Basic Surgical Principles

No matter the surgical procedure performed on the urinary tract, there are certain principles that require adherence. It is important to achieve adequate visualization of the area of interest, while simultaneously preventing contamination of nearby tissues with urine. The approach to the surgery should allow for both correction of the issue at hand, as well as collecting appropriate samples for analysis. Closure of the urinary tract is best performed with fine, monofilament absorbable suture, and urinary diversion can be protective and promote healing.

Cystotomy

Perhaps the most familiar surgical procedure for removal of uroliths, open cystotomy is readily performed via a midline celiotomy. The advantages of surgical cystolith removal are that the results are rapid, a diagnosis of cystolith type is easily obtained, and risk of obstruction is removed. However, cystotomy is an invasive procedure. Therefore, if medical or minimally invasive therapies are an option, they should be considered prior to intervention.

Following a midline approach to the abdomen, the urinary bladder is isolated and surrounded with moist laparotomy sponges to protect the viscera from inadvertent spillage of urine. Cystotomy is classified as a clean-contaminated procedure; therefore prophylactic antibiotics are indicated. Stay sutures are used to harness and manipulate the bladder. The safest and easiest approach into the urinary bladder is on the ventral surface, away from the ureteral openings. A stab incision is made into the lumen, and suction used to remove urine from the bladder. The incision is then lengthened carefully on midline with a blade or scissors. A cystotomy spoon can be used to gently manipulate stones out of the neck of the bladder and proximal urethra. In male dogs, the prepuce is flushed prior to surgery with 0.05% chlorhexidine diacetate. A urinary catheter is passed during the procedure, and flushed multiple times to ensure that there are not stones trapped in the urethra. In female dogs, a large catheter can be placed antegrade to ensure complete urolith removal. Closure is with an inverting pattern or appositional pattern. A single layer of suture is as effective as a double-layer closure. 3-0 to 4-0 is generally sufficient for companion animals, and the smallest gauge required to maintain strength at the incision is desired. If infection is suspected, or if the patient has any disease processes that may delay healing of the urinary bladder, PDS or Maxon may be preferred to Monocryl, as Monocryl degrades quickly in infected urine.

Following cystotomy for urolithiasis, post-operative radiographs are imperative, as up to 20% of companion animals may have residual stones after surgery. Post-operatively, fluid diuresis is important, to prevent obstructive blood clots from forming in the urinary bladder. Urge incontinence, hematuria and pollakiuria will be noted for several days after surgery, and should decrease precipitously with time. Complications include recurrent obstruction (stones, blood clots) and uroabdomen. In a recent study of 144 cases of open cystotomy, the incidence of uroabdomen was 1.4%. Urothelium begins to migrate across incisions in 24 hours, and is complete by 96 hours. 100% of original strength is acquired within 14-21 days.
Cystoscopic-Assisted Cystotomy

Minimally invasive options are becoming increasingly available in the veterinary field. This is perhaps most notable in the area of urinary surgery. Due to the nature of the urinary tract, endoscopic examination is relatively easy. Over the past five years or so, urethroscopy and cystoscopy have transitioned from exclusively diagnostic tools to therapeutic tools with success rates that approach or exceed traditional surgical methods.6

Traditional surgical methods result in incomplete stone removal up to 20% of the time,7 the magnification and complete view afforded by cystoscopy should reduce this percentage, especially in the face of radiolucent stones. Similarly, suture nidus cystoliths represent up to 9.4% and 4% of recurrent cystoliths in dogs and cats respectively.8 The minimal incision will therefore be beneficial to many patients.

Cystoscopic-assisted cystotomy is performed through a 1-2 cm midline incision, made at the level of the apex of the palpable urinary bladder. Rather than use a laparoscope to assist in urinary bladder identification and entry, which requires additional specialized equipment and establishment of pneumoperitoneum, cystoscopic-assisted cystotomy relies on the surgeon to isolate the apex of the urinary bladder and temporarily fasten it to the linea alba, where cystoscopy and stone removal can be performed through a small stab incision.

A recent report of the use of this technique in 27 cases indicated a procedure time of 50-80 minutes. One patient had a residual urolith on radiographs that had to be retrieved with a second procedure. No major short- or long-term complications were reported.9

Urinary Bladder Biopsy:

Biopsy of the urinary bladder is simple to perform, and can be extremely useful not only for histopathologic analysis, but also for bacteriologic culture and sensitivity. Mucosal biopsy has been shown to be positive in dogs with bacterial urinary tract infection and urolithiasis more frequently than cystocentesis (14 of 16 cases versus 12 of 16 cases).10

Cystostomy Tube Placement/Management

Since urine diversion favors wound healing, cystostomy tubes can be used either for pre-operative stabilization, post-operative diversion, or for management of chronic urethral obstructive disease.11-13 When used in a short-term manner, the stoma is left to heal via second intention. Following placement in 10 dogs and one cat, micturition returned to normal after tube removal, with leakage from the stoma for up to four days while granulation occured.12

Common complications of tube cystostomy, especially when used for long-term management of urethral obstruction include urinary tract infection, inadvertent tube removal and stomal infection or inflammation.12,13 Low profile tubes can be substituted for traditional cystostomy tubes to minimize mutilation of the tubes by the patient. However, an e-collar should be used whenever
the patient is unsupervised. Should the patient inadvertently remove the tube, time is of the essence for replacement, since the stoma tends to contract rather quickly.

**Nephrectomy**

Removal of a kidney can be a salvage procedure for nephroureterolithiasis, intractable pyelonephritis, renal hematuria, and renal neoplasia. It is important to discuss potential complications with the owner prior to surgery, including the potential for symptomatic renal failure if the contralateral kidney is diseased. Glomerular filtration rate is an excellent means of determining the safety of nephrectomy. Excretory urography may also be employed, however this test is qualitative not quantitative – it will show whether or not both kidneys are functional, but will not yield percent function.

To obtain adequate visualization of the kidney, pack the abdominal viscera behind the physiologic retractors – the descending duodenum on the right and the mesocolon on the left. It is important to identify both ureters, as they run in close association with each other, to ensure that the contralateral ureter is preserved. The kidney is then released from its peritoneal attachments, and rolled medially to expose the hilus. The renal artery is double ligated, as is the renal vein. In intact animals, the left gonadal vein is a tributary of the renal vein and should be preserved. The ureter is then ligated and transected at its junction with the urinary bladder and the kidney is removed.

**Ureteral Bypass**

This surgically placed device consists of a locking-loop pigtail catheter placed in the renal pelvis and tunneled subcutaneously to a reservoir button secured to the lateral abdominal wall. A second catheter then travels from the reservoir and is passed through the abdominal wall and inserted into the apex of the urinary bladder. Use of this device essentially bypasses the entire ureter. These devices are easy to place, but data regarding their use is lacking in the veterinary literature.

**Primary Urethral Repair**

Anatomically, the proximal urethra is contained within the abdominal cavity, and compromise can lead to uroabdomen. Damage to the intrapelvic and distal urethra can cause urine extravasation under the skin with subsequent slough. This usually presents as bruising, swelling, erythema and pain progressing dependently down the hind limbs.

The urethra has an amazing capacity for healing. Therefore, conservative management of urethral tears is possible. Urethral healing relies on mucosal continuity, and lack of significant urine extravasation. A small, persistent strip of mucosa is all that is necessary to allow urethral healing, generally without stricture formation.

Primary alignment has been described in 10 cats, in which a urinary catheter was used to span the ruptured area for 5-14 days. A 100% success rate for urethral healing was reported, with a single case of urethral stricture. An appropriate-sized catheter should approximate the diameter of the urethra without exerting outward pressure, as this may slow wound healing. If a
retrograde catheter cannot be passed, a laparotomy may be useful to pass a urinary catheter from inside the bladder through the urethra. A second urinary catheter can then be attached to the end of the first and pulled into the bladder.\textsuperscript{18,19}

Should leakage persist following conservative management, or if primary repair is chosen, fine gauge (4-0 or smaller) suture material is used to repair the defect. Pubic osteotomy or ostectomy may be required to access the intrapelvic urethra.\textsuperscript{17,20} Urethral resection and anastomosis is necessary in cases of complete transection of the urethra. Interrupted sutures can be pre-placed, to facilitate inclusion of the mucosa and submucosa. A urethral catheter is left in place for 3-5 days to divert urine away from the operative site. Stricture and dehiscence are the most common complications.

**Prescrotal Urethrotomy**

This technique is used to remove stones at the base of the os penis. As most stones can be hydropulsed into the urinary bladder, this should be attempted first. General anesthesia is necessary for adequate hydropulsion, as it affords maximal urethral relaxation. For stones that cannot be hydropulsed, a small incision is made at the base of the os penis, directly over the stone. The retractor penis muscle is elevated, and the urethra is incised on midline. If the urethra appears to be healthy and minimally traumatized, the incision is closed with 4-0 or smaller interrupted absorbable sutures. If severe trauma to the urethra is present, the incision can be left open to heal by second intention.\textsuperscript{21,22} If the stone cannot be removed, or if stricture occurs, a scrotal urethrostomy will be required.

**Scrotal Urethrostomy**

Urethrostomy is the permanent creation of a new urethral orifice in dogs to bypass stricture formation (usually at the base of the os penis), recurrent obstruction with urethroliths, or in cases of penile trauma. Creation of a new large stoma will hopefully also allow future uroliths to pass. The scrotal location of the urethrostomy is chosen as the urethra is very superficial in this location, with much less cavernous tissue. In addition, this placement allows the stoma to be directed ventrally.\textsuperscript{21,23} Principles of urethrostomy must be adhered to in order to achieve best results. These include:

- Tension-free closure
- Incision of the urethra on midline to ensure appropriate amount of tissue for closure
- Meticulous apposition of urethral mucosa to the skin
- Creation of a large urethrostomy opening to allow diminished size expected after healing
- Prevention of self-trauma

The patient is placed in dorsal recumbency. An elliptical skin incision is made in the scrotal area, using care to ensure that there is sufficient tissue for closure without tension. If necessary, the patient is neutered. Using blunt dissection, the paired retractor penis muscles are localized and lateralized. If possible, a retrograde urethral catheter is placed to facilitate incision of the urethra on midline. A #11 or #15 blade is used to start the incision, which is then extended using iris scissors (or similar). The stoma should be 5-8 times the width of the urethra (usually a total
of 2-4 centimeters). During healing, the stoma is expected to diminish in length by $\frac{1}{3}$ to $\frac{1}{2}$. The urethral mucosa is then sutured to the skin.$^{21,23}$

Simple continuous suture patterns have been recommended, both to decrease incisional bleeding as well as subcutaneous bruising.$^{24}$ A bite of the fibrous tunica albuginea can also limit hemorrhage and provide strength to the closure. Continuous closure has been shown to decrease active bleeding from 4.2 to 0.2 days.$^{24}$ Bleeding during urination is still expected for several days after the procedure. Appropriate sized monofilament suture (4-0 or smaller) is used for closure; both absorbable and non-absorbable have been described.

It is important to outfit the animal with an Elizabethan collar prior to complete anesthetic recovery. Self-mutilation is extremely common, and is catastrophic in these cases with respect to continued bleeding as well as scarring and stricture of the orifice. Similarly, staff that will be working with the animal should be advised that the clot at the surgical site not be disturbed. Other complications include an increased incidence of urinary tract infection, likely from the reduced length of the urethra, and re-obstruction with calculi. A study evaluating long term outcome of scrotal urethrostomies in dogs found a 15% infection rate.$^{25}$ Treatment should be directed via culture and sensitivity results.

**Perineal Urethrostomy**

This is the procedure of choice to treat recurrent urethral obstruction in male cats, obstruction that cannot be relieved with catheterization, and distal urethral tears created iatrogenically during attempts to unblock cats.

An elliptical incision is made around the scrotum and penile body. The penis is bluntly dissected to the level of the bulbourethral glands. It is essential that the ischiocavernosus muscles and ventral penile ligament are completely transected to free the penile body from the pelvis. A gloved finger should easily pass from the 3:00 position ventrally and across to the 9:00 position without encountering any resistance. Minimal dissection is carried out dorsally, to prevent damage to the nervous structures which could lead to potential incontinence. The urethra is incised on midline with sharp iris scissors to the level of the bulbourethral glands, and far enough forward that a pair of curved hemostats could be passed into the urethra to the level of the box locks. The mucosa is again sutured to the skin with fine monofilament suture (5-0 to 7-0) in a continuous pattern. The dorsal sutures are the most difficult to place, and are often pre-placed in an interrupted fashion, followed by continuous closure of the rest. The distal penis is amputated, and the sutures are allowed to dissolve over time. Therefore, a rapidly dissolving suture material is preferred. If there is any concern about tension on the operative site, especially in an obese cat, a urethral catheter can be placed to avoid subcutaneous urine leakage. A large clot will appear over the incision which should not be disturbed, and the cat should wear an e-collar at all times for 2-3 weeks.

Infection rates following permanent urethrostomy can approach 53%.$^{26}$ In a study of 59 cats that had undergone perineal urethrostomy, there was a 25% complication rate within the first month of surgery, including stricture formation, urinary tract infection and perineal urine leakage.$^{27}$ In general, complications from urethrostomy include stricture formation, urine leakage into the
subcutaneous space, chronic urinary tract infection, perineal hernia and possible incontinence. In cats with perineal urethrostomy, complete dissection to the level of the bulbourethral glands will prevent stricture formation. In a study of failed urethrostomies, 8/11 cats with stricture formation had evidence of incomplete dissection and improper surgical technique. Other causes of stricture formation are inappropriate apposition of the mucosa to the skin resulting in scarring, and self-mutilation by the patient.

**Urethral Prolapse Repair**

Urethral prolapse is an uncommon condition in intact male bulldogs and other brachycephalics. While the exact cause is unknown, proposed etiologies include urethritis, cystitis, other inflammation or excess sexual activity. The prolapse is seen at the tip of the penis, and is essentially the mucosa turned inside-out. It appears as a reddish to purple, cauliflower like lesion. Hemorrhage from these prolapsed areas is common.

Treatment of this condition is surgical, and includes neutering to decrease sexual drive, as well as either prolapse resection and anastomosis, urethropexy, or penile amputation and scrotal urethrostomy. A urine culture should be submitted, as infection can exacerbate this condition. Recurrence is problematic, especially if the animal is not castrated at the time of surgery, or if the dog was not appropriately managed after surgery. As with all urethral surgery, hemorrhage is common and stricture can be seen. Management is similar to dogs with scrotal urethrostomies (see above).

To resect the prolapse, the prepuce should be retracted to expose the penis. The dog is catheterized with a red rubber catheter to facilitate resection. Fine scissors are used to remove the prolapse. A cut– and –sew technique is used to appose the mucosa to the skin in 1/3 circumference intervals. A simple continuous pattern of fine absorbable suture is used.

Urethropexy has also been described, where the prolapse is reduced, and a suture is passed through the penile body and urethra to maintain reduction. Post-operative care is similar to that of other urethral surgeries. If an underlying cause of the prolapse is determined, appropriate therapy is necessary to prevent recurrence.

**Urethral Occluders**

Silicone implants are available that consist of an inflatable cuff that can be placed around the pelvic urethra and attached to a reservoir that is tacked to the lateral abdominal wall. Suitable for urethral sphincter mechanism incontinence (spay incontinence, residual incontinence after ectopic ureter repair, etc…), these devices are placed via a midline abdominal approach. The urethra is measured, and an appropriate device placed once the urethra is bluntly dissected from the surrounding adipose tissue using right angle forceps. The filling volume of the occluder is recorded, and the occluder secured in place without inflation of the device. Continence is improved in many dogs during the first month after surgery. After that time, if incontinence is still noted, small volumes (0.1 to 0.2 mL) of sterile saline are infused via a Huber needle into the subcutaneous reservoir, thereby filling the cuff. Initial results in four dogs have been published, with 3 of 4 completely continent at two years.
Recessed Vulva

A recessed, or juvenile vulva has also been associated with urinary tract infections. This anomaly is seen primarily in medium- to large-breed dogs in which ovariohysterectomy was performed before one year of age.\textsuperscript{32,33} In one study, 12/22 dogs with recessed vulva had culture-positive urinary tract infections.\textsuperscript{32} This conformational deformity is thought to contribute to lower urinary tract clinical signs by causing urine retention within the vagina, and irritation of skin folds resulting in perivulvar dermatitis, incontinence and infection.\textsuperscript{32,33} Vulvoplasty is a reconstructive procedure by which a crescent-shaped piece of skin and associated subcutaneous tissue is removed between the anus and vulva. Resultant elevation of perivulvar skin and closure of the wound acts to evert the vulvar lips and expose the vestibular opening. This procedure was successful in resolving urinary tract infections in 84\% (16/19) of dogs.\textsuperscript{33}


**Principles**

When considering gastrointestinal surgery, contamination is of prime concern. Every effort should be made to minimize exposure of intestinal contents to the abdominal cavity. All clean procedures (hepatic biopsy, lymph node removal, etc…) should be performed prior to techniques that enter the GI tract. Proper isolation of the segment of tract to be opened is crucial. Stay sutures and atraumatic forceps should be used for manipulation. Abrasion and dessication can increase adhesion formation and reduce GI motility. Moistened laparotomy pads should be used as a barrier to cordon off the GI segment in question from the rest of the abdomen. This will also prevent dessication of the tissues. A set of clean instruments should be set aside prior to entry of the GI tract, and used for abdominal closure. Gloves should be changed prior to closure of the abdomen. Powder should be rinsed from the outside of gloves to reduce granuloma and adhesion formation. Frequent and copious lavage is essential. Use warm fluid. Fluid that is too hot may increase adhesion formation and cause vasodilation with subsequent hypotension. Cold fluids exacerbate hypothermia. Evacuate all fluid prior to closure. Residual fluid inhibits immune clearance.

Should a breach in technique occur, it is beneficial to have chosen appropriate antibiotics for the segment of GI tract entered. Antibiotics should be given at the time of anesthetic induction, and dosing may be repeated during lengthy procedures. For gastric procedures, first generation cephalosporins (e.g. cefazolin) or aminopenicillins are adequate, due to low pH and minimal bacterial inhabitants. As transit through the small intestine occurs, gram positive and gram negative inhabitants occur in increasing numbers. Therefore, appropriate spectrum, such as ampicillin/enrofloxacin, or higher generation cephalosporins are indicated. Particular attention is paid to anaerobes once the ileum/large intestine is affected.

Suture choice recommended for the majority of GI surgery is 2-0 to 4-0 absorbable monofilament. Swaged needles result in the smallest holes through tissue, and taper needles provide the most protection against tissue tearing. It is important to ensure that the submucosa is engaged, as this is the holding layer of the gastrointestinal tract. Full-thickness, appositional suture patterns are placed with the most ease, and are not disadvantageous to inverting patterns. Non-absorbable suture may be used if delayed wound healing is anticipated, but has been associated with entrapment of foreign bodies with subsequent obstruction in rare cases. Braided suture may encourage bacterial colonization, and serve as a nidus. Braided suture also causes increased inflammation when compared to monofilament. This may prolong the lag phase and delay wound healing. Continuous suture patterns provide adequate strength when applied properly, and leave less foreign material in the wound. Various stapling devices are also available for GI surgery.

Preoperatively, it is important to correct fluid imbalances. Crystalloids can be used for immediate volume; however approximately 75-85% moves into the interstitial space within one hour of administration. Combination use with colloids will allow fluid to remain in the intravascular space, as well as attract fluid from the interstitium. Electrolyte imbalances are corrected, and additional pharmacologics can be administered, based on the level of the
gastrointestinal tract affected. Last, but certainly not least, the majority of gastrointestinal maladies are incredibly painful, so appropriate analgesic therapy is vital.

The “danger zone” of gastrointestinal healing is between days 3-5 for gastric and small intestinal incisions, and can be as long as seven days with large intestinal procedures. This is due to the lag phase of healing, generally accepted as post-operative days 0-4, in which holding strength is provided by suture. The proliferative phase of gastrointestinal wound healing occurs between days 3-14. During this time, there is a rapid increase in wound strength, which approximates normal in 10-17 days. Finally, collagen remodeling occurs during the maturation phase, from post-operative day 10-120.

**Biopsy technique**

The ideal technique for gastrointestinal biopsy includes obtaining a full-thickness sample of adequate size in such a manner that artifact is minimized. In addition, there should be minimal complications associated with the biopsy technique. There are two techniques that have yielded excellent histopathologic results in my hands, with minimal complication. The first involves use of a sharp (preferably new) 4-6 mm biopsy punch. Care must be used to avoid damage to the mesenteric surface from overzealous application. This technique is most useful in areas where the intestinal wall is extremely thick, as it allows controlled sampling of all layers without fear of missing the mucosal layer, or creating a very large defect.

Another technique that is simple, and very effective in more normal pieces of gastrointestinal tract involves the use of a stay suture for manipulation, which minimizes crush artifact. It also allows the wedge biopsy to be removed with a scalpel blade, further minimizing artifact when compared to use of scissors. Due to the tapering nature of a wedge biopsy, a common error is to include too small of a piece of mucosa; ensure that the angle of removal is not too steep.

Gastrointestinal biopsies are closed in a simple interrupted or continuous manner with appropriate suture material. Mucosal eversion can be trimmed, or a modified Gambee pattern used to invert the mucosa while apposing submucosa. However, this is not essential, as there is no difference between an appositional and inverting pattern. The most important aspect of any suture pattern is incorporation of the submucosa in the closure. Complications of intestinal biopsy include leakage, dehiscence and possible stricture. If a grossly abnormal area is to be biopsied, consider excisional biopsy (resection and anastomosis) with apposition of healthy tissue, rather than incisional biopsy, as wound healing capacity may be diminished.

**Patching**

Any GI repair can be fortified with either an omental or serosal patch. Omentum brings blood supply, angiogenic factors, immunocytes and physiologic drainage to an incision. The simple act of tacking a portion of omentum to a wound may increase the likelihood of a good seal over allowing physiologic migration. Do not tack omentum circumferentially around a loop of intestine, as strangulation may occur. Serosal patching is accomplished by gently laying loops of intestine over a defect, and suturing them in place.
**GDV/Gastropexy**

Gastropexy is the treatment of choice for gastric dilatation, with or without volvulus. In this condition, accumulation of gas in the stomach occurs primarily from aerophagia. Fermentation leads to further distension, and inflow/outflow obstruction is certainly a component. It is unclear as to whether volvulus is secondary to gas accumulation, or whether it occurs early in the disease process, causing obstruction and gas accumulation.

Breeds at increased risk for this condition are Great Dane, Irish Wolfhound, German Shepherd, Rottweiler, Doberman Pinscher, Newfoundland, Irish Setter, Akita, Weimaraner, Saint Bernard and Standard Poodle. It has been shown that an increasing thoracic depth:width ratio may predispose animals to the disorder. A number of risk factors have been suggested, including genetics, thoracic depth:width ratio, food particle size, number of meals per day, exercise after meals, prior splenectomy, attitude, etc…

GDV is definitely a surgical disease. In one study, 66% (55/83) of animals survived initial decompression, but without surgery 71% experienced recurrence, and of this 71%, 77% died or were euthanized due to the disease process. A second study reported a 4.3% recurrence of GDV when gastropexy was performed, vs. a 54.5% recurrence rate with conservative management.

There are many techniques described for gastropexy. The technique used should lead to a permanent adhesion, with minimal complications. The appropriate area for pexy is just caudal to the 13th rib, approximately 8 cm to the right of midline. AVOID incorporational gastropexies unless the patient is absolutely dying before your eyes! In this technique, the stomach is incorporated into the linea alba closure. This almost guarantees entry and contamination of the abdomen if celiotomy is again warranted.

**Gastrotomy**

Gastrotomy is typically performed for foreign body removal. The incision should be made in the fundus, away from the major branches of the gastroepiploic vessels. Intraluminal hemorrhage is quite common with this technique, and may be minimized with a two layer closure – the first involving the mucosa and submucosa, and the second involving the muscularis and serosal layers.

**Resection and anastomosis**

This procedure is most often performed for foreign body removal, but is also employed for neoplasia, intussusception, and stricture removal. The goal is to re-appose healthy tissue. The most common complication is leakage and dehiscence, which usually occurs on the mesenteric border, due to obscured visualization of suture placement by fat. Tips to reduce this complication include placement of a mesenteric and antimesenteric stay suture first, and using these to manipulate the segments of bowel, leak testing anastomotic sites, and approximating luminal diameter. Means of luminal approximation include spatulating the smaller bowel loop, oversewing the larger bowel loop, and cutting the smaller bowel loop on a steep angle to approximate the larger lumen. If the loop is cut on an angle, be sure that the mesenteric base is the longer side of the angle, to provide maximal blood supply. Finally, when luminal disparity is mild, suture placement can be used to minimize differences.
Treating peritonitis and hypoproteinemia appropriately is crucial for anastomotic healing, as well as prevention of dehiscence. A study of 121 dogs revealed a higher incidence of leakage when resection and anastomosis or enterotomy was used to remove foreign bodies, and when hypoproteinemia was present. This was confirmed in a study of 115 dogs and cats. Pre-existing peritonitis was also found to be significantly associated with dehiscence. Finally, with any gastrointestinal surgery, early enteral nutrition is associated with healing, as enterocytes receive much of their nutrition from


Under ideal circumstances, wounds heal in a predictable manner. It is essential to understand the process of normal wound healing, so that wounds are managed appropriately, and complications are recognized. Wound healing can be divided into four overlapping categories: initiation, inflammation/debridement, proliferation and maturation. It is important to recognize that wound healing is a fluid process, and the phases described below occur on a continuum until the wound has completely healed. Rather than thinking of these phases having a distinct beginning and end, consider instead that they occur in peaks and valleys, with some stages predominating at any given time, but not in absence of the others.

In a nutshell: The initiation phase describes the local response to wounding. Paracrine factors (substances secreted by one cell type that attract other cell types) and autocrine factors (substances from one cell type that attracts like cells) then result in the arrival of inflammatory and proliferative cells to the wound. Dead tissue and contaminants are removed, while fibroblasts begin the repair process. Capillaries are restored, collagen is produced, and the wound begins to contract. Finally, epithelial cells migrate over the wound surface, restoring the environmental barrier. During maturation, collagen remodeling and rearrangement results in a significant increase in wound strength.

Initiation: As the name implies, this stage begins immediately at the time of wounding. Bleeding serves to cleanse and moisten the wound surface. In response, the body immediately secretes vasoconstrictive compounds to minimize blood loss. This constriction is short-lived, lasting only minutes. The vessels then begin to dilate, allowing platelets to comingle with blood and fluid and create a clot. The clot serves to arrest bleeding, as well as provide a template on which further wound healing can occur. While the clot provides a mechanical resistance to infection, it does not contribute to wound strength. The surface of the clot dries into a scab, below which the healing process continues. The dilated blood vessels contribute to cardinal signs of inflammation: heat, redness, and swelling.

Inflammation/debridement: This phase is characterized by the arrival of white blood cells into the wound defect. It typically begins within 6 hours of injury. Platelets that have arrived at the area of tissue disruption degranulate, releasing a host of cytokines. These cytokines are chemoattractants for various other cell types. In essence, the inflammatory cells serve to tidy-up the wound environment, and set the stage for healing. Neutrophils are the first leukocyte population to arrive, and can be measured in the wound bed at 24-48 hours. Platelet-derived growth factor (PDGF) is a potent chemotactic factor for neutrophils, as are fibrinopeptides, created from the conversion of fibrinogen to fibrin. Neutrophils are then activated by transforming growth factor beta (TGF-β), tumor necrosis factor alpha (TNF-α), interleukin one (IL-1), complement, and bacterial products. Neutrophils release potent reactive oxygen species, and are efficient bacterial killers. Superoxide and hydrogen peroxide are generated, which require a high partial pressure of oxygen at the wound surface. As the environment becomes oxygen-depleted, bacterial killing by neutrophils is impaired. Along with reactive oxygen
species, neutrophils also secrete proteases. These compounds serve to break down necrotic tissue, which is then phagocytosed along with wound bacteria. The proteases attract even more neutrophils to the wound. The combination of neutrophils, wound fluid and debris is commonly recognized as pus. Neutrophils, however, are not essential for wound healing. Monocytes migrate into the wound along with neutrophils and transform into macrophages. Additional monocytes are attracted via the oxidative burst and cytokine release from neutrophils. As neutrophils are short-lived cells, the population of white blood cells within the wound bed shifts over time, until macrophages predominate (46-72 hours after wounding). Macrophages are essential for wound healing. Macrophages produce important growth factors, including fibroblast growth factor (FGF), epidermal growth factor (EGF), platelet-derived growth factor (PDGF), TGF-α, TGF-β, tumor necrosis factor (TNF), and various interleukins. Monocytes can differentiate into epithelial cells and histiocytes, and are capable of proliferating within the wound. Macrophages also release matrix metalloproteinases (MMPs) that serve to degrade the extracellular matrix. Macrophages are efficient phagocytic cells, and continue to remove bacteria and wound debris.

**Proliferation:** Following the destructive nature of inflammation, tissue is replaced during the proliferative phase, which usually lasts about two weeks after wounding. The goal of the proliferative phase is coverage of the wound via replacement of soft tissue. This occurs via angiogenesis, fibroplasia and epithelialization. Vascular endothelial growth factor (VEGF), fibroblast growth factor (FGF), and other factors from the wound bed encourage vascular outcropping from surrounding vessels. Newly sprouted capillaries within the wound bed then serve to deliver oxygen and nutrients to the healing process. It is believed that this capillary network is also stimulated by low oxygen tension within the wound. Fibroblasts migrate into the wound under the influence of PDGF, TGF-β and EGF provided by the platelets and macrophages. These fibroblasts begin to synthesize type III collagen. Type III collagen is the weakest of collagen, but does add incredible strength to the wound bed. Type III collagen, fibronectin and hyaluronic acid within the wound bed is known as ground substance. Along with capillaries, fibroblasts and macrophages, a robust, vascular tissue known as granulation tissue is born. Granulation tissue consists of approximately 30% type III collagen. Granulation tissue is present within the wound at 3-5 days. TGF-β is responsible for differentiation of wound fibroblasts into myofibroblasts. These cells express actin, and are capable of contraction. The wound fibroblasts also transition into production of type I collagen, creating a durable connective tissue. Once the collagen content stabilizes, the fibroblasts undergo apoptosis, leaving a scar. Epithelialization begins at the margin of the wound, and appears as a light pink rim that gradually progresses inward. This can be seen beginning 4-5 days post-wounding. However, this is markedly affected by wound size, as sharply created incisions that have been sutured can be epithelialized within 1-2 days. Epithelial cells creep across the wound surface until they contact other epithelial cells. At this point migration ceases, and stratification begins. This phenomenon is known as contact inhibition. During the proliferative stage of wound healing, contraction is also occurring, which substantially reduces wound size. Contraction is dependent on the tension of the wound and surrounding tissue. As healing progresses and myofibroblasts decrease in the wound, contraction slows. The collagen that has been deposited does not have contractile properties. Contraction will also stop once the tension on the wound exceeds the capabilities of myofibroblasts.
Maturation: Wound maturation consists of remodeling collagen into a tough scar. There is essentially no appreciable wound strength during the first 3-5 days after injury. Historically, this was termed the “lag phase” of wound healing, although now we know that there is a LOT going on that sets the stage for proliferation and maturation. At the end of the proliferative phase, wounds achieve approximately 20% of their final strength. Proliferation was initially termed the “log phase” of healing, representing logarithmic acquisition of strength (see graph above). Maturation of the wound consists of massive collagen remodeling. The bundles become thicker and orient themselves along the lines of tension. This reorganization can take months to years. At maximum strength, a scar is 70-80% as strong as normal, unwounded tissue.

The description of wound healing above is also known as “second intention healing” i.e. allowing the wound to heal on its own, via the process of contraction and epithelialization. When a wound is created surgically and then sutured closed, “first intention healing” occurs. By definition, a surgical incision is sharp, and causes minimal tissue trauma – crushing or devitalizing tissue in the process is not anticipated. Surgical wounds are also created under sterile conditions. There is minimal inflammation, and the wound size is markedly reduced through the application of suture material. The gap, or wound size, is one millimeter or less. Therefore, there is little need for fibroplasia and angiogenesis, epithelialization can occur rapidly, and there is minimal scarring. “Third intention” healing is a happy medium of first and second intention. This refers to suturing a wound once healthy granulation tissue appears. Clinically, wounds should progress in an orderly fashion. Purulent debris is expected early, followed by the appearance of granulation tissue at 3-5 days. As granulation tissue matures, it should appear robust, vital, and a deep red color. With minimal manipulation, granulation tissue bleeds due to the marked capillary content. Once the granulation bed is continuous throughout the wound bed, a ring of light pink epithelial cells should be noted on the periphery of the wound. As contraction progresses, migration of the epithelium is evident across the wound surface. The wound takes on a stellate (star-like) appearance as contraction progresses and lines of tension are evident. Once the wound can contract no further, the remainder of the healing process occurs by epithelialization, leaving a variably-sized, fragile epithelial scar.

Any delay in wound progression should cause a clinician to pause, and consider factors integral or supportive to wound healing. These factors can be intrinsic to the wound, and include infection, persistent inflammation, presence of foreign material, lack of appropriate blood supply to support healing, repeated trauma to healing tissue, and the presence of cancer, to name a few. These can also be patient factors, or those extrinsic to the wound, including poor nutritional status, systemic disease, and congenital abnormalities of wound healing.

Wounds should advance in an orderly fashion towards healing. It is important to have a plan in mind of how a wound should appear each day. Any delay in the predictable maturation of a healing wound often indicates a problem.

Wounds have been classified according to various criteria. The scheme that I find most helpful is dictated by the condition or character of the wound. A clean wound is a surgical incision created under sterile conditions. These wounds do not include entry into contaminated areas (gastrointestinal, respiratory, genitourinary). A clean-contaminated wound does enter one of
the aforementioned body systems without major contamination. In addition, clean wounds with a minor breach of sterile technique fall into this category.

Most wounds acquired via injury fall into the last two categories, contaminated and dirty/infected. Contaminated wounds include open traumatic wounds, and surgical wounds with major breaks in sterile technique. Dirty/infected wounds include old traumatic wounds in which greater than $10^5$ organisms per gram of tissue are present.

Removal of devitalized and necrotic tissue is an important part of wound management. It may take several days for a wound to fully “declare” itself, and serial debridement may be necessary. Removal of dead and dying tissue as well as foreign material in the wound decreases inflammation, and speeds wound healing. In addition, the risk of infection increases with debridement delay. As soon as the patient is stable for surgery, debridement should be accomplished.

There are few indications for wet-to-dry bandages in veterinary medicine, except in heavily contaminated wounds such as shear wounds. A wide-meshed gauze can trap particulate matter and remove it from the wound surface at the time of bandage change. It is important to recognize that healing tissue is removed just as effectively – therefore, these bandages are only indicated in the earliest stages of wound management. Once granulation tissue begins to appear, this is no longer an appropriate means of debridement.

It is essential to cover wounds, keeping their surface moist and providing an optimal environment for healing to occur. The primary layer of a bandage is that in contact with the wound surface. A myriad of products are available, and many contain antimicrobial agents. The contact layer is chosen based on the stage of wound healing, the degree of contamination of the wound, and amount of exudate coming from the wound. The secondary layer of a bandage is the absorbent layer that draws and removes wound exudate. It should be applied thick enough that strikethrough is not anticipated prior to the next scheduled bandage change. This will maintain a capillary effect across the bandage. The tertiary layer simply holds the bandage together and protects it from the environment.

A variety of commercial products are available, and should be used according to the manufacturer’s instructions. These range from films, which provide a gas permeable but relatively fluid impermeable environment to hydrogels and alginates, designed to absorb large amounts of wound fluid. Topical antimicrobials are also available, such as silver and tri-peptide copper complex. Triple antibiotic ointment and gentamycin ointments may also be used sparingly, although petrolatum may inhibit epithelialization. Sugar and honey are also making a comeback as topical wound therapeutics, and can be combined with aminoglycosides or betadine for antimicrobial properties. It is important to recognize that there is no “magic bullet” for wound healing. Wound dressings may speed healing by a day or two over untreated wounds, and they are not a cure for poor wound management.

If at any time, wound healing is not progressing in an orderly, anticipated fashion, the wound should be cultured. This process involves flushing and cleaning the surface of the wound aggressively, and obtaining a piece of granulation tissue in a sterile fashion. It is essential to
culture tissue, rather than exudate, as the offending organism is deep-seated. Both aerobes and anaerobes are suspect.
The choice of closure depends on the classification of the wound, as well as the size and location of the defect. It is imperative that infection be controlled, and contamination be minimized prior to wound closure.

In general, primary wound closure is reserved for wounds created under aseptic conditions, or those which were created sharply, with minimal tissue dissection. Delayed primary closure describes closure in 3-5 days if no evidence of necrosis or infection is noted. Secondary closure is closure performed after the formation of granulation tissue. This can be accomplished either by closing the skin and granulation tissue, or by excising the granulation tissue and closing the skin.

Second intention healing is the process by which wounds heal by contraction and epithelialization. This requires appropriate wound management during the healing period, and may result in a less cosmetic result than other closure methods. While economical, some wounds are too large to heal, and result in a fragile epithelial scar. Others may heal by contracture, resulting in loss of limb function. A good rule of thumb when determining whether a wound can or will heal by second intention is to pinch the skin together. If the skin edges do not meet, the wound is unlikely to heal by contraction alone.

Methods to increase skin stretch can be employed prior to closure, or during the closure process. While implantable skin stretchers are commercially available, they are often not feasible for veterinary patients. Tie-over bandages are an excellent means to recruit nearby skin during the wound preparation process. Skin has a remarkable ability to adjust to and lessen tensile forces over 12-48 hours. Application and adjustment of tie-over bandages gradually increases the amount of recruited skin around the wound for eventual closure. Similarly, adjustable mattress sutures can be placed intradermally, and used to gradually bring wound edges closer together. Walking sutures can be placed to combat tension across stretched skin; and releasing incisions can be employed to relieve excess tension in areas of limited soft tissue coverage.

When local tissue is unavailable to close a defect, flaps can be used to mobilize nearby (reliant on the subdermal plexus) or distant skin (with direct cutaneous arterial blood supply) to cover a defect. Subdermal plexus flaps are either advanced, or rotated into position to fill a defect, and circulation is collateral. It is important to plan these flaps keeping in mind lines of tension over the skin. The base of the flap should be slightly wider than the flap to preserve blood supply. It is also important to recognize that these flaps are limited in the distance they can cover. Flap necrosis will occur if the metabolic demands of the tissue cannot be met by the subdermal blood supply.

Axial pattern flaps are a much better choice when larger areas require coverage. These flaps have well-defined parameters, which are dependent on a cutaneous artery and nerve branch. Axial pattern flaps are not difficult to employ; however, it is crucial that the animal is positioned properly, as to accurately estimate where the cutaneous vasculature lies. The boundaries of the
flap are then drawn on the animal with a sterile marking pen, to ensure adherence to the known borders of the flap. The flap is then elevated below the level of the cutaneous musculature, and used to cover the defect. Care is exercised at the base of the flap, as if the cutaneous vasculature is damaged, the flap will uniformly fail.

Other complications associated with any type of flap are seroma formation, infection, dehiscence, and either partial or full necrosis. Adherence to careful surgical technique is expected to minimize these complications. The edge of flaps should be manipulated with stay sutures, or towel clamps, as to protect them from crush artifact of tissue forcep use. Similarly, the less electrocautery used at flap edges, the better. A good rule of thumb is if the thought of using a drain crosses your mind, then use a drain! Principles of placement should be followed – the drain should be placed in an aseptic manner, and exit in a dependent fashion, at a site away from the wound closure. In addition, the drain should not lie directly below the suture line. All drain exits should be bandaged, to absorb exudate and protect the wound from external contamination.

Skin without its own blood supply, in the form of a graft, (either partial or full thickness) can also be harvested to cover defects. In order for grafts to survive, immobilization of the wound is key. All exposed bone, tendon and ligament must be covered with granulation tissue for the graft to “take”. For the first several days, nutrition of the graft is through fluid from the wound bed, known as plasmatic imbibition. Then, capillaries invade the graft, in a process known as inosculation. Once this process begins, the graft takes on a more healthy, reddish hue, and is typically quite incorporated by 7-10 days post-placement. Grafts can be full, or partial thickness. Full thickness grafts are more robust, and heal with a more cosmetic appearance, while partial thickness grafts tend to take more easily, with a less satisfactory visual result.
Perineal Hernias

The pelvic diaphragm serves to separate the abdominal contents from the perineal area. It consists of the external anal sphincter, levator ani and coccygeus muscles, along with the sacrotuberous ligaments (absent in the cat). These muscles serve to assist with tail movement as well as resist forces from abdominal contents during periods of increased abdominal pressure.

86-95% of dogs affected by perineal herniation are intact male dogs, suggesting a hormonal influence on the condition. Other considerations that have been proposed are neurogenic muscular atrophy, close cropping of the tail, as well as any condition that may lead to chronic increases in intra-abdominal pressure (intractable cough, severe GI disease, etc…). Regardless of the etiology of perineal herniation, most affected dogs will become clinical for the disease with time. Typical signs include straining to defecate, dyschezia, hematochezia and varying degrees of perineal swelling. While affected animals may show progressive signs over the course of years, it is important to recognize that perineal hernias can have acute, life-threatening emergency presentations. Acute urethral obstruction and urinary bladder entrapment/necrosis can occur, as can entrapment and strangulation of other abdominal contents, most notably the small intestine.

Conservative management of perineal hernia often includes diet modification and stool softeners. Enemas with deobstipation may be intermittently necessary. As 25-50% of dogs with perineal hernias have concurrent prostatic disease that may be contributing to caudal pressure, castration is always indicated. 47-66% of hernias are unilateral, but bilateral disease is common. About 10% of unilateral cases will herniate the contralateral side within months to years of surgery, more commonly in intact males, further strengthening the argument for castration.

Should life-threatening consequences ensue, aggressive fluid therapy, stabilization and emergency abdominal exploration may be necessary in addition to hernia repair. In the case of urinary bladder entrapment, decompression during the stabilization process is paramount to assist in treatment of hyperkalemia (if present) and for urinary diversion in the rare case of uroperitoneum. If an indwelling urinary catheter cannot be passed easily, decompression via cystocentesis with ultrasound guidance is indicated, followed by catheter placement.

Traditional herniorrhaphy consists of placement of interrupted mattress sutures between the external anal sphincter and surrounding available musculature. In the dog, the sacrotuberous ligament is often employed, and may lead to sciatic nerve entrapment. Should this occur, animals recover from anesthesia in excruciating, intractable pain, necessitating additional surgery. The sciatic nerve is explored via a caudal approach to the coxofemoral joint, and the offending suture is removed. Other more common complications of this technique include seroma formation, dehiscence, reherniation and incisional infection.

As there is often a paucity of tissue with which to perform traditional repair, other methods of herniorrhaphy involve transposition of additional musculature into the perineal area to fill the
pelvic diaphragmatic defect. Techniques described include use of the internal obturator muscle, the superficial gluteal muscle, and the semitendinosus muscle. Each of these techniques varies with respect to invasiveness, ease of performance, and complication rate.

Various materials have been used as sole products for hernia repair, or to augment muscular transposition. These include fascia lata, porcine small intestinal submucosa, and polypropylene mesh, among others. Additionally, supportive intra-abdominal procedures can be employed. The object of these procedures is to help prevent caudal displacement of abdominal organs and pressure on the hernia repair. Cystopexy and colopexy are the most common procedures performed, where the urinary bladder and descending colon are scarified and sutured to the abdominal wall. The resultant adhesion formation, prevents caudal displacement. Vas deferentopexy has also been described.

Regardless of the technique chosen for herniorrhaphy, some general tricks to assist in hernia reduction are a Trendelenburg position, where the head is directed downward. This helps keep the abdominal structures within the abdominal cavity through gravity. Also, a gauze sponge rolled and held with Allis tissue forceps can be placed through the hernia defect to help keep the contents from the surgical field. A purse string suture is essential in the rectum to prevent fecal contamination of the surgical site, and any stool softeners should be discontinued a few days prior to surgery to decrease fecal contamination.

Post-operative management of these cases includes a low-residue diet, restricted activity levels, and treatment of other diseases that may increase intraabdominal pressure. The animal should not be allowed to lick or chew the incision, or “scoot” it along the ground. Complications are seen in up to 45% of cases with internal obturator transposition, and 60% of cases where traditional herniorrhaphy is employed. Many are self-limiting, including swelling, seroma formation and pain. Infection may also be seen.

Certainly the most concerning complications include sciatic nerve damage, fecal incontinence and reherniation. Avoiding the use of the sacrotuberous ligament in hernia repair can prevent sciatic nerve damage. Fecal incontinence can be temporary or permanent, and results from damage to the caudal rectal branch of the pudendal nerve, external anal sphincter or both. Unilateral nerve damage resolves over time as the contralateral caudal rectal nerve reinnervates the external anal sphincter muscle. However, bilateral damage to these nerves causes permanent incontinence (reported in<15% of cases).

Dysuria has also been reported, especially after urinary bladder entrapment and resultant atony. This may have a higher incidence in animals undergoing cystopexy or vas deferentopexy. Tenesmus is also relatively frequent and concerning after surgery, since straining to defecate places immense pressure on the repair, as well as the contralateral pelvic diaphragm.

Reherniation occurs in 10-50% of dogs undergoing traditional herniorrhaphy, and up to 36% of dogs after internal obturator transposition. However, some studies show a recurrence rate as low as 8%. Recurrence rates for inexperienced surgeons far exceeds that of the seasoned surgeons (70% vs 10%). As with most surgeries, the first chance at repair yields the best chance of success. A 90% success rate has been reported in one recent study that augmented internal
obturator transposition with intraabdominal techniques, and a review of 59 cases operated by experienced surgeons described a reherniation rate of 12% when mesh was used to augment the surgical repair. These results suggest that a more aggressive approach during initial surgery may decrease reherniation rates, and need for additional surgery.

**Anal Sac Disease**

Anal sacs are paired diverticula located between the internal and external sphincter muscles, and it is estimated that up to 12% of veterinary visits involve these structures. Each empties via a single duct, which can become impacted. Apocrine glands open into the glands themselves, with sebaceous glands opening into the ducts. Arterial supply is via branches of the internal pudendal and caudal gluteal arteries, and innervation via the perineal nerve.

Anal gland secretions consist of desquamated keratinocytes, and material from sebaceous and apocrine glands. Various species of bacteria and yeast are also normal inhabitants. Large amounts of amorphous basophilic debris is also noted on stained slides. One report indicated that neutrophils, when present are non-degenerative, whereas erythrocytes should be absent. A second report, however, described the majority of neutrophils in normal animals as degenerate. A third study concluded that cytology is not useful in distinguishing between normal and diseased anal glands. It is agreed that color and consistency of anal sac secretions are variable, and are not valuable predictors of anal sac disease. Further confounding assessment of anal glad secretions is the fact that bacterial species found in normal and diseased anal sacs tend to be the same. Therefore, it is difficult to use cytology or bacteriologic culture to confirm anal sac disease, or predict animals at risk of impaction of abscessation.

Anal sacculitis and impaction are common conditions, and are diagnosed via clinical signs and digital rectal examination. The glands are often enlarged and painful, with blood contamination of the expressed contents. Numerous predisposing factors, such as the size of the animal, obesity, skin disease, inflammatory intestinal disease, diet and poor activity level, have been proposed. Impaction and abscessation can be a sequellae to this process in which the gland swells, is extremely painful, and can fistulate through the skin. Often, dogs with anal gland abscesses are systemically ill.

In order to determine whether anal sacs are diseased, and to treat anal gland impaction, a digital rectal examination is performed. Each gland is evaluated and digitally manipulated to evacuate the contents. Internal expression is preferred, as it allows complete removal of contents. If the animal is painful, sedatives may be required for this procedure. Local flushing and infusion of the glands with a chlorhexidine solution or otic preparation containing topical antibiotics +/- steroids is often employed. Parenteral therapy is indicated only with signs of systemic illness. It is essential to completely evacuate the gland contents to examine the gland itself for masses that can be consistent with anal gland adenocarcinoma.

Anal sacculectomy is recommended in cases of recurrent anal sacculitis, abscessation or neoplasia. Both closed and open techniques (in which the gland is entered during removal) have been described. The closed technique results in less bacterial contamination of the surgical site.
Briefly, a small incision is made over the anal sac, which can be augmented with water-soluble lubricant instilled into the gland, paraffin wax, or even a small foley catheter. The dissection is continued very close to the gland until it can be removed, ligating the duct at its attachment to the rectal opening. The surgical site is then copiously lavaged and closed with fine absorbable monofilament suture material. In the open technique, small scissors are introduced through the anal gland duct and an incision is made, essentially filleting the duct and gland open, which are then dissected.

Complications of anal sacculectomy include infection, abscessation with fistula formation, and fecal incontinence. Incontinence is rare, and is due to damage to the caudal rectal nerves bilaterally with aggressive dissection, or through removal of >50% of the anal sphincter muscle. In a retrospective study comparing the open and closed technique for non-neoplastic anal sac disease in dogs, the open technique was associated with a greater complication rate. 14 of 95 dogs had long term complications, including stricture formation, fecal incontinence and fistulation.

Anal gland adenocarcinoma should be considered with any mass located in the vicinity of the anal sac, and excision is a standard part of multimodal therapy. Prognosis is better for tumors that are less than 10cm at the time of diagnosis. Hypercalcemia was noted in 27% of dogs, with confirmed pulmonary metastasis in 8/95. The median survival time was significantly shorter for dogs with pulmonary metastasis. In another study of apocrine gland adenocarcinomas, four negative prognostic indicators were determined: lack of therapy, distant metastasis, local lymph node metastasis and tumor size. Median survival time is approximately 18 months, and surgical intervention provides a survival advantage. Other therapies that can be employed include local radiation therapy and chemotherapy for advanced disease. As very few animals are presented with noticeable anal sac masses, complete evaluation including rectal examination must be performed yearly to diagnose adenocarcinoma in its early stages. Similarly, any animal presenting with hypercalcemia should have a digital rectal exam.


Preoperative planning is perhaps the most important aspect of oncologic surgery. Advances in imaging, anesthesia, emergency and critical care have been essential in moving the discipline of veterinary oncology forward, allowing more radical procedures to be performed. Complete perioperative staging can yield information critical to estimating prognosis for a given animal, further directing surgical recommendations.¹

Surgical biopsy is an important and often overlooked area in veterinary oncology. It is accepted that the first attempt at surgery often gives the best chance of operative success.²,⁷ Knowledge of tumor type not only helps predict biologic behavior, but also is essential in guiding the surgeon with respect to the extent of surgical excision. With respect to soft tissue sarcomas, three centimeter margins are recommended to prevent local recurrence, whereas mast cell tumors can be more conservative at two centimeter margins and one fascial plane deep.³ Current recommendations for feline vaccine-associated sarcomas are five centimeters around the tumor.⁴ Another study showed similar results for recurrence with clean and close surgical margins, emphasizing the need for proper planning prior to surgery.⁵

Biopsy can be extremely useful not only to determine a diagnosis, but degree of local invasion, expected metastatic activity, and other biologic behavior of the tumor in question. This information assists the surgeon in determining the best plan for surgical excision, and provides information for the owner regarding extent of surgery and an expectation following the procedure.¹,²,⁶ Biopsy also ensures that other similarly efficacious treatment modalities, if available, can be explored with the owner prior to surgery.

Prior to discussion of biopsy, it is important to perform a complete physical examination, and staging of the patient. This will allow discovery of comorbid conditions, paraneoplastic syndromes and potential metastatic disease: all of which may alter the surgical plan.⁶ Typical staging includes a complete blood count, serum chemistry panel, three view thoracic radiographs, fine needle aspirate of the tumor and local lymph nodes, +/- abdominal imaging.

Fine needle aspirates can yield a definitive diagnosis in some instances, such as with mast cell tumors and lymphosarcoma. In the case of equivocal results, biopsy is recommended for further classification. Biopsy can be of needle type, incisional, or excisional. Regardless of the type of biopsy chosen, all instruments and suture material should be changed when more than one mass is biopsied.²,⁶ Certain masses may not require biopsy, such as with solitary splenic or lung masses, as the surgical treatment is not altered. Similarly, if biopsy would carry the same risks as surgical excision, excision is planned.

In general, the biopsy technique chosen should be simple to perform, yield sufficient tissue for histologic diagnosis, with few complications. Electrocautery is used minimally on the sample submitted for biopsy. Proper preservation techniques (1:10 volume of tissue to formalin) must be known and followed, and the sample submitted to a veterinary pathologist for definitive diagnosis.
Needle biopsy, such as with a Tru Cut is superior to fine needle aspiration, but inferior to incisional or excisional biopsy. A small core of tissue is removed, which then is manipulated carefully to ensure that the architecture of the sampled tissue is unchanged. Excessive trauma to the tissue from forceps or other instrumentation may yield the sample as non-diagnostic. Multiple samples are collected to improve diagnostic accuracy. It is also important to map the location where the biopsies were collected, as all biopsy tracts must be removed with the tumor.

Incisional biopsy is removal of a portion of the tumor, along with a margin of healthy tissue. Incisional biopsy should be avoided in areas of necrosis or ulceration to prevent collection of a non-diagnostic sample. Excisional biopsy describes removal of the entire tumor, often without knowledge of appropriate margins. When performing incisional and excisional biopsies, scar location and orientation is of paramount importance, and is often overlooked. When complete margins are not obtained, by definition, the remaining mass and previous scar are considered contaminated. Appropriate margins must now be taken around the mass as well as the scar. In some clinical scenarios, this results in much more aggressive surgery than would be required with preoperative forethought.

After surgical biopsy, drains are never used. Drains act to facilitate removal not only of fluid and debris, but cancer cells that can then seed the drain tract. Again, if further surgery is pursued, the drain tract is also considered contaminated.

When planning for surgical excision of a tumor, consider first the diagnosis if known, and ensure that appropriate staging has been performed. Next, confirm that the histologic diagnosis matches the clinical course seen in the patient. Then, consider tumor location, and whether advanced imaging (CT/MRI) would be beneficial in determining the extent of tumor invasion prior to surgical resection. In contrast, if adjunctive therapy is available, marginal excision may be chosen, where microscopic disease is left behind in the wound bed to be addressed by multimodal therapy.

Radical resection is considered when the surgery has curative intent. The skill level of the surgeon is important if the mass is adjacent to important neurovascular structures, or if an advanced knowledge of anatomy is essential for success. The excision is planned and marked out on the patient prior to incision. Separate instruments are used for excision of the mass and closure. During excision, major vascular structures are ligated early, to prevent spread of tumor microthrombi through the vasculature during tumor manipulation. Attention is given to meticulous dissection and accurate hemostasis. Gloves should be changed between removal and closure, and the wound bed copiously lavaged. Closure is with appropriate gauge monofilament absorbable suture.

Once removed, the tissue is marked for orientation. This can be performed with sutures or staples. Ink is available to coat the entire lateral and deep margins to give the pathologist a reliable indicator of the cut edge. Again, a 1:10 ratio of tissue to formalin is a must, and since formalin penetrates maximally to 1 cm, the tissue should be incised at regular intervals to allow adequate fixation. Special handling (as for eye, nerve or brain tissue) if necessary, must be
known prior to surgery, so that appropriate samples are put aside and treated appropriately prior to desiccation.

Diagnosis and Medical Management of Collapsing Trachea

**Diagnosis:**

“Tracheal collapse” is a blanket diagnosis that covers a myriad of structural anomalies of the conductive airways. Collapse can be ventrodorsal or lateral, generalized or focal, can involve neither, one or both principal bronchi, etc... An underlying primary cartilage defect is suspected, along with mitigating factors that can precipitate or exacerbate clinical signs. Due to the dynamic nature of this disease and its unique presentation in each patient, the options for medical management are vast and the criteria for surgical intervention are often indistinct.

Tracheal collapse is a progressive, irreversible condition of the lower airways commonly associated with a “goose honk” cough and varying degrees of airway obstruction. Early affliction is characterized by laxity of the trachealis muscle, which progresses to weakness of the cartilagenous rings. The collapse of the cartilage infrastructure ultimately leads to obliteration of the tracheal lumen, usually in a dorsoventral manner. Tracheal collapse is a condition that normally affects toy and small breed dogs, specifically Yorkshire terriers, Miniature Poodles, Pomeranians, Chihuahuas and Pugs. A sex predilection has not been described; however, there is an age predilection for middle-aged dogs. As many as 25% of affected dogs are symptomatic by approximately 6 months,\(^1\) and some studies have shown that younger dogs are more severely affected than those presented in middle age. It is hypothesized that a congenital component is present in many affected dogs, but that other external factors such as obesity, environmental allergens, cigarette smoke, and Bordetellosis exacerbate clinical signs. This has been described as a congenital tendency with “initiating” factors, and of 100 cases studied, 55% had one or more co-existing diseases.\(^1\)

While the above signalment is typical, tracheal collapse has been reported in both large breed dogs and a cat.

Histopathologic examination of the tracheal cartilage in affected animals is found to be hypocellular with a reduction in glycoprotein and glycosaminoglycan, allowing for decreased retention of water within the matrix. The decreased water retention leads to an increased compliance and decreased rigidity of the tracheal cartilage. Decreased chondroitin sulfate and calcium may also allow for replacement of hyaline cartilage with collagen and fibrocartilage, enhancing the weakness of affected tracheal rings. In collapsed tracheas, width to height ratios can approach 1.5:1 to 4:1 depending on severity and location within the trachea. A vicious cycle of cough and perpetual inflammation ultimately leads to loss of normal tracheal epithelium and replacement with a fibrinous membrane epithelium, followed by formation of squamous metaplasia and a reduction of ciliated cells with secretion of increasingly viscous mucus. Pulmonary hypertension with right ventricular enlargement and cor pulmonale has been reported in dogs with tracheal collapse.

There are various modalities used for the diagnosis of tracheal collapse, and the intensiveness of the tests pursued is based on the likelihood of adjunctive therapy. A thorough physical
examination is often an excellent means of diagnosis, in that an elicitable cough may be present on tracheal palpation, or the cervical tracheal rings may be flattened. Similarly, in dogs with intrathoracic collapse, careful auscultation may confirm narrowing of the airway and wheezing as the patient exhales. At our tertiary referral center, dogs rarely present for mild tracheal collapse. Therefore, we attempt to educate the owners of susceptible breeds when they present for other problems, such as luxating patellas, portosystemic vascular anomalies, routine ovariohysterectomy or castration, etc…

Radiographs are often used to confirm a diagnosis of tracheal collapse, as well as to rule-out other etiologies of cough. It is best to capture both an inspiratory and expiratory film to allow examination of the cervical and thoracic trachea when most likely to collapse. However, radiographs represent a static moment in time, and can miss a diagnosis of tracheal collapse. When available, fluoroscopy is also an excellent means of diagnosing tracheal collapse, as the unsedated patient can be observed in real time. Often, the most accurate extent of collapse can be seen when a cough is elicited.

Tracheobronchoscopy has emerged as the gold standard test for the evaluation of tracheal collapse. The extent of collapse can be accurately graded and measured, and the tracheobronchial mucosa can be directly visualized. Advancement of the scope into the principal bronchi and beyond yields information regarding patency of the smaller airways, and sampling of these areas either with cytology brushes or bronchoalveolar lavage can be accomplished. The biggest limitation of this technique is the need for general anesthesia. While uncommon, occasionally an anesthetic episode will cause acute exacerbation of tracheal collapse, rendering extubation impossible. This is discussed with the owners prior to tracheoscopy, to allow decision-making prior to a period of crisis.

Medical Management:

The cornerstone of therapy for dogs with tracheal collapse is aggressive medical management. Weight loss is an important component of this process, as excess fat deposition in the thorax can further impinge on the trachea, and obese dogs have more difficulty with thoracic excursions. Exercise may be prohibitive in severely affected patients until a measurable proportion of their weight is lost, so a calorie-restricted diet is a must. A prescription weight loss diet is ideal for these patients, as it will facilitate the most weight loss in the shortest amount of time. It is worthwhile to spend a great deal of time designing a weight loss and exercise regime for these dogs and to encourage the owner to be an active participant in the health of their pet, as compliance is often difficult. Another advantage of using a prescription diet is that the owner can be taught to think of the diet as a drug, further emphasizing the importance of calorie restriction.

Environmental modification can also be extremely helpful in controlling the clinical signs of tracheal collapse. Dogs should be walked with a harness, rather than a collar to minimize pressure on the neck. Similarly, slow controlled walks are preferred to bursts of vigorous activity. This will encourage weight loss without precipitating cough from increased airway pressure. Exposure to airway irritants should be minimized – common culprits include cigarette
smoke and heavily perfumed products such as air fresheners, candles and carpet treatments. Airway humidification can also diminish clinical signs.

Treatment of concurrent diseases is also recommended, and can be beneficial in reducing or controlling clinical signs. Left atrial enlargement from cardiac disease places pressure on the carina, and can exacerbate bronchial collapse. Untreated endocrinopathies may preclude weight loss and predispose to infection.

**Pharmacologic management:**

Numerous drugs have been used for the management of tracheal collapse, and a regime must be tailored to each individual patient. Just as some animals respond preferentially to one NSAID over another for the treatment of arthritis, experimentation with multiple drugs in the same class may be necessary to determine which is best suited for the dog. Drugs that are considered “mainstays” of therapy include antitussives, sedatives and bronchodilators. Short courses of corticosteroids are also beneficial in breaking the cycle of inflammation. Chondroprotectants have also been used, but their benefit in the etiology of tracheal collapse has not been definitively demonstrated.

Narcotic medications are potent cough suppressants. Hydrocodone, butorphanol and codeine are commonly used. These drugs are given to effect, and require dose and interval modification over time. Of these, butorphanol is the most potent cough suppressant (100 times greater than codeine), but its short duration of action makes hydrocodone a more suitable choice for most patients. Dextromethorphan may also be used, as some owners appreciate less of a sedative effect; however potency is equal to that of codeine.

Sedatives can be used intermittently, especially if a particularly stressful situation or period of excitement is expected. However, in severely affected animals, chronic low-level use may be indicated.

Bronchodilators may be helpful, as their use may result in an overall decrease in intrathoracic pressure during expiration. In addition, mucociliary clearance rate may improve with the use of these medications.

Although anticholinergics have been used in the past to decrease cough from irritation, they are generally contraindicated in cases of tracheal collapse. These drugs can induce bronchoconstriction, dry airway secretions and slow ciliary motion.

Intermittent use of antibiotics may be necessary, especially if there is an acute exacerbation in clinical signs. Ideally, tracheobronchoscopy is used in order to collect airway samples for cytology and bacterial culture. Many of these patients have been empirically treated with antibiotics, and resistant strains of *Bordetella* are particularly problematic. *Mycoplasma* may also be isolated, and appropriate treatment of these infections may result in substantial improvement, further delaying surgical intervention.
Similarly, short courses of corticosteroids at anti-inflammatory doses may be used occasionally in an attempt to quell the cycle of inflammation. Routine use should be avoided if possible, to prevent iatrogenic Cushing’s disease, weight gain, and decreased resistance to infection.

**Surgical Management of Collapsing Trachea**

Controversy continues to exist regarding the timing of surgical intervention, as well as the preferred means of tracheal support (intraluminal, extraluminal or both). Client education is extremely important, as life-threatening complications may be experienced with any of these techniques. In addition, these dogs will continue to cough after surgery. Therefore, if the chief complaint is cough, it is likely that the client will be less than satisfied with the outcome. We typically reserve surgical options for those animals that have failed appropriate medical management, or have acutely begun to experience life-threatening cyanotic episodes that have required hospitalization.

In my practice, self-expanding veterinary nitinol stents are employed for intrathoracic collapse, and extraluminal prosthetic rings are used for isolated cervical collapse. Extraluminal rings are available commercially, or can be constructed from polypropylene syringe cases. A midline cervical approach is used, and the prostheses are placed no more than 2-3 tracheal rings apart, to negate the possibility of collapse between the supported areas. It is essential that sutures are placed 360 degrees around the trachea, and that the trachealis dorsalis muscle is engaged to maintain luminal patency. Traction is used to mobilize the trachea, and draw as much of the thoracic trachea into the surgical field as possible. We place a steel suture or hemoclip at the level of the last prosthetic ring to confirm location on post-operative radiographs, and find that the thoracic inlet can be spanned to the level of the first or second rib on a lateral film. Often, smaller rings are employed as the cervicotracheal junction is reached, and the trachea narrows. Complications with this technique are minimized when the modified approach is used, but tend to be serious and include laryngeal paralysis, tracheal necrosis, pneumomediastinum and pneumothorax.

Intraluminal stenting is an attractive option, as placement is rapid, improvement is immediate, laryngeal function is not adversely affected, and incisional complications are negated. Unfortunately, at our institution approximately 10% of stents have fractured after placement, resulting in a poor outcome and death. Other complications include respiratory infections, tracheitis and excessive granulation tissue formation. The cost of stent placement is also double that of prosthetic rings, and may be cost-prohibitive for many owners.

**Stent sizing and placement:** Appropriate stent sizing is crucial. The description of sizing and placement in these notes is my personal preference; there are modifications of these techniques that are used at other institutions. Accurate tracheal length and width is necessary to determine stent size. We obtain lateral radiographs under general anesthesia, and place the endotracheal tube cuff as close to the larynx as possible. A positive pressure breath of 20-25 cm of water is maintained as the films are taken, effectively distending the tracheal lumen. A calibrated esophageal marker is also used to account for magnification. Multiple measurements of tracheal width are collected from the entire length of the trachea. The stent chosen should exceed the
width of the trachea at its widest point to prevent dislodgement during cough. Due to the discrepancy in width between the cervical and thoracic trachea, it is possible that the stent chosen will not expand fully in some areas. The manufacturer’s shortening charts should be used to ensure that the chosen stent will not be longer than the trachea.

I prefer to place the stent under direct visualization using a rigid scope. I believe that this allows the most accurate placement of the distal portion of the stent. It is important to maintain the scope at a location in which the carina is easily observed, but that complete expansion of the distal portion of the stent is not inhibited. After the stent is deployed, the scope can be gently removed from the trachea and reinserted in the stent lumen to document placement.

Post-Operative Management:

The main concern after both extraluminal ring placement and stent placement is the control of airway inflammation and the prevention of cough. This is especially critical for dogs with stents. Under the continual outward pressure exerted by the expanded stent, the tracheal mucosa is expected to migrate over the implant, re-instituting the mucociliary escalatory apparatus. It is hypothesized that fracture incidence may be reduced if this process occurs uneventfully. Each time the animal coughs, the fragile mucosa is disrupted and the embedding process is delayed. Cough will also fatigue the material of the stent, making fracture more likely. Typically, our post-operative protocol consists of routine acepromazine for two weeks after the procedure and hydrocodone as needed indefinitely to prevent cough. A two-week course of amoxicillin/clavulanate is prescribed, as well as a tapering dose of anti-inflammatory prednisone. Continued medical management is typically required, and again is tailored for the individual patient.


