was sufficiently thin to allow characterization of intraluminal material. A discrete pellet that was round, smooth, brown in color, and moderately pliable was considered most consistent with a CHP. Discrete bruising or petechial hemorrhage was frequently identified on the serosal surface of the gastrointestinal tract and often located at the site of obstruction.

For presentations in which a CHP-like or foreign body was identified, this was gently manipulated extraluminally to determine whether it could be moved along the intestinal tract **(Figure 1)**. Where manipulation was possible and the gastrointestinal tract appeared viable in its entirety, the CHP-like or foreign body was gently manipulated extraluminally aborad along the length of the small intestine past the ileocecocolic junction into the cecum. During this process, any exteriorized abdominal viscera were regularly moistened with warm sterile saline.

Infrequently, full-thickness perforation of the gastric or small intestinal wall was identified together with contamination of the abdominal cavity with gastrointestinal contents. Iatrogenic perforation of the intestinal wall also occurred infrequently during extraluminal manipulation of an obstruction, possibly due to the increased intestinal wall friability encountered in some presentations. Repair of the gastrointestinal tract and abdominal cavity decontamination was performed

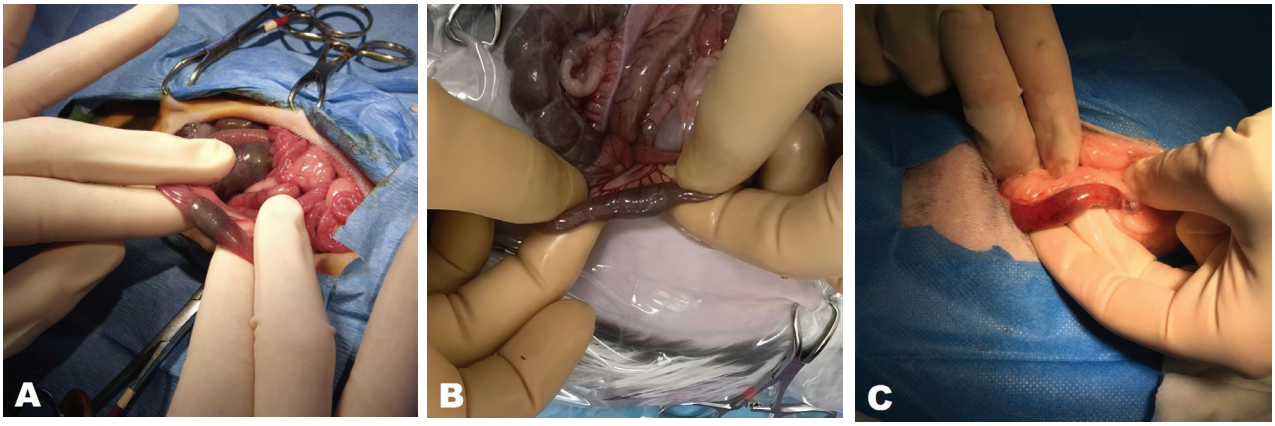

Figure 1—Intraoperative images during exploratory laparotomy from 3 presentations of rabbit small intestinal obstruction between June 2011 and December 2021. A compressed hair pellet was identified to be the cause of obstruction in all 3 presentations, and all were treated successfully by extraluminal manipulation of the pellet into the cecum. Note the round, smooth, brown-colored appearance typical of a compressed hair pellet (A). Gentle digital extraluminal manipulation confirmed its pliable consistency and ability to be moved aborally along the small intestines (B). Discrete bruising and petechial hemorrhages were often observed on the serosal surface of the small intestine at the site of obstruction (C).

following similar surgical principles as in small animals when either circumstance was encountered.

Enterotomy or enterectomy was performed when a nonmobile CHP-like or foreign body was identified or where there was gross evidence of intestinal wall devitalization. Techniques following similar principles as for small animal intestinal surgery were used.[19,25] Omentalization of the surgical site following closure was typically not performed due to the small omentum in rabbits.

The abdomen and remaining abdominal viscera were visually inspected and the abdominal cavity lavaged with warm sterile saline. The abdomen was closed routinely in 3 layers using monofilament absorbable sutures.

Rabbits were continuously monitored during anesthesia and in the recovery period. Monitored parameters included heart rate, pulse, electrocardiography, oxygen saturation, respiratory rate, end-tidal carbon dioxide, blood pressure, and body temperature.

Preoperative antibacterial prophylaxis was used in some presentations. This typically consisted of cefazolin, 22 mg/kg, IV, administered within 1 hour before skin incision and repeated every 90 minutes. This was typically discontinued at the end of the procedure unless peritonitis was considered a risk.

Postoperative care and discharge

Free-choice rabbit pellets, grass hay, and leafy vegetables were offered. Additional nutritional support via syringe feeding of a specialized herbivore feeding formula was administered if anorexia persisted beyond 24 hours postoperatively. Intravenous fluid therapy and analgesia was typically continued postoperatively until resumption of normal demeanor, food intake, and defecation or until normalization of clinicopathologic parameters.

Intestinal promotility agents such as cisapride, 0.5 mg/kg every 8 hours, PO, or ranitidine 2 to 5 mg/kg, every 12 hours, IV or PO, were administered in most presentations during the postoperative period. Additionally, postoperative antibacterial agents were administered in presentations considered at risk of peritonitis, particularly those in which gastrointestinal wall injury was identified. Antibacterial choice was based on knowledge regarding typical rabbit intestinal microbiota and commonly consisted of procaine penicillin 30 mg/kg every 24 hours, SC, with or without metronidazole 20 mg/kg every 12 hours, IV or PO.

Rabbits were monitored regularly for normalization of demeanor, vital signs, and food intake and defecation. Discharge from hospital occurred once these criteria were met.

Outcome

Survival was considered as being successfully discharged from hospital.

Statistical analysis

Variables assessed included age, rectal temperature, and clinicopathologic findings on presentation, specifically BUN, plasma glucose, sodium, potassium, and calculated plasma osmolarity and tonicity. Intra- and postoperative information was similarly summarized and included cause and site of obstruction, presence of full-thickness gastrointestinal wall perforation, surgical technique(s) used, and total number of intestinal obstruction surgeries to date.

As age in most pet rabbits was often approximated, this was categorized as follows: < 25 months, 25 to 72 months, and > 72 months, where > 72 months was considered geriatric.[26]

To minimize any overlap between full-thickness gastrointestinal wall perforation, enterotomy, and enterectomy, all presentations positive for these variables were grouped into 1 new variable, full-thickness gastrointestinal wall injury (FGIWI).

Descriptive statistics were used to report categorical variables by count (percentage) and continuous

variables as mean and SD. These are based on recorded data from each presentation.

Due to the retrospective nature of this study, medical records showed clinician variation in documentation and choice of diagnostic testing. Therefore, there were varying amounts of missing data for different variables. For statistical analysis, inclusion of only the presentations with complete data would result in an unhelpful reduction in sample size. As presentations with incomplete data can contribute to the overall understanding, multiple imputation using chained equations were used to impute missing values, assumed to be missing at random.[27,28] This was implemented using the mice package in R statistical software (version 4.2.3; The R Project for Statistical Computing). Imputation was based on 20 variables, with a maximum of 5 iterations. Twenty imputed datasets were used in subsequent modeling. Results were presented combined according to Rubin's rules.[29] Plasma osmolarity and tonicity were derived variables and calculated as stated previously.

Some rabbits had multiple presentations of small intestinal obstruction over their lifetime, and surgical intervention may have been required more than once. As repeated presentations of a rabbit cannot be strictly considered independent observations, the Akaike information criterion was used to assess the need for inclusion of the random effect of rabbit in modeling. This indicated that there was little random effect of rabbit (χ^2 test comparing Akaike information criterion for a model with and without random effect, $P = .759$); hence, this was excluded from consideration in statistical modeling.

Univariable logistic regression was used to estimate the effect of a single variable on the odds of survival, expressed using an OR. The OR for continuous explanatory variables, such as BUN, indicated the change in the odds of survival with an increase in the value (usually by 1 unit) of the variable. For categorical explanatory variables such as FGIWI, the baseline in the construction of the odds was specified for each analysis and based on clinical relevance. The estimate of the OR was provided with a 95% CI, with P values < .05 considered statistically significant.

Multivariable logistic regression models were subsequently developed to evaluate whether the association between a variable and survival persisted after controlling for potential confounders. Variables in univariable analysis that had relatively precise estimates of the OR and low P values were entered into this final model. All statistics were performed using R statistical software (version 4.2.3; The R Project for Statistical Computing).

Results

There were a total of 141 presentations arising from 114 different rabbits. In 93 (81.6%) presentations, this was the first recorded small intestinal obstruction surgery, and it was the second surgery for 16 (14.0%) presentations, the third for 4 (3.5%) presentations, and the fourth for 1 (0.9%) presentation.

Signalment

Most presentations were neutered males, and most were in the 25- to 72-month age group **(Table 1)**. The youngest documented age was 9 months and the oldest, 144 months.

Table 1—Summary statistics for signalment (weight, age, and sex/neuter status) of 141 presentations of surgically managed small intestinal obstruction in 114 pet rabbits across 2 specialist exotic animal veterinary services in Sydney, Australia, between June 2011 and December 2021.

Variable	No. of presentations	Mean (SD)	Percentage
Weight (kg)	141	2.15 (0.57)	—
Age group			
< 25 mo	23	—	16.3
25–72 mo	81	—	57.5
> 72 mo	37	—	26.2
Sex/neuter status			
Female neutered	47	—	33.3
Female entire	0	—	0.0
Male neutered	85	—	60.3
Male entire	8	—	5.7
Data missing	1	—	0.7

Presenting rectal temperature and clinicopathologic findings

Most presentations were hypothermic (108/133 [81.2%]), were hyperglycemic (112/126 [88.9%]), had elevated BUN (72/100 [72.0%]), and were eunatremic (80/96 [83.3%]) and eukalemic (66/92 [71.7%]). Specifically, 66 of 126 (52.4%) presentations had severe hyperglycemia > 20 mmol/L. Calculated plasma osmolarity was elevated in 58 of 96 (60.4%) presentations. Calculated plasma tonicity was elevated in 44 of 96 (45.8%) and decreased in 3 of 96 (3.1%).

Surgical findings

The cause of small intestinal obstruction in most presentations was consistent with a CHP (130/141 [92.2%]). Less commonly, obstruction occurred from other causes (9/141 [6.4%]), including abdominal adhesions causing entrapment of a loop of intestine and foreign bodies such as fabric and an uncooked legume seed, both identified on enterotomy. In 2 of 141 (1.4%) presentations, a CHP-like body was found in conjunction with other causes, as follows: with intestinal adhesions in one and attached to a seed-like foreign body in another.

The proximal duodenum was the most common site of obstruction (78/141 [55.3%]), followed by other areas of the small intestine excluding the distal ileum (52/141 [36.9%]). The distal ileum was involved in 9 of 141 (6.4%) presentations, of which 2 included another part of the small intestine due to abdominal adhesions. The location was not recorded in 2 of 141 (1.4%).

Extraluminal manipulation of a CHP-like body into the cecum was successful in 124 of 141 (87.9%) presentations. Two (1.4%) presentations required manual disruption of abdominal adhesions. FGIWI was reported in the remaining 15 (10.6%) presentations. Within this category, 5 presentations were

a result of iatrogenic perforation during attempted extraluminal manipulation of a CHP-like body, which was subsequently confirmed to be a CHP on visualization. Enterotomy was performed in another 5 presentations, gastrotomy in 2, and enterectomy in 1. Spontaneous rupture of the gastric wall was noted in one presentation and iatrogenic perforation of the cecal wall during laparotomy in another.

Outcome

Overall, 106 (75.2%) presentations survived and 35 (24.8%) presentations died **(Table 2)**. Presentations involving rabbits < 25 months showed 95.7% survival, while those between 25 and 72 months showed 80.2% survival. Just over half (51.4%) of the presentations > 72 months survived.

Necropsy and histopathological information for presentations that died was not available. Reported findings prior to death (n = 35) included single- or multiorgan failure based on clinicopathologic findings (8), persistent ileus on diagnostic imaging (6), found collapsed in cage between 3 and 12 hours postoperatively (5), found collapsed in cage < 3 hours postoperatively (4), respiratory distress (3), peritonitis on diagnostic imaging (2), previously unidentified cardiomyopathy on diagnostic imaging (2), nosocomial trauma (1), and unspecified (4). Apart from 1 presentation that died intraoperatively, time of death ranged from the immediate postoperative period (< 3 hours) to 14 days postoperatively. Three presentations were euthanized due to poor prognosis.

Table 2—Summary statistics of variables and their association with outcome (survival to hospital discharge) in 141 presentations of surgically managed small intestinal obstruction in 114 pet rabbits across 2 specialist exotic animal veterinary services in Sydney, Australia, between June 2011 and December 2021. These variables included age and rectal temperature on presentation, clinicopathologic findings (BUN, plasma glucose, sodium and potassium, and calculated plasma osmolarity and tonicity), surgical findings (site and cause of the small intestinal obstruction), presence of full-thickness intestinal wall injury (encompassing spontaneous or iatrogenic full-thickness gastrointestinal wall perforation, or where enterotomy or enterectomy was performed), and total number of small intestinal obstruction surgeries.

Variable	Alive	Dead
Rectal temperature (°C)	36.9 (1.2)	36.7 (1.5)
BUN (mmol/L)	16.7 (8.6)	18.3 (8.9)
GLU (mmol/L)	20.1 (9.4)	22.8 (8.6)
Na (mmol/L)	140 (7)	141 (5)
K (mmol/L)	3.9 (0.8)	4.3 (0.8)
Calculated plasma osmolarity (mOsm/L)	316 (15)	323 (14)
Calculated plasma tonicity (mOsm/L)	300 (12)	305 (11)
No. of surgeries	0.2 (0.5)	0.2 (0.5)
Age group		
< 25 mo	22 (95.7)	1 (4.3)
25–72 mo	65 (80.2)	16 (19.8)
> 72 mo	19 (51.4)	18 (48.6)
Site		
Proximal duodenum	59 (75.3)	19 (24.4)
Distal ileum	6 (66.7)	3 (33.3)
Other SI sites	40 (76.9)	12 (23.1)
Cause		
CHP or CHP-like body	96 (73.8)	34 (26.2)
Other	8 (88.9)	1 (11.1)
Both	2 (100.0)	0 (0.0)
FGIWI		
Absent	96 (76.2)	30 (23.8)
Present	10 (66.7)	5 (33.3)
Overall survival	106 (75.2)	35 (24.8)

Continuous data are reported as mean (SD). Categorical data are reported as number of observed events (percentage of total). Plasma osmolarity and tonicity were calculated using the formulas below:

Plasma osmolarity (mOsm/L) = 2 X sodium(mmol/L) + glucose(mmol/L) + BUN(mmol/L)

Plasma tonicity (mOsm/L) = 2 X sodium(mmol/L) + glucose(mmol/L)

CHP = Compressed hair pellet. FGIWI = Full-thickness gastrointestinal wall injury. GLU = Plasma glucose. K = Plasma potassium. Na = Plasma sodium. SI = Small intestine.

Statistical analysis

On univariable modeling, the strongest relationship to survival was identified with age, with the most statistically significant relationship identified between the oldest (> 72 months) and youngest (< 25 months) age categories (OR, 0.05; 95% CI, 0.01 to 0.40; P = .005; **Table 3**). The effect on survival between the 25- to 72-month age group compared with the youngest was not statistically significant (OR, 0.19; 95% CI, 0.02 to 1.50; P = .113).

No statistically significant relationship was established between survival and rectal temperature on presentation or with any clinicopathologic findings (Table 3). Similarly, site and cause of obstruction, presence of FGIWI, and previous small intestinal obstruction surgery all showed no statistically significant relationships to survival.

Based on the criteria described previously, the multivariable logistic regression model included age, plasma potassium, and calculated plasma osmolarity and tonicity (Table 3). After multivariable adjustment, the association with survival between the oldest and youngest age groups persisted, with the odds of survival in presentations of rabbits > 72 months 95% lower than for those < 25 months (OR, 0.05; 95% CI, 0.01 to 0.46; P = .009).

Discussion

To the authors' knowledge, this was the first retrospective observational study evaluating risk factors and outcomes of surgically managed rabbits with small intestinal obstruction since Harcourt-Brown's seminal study in 2007.[1] More recent studies assessing medical management and orogastric decompression in rabbit small intestinal obstruction appeared to show high survival rates,[4,12] but comparison between these studies and surgical intervention can be difficult. In the absence of advanced imaging, such as ultrasonography or CT, a definitive antemortem diagnosis of small intestinal

Table 3—Results of univariable and multivariable logistic regression analyses to identify variables associated with survival in presentations of surgically managed small intestinal obstruction in pet rabbits as described in Table 2. Variables in univariable analyses that had relatively narrow estimates of the OR and low *P* values were entered into the multivariable model, which evaluated the effect of these variables with adjustment for possible confounding factors.

	Univariable models			Multivariable model		
Variable	**OR**	**95% CI**	***P* value**	**OR**	**95% CI**	***P* value**
Rectal temperature (°C)	1.15[a]	0.85–1.58	.366	—	—	—
BUN (mmol/L)	0.81[b]	0.48–1.37	.424	—	—	—
GLU (mmol/L)	0.73[b]	0.47–1.13	.153	—	—	—
Na (mmol/L)	0.71[b]	0.32–1.60	.403	—	—	—
K (mmol/L)	0.62[a]	0.34–1.14	.119	0.64[a]	0.31–1.32	.220
Calculated plasma osmolarity (mOsm/L)	0.73[b]	0.53–1.02	.063	0.69[b]	0.35–1.33	.250
Calculated plasma tonicity (mOsm/L)	0.70[b]	0.47–1.05	.087	1.13[b]	0.52–2.44	.761
No. of surgeries	1.13[a]	0.49–2.59	.777	—	—	—
Age group						
< 25 mo	Baseline	—	—	Baseline	—	—
25–72 mo	0.19	0.02–1.50	.113	0.27	0.03–2.63	.261
> 72 mo	0.05	0.01–0.40	.005	0.05	0.01–0.46	.009
Site						
Proximal duodenum	Baseline	—	—	—	—	—
Distal ileum	0.64	0.15–2.87	.561	—	—	—
Other SI sites	1.07	0.47–2.47	.867	—	—	—
Cause						
CHP or CHP-like body	Baseline	—	—	—	—	—
Other	2.83	0.34–23.95	.336	—	—	—
Both	—	—	.989	—	—	—
FGIWI						
Absent	Baseline	—	—	—	—	—
Present	0.625	0.196–1.99	.424	—	—	—

For univariable analyses, estimates of the ORs for continuous variables were each fitted separately using multiple imputation data. In the multivariable model, estimates of the ORs for continuous variables were fitted into 1 model using multiple imputation data.

[a]The OR reflects the change in the odds of survival with a 1-point increase in the value of the variable. [b]The OR indicates the change in odds of survival for a 10-point increase in the value of the variable.

See Table 2 for remainder of key.

obstruction cannot be warranted. Successful medical management based on clinicopathologic and radiographic findings alone, without a definitive diagnosis, remains presumptive.

In the present study involving 141 presentations of confirmed rabbit small intestinal obstruction managed surgically across 2 specialist exotic animal veterinary services, the overall survival rate was 75.2%. Of note, 95.7% presentations of rabbits < 25 months survived. There was a decline in survival in presentations of advancing age groups; however, on multivariable analysis, a statistically significant association was only found between the youngest and the oldest age groups. Presentations of rabbits > 72 months had a 95% statistically significant lower odds of survival compared to those < 25 months (OR, 0.05; 95% CI, 0.01 to 0.50; *P* = .012).

In human gastrointestinal and abdominal surgery, increased age and presence of comorbidities are considered independent risk factors for nonsurvival.[30–32] While increased prevalence of cardiovascular, renal, musculoskeletal, and neoplastic diseases are well recognized in aging rabbits, protocols for routine health examination and preemptive disease screening and control for this population are currently not well established and remain in their relative infancy.[26,33] As such, in addition to the physiological changes of aging that can increase the impact of disease and surgery, underlying and unrecognized comorbidities may be more common in older rabbits, which can negatively affect survival in this population.

Nonsurvival in this study primarily occurred in the postoperative period, with persistent ileus and single- or multiorgan failure reported to be common antemortem findings. Although necropsy and histopathological results were not available, these findings are recognized as consequences of prolonged anorexia, decompensatory shock, and systemic inflammatory response syndrome in rabbits and may be associated with effects following general anesthesia and surgery.[6,34–36] However, these findings may also reflect end-stage pathophysiologic changes in rabbit small intestinal obstruction. While a comparison between medical and surgical management in rabbit small intestinal obstruction cannot be made on the basis of the current study design, the criteria for surgery in this study included a poor or declining clinical status and lack of positive response to medical interventions. Therefore, the decision for surgery in all presentations regardless of outcome may have at least represented an opportunity for survival.

Hypothermia, severe hyperglycemia (> 20 mmol/L), true hyponatremia, and elevated BUN concentration on presentation have been associated with increased mortality in rabbits.[2,20,24,37] However,

in the present study, rectal temperature and clinicopathologic findings on presentation did not show statistically significant relationships to survival. This unexpected finding may be a reflection of case management strategies employed in this study. In studies that assess the relationship of a single variable on rabbit mortality, multiple underlying etiologies and their management strategies may act as confounding factors.

A recent study[4] assessing orogastric decompression in rabbit intestinal obstruction suggested that increased calculated serum osmolarity was associated with rabbits in a critical condition. Similar to other clinicopathologic findings, this relationship was not observed in the present study and could be associated with differences in the study population and inclusion criteria.

The decision for medical management or surgical intervention in rabbit intestinal obstruction can be complex. Increased anesthetic risks are associated with alterations in cardiovascular, acid-base, and electrolyte parameters, but delaying surgery may risk gastrointestinal wall injuries such as hyperemia, bruising, necrosis, and perforation. In a study[38] on the timing of surgical intervention for gastrointestinal foreign body obstruction in dogs, there was no difference in outcome between dogs that were treated immediately or over 6 hours after presentation. However, a higher prevalence of intestinal necrosis and perforation was reported among the delayed group, requiring more complex surgical procedures and increased surgical time, together with a delayed return to feeding postoperatively.[38]

In the current study, univariable analysis of intraoperative variables, including site and cause of small intestinal obstruction, and presence of FGIWI did not show statistically significant effects on survival. These findings may be due in part to study design. The retrospective nature of the study with clinician variation in documentation precluded sufficiently reliable time measurement between presentation and surgical intervention and intraoperative assessment of gastrointestinal wall health as measured variables. The combined variable, FGIWI, was used to encompass any full-thickness disruption to gastrointestinal wall integrity irrespective of etiology and did not differentiate between immediate and delayed surgical intervention.

The most common cause of rabbit small intestinal obstruction in the present study was most consistent with a CHP. The authors advocate extraluminal digital manipulation of an obstructive small intestinal CHP-like body into the cecum where possible. Although not specific for CHP, 87.9% of surgeries performed did not involve FGIWI and carried a 76.2% survival rate, slightly higher than the overall survival rate. Postoperative complications following gastrointestinal foreign body retrieval via enterotomy or enterectomy in dogs and cats are often associated with enteric dehiscence and subsequent septic peritonitis.[38,39] In comparison, minimal and only relatively minor postoperative complications were noted in the same species using a novel technique of laparotomy-assisted foreign body manipulation and retrieval.[41,42] This procedure did not involve incision into the gastrointestinal tract and was associated with reduced surgical time compared to traditional techniques.[41,42]

Iatrogenic full-thickness intestinal perforation occurred in a very small number of presentations during extraluminal manipulation in the present study and required conversion to enterotomy. Partial-thickness intestinal wall injury may also occur during manipulation,[40] potentially giving rise to postoperative complications such as enteric dehiscence and adhesion formation. However, these risks may be low, as small intestinal serosal injuries in a rabbit model did not result in perforation or leakage at physiological intraluminal pressures.[42] Additionally, abdominal adhesions were not found to be a common etiology of rabbit small intestinal obstruction in the current study despite the relatively high number of rabbits with multiple presentations during their lifetime.

Etiology and previous surgery for small intestinal obstruction in this study did not significantly impact survival. The reasons behind rabbits that presented with small intestinal obstruction on multiple occasions are unclear. Although infrequently observed in this study, formation of abdominal adhesions in rabbits is considered a common complication after abdominal surgery.[19,25] In humans, acute small bowel obstruction is most commonly caused by abdominal adhesions and is positively correlated with a history of emergency laparotomy and multiple laparotomies.[43–45]

Repeated presentations of small intestinal obstruction have also been anecdotally observed by the authors in rabbits that were successfully managed medically. It is possible that rabbits with repeated presentations have underlying intestinal abnormalities. Intestinal luminal stenosis secondary to mucosal injury may occur from pressure during an episode of small intestinal obstruction or from passage of an obstruction through the small intestine either spontaneously or by extraluminal manipulation. Primary intestinal disease has not been reported as a cause of small intestinal obstruction in rabbits, but in cats, obstructive trichobezoars have been associated with inflammatory bowel disease.[46,47] Histopathological examination of the intestinal wall was not possible on the basis of the present study design but could be a feature for future studies.

The main limitation of this current study was its retrospective nature. Client and clinician factors influenced individual case management, and there was variation in medical record documentation. As such, there would be an inherent bias in conclusions drawn from this population. Lack of statistical power due to insufficient sample size in this study could not be fully excluded and could have resulted in failure to identify relationships between measured variables and outcome.

It is important to note that the present study was not a comparison between medical and surgical management in rabbit small intestinal obstruction. Rabbits often respond positively to appropriate medical management, and then surgical intervention

is not indicated. This study only encompassed presentations in which surgical intervention was considered at the time to offer the most optimal outcome. Rabbits < 72 months presented with small intestinal obstruction showed good outcomes with surgical intervention. The most common etiology was consistent with a CHP, and extraluminal digital manipulation into the cecum was an appropriate and successful surgical technique in most presentations.

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Disclosures

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