Complications of Gastrointestinal Surgery in Companion Animals

Gary W. Ellison, DVM, MS

KEYWORDS
- Gastric dilatation
- Volvulus
- Gastropexy
- Laparoscopic gastropexy
- Intestinal anastomosis
- Intestinal dehiscence
- Short bowel syndrome
- Subtotal colectomy

The small animal surgeon routinely creates wounds in the gastrointestinal (GI) tract for biopsy, for foreign body or neoplasm removal for correction of gastric dilatation volvulus, or to relieve intestinal and colonic obstruction. Unlike dehiscence of a skin wound, which is often easily remedied with appropriate local wound treatment, dehiscence of a wound of the GI tract often leads to generalized bacterial peritonitis and potentially death. Consequently, technical failures and factors that negatively affect GI healing are of great clinical significance to the surgeon. Surgery of the GI tract must be considered clean-contaminated at best, and as one progresses aborally down the GI tract, the bacterial population increases. Therefore, intraoperative spillage, wound dehiscence, or perforations that occur in the lower small intestine or colon tend to be associated with a higher mortality rate than those of the stomach or upper small intestine.

WOUND HEALING OF THE GI TRACT

Basic understanding of GI tract healing is essential to the surgeon since it dictates proper clinical approach in those cases in which GI complications develop. Immediately after wounding, platelets aggregate, the coagulation mechanism is activated, and fibrin clots are deposited to control hemorrhage. The fibrin clot offers minimal wound strength on the first postoperative day, but the main wound support during the lag phase of healing comes from the sutures. Fibrin also has adhesive properties and may increase the risk of secondary obstruction since these fibrinous adhesions may ultimately be converted to fibrous adhesions. Enterocyte regeneration begins almost immediately after wounding; however, the epithelium offers little biomechanical

The author has nothing to disclose.
Department of Small Animal Clinical Sciences, College of Veterinary Medicine, PO Box 100126, Health Science Center, University of Florida, Gainesville, FL 32610-0126, USA
E-mail address: ellisong@ufl.edu

doi:10.1016/j.cvsm.2011.05.006 vetsmall.theclinics.com
0195-5616/11/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
support. This lag or inflammatory phase is the most critical period during GI wound healing, and most dehiscences take place within 72 to 96 hours.

The proliferative or logarithmic phase of GI wound healing lasts from days 3 through 14. Fibroplasia occurs logarithmically during this period. The fibroblasts produce large amounts of immature collagen, resulting in rapid gains in wound strength, but this is a dynamic process in which collagen synthesis takes place in the presence of collagenolysis. In the stomach and small intestine, collagenase activity at the wound edge is minimal and rapid gains in tensile and bursting strength occur. At the end of 14 days, gastric and small intestinal wound bursting strength is approximately 75% that of normal tissue. Conversely, the colon heals much more slowly due to marked collagenase activity at the wound edge and regains only about 50% of its normal tensile strength 14 days post wounding. Factors such as traumatic suturing, fecal contamination, and infection all increase the amount of local collagenase produced at the wound and hence can increase the risk of infection.

The maturation phase of wound healing is characterized by reorganization and cross-linking of collagen fibers. This phase extends from day 14 through day 180 in the gastrointestinal tract of the dog. Similar to skin wounds, the size and thickness of the scar decrease during this time without weakening the wound. The maturation phase is relatively unimportant clinically in GI wound healing, except in those cases where significant adhesions are present or in cases of sclerosing encapsulating or fibrosing peritonitis.

COMPLICATIONS ASSOCIATED WITH GASTRIC DILATATION VOLVULUS
Predictors of Mortality and Gastric Necrosis

Mortality continues to occur in all published reports of gastric dilatation volvulus (GDV). However, over the past four decades, survival rates have improved due to early recognition, rapid gastric decompression, earlier cardiovascular resuscitation, and availability of better medical and surgical care. In older studies from the 1970s and early 1980s, GDV-related mortality rates ranged from 43% to 60%. However, in a large epidemiologic study of over 1900 dogs with GDV, the mortality rate had reduced to 33% in cases evaluated during the late 1980s and early 1990s and was even reported to be as low as 15% in the mid 1990s. In a recent study the postoperative mortality rate of 306 dogs with GDV was 10%. Those dogs receiving gastropexy alone had mortality of only 3%, while dogs receiving partial gastrectomy with gastropexy had a rate of 9% and those receiving partial gastrectomy, splenectomy, and gastropexy had a rate of 20%. That study also showed a reduction of mortality in dogs if the clinical signs occurred less than 6 hours prior to presentation. While one study suggested that reduced duration of clinical signs and shorter time from presentation to the surgery table also decreased mortality rate in 166 dogs with GDV, a second study contradicted these findings. Severity of clinical presentation has also been related to outcome, with recumbency at presentation increasing risk of death by 4.4 times and dogs with varying degrees of obtundation having mortality that ranged between 3% and 36%.

The presence of preoperative cardiac ventricular dysrhythmias has been evaluated as a predictive indicator for survival in dogs with GDV since they may act as a sentinel for gastric or splenic ischemia. In one study, dogs having intermittent ventricular arrhythmia on admission had a significantly higher mortality rate than did dogs with ventricular tachycardia. Additionally, 48% of those dogs presenting with preoperative cardiac arrhythmias underwent splenectomy or partial gastrectomy, whereas just 27% of the dogs without arrhythmias required those procedures. However, in
another study of 295 dogs with GDV, 40% of the animals developed arrhythmias perioperatively and survival rate was unaffected by their presence.8

Approximately 40% of dogs with GDV also develop concurrent disseminated intravascular coagulopathy (DIC). Reported abnormal hemostatic profiles with GDV include prolonged prothrombin time (PT), prolonged activated partial thromboplastin time (aPTT), reduced fibrinogen concentration, increased fibrin degradation product (FDP) concentration, reduced platelet counts, and reduced antithrombin III (ATIII) activity, and these may be useful in estimating gastric ischemia/necrosis and DIC. In a study of 20 dogs with GDV, thrombocytopenia occurred in 9 of 20 dogs, followed by decreased ATIII (8 of 20), elevated FDP (6 of 20), prolonged PT (6 of 20), hypofibrinogenemia (6 of 20), hyperfibrinogenemia (5 of 20), prolonged aPTT (5 of 20), and shortened aPTT (4 of 20). Approximately 70% of dogs with more than one abnormal hemostatic test result had gastric necrosis, whereas dogs with one or no abnormality rarely had gastric necrosis.13

Considerable attention has turned to serum lactate as predictor of gastric necrosis and increased mortality. In an original retrospective study of 102 dogs with GDV, dogs with serum lactate values less than 6 mM had a survival rate of 99%, whereas dogs with initial lactate concentrations of greater than 6 mM were associated with only a 58% survival rate.13 A more recent study showed a positive predictive correlation between lactate values before and after intravenous fluid resuscitation. In that study, even animals with an elevated initial serum lactate less than 9 mM were likely to survive, as long as the post resuscitation value dropped to 5.6 mM or less.14 Other factors reported to increase postoperative mortality include hypotension, concurrent peritonitis, DIC, and blood plasma transfusions.10

Although the timing of surgery varies between studies, what is clear is that shock therapy and gastric decompression need to be followed by definitive surgical management of GDV. Definitive management of GDV involves (1) repositioning of the stomach with resection or involution of any devitalized gastric wall and (2) a prophylactic gastropexy technique to prevent recurrence. In studies using shock therapy and gastric decompression without gastropexy, the recurrence rate of GDV was 56% to 76%, with many recurrences within 3 months after initial presentation.15,16 Because of this we now advocate laparotomy as soon as the patient is a reasonable anesthetic risk. This allows for early assessment of gastric wall viability and gastric derotation, which increases gastric circulation and helps with cardiovascular resuscitation.

DIAGNOSIS AND MANAGEMENT OF GASTRIC NECROSIS

Intraoperative clinical criteria for determining gastric wall viability include assessment of color, peristalsis, and tissue thickness. Viable gastric wall may bered and blue or dark red in appearance but is normal thickness upon palpation and will often contract when pinched. Ischemic or necrotic gastric wall, on the other hand, is black, gray, or green and is thin on palpation and lacks peristalsis.17 Fluorescein dye is not an accurate indicator of ischemia since the gastric wall is too thick to be affected by vital dyes. However, surface laser Doppler flowmetry of the gastric serosal surface has been shown to be a relatively good predictor of viability.18

Standard methods for gastrectomy involve ligation of branches of the left gastroepiploic arteries and veins, allowing areas along the greater curvature of the stomach to be resected. The stomach is resected back to areas of healthy bleeding. Spillage is prevented through the use of Babcock forceps or stay sutures. The mucosa and submucosa are closed with a continuous inverted Cushing pattern. The serosa and muscularis are then closed with a similar pattern. We have also used utostapling
equipment for rapid gastrectomy procedures with minimum risk of spillage. The TA 90 autostapler is used with the green (4.8 mm) or blue (3.5 mm) cartridge. Often the surgeon needs to overlap the staple lines by a few mm to prevent leakage between the staples. The author has seen one clinical case in which perforation and leakage occurred between the overlapping staple lines several months after the original resection. Partial invagination of the stomach has been a useful technique for those animals with small areas of gastric necrosis (Fig. 1A). With this technique, ligation of some of the short gastric vessels may be necessary to allow transection of the gastrosplenic ligament. The area of gastric necrosis is then invaginated using a continuous Lembert suture pattern (see Fig. 1B). Since the invaginated tissue will ultimately slough, an H2 antagonist such as cimetidine or mucosal protectant such as sucralfate should be given for 5 to 7 days postoperatively. While the development of a bleeding ulcer in a single dog 21 days after gastric resection prompted a recommendation for prolonged administration of gastric protectants after this procedure, the author has used the invagination technique successfully on many dogs that failed to develop overt signs of gastric ulceration after surgery.

RATIONAL FOR PROPHYLACTIC GASTROPEXY

There are reports documenting the occurrence of GDV following splenectomy for large splenic tumors or splenic torsion in dogs. Because of this, many veterinary
surgeons in North America advocate the practice of performing a prophylactic gastropexy after a splenic mass is removed in large or giant breeds of dogs. A recent report from the United Kingdom controverts these earlier studies, suggesting that there was no increased risk of dogs with splenectomy developing GDV compared to the risk incidence for the general population of dogs. The contradictory conclusions of these studies may be related to differences in breed distribution, leaving the issue of prophylactic gastropexy after splenectomy somewhat controversial.

While gastropexy is clearly indicated as a therapeutic procedure in cases of naturally occurring GDV, there is now growing evidence that it may be indicated as a prophylactic procedure in dogs at risk for developing the syndrome. In 136 dogs with GDV, there was only a 4.3% recurrence rate in dogs and a 547-day median survival time in dogs receiving a gastropexy procedure. Conversely, there was a recurrence rate of 54.5% with a median survival time of 188 days in those dogs not receiving a GDV. The mortality associated with GDV recurrence was reported to be 83% in those dogs not receiving gastropexy.

Breed incidence of GDV has been closely evaluated, with giant and large breeds having a lifetime probability of 22% to 24% in 1914 dogs as determined by studies using the Veterinary Medical Data Base. Also, great Danes with moderate and high abdominal height-to-width ratios were approximately 5½ to 8 times as likely to develop GDV as were those with low abdominal height-to-width ratios. Breeds such as the great Dane and bloodhound had reported lifetime incidences of 53% and 39%, respectively. A decision-tree analysis for prophylactic gastropexy using lifetime probability of death from GDV and expected cost savings for veterinary services as outcome measures was undertaken to determine the preferred course of action in several dog breeds. Prophylactic gastropexy was the preferred choice of action for all breeds examined, with the reduction in mortality (vs no gastropexy) ranging from 2.2-fold (Rottweiler) to 29.6-fold (great Dane). Assuming a prophylactic gastropexy costs US$400, the procedure was cost effective when the lifetime risk of GDV was 34% or greater.

Complications associated with gastropexy
Most North American surgeons use an antral gastropexy procedure to affix the stomach to the right abdominal wall and prevent GDV. Common antral gastropexy techniques used in North America include the tube gastrostomy, the incisional gastropexy, the circumcostal gastropexy, the belt-loop gastropexy, and the ventral midline gastropexy. Recurrence rates are typically reported 5% to 29% for the tube gastrostomy and between 3% and 8% with the other techniques. In most reports, recurrence is typically defined to include the occurrence of gastric dilatation without volvulus and does not necessarily indicate failure of the gastropexy site. Prophylactic gastropexy techniques may also be performed using minimally invasive techniques such as laparoscopy or endoscopy.

Potential advantages of the tube gastrostomy are that the tube not only creates a permanent adhesion of the gastric antrum to the abdominal wall but also allows for continued gastric decompression in the early postoperative period. In addition, slurried food or medications can be offered through the tube. The main disadvantages of the technique are the nursing care and long hospital period required for tube management and the potential for fatal peritonitis secondary to leakage around the tube or early removal by the dog (Fig. 2). In a study by Fox and others, complication rate of tube gastrostomy was approximately 18%, with local cellulitis around the tube site being the most common complication and 2 of 24 dogs developing fatal peritonitis.

Incisional gastropexy is performed by making a 3- to 4-cm longitudinal incision in the seromuscular layer of the antrum, suturing this to a similar length incision in the
transversus muscle and peritoneum of the right ventral abdominal wall. Advantages of the incisional gastropexy are that the procedure is rapidly performed, the stomach lumen is not entered, and fibrous connective tissue enters the abdominal rectus muscle and stomach wall to form a strong mature adhesion. Pneumothorax is a potential complication if the incision in the peritoneum is made too far cranially, so the surgeon must take care to identify the caudal extent of the diaphragm before selecting the site of gastropexy. Incisional gastropexy is popular among many North American surgeons, but unfortunately few retrospective studies are available to determine the rate of failure or recurrence rate with this technique.

The circumcostal gastropexy technique uses a viable muscle flap to create a mechanically strong adhesion by wrapping the flap around one of the caudal ribs. In a clinical study by Lieb and others, circumcostal gastropexies were associated with a lower recurrent rate (2.6% at 13.7 months) than tube gastrostomy. Use of this technique allows the surgeon to achieve proper anatomic placement of the stomach, although the complicated nature of the technique prolongs surgical time compared to other methods of gastropexy. Complications of circumcostal gastropexy include rib fracture during dissection for passage of the flap and pneumothorax because of the close proximity to the diaphragm.

The belt-loop gastropexy offers similar advantages to the circumcostal and incisional gastropexies in that the gastric lumen is not entered and the risk of peritonitis if properly performed is minimal. A seromuscular flap is threaded through a tunnel in the transversus and peritoneum of the right ventral abdominal wall, before being sutured back down to the donor bed. In a series of 20 dogs receiving this technique there were no reported recurrences of GDV within 3 to 13 months after the procedure was performed. The technique can be performed by an unassisted surgeon but is technically more difficult than the incisional gastropexy and, as a result, is not as popular in the United States. Although the gastric flap has the potential to undergo necrosis if a narrow flap is created, this complication has not been recognized in clinical studies of the technique. The ventral midline gastropexy is possibly the easiest gastropexy to perform. The gastric antrum is incorporated into the celiotomy closure with this technique. After the serosa is abraded with a dry surgical sponge, the seromuscular layer of the stomach is incorporated in the linea alba closure using 0 polypropylene sutures. The main disadvantage of this technique...
is that if a future laparotomy is performed, there is risk that an inadvertent gastrotomy might occur with secondary gastric spillage.16

Laparoscopy-assisted or extracorporeal gastropexy procedures have been used as elective procedures in breeds at risk for developing GDV. These elective procedures are commonly done on an outpatient basis and consistently are reported as creating less pain for the patient and good efficacy for creation of a permanent adhesion. Potential complications include perforation of the gastric lumen or any laparoscopy-related complication such as splenic laceration during insufflation. In a series of 25 client-owned dogs, 23 received laparoscopy-assisted gastropexy as an elective procedure and 2 as a treatment for GDV. None of the dogs developed GDV the year after surgery and 20 evaluated with ultrasonography were found to have intact gastropexy attachments.31

In summary, with the exception of the tube gastrostomy a variety of open and minimally invasive gastropexy techniques are associated with a low failure rate and minimal complications if properly performed. There are inherent advantages and disadvantages with each technique, making the choice of the procedure a matter of surgeon’s preference.

COMPLICATIONS FOLLOWING PARTIAL GASTRECTOMY

Gastric resection for GDV related necrosis usually has few long-term side effects since the gastrectomy site is typically fundic in origin. Unfortunately, since most malignant neoplasms involve the pyloric antral area, resection of the pylorus is required. Pyloric resection may necessitate an end-to-side anastomosis of the duodenum to the stomach also known as a Billroth I gastroduodenostomy procedure. Alternatively, creation of a blind duodenal loop with end-to-side-to-side anastomosis of the stomach to the jejunum is known as a Billroth II gastrojejunostomy. Of these 2 procedures, there is less postoperative vomiting and morbidity associated with the gastoduodenostomy procedure.34 The tumor mass may also invade the proximal duodenum and common bile duct, forcing the surgeon to anastomose the gallbladder to the duodenum (cholecystoduodenostomy) to reestablish bile flow back into the intestine. Ascending cholecystitis has been reported as a common sequelae to a cholecystoenterostomy. The pathogenesis is thought to be due to a reflux of duodenal contents into the gallbladder. Clinical signs include fever, abdominal pain, vomiting, neutrophilia, and elevation of liver enzymes. Patients usually respond to oral antibiotic therapy, but recurrent episodes are common. Creation of a stoma at least 2.5 cm in length may decrease gallbladder retention of ingesta and minimize the occurrence of postoperative cholecystitis (see Complications of Biliary Surgery). Other reported complications of cholecystoenterostomy in dogs include hepatic abscess, acquired portosystemic shunts, pancreatitis, and vomiting.35

Gastric bypass procedures are technically difficult to perform and have numerous complications associated with them, such as the dumping syndrome, marginal ulcers at the anastomosis site, and cholecystitis.34 After gastric resection and especially gastrojejunostomy procedures, rapid gastric emptying (dumping) occurs, which may lead to abdominal bloating, pain, vomiting, and diarrhea as well as vasomotor symptoms, which also cause tachycardia.36 Since the pyloric antrum contains the mucus-secreting cells of the stomach and is often removed during the resection, marginal ulceration of the anastomosis site may also occur.34 Damage to the pancreatic duct may cause resultant pancreatitis after any of the aforementioned gastrectomy techniques.35 Sporadic vomiting is usually seen during the first 24 to 72 hours after pyloric surgery and is possibly due to bilious duodenal reflux into the causing secondary gastritis. We therefore recommend treating the animal with gastric
protectants such as sucralfate or using H2 blockers such as ranitidine or famotidine for 5 to 7 days postoperatively.

**COMPLICATIONS ASSOCIATED WITH INTESTINAL SURGERY**

**Intestinal Wound Dehiscence**

*Wound dehiscence* of intestinal biopsy, enterotomy, or intestinal resection and anastomosis sites often leads to generalized bacterial peritonitis and subsequent death. Risk of intestinal anastomotic leakage can be affected by the cause of the obstruction, failure to adequately identify ischemic tissue, improper suturing or stapling technique, and a variety of factors that negatively affect wound healing such as sepsis, malnutrition, and antineoplastic therapy. In a retrospective study of 115 cases of intestinal anastomosis in dogs and cats, leakage occurred in 13 of 90 dogs but in none of 25 cats. The incidence of leakage and postoperative complications was directly related to the cause of the problem, and mortality was higher in dogs that needed intestinal surgery because of foreign body obstruction compared to those with intestinal neoplasia. In this study, discriminate analysis indicated that dogs with preoperative peritonitis, intestinal foreign body, and serum albumin concentration of 2.5 g/dL or less were also most likely to have leakage from the intestinal wound. A simple method of checking the anastomotic wound site for leakage is to inject the sutures site with saline to check for an adequate seal. In a recent study, jejunal biopsies in dogs were performed and closed using 3 or 4 full-thickness simple interrupted sutures. Saline volumes needed to achieve intraluminal pressures of 20 and 34 cm H2O in a 10-cm canine jejunal segment containing a closed biopsy site using 2 methods of luminal occlusion were recorded. The 95% confidence intervals for the volume of saline needed to achieve 20 and 34 cm H2O intraluminal pressure with digital occlusion were 10.9 to 13.6 mL and 16.3 to 19.0 mL, respectively, and with Doyen occlusion, 8.5 to 11.1 mL and 12.1 to 14.8 mL, respectively. Therefore, intestinal surgical sites can be checked intraoperatively for leakage by intraluminal injection of 10 to 12 mL of saline if the loop of intestine is sealed with Doyen forceps placed 10 cm apart.

**FACTORS INCREASING THE RISK OF INTESTINAL LEAKAGE**

**Inadequate removal of ischemic tissue**

Ischemic intestine is often black or gray and easily discernible from normal bowel. Determining viability in cyanotic appearing bowel is sometimes difficult. The intestine first should be decompressed with a needle and suction apparatus to relieve venous congestion. Intraoperative criteria for establishing intestinal viability are color, arterial pulsations, and the presence of peristalsis. Questionable areas of bowel should be pinched to determine whether smooth muscle contraction and peristalsis are present. If clinical criteria are inadequate to determine viability, intravenous fluorescein dye or surface oximetry can be used. A 10% fluorescein solution is given at a dosage of 1 mL/5 kg intravenously through any peripheral vein. After 2 minutes, the tissues are subjected to long-wave ultraviolet light (Wood’s lamp). Areas of bowel are considered viable if they have a bright green glow. Areas of bowel are not viable if they have a patchy density with areas of nonfluorescence exceeding 3 mm, have only perivascular fluorescence, or are completely nonfluorescent. Oxygen saturation may also be a reliable method of determining intestinal wall viability. A sterile probe is placed on the surface of the bowel and an oxygen saturation level reading will occur. According to published reports in rabbits, saturation levels above 81% typically indicate that the bowel is viable, whereas values below 76% were consistent with mucosal necrosis and those below 64% indicated transmural intestinal necrosis.
Poor wound apposition

Direct approximation of the wound edge allows for optimum rapid healing characterized by primary intestinal wound healing. Accurate apposition allows for rapid mucosal reepithelialization, and early formation occurs of young well-vascularized collagen between the submucosa, muscularis, and serosa. Other advantages of approximating patterns for intestinal anastomosis are that (1) the lumen diameter is not compromised, (2) the wound strength meets or exceeds everting or inverting wound strengths after 24 hours, and (3) the adhesions are minimal. Sutures should not be tied too tight since crushing of tissue has been shown to cause more tissue ischemia directly at the suture line and is discouraged. Mucosal eversion or tissue overlap retards healing and should be avoided. Mucosal eversion results in delayed fibrin seal formation, delayed mucosal reepithelialization, increased mucocele formation, prolonged inflammatory response, and marked adhesion formation. Eversion may initially widen the intestinal lumen diameter, but the prolonged inflammatory response eventually narrows the lumen, contributing to the risk of stenosis. Everting anastomoses also have an increased tendency for leakage, especially in the face of septic peritonitis, and should never be used in the colon. Inversion of the wound edge creates an internal cuff of tissue that reduces lumen diameter. Hemodynamic compromise of the inverted submucosa occurs, resulting in mucosal edema and necrosis. After 5 days the internal cuff usually sloughs. Inverting anastomoses are characterized by a rapid serosa-to-serosa seal and minimal adhesion formation. Yet because of their safety against leakage, inverting patterns may be the preferred technique for the colon.

As an alternative to hand suturing, autostapling may be used for intestinal anastomosis. The GIA and TA auto staplers lay an overlapping double row of staples for security and, when used in combination, create a functional “end-to-end anastomosis.” The GIA portion of the anastomosis is inverted, whereas the TA portion of the anastomosis is everted. Recent studies in human have shown that leakage rates are similar to hand-sewn techniques but autostapler use significantly reduces surgical time. In veterinary surgery, direct comparisons between hand-sewn and stapled anastomosis are poorly documented, but in a recent study, nonspecialists were able to achieve very good results with stapling devices in 25 of 30 dogs, with anastomotic problems occurring in only 2 dogs. An alternative to sutured anastomosis is the use of an AutoSuture Premium 35 skin stapler with stainless skin staples (Covidien, Norwalk, CT, USA). After triangulating the intestine with 3 stay sutures, the skin stapler is used to place staples every 2 to 3 mm around the perimeter of the wound. These closures are more rapidly done than hand-sewn anastomosis and have similar bursting strengths. However, mucosal eversion may occur between staples.

Improper selection of suture material

For hand-sewn anastomoses, either continuous or interrupted patterns can be used with equal efficacy. Although both absorbable and nonabsorbable suture materials have been used successfully for anastomosis, the braided nonabsorbable suture materials such as silk may harbor bacteria and create granulomatous inflammatory reaction or draining suture sinus. Monofilament nonabsorbable sutures such as Nylon and polypropylene are safe in contaminated environments. However, polypropylene has been associated with foreign body adherence in one case series. Absorbable suture materials reported in the veterinary literature for intestinal suturing include chromic gut, polyglycolic acid (Dexon), polygalactin 910 (Vicryl), polydioxanone (PDS), polyglyconate (Maxon), and poliglecaprone (Monocryl). Of these, surgical gut is not recommended for anastomosis because it is rapidly broken down by collagenase.
Polygalactin 910 and polyglycolic acid are braided and retain good tensile strength for up to 28 days. Vicryl is commonly used for intestinal anastomosis in humans with good published success and is popular in Europe for veterinary use. In North America, monofilament sutures such as polydioxanone (PDS) and polyglyconate (Maxon) are more commonly used. These polyester monofilament suture materials are absorbed by hydrolysis and therefore are unaffected by contaminated environment. They maintain up to 40% of their original tensile strength after 3 weeks. Many surgeons are also starting to use shorter acting monofilament suture such as Monocryl or Biosyn for intestinal anastomosis. They have similar handling properties to PDS but are degraded more quickly. The newer “Plus” sutures are impregnated with the antibacterial agent Triclosan. Their efficacy in reducing infection in contaminated dermal wounds may foster an increased use in intestinal anastomosis.

**Omentalization**

All anastomoses should be covered with a vascularized omental flap that is tacked in place. Omentum is useful in (1) restoring blood supply to a devascularized area, (2) facilitating lymphatic drainage, and (3) minimizing mucosal leakage and secondary peritonitis. The role of omentum is significant when one considers that in one study 90% mortality rates were seen with intestinal anastomoses after omental resection was performed in dogs. Free omental flaps are not as effective as pedicle omental flaps and may in fact lead to anastomosis failure.

**OTHER FACTORS AFFECTING DEHISCENCE**

Healing of visceral wounds is negatively affected by a number of other factors. Chronic weight loss of 15% to 20% due to cancer cachexia or other reasons has a negative effect on visceral wound healing. Correction of cachexia as well as early postoperative enteral feeding appears to increase collagen deposition and bursting wound strength. Glucocorticoids have a negative effect on wound healing when given in large doses prior to the third day after wounding. NSAIDs appear to affect the early inflammatory phase of wound healing but do not appear to interfere with the proliferative phase of wound healing or have a significant negative effect on visceral healing strength. Radiation therapies interfere with fibroblast mobilization, replication, and collagen synthesis as well as causing sclerosis of microvasculature, thereby reducing oxygenation at the wound site. Whenever possible, radiation therapy should be initiated after visceral wound healing is complete. The negative effects of cancer on wound healing appear to be secondary to nutritional deficiencies rather than direct tumor impairment on wound healing. Visceral wound healing may actually be mildly augmented, owing to release growth factors by the neoplasm. Effects of chemotherapeutic agents on visceral wound healing are variable. Drugs such as vincristine, vinblastine, and azathioprine seem to be safe when used in therapeutic doses. Drugs such as cyclophosphamide, methotrexate, 5-FU, and doxorubicin have been shown to delay wound healing in both experimental and clinical studies. Cisplatin appears to significantly impair intestinal wound healing in rats and should be used with caution after intestinal surgery.

**EFFECT OF EARLY POSTOPERATIVE ENTERAL FEEDING ON VISCERAL HEALING**

Malnutrition induces intestinal mucosal atrophy, reduced motility, increased incidence of ileus, and the potential for bacterial translocation through the bowel wall, with resultant sepsis. Impaired wound healing due to nutritional causes may be reversed by feeding an enteral or a parenteral diet that supplies energy needs in the
form of fatty acids and sugars and provides essential amino acids. Feedings of high protein meals after injury can optimize conditions for normal visceral wound healing. Amino acids provided through enteral nutrition are utilized for the synthesis of structural proteins such as actin, myosin, collagen, and elastin. Early, if not immediate, postoperative enteral feeding has been shown to have a positive influence on the healing rate of intestinal anastomosis in dogs.51 Bursting pressures and collagen levels of ileal and colorectal anastomosis were compared in beagles fed elemental diets versus those fed only electrolytes and water for 4 days.51 The dogs fed orally had nearly twice the bursting strengths of the control group and nearly double the amount of both immature and mature collagen at the wound site.51 Total parenteral nutrition (TPN) does not appear to ameliorate the mucosal atrophy or increase collagen deposition as did enteral nutrition.50 In human studies, the incidence of septic complications is significantly lower in people fed between 8 and 24 hours after surgery versus those maintained on TPN. Additionally, early-fed patients had a reduced incidence of postoperative ileus and reduced hospital stay.50

**EFFECTS OF MASSIVE SMALL INTESTINAL RESECTION**

The propensity for short-bowel syndrome after massive intestinal resection depends on the amount of tissue excised, the location of the resection, and the time allowed for adaptation. Resection of up to 80% of the small intestine in puppies may allow for normal weight gain, whereas resection of 90% produces morbidity and mortality in dogs.52 After resection of large portions of small intestine, maldigestion, malabsorption, diarrhea induced by fatty acids or bile salts, bacterial overgrowth, and gastric hypersecretion may occur. Location of the resection is important in people. High resection of the duodenum and upper jejunum may decrease pancreatic enzyme secretion because pancreatic-stimulating hormones such as secretin and cholecystokinin are produced in the mucosa of these sections. These reductions in release of pancreatic enzymes contribute to maldigestion. Maldigestion of protein, carbohydrate, and fat leads to catabolism, negative nitrogen balance, and steatorrhea. Unabsorbed sugars also may cause osmotic diarrhea. If the ileocecal valve is resected, bacteria may ascend, overgrow in the small bowel, and contribute to diarrhea. After massive resection, the remaining small intestine adapts by increasing lumen diameter, enlarging microvilli, and increasing mucosal cell number. These compensatory changes may take several weeks; during this period, parenteral fluids, electrolytes, and hyperalimentation may be necessary for the survival of the animal. With proper supportive care, the animal will be able to maintain weight even with diarrhea. Medical treatments for unresponsive diarrhea after massive resection in dogs include frequent small meals, low-fat diets such as intestinal diet (I/D Hills, Topeka, KS), elemental diet supplements, medium-chain triglyceride oils, pancreatic enzyme supplements, B vitamins, kaolin antidiarrheals, and poorly absorbed oral antibiotics such as neomycin.

A recent retrospective study determined outcome in 13 dogs and 7 cats that underwent extensive (ie, >50%) resection of the small intestine.53 In this study, in all 7 cats and 8 of the 13 dogs, extensive intestinal resection was performed because of a foreign body. Mean ± SD estimated percentage of intestine that was removed was 68 ± 14% (range, 50%–90%). Two dogs were euthanized 3 days after surgery because of dehiscence of the surgical site and development of septic peritonitis; 1 dog died of acute respiratory distress syndrome 5 days after surgery. The remaining 10 dogs and 7 cats were discharged from the hospital, and follow-up information was available for 15 of the 17. Median survival time was 828 days, and 12 of the 15 animals for which long-term follow-up information was available had good...
outcomes. However, none of the factors examined, including percentage of intestine resected, were significantly associated with outcome. In summary, most dogs and cats that underwent extensive resection of the small intestine had a good outcome after a variable period of intestinal adaptation. The amount of intestine resected was not always associated with outcome.

SURGICAL MANAGEMENT OF INTESTINAL LEAKAGE

Revision of the primary surgical site, copious abdominal lavage, and broad-spectrum intravenous antibiotic therapy are the mainstays of addressing intestinal anastomotic leakage and are addressed separately in this chapter (Diagnosis and Drainage Options for Septic Abdomen). After revision of the primary anastomotic site, mechanical reinforcement if the anastomosis is typically performed. Use of an omental pedicle graft (described earlier) is sufficient in most animals; however, when the omentum is devitalized or when more substantial mechanical reinforcement is desired, intestinal serosal patching is recommended. The serosal patch technique uses the antimesenteric surface of the small bowel to cover or buttress an adjacent area of questionable tissue viability or an area that cannot be reliably sutured. Jejunum is commonly used because its freely movable mesentery allows it to be mobile. The serosal patch provides mechanical stability and will help to induce and localize a fibrin seal over the questionable area. A section of jejunum free of mesenteric tension is transposed over the perforation or area to be buttressed. It is important not to stretch, kink, or twist its mesenteric root or the vascular supply may be disrupted. The bowel chosen for the patch is then gently looped to prevent luminal bowel obstruction. Multiple perforations sometimes require patching using a back-and-forth looping of the entire segment of bowel. The lateral aspects of the bowel wall or antimesenteric border are used for the patch (Fig. 3A). The patch is not sutured directly to the edges of the defect but rather 3 to 4 mm beyond its margins. Simple interrupted sutures of 4-0 nylon or polypropylene are placed 3 to 4 mm from the wound edges and 3 to 4 mm apart (see Fig. 3B). The sutures grasp the submucosa of the patch and bowel wall but do not penetrate the lumen.

Externalized intestinal anastomosis has been used in humans in the management of leaking colonic anastomosis, and this novel approach was successfully used to manage a leaking ileocolic anastomosis in a dog. A 6-year-old, spayed female Labrador retriever was presented 48 hours after an intestinal resection and anastomosis for management of a small intestinal foreign body. Abdominal ultrasound confirmed the presence of peritoneal effusion. Cytology of fluid collected by abdominocentesis revealed a large number of degenerate neutrophils with intracellular cocci. A diagnosis of septic peritonitis was made, presumably because of dehiscence of the anastomosis. Upon repeat exploratory celiotomy, the intestinal anastomosis was found to be leaking intestinal contents into the abdomen. An end-to-end, ileocolic anastomosis was performed and subsequently exteriorized into the subcutaneous space via a paramedian incision through the abdominal wall. The anastomosis was inspected daily for 4 days before it was returned to the abdomen and the subcutaneous defect was closed. Serial cytology of the peritoneal fluid, which was performed during this 4-day postoperative period, confirmed progressive resolution of the peritonitis and the dog was discharged from the hospital with a successful recovery.

DIAGNOSIS AND DRAINAGE OPTIONS FOR SEPTIC ABDOMEN

With generalized septic peritonitis, massive fluid and protein movement to the peritoneal cavity result in a shift of fluid away from the intravascular space, causing
hemoconcentration and eventual hypovolemic shock. The presence of large numbers of free bacteria or endotoxins causes massive shifts of neutrophils to the abdomen, vasodilation of the visceral vasculature, high hepatic energy demand (hypoglycemia), metabolic acidosis, and often fatal septic shock. Mortality rates with septic peritonitis secondary to leaking intestinal anastomosis may be as high as 70%. In cases where cytologic evaluation of peritoneal fluid is not diagnostic, clinicians are now using comparisons of serum versus intraperitoneal glucose and lactate values as a means of determining the diagnosis of septic peritonitis. In a study evaluating 18 dogs and 12 cats with septic effusion dogs with septic effusion, all animals had peritoneal fluid glucose concentration lower than the blood glucose concentration. A blood-to-fluid glucose (BFG) difference greater than 20 mg/dL was 100% sensitive and 100% specific for the diagnosis of septic peritoneal effusion in dogs. Also, in the 7 dogs in which it was evaluated, a blood-to-fluid lactate (BFL) difference less than −2.0 mM was also 100% sensitive and specific for a diagnosis of septic peritoneal effusion. In cats, the BFG difference was 86% sensitive and 100% specific for a diagnosis of septic peritonitis. In dogs and cats, the BFG difference was more accurate for a diagnosis of septic peritonitis than was peritoneal fluid glucose concentration alone.

Once diagnosed, treatment of septic peritonitis is directed toward the correction of electrolyte and colloid abnormalities, appropriate antimicrobial therapy, and exploratory celiotomy to determine and surgically correct the underlying cause of the peritonitis. After aerobic and anaerobic culture and correction of the offending

Fig. 3. (A) Intraoperative image of a leaking enterotomy that had been closed with chromic gut. (B) A loop of jejunal has been sutured in place over the previous enterotomy site to create a serosal patch.
problem, aggressive peritoneal lavage is performed; either the abdomen is closed primarily or closed peritoneal drainage techniques are used. Thorough peritoneal lavage of the abdominal cavity is performed with body-temperature 0.9% NaCl or lactated Ringer’s solution. Lavaging a cat with 500 to 750 mL and a large dog with 3 to 5 L of fluid will help remove the bacteria and foreign debris, which are the initiators of the peritoneal inflammation. Although lavage of the peritoneum may have the theoretical disadvantage of spreading bacterial contamination, peritoneal lavage is well established as a means of reducing morbidity and mortality due to septic peritonitis. All lavage fluid should be aspirated because when bacteria are suspended in residual lavage fluid, phagocytosis is impaired. Three cycles of lavage and aspiration are recommended.

Peritoneal drains, when used, vary in their effectiveness with single-lumen passive drains such as Penrose tubes, recovering much less fluid than that collected by double-lumen active drains in most studies.56 Gravity drains have several other disadvantages, including early occlusion of the drain by the omentum, fibrin, or exudate and mechanical irritation of the peritoneum. Last, passive drains may facilitate migration of bacteria into the peritoneal cavity. Active suction drains, such as the Jackson-Pratt drain, improve efficacy of fluid removal and maintain a closed system that minimizes bacterial contamination of the peritoneum, making them the clear choice if closed abdominal drainage is elected for following surgery. As an added benefit to the use of closed suction drains, the clinician is able to monitor changes in gross and cytologic features of peritoneal fluid on a daily basis until drain removal is performed. Intra-abdominal drains may also be used to perform a technique called intermittent peritoneal lavage. Isothermic, sterile fluids are administered via a peritoneal catheter or fenestrated tube. The fluids are then removed by gravity flow back through a separate outflow tube. Our clinical impressions are that this technique has been helpful in reducing mortality associated with diffuse peritonitis. However, experimental results suggest that good lavage of the entire abdomen is not provided.57 The development of hypoproteinemia and hypokalemia is common, although these complications are less severe than those noted during open peritoneal drainage.

Open peritoneal drains are a process by which the linea alba and skin are left partially or completely open and covered with sterile dressings, which are changed at frequent intervals. The main advantages of open peritoneal drainage are that it allows unimpeded drainage of fluid and exudate from the peritoneal cavity and at the same time alters the anaerobic environment of the peritoneum. Many surgeons advocate open peritoneal drainage as the optimal treatment for generalized septic peritonitis.58–60 The mortality rate associated with open peritoneal drainage for management of septic peritonitis in dogs and cats ranges between 11% and 48%.56–58 Most studies document that mortality is increased if sepsis is secondary to GI leakage compared to leakage from the reproductive tract.58,59 The author facilitates open peritoneal lavage by placing continuous or interrupted Nylon or polypropylene sutures loosely in the linea alba, allowing it to gap 1 to 2 cm. The skin and subcutaneous tissues are not closed and are covered with antibiotic ointment and nonadherent gauze dressing before applying a large cotton padded bandage (Fig. 4). The animal is continuously observed and the bandage aseptically changed at 12- to 24-hour intervals under general anesthesia and strict aseptic technique. The abdominal wound is closed primarily in 1 to 5 days depending on when the peritoneal inflammation has resolved. Common complications associated with open peritoneal drainage are patient dehydration and hypoproteinemia secondary to massive fluid and protein loss into the bandage.
It is unclear whether open or closed peritoneal drainage is superior in the treatment of septic peritonitis in dogs and cats. Open peritoneal drainage is a more effective technique for achieving peritoneal drainage than is tube drainage and is generally recommended if contamination is diffuse and not readily removed during the initial exploratory celiotomy. With open drainage, large volumes of abdominal fluid and exudate can be removed from the abdomen and the bacterial environment can be favorably altered, therefore decreasing the number of anaerobic microorganisms. In humans it has been reported that open abdominal drainage can improve a patient’s metabolic condition, reduce abdominal adhesion formation, and leave access for repeated exploration and inspection of the abdomen. Yet that same study actually indicated a higher mortality rate associated with patients managed with open peritoneal drainage compared to patients managed with closed abdomens, largely due to the acquisition of nosocomial infections. Other reported complications included massive fluid and protein loss, increased nursing care, increased cost, additional anesthetic, enteric fistula formation, incisional herniation, evisceration, small bowel obstruction secondary to adhesion formation, and nosocomial infection. Information provided by a limited number of retrospective studies in veterinary medicine offer guidelines as to when open peritoneal drainage may be indicated. In general, open peritoneal drainage is considered in cases where the source of contamination cannot be

Fig. 4. (A) Image from a cat with multiple intestinal perforations secondary to an arrow traversing the abdomen. After repair of all intestinal wounds, the abdomen was thoroughly lavaged and open abdominal drainage was performed. The abdominal wall has been partially closed with a loosely placed polypropylene sutures. (B) The abdomen is covered with a sterile dressing that is changed under general anesthesia or deep sedation on a daily basis. The abdominal is typically closed within 1 to 5 days depending on the degree of inflammation.
identified, the contamination is severe or longstanding, or the virulence of organisms is considered high, such as that seen with fecal contamination or anaerobic infections. In these situations, open peritoneal drainage offers the possibility of reexploration and subsequent lavage. On the other hand, if the source of contamination is successfully eliminated and lavaging the abdomen is effective at removing residual debris, the abdomen may be closed with good results in a majority of the cases.\textsuperscript{62}

Vacuum-assisted closure (VAC) (V.A.C., Kinetic Concepts, Inc, San Antonio, TX, USA) is a relatively new concept in veterinary medicine that can be adopted for use in cases of septic peritonitis. Vacuum-assisted therapy consists of placing a dressing sponge made of open-cell polyurethane ether foam over the partially closed abdominal incision. Embedded in this sponge is a noncollapsible, side-ported evacuation tube that is connected to an adjustable pump. The vacuum applied may be used intermittently or continuously. All the cells in the open cell foam communicate so the vacuum is evenly applied to all wound surfaces in contact with the sponge. A plastic adhesive drape (Ioban) is placed around the abdomen to create an air-tight seal. The excellent drainage characteristics provided by vacuum therapy appear to be a therapeutic option for the treatment of septic peritonitis. One human study compared different bandaging techniques for the management of patients with open abdomens and found a 40% reduction in mortality in patients treated with VAC therapy.\textsuperscript{64} There are limited studies in the human literature supporting the use of VAC therapy in patients with septic peritonitis, but the positive results from these studies are encouraging.\textsuperscript{64,65}

**COMPLICATIONS AFTER SUBTOTAL COLECTOMY**

Subtotal colectomy is a salvage technique for treatment of recurrent megacolon. In North America, dogs have traditionally been treated medically because of their propensity for postoperative diarrhea after removal of large segments of the colon. However, in a recent UK study, 8 dogs with acquired megacolon underwent subtotal colectomy with preservation of the ileocolic junction.\textsuperscript{66} The diagnosis was confirmed in all animals by abdominal palpation, plain radiography, and postoperative histopathologic findings. There were no intraoperative complications, although 1 dog died postoperatively as a result of septic peritonitis. Long-term follow-up was obtained by clinical records and telephone interviews with the owners of the 7 surviving dogs. Resolution of obstipation and improved stool consistency of the remaining dogs were improved at discharge and all surviving animals eventually returned to normal defecation in 5 to 10 weeks and were alive 11 to 48 months (mean 40.5 months) after surgery. These results emphasized the long-term effectiveness of subtotal colectomy with preservation of the ileocolic junction in dogs with idiopathic megacolon.

In cats, subtotal colectomy has been a successful salvage procedure for idiopathic megacolon for more than 25 years.\textsuperscript{67–70} Some controversy exists as to whether the cecum should be preserved and a colon-to-colon anastomosis (colocolostomy) done or whether it can be sacrificed and an ileum-to-colon anastomosis (ileocolostomy) performed. Ileocolostomy has the inherent luminal disparity to deal with but ligation of the ileocolic artery and removal of the cecum allow easy transposition of the mobile ileum down to the colonic stump. With colocolostomy, luminal disparity is kept to minimum, but the technique may be technically demanding because the relatively immobile mesocolon places considerable tension on the suture line. Studies indicate that removal of the cecum does not lead to ascending bacterial enteritis, and cats with ileocolostomies do as well clinically as those with the cecum preserved.\textsuperscript{69,70}
Colocolostomy can also be performed using an end-to-end anastomosis autostapler, but it must be done via a typhlotomy incision (EEA; Covidien Inc).

Cats are often somewhat depressed and anorectic for 48 hours following subtotal colectomy. They will sometimes have a moderate fever of $103^\circ$ to $103.5^\circ$F in the absence of leukocytosis. Dark tarry liquid feces are usually noted for about 3 to 4 days. The presence of abdominal tenderness, vomiting, detection of intracellular bacteria on peritoneal fluid cytology, or significant glucose differential between peritoneal fluid and serum warrants early reexploration of the abdomen. Normally, feces remain liquid and poorly formed for 2 to 6 weeks after surgery, at which time they usually become soft and poorly formed for the remainder of the cat's life. Long-term follow-up studies indicate that most cats seem to maintain their normal body weight or even gain weight after the procedure. After surgery, cats generally use the litter box 2 or 3 times a day, but the total amount of water loss in the feces equals that of normal cats. The ileum increases it absorptive capacity by increasing villous height. Bacterial overgrowth, folic acid deficiency, and anemia are not uncommon, despite initial concerns. The major complaint of cat owners is chronic perineal soiling caused by the loose feces. If this becomes a problem, it can often be managed by clipping hair in the perineal area. Occasionally cats become reconstipated and must be treated medically with lactulose and cisapride for a period of time. In recurrent cases, reexploration and removal of additional residual colon are sometimes necessary.

SUMMARY

A large number of naturally occurring disease conditions are treated by GI surgery in small animals. The GI tract is rich in blood supply and has the potential to heal in rapid fashion but GI effluent is contaminated and surgery is fraught with many pitfalls, the most notable of which is leakage of the surgical site due to technical error, patient cachexia, chemotherapy, metabolic disorders, or preexisting septic peritonitis. Once present, septic peritonitis requires reoperation, patching techniques for the leakage sites, aggressive fluid resuscitation, and appropriate antibiotic therapy based on culture and sensitivity. Innovative surgical techniques such as the VAC drainage or extra abdominal anastomosis placement may increase the survival rates in these critical patients but need further investigation.

REFERENCES

5. Muir WW. Gastric dilatation-volvulus in the dog, with emphasis on cardiac arrhythmias. J Am Vet Med Assoc 1982;180:739–42.
32. Fox SM. Gastric dilatation volvulus: results from 31 surgical cases of circumcostal vs tube gastrostomy. Calif Vet 1985;8:8–11.


