Brachycephalic syndrome is a complex of abnormalities associated with the short nosed, flat faced phenotype of brachycephalic breeds. The most common abnormalities are elongated soft palate and stenotic nares. “Normal” tracheal size is smaller in English bulldogs; if considered “abnormally small”, the animal is considered to have tracheal hypoplasia. Surprisingly enough, tracheal size is not related to outcome of brachycephalic surgeries. Secondary conditions that develop from negative inspiratory pressure from stenotic nares or elongated soft palate include everted laryngeal saccules, laryngeal collapse, and tracheal collapse. Many brachycephalic dogs also develop secondary changes of the digestive tract (e.g. esophagitis, hypertrophic gastropathy, and gastroduodenal inflammation or ulcerations) that resolve with correction of airway obstruction. These gastrointestinal changes may further predispose brachycephalic dogs to regurgitation and aspiration pneumonia.

Elongated Soft Palate

At rest, the soft palate normally divides the nasopharyngeal and oropharyngeal spaces. During swallowing, the palate is elevated dorsally, covering the caudal aspect of the nasopharynx, to prevent food, water, and saliva from entering the nasal cavity. The soft palate normally covers the rostral tip of the epiglottis at rest. Palates that extend caudal to that point may interfere with respiration.

Elongated soft palate is most commonly reported in brachycephalic dog breeds such as English bulldogs and pugs. Palates may also elongate with increased negative inspiratory pressure secondary to upper respiratory diseases that block the airway, such as laryngeal paralysis in Labrador retrievers or tracheal collapse in Yorkies. Initially, clinical signs of elongated soft palate include snoring and mild exercise intolerance. As the palate thickens, dogs may vomit or gag. With stress, heat, or overexertion, affected animals can present with cyanosis, collapse, and hyperthermia. Severely affected animals may require emergency intubation or tracheostomy.

Diagnosis of elongated soft palate is based on evaluation of palate length under anesthesia. Brachycephalic dogs suspected to have elongated soft palates should also be evaluated for associated respiratory abnormalities. About 20% of affected dogs and cats will have abnormal nasal turbinates that obstruct the choanae (“nasopharyngeal turbinates”). This abnormality is diagnosed with computed tomography or endoscopy.

Treatment

Before surgery, patients should undergo thoracic radiographs to rule out pulmonary edema, aspiration pneumonia, or heart enlargement and to evaluate the trachea size. If pneumonia is suspected, the animal is treated with antimicrobials such as amoxicillin or amoxicillin-clavulanate. A transtracheal wash may be required to obtain samples for culture and sensitivity in animals that do not respond to antimicrobials. Because of associated gastrointestinal disease, drugs that enhance gastric emptying (e.g., metoclopramide), reduce vomiting (e.g., Cerenia), and decrease gastric acid production (e.g., famotidine, omeprazole).

Patients are premedicated with buprenorphine or butorphanol and acepromazine (0.01 mg/kg IV) or another sedative, and preoxygenated by face mask for 5 minutes. Induction should be rapid (e.g.
propofol IV) so that the animal can be quickly intubated with a cuffed endotracheal tube. Most clinicians will give an anti-inflammatory dose of glucocorticoids (e.g. dexamethasone SP, 0.05-0.1 mg/kg IV) after induction to reduce postoperative swelling. Postoperative nonsteroidal anti-inflammatory drugs should be avoided when glucocorticoids are used.

The animal is positioned in sternal recumbency with the mouth propped open. Palate length is estimated and usually based on the clinician's judgment. Some veterinarians will trim the palate so that it slightly overlaps with the tip of the epiglottis when in a resting position, while others will remove it at the caudal margin of the tonsils, which is usually farther forward than the tip of the epiglottis, resulting in a shorter palate. Palate resection is performed with a carbon dioxide (CO₂) laser, radiosurgical scalpel, or cut-and-sew technique. Laser resection provides immediate hemostasis and a comfortable recovery. Hemostasis is also good with a radiosurgical scalpel, as long as the veterinarian cuts slowly.

The cut and sew technique often requires long handled scissors, thumb forceps, and needle holders. The endotracheal tube is secured to the lower jaw, and the mouth is propped open on a wire stand, with Gelpi retractors, or by suspending the head on a rope or gauze tie. Stay sutures are placed in the caudal edge of the palate to pull it forward. A portion of the palate width is cut with scissors, and the nasal and oral mucosa of the cut margin is sutured together with 4-0 rapidly absorbable monofilament suture (Monocryl or Biosyn). Transection is continued until the entire palate is cut; the remaining edges are sutured together, and suture ends are cut short once the knots are tied. If stenotic nares are present, they should be corrected under the same anesthetic episode. Everted laryngeal saccules are thought to resolve in some dogs after the palate is shortened; however, this has not been confirmed.

Animals are recovered on oxygen. If necessary, animals can be given light sedatives and mild analgesics after surgery. Heavy sedation should be avoided to reduce the risk of aspiration. To prevent panting that could lead to swelling dexmedetomidine can be used to provide a slow, stress free recovery. Reported outcomes for laser and cut-and-sew techniques are similar. Mortality rate is less than 5%, but postoperative vomiting or regurgitation is reported in 18% of animals. Death is usually associated with aspiration pneumonia, pulmonary edema, or airway obstruction from swelling. Animals with postoperative distress should undergo placement of a temporary tracheostomy tube. If the palate resection is inadequate, clinical signs will likely reoccur. If palate resection is excessive, the animal will reflux water and food through the nose when drinking and may develop coughing and rhinitis.

**Stenotic Nares**

Stenotic nares are most commonly seen as a component of brachycephalic syndrome in short nosed dogs and cats. Predisposed breeds include English and French bulldogs, Pugs, Boston terriers, Pekingese, and Cavalier King Charles dogs and Persian and Himalayan cats. Shih tzu may present with severe clinical signs as early as 6 to 8 weeks of age; at that age, they tend not to have other components of brachycephalic syndrome (e.g. elongated soft palate), but those components will develop if the condition is not treated early. The cause of stenotic nares is axial deviation of the dorsolateral nasal cartilage and its associate skin and mucosa (the “wing” or alar fold of the nostril). The negative pressure produced by this airway blockage instigates severe stress on the soft palate, larynx, and trachea and can result in development of tissue swelling and airway collapse. Many animals will also have abnormal conchal development; in fact, the alar folds are actually extensions of the ventral nasal concha, which must be addressed when surgery is performed. About 20% of brachycephalic dogs and cats will have "nasopharyngeal" turbinates that protrude down into the nasopharynx, blocking nasal flow of air. In Europe, nasopharyngeal turbinates are most common in pugs. Repair of stenotic nares in animals with nasopharyngeal turbinates is unlikely to resolve the clinical signs.

Clinical signs of stenotic nares include inspiratory dyspnea, recurrent nasal infections, and sometimes exercise intolerance or poor appetite. Stenotic nares are easily diagnosed on physical examination.
Evaluation of concurrent conditions will require anesthesia (e.g., elongated soft palate, laryngeal collapse), radiographs (e.g., hypoplastic trachea), and CT or scoping (e.g., nasopharyngeal turbinates).

When a brachycephalic dog has an apparent gap or airway ventrally but no “vertical opening” - in other words, no space between the medial (axial) wall of the alar fold and the lateral (abaxial) wall of the planum along the philtrum - the dog has stenosis. Air flowing into the ventral portion of the nares must pass dorsomedially to actually enter the nasal cavity. On rhinoscopy this area looks like a blind sac in some dogs because they have dorsal and medial collapse of the nares. Therefore, these dogs also need reconstructive surgery.

**Treatment**

In puppies or cats with small alar folds, stenotic nares can be widened by removal of the alar folds. When performed with a scalpel blade, this is known as the “Trader technique”. In puppies, the ventral half of the fold, with associated ventral nasal concha, is excised with a #11 blade inserted at 40° angle ventrolaterally. Alternatively the cut can be made with a punch biopsy. Bleeding is controlled with digital pressure. The fold can also be removed with a laser, which reduces bleeding; the subsequent white scar gradually regains pigment over 6 months.

In older dogs and some cats, a wedge of tissue is taken out of the central or lateral portion of the alar fold and rostral extent of the ventral nasal concha with a number 11 blade. The remaining gap is apposed with 4-0 or 5-0 rapidly absorbable suture in an interrupted pattern.

**Laryngeal Collapse**

Laryngeal collapse represents an advanced stage of brachycephalic airway syndrome. As a result of airway narrowing, increased resistance, and high negative pressure, the arytenoid cartilages lose their rigidity, allow them to deviate medially and block the airway. Initially, laryngeal saccules evert and the cuneiform processes are displaced toward midline; eventually, the corniculate processes collapse as well. Mild cases respond to correction of associated conditions (stenotic nares, elongated soft palate). Moderately to severely affected animals have a more guarded prognosis. These dogs require placement of a temporary tracheostomy tube and some sort of surgical intervention, such as laryngeal tieback or permanent tracheostomy. About 80% of affected dogs that undergo temporary tracheostomy and unilateral laryngeal tie back do well after surgery, as long as the tracheostomy tube is left in for at least 24 hours after surgery. About 50% of surviving dogs have intermittent episodes of regurgitation.
General Principles:

Healing of the urethra is dependent on urethral continuity and local urine extravasation. If a strip of urethra remains intact and urine is diverted from the site, the urethral mucosa can seal the wound in one week. If the urethra is completely transected, the mucosal ends will retract and fibrous tissue fills the intervening gap, obstructing the urethra. Primary repair is therefore required with complete urethral transection. Urethral injuries can seal within 3 days but heal best when urine is diverted from tears or surgical sites. Urine diversion can be performed with transurethral catheters or cystostomy tubes; either method will decrease the risk of stricture compared to primary anastomosis alone. Risk of urethral stricture formation is increased with tension on the anastomosis or use of oversized urethral catheters.

Surgical Approach:

The distal urethra can be approached through a perineal or scrotal approach (males) or through an episiotomy (females). Perineal and episiotomy approaches are often performed with the animal in sternal recumbency with its rear legs hanging over the end of a tilted, padded table. If identification or catheterization of the urethra is expected to be difficult, concurrent cystotomy is needed, or a mass is present that extends into the abdominal cavity, surgery is performed with the animal in dorsal recumbency. If necessary, the rear legs of the animal are pulled cranially to provide a perineal view; this is particularly useful in cats during perineal urethrostomy. In female dogs, the perivulvar area is clipped and prepped and included in the draped field to allow retrograde or antegrade catheterization. In male dogs, the prepucce is included in the prep and sterile field.

The proximal urethra can often be reached through a caudal abdominal incision. Approach to the midportion of the urethra may require pelvic osteotomy or ostectomy. Pubic osteotomy alone (a raised flap incorporating the pubic bone) will expose the cranial half of the intrapelvic urethra. Adductor muscular attachments are left in place along one edge of the pubis to improve blood supply and stability. If possible, a portion of the prepubic tendon can also be left attached to the pubic flap. The bone flap is reflected ventrally and caudally during surgery. If a wider exposure is required, a bilateral pubic and ischial osteotomy (sagittal pubic osteotomy) or symphyseal ostectomy can be performed. For sagittal pubic osteotomy, the pubis is divided along its length with an oscillating saw and its edges gently separated with a rib spreader. The edges are wired back together once the intrapelvic procedure is complete. With bilateral pubic and ischial osteotomy, muscular attachments are left in place along one lateral margin of the bone flap, and the flap is reflected laterally along these attachments. To facilitate closure of osteotomies, holes can be drilled in the pubis and ischium before osteotomy. The prepubic tendon can be secured to the bone fragment through additional drill holes or reapposed as needed along its midline and then sutured caudally to the adductors. Pubic ostectomy can be performed with rongeurs or burr. The cranial half of the pubis can be removed to expose the urethra immediately caudal to the prostate and trigone. If more extensive exposure is required, the entire pubic and ischial symphysis can be removed to produce a gap that is 2 to 3 cm wide, depending on the size of the animal; rib retractors can be used to widen the gap even more. A portion of the cranial (acetabular) branch of the pubis medial to the iliopubic eminence should be left intact with the attached prepubic tendons. During closure, the prepubic tendon and adductors are apposed along the midline and the tendon is sutured caudally to the cranial edge of the adductors.

Urethral Repair

Urethral tears and lacerations are usually secondary to trauma, urethral catheterization, or calculi but can also occur inadvertently during surgery. If a strip of the urethral wall remains intact, most patients can be treated with urinary diversion. If the urethra cannot be catheterized retrograde, a cystotomy is performed and a catheter passed antegrade through the bladder and out the urethra; a
Foley catheter is tied to the catheter and pulled retrograde into the bladder. If the urethra is completely transected, primary repair is required. Urethral resection and anastomosis is occasionally performed to resolve strictures or remove tumors. Urinary diversion is important for healing and should be maintained for a minimum of 3 to 5 days, depending on the health of the urethral tissues and the amount of tension on the anastomosis. Urine should be cultured after catheters are removed. In male dogs undergoing intrapelvic urethral resection and anastomosis, there was no significant difference in urethral healing in those that had an indwelling urethral catheter, cystostomy tube, or a combination of both after surgery.

**Prescrotal Urethotomy**

Under general anesthesia, most urethral calculi can be retropulsed into the urinary bladder and removed with cystoscopy, cystoscopically assisted cystotomy, or open cystotomy. Those that cannot be shifted are usually lodged within the urethra at the caudal end of the os penis. Many of these calculi become embedded within the mucosa and are not easily removed, even through a urethrotomy; in these dogs, scrotal urethrotomy is usually performed. In a few dogs, the calculus can be dislodged through a prescrotal urethral incision. Prescrotal urethrotomies are usually closed primarily to reduce postoperative hemorrhage. Urethral incisions that are left open to heal by second intention will bleed for 3 to 14 days, particularly when animals are excited. Rarely, dogs may undergo permanent prescrotal urethrostomies. Owners should be warned of the potential for urine scald along the scrotum and inner thighs.

**Scrotal Urethrostomy**

Persistent or severe hemorrhage and dehiscence are uncommon after scrotal urethrostomy when the urethrocutaneous apposition is performed with a continuous pattern, suture bites include mucosa, and postoperative self-mutilation is prevented. A rapidly absorbable monofilament synthetic suture can be used for closure; sutures are usually not visible 3 weeks after surgery and therefore do not need removal. Addition of a mattress suture at the cranial and caudal extents of the urethrostomy may prevent hemorrhage from the sites, since the “crotches” of the incisions are often missed during urethrocutaneous apposition.

**Perineal Urethrostomy (PU)**

For cats with concurrent cystic calculi and urethral obstruction or those with strictured PU sites, surgery is most easily performed with the cat on its back and the rear legs pulled forward so that the bladder and urethra can be approached simultaneously. The veterinarian must take care to incise the correct side of the penile body— the one closest to the anus— when opening the urethra. As with dogs, the PU site can be closed with a simple continuous pattern with rapidly absorbable monofilament. However, preplacement of the first 3 to 5 sutures in an interrupted pattern will help secure the urethral mucosa to the skin appropriately. When preplacing the top 3 sutures, bites should be taken as close to the top (“crotch”) of the urethrostomy incision as possible. The first 2 sutures pass through this “crotch” area and angle out to grab skin at the 10 and 2 o’clock positions. The top suture also passes through this area and angles out slightly higher (a less acute angle at about the 1 o’clock position) instead of grabbing the skin directly dorsal to the urethrotomy. This will prevent kinking of the skin and shortening of the distance between the urethrostomy and the anus. Perineal urethrostomy is not always required for cats with obstructions; in fact, 73% of cats in one study responded to treatment with sedatives, analgesics, intermittent cystocentesis, subcutaneous administration of fluids, and a stress free environment.

Perineal urethrostomy through an episiotomy can be performed in female dogs that require vaginal and distal urethral resection (e.g. for leiomyomas). Because of the aggressive nature of the tumor, it is not recommended for dogs with distal urethral transitional cell carcinomas; instead, those dogs may benefit from urethral stenting and appropriate chemotherapy (e.g. piroxicam). In female dogs the distal urethra can be resected and the proximal end anastomosed onto the remaining vagina (vaginourethroplasty) or the vestibule.
Subpubic and Antepubic Urethrostomies:
When the urethral end is too short to reach the skin without tension, it can be brought cranial to the pubis (antepubic urethrostomy), or a portion of the pubis can be removed with rongeurs (subpubic urethrostomy). Because of the curve produced in the urethra, subpubic urethrostomy does not always reduce the length of urethra needed to reach skin. Antepubic urethrostomy has a high complication rate (incontinence, urine scald) and is considered a salvage procedure. In some species, transposition of the urethra to the prepuce may reduce the risk of urine scald.

Urethral Prolapse:
Repair techniques for urethral prolapse include resection and anastomosis or urethropexy. For anastomosis, fine rapidly absorbable suture is recommended. Recurrence (57%) has been reported with both procedures, and postoperative hemorrhage (39%) is also common.

Urinary Incontinence
Hydraulic occluders are becoming more popular for treatment of incontinence caused by urethral sphincter mechanism incompetence. A silicone cuff is placed around the proximal urethra about 2 cm distal to the bladder neck and is attached by tubing to a subcutaneous vascular access port inserted along the caudal abdomen. Many dogs do not need any cuff inflation because of local pressure in the area from the cuff or resultant scar tissue. Those that need extra pressure to maintain continence must be managed cautiously; sometimes addition of as little as 0.1 ml of saline to the cuff can result in obstruction of the dog.

UPDATES IN REPRODUCTIVE SURGERY
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Key Points
- Ovariectomy is just as effective as ovariohysterectomy and does not increase the risk for pyometra.
- Castration and spay at <3 months and at 6 months are both prepuberal and have similar effects.
- Some conditions (e.g., pyometra, mammary tumors, prostatic hypertrophy) are dramatically reduced by neutering.
- Preliminary evidence may indicate increases in joint disease and certain cancers with neutering in some breeds of dog.

Ovariohysterectomy
Elective ovariohysterectomy (“spay”) is commonly performed to prevent estrous cycles and unwanted pregnancy. Additional benefits include prevention of pyometra and ovarian or uterine neoplasia. Incidence of mammary tumors is reduced dramatically when animals are spayed at a young age. In dogs, the lifetime risk for development of malignant mammary tumors ranges from 2% to more than 20%. Risk of mammary neoplasia is 0.5%, 8%, and 26% of normal for dogs spayed before their 1st, 2nd, or 3rd estrus, respectively. In cats, spaying before 6 months, 12 months, and 24 months of age reduces the risk of mammary tumor development 91%, 86%, and 11%, respectively. Spaying cats after 2 years of age or dogs after 2.5 years of age has minimal effect on mammary tumor development. Depending on the study, pyometra has been reported in 5% to almost 25% of dogs that are not spayed.

Ovariohysterectomy is performed therapeutically in animals with pyometra, dystocia, uterine or ovarian cancer, and vaginal hyperplasia or prolapse. In dogs with congenital clotting disorders, ovariohysterectomy prevents life threatening hemorrhage than can occur during estrus.
Ovariohysterectomy also eliminates hormonal changes that interfere with medical therapy for diabetes mellitus or epilepsy. Ovariohysterectomy increases the life expectancy of female dogs by 26.3%. Sterilization of dogs reduces the risk of infectious, degenerative, and vascular diseases and risk of trauma. Sterilized dogs are more likely to die from neoplasia or immune mediated disease.

Purported adverse effects of ovary removal include obesity, urinary incontinence, poor development of external genitalia, and decreased lifespan in some studies. In one paper, urinary incontinence was almost eight times greater in spayed female dogs than in those left intact. Many studies regarding urinary incontinence are biased, however, and evidence is inconsistent that spaying after 3 months of age results in urinary incontinence in female dogs. Urinary incontinence rates of spayed dogs are 5% to 20%, compared to 0.2% to 0.3% in intact bitches. Spayed dogs are twice as likely to be obese as intact dogs; fortunately, normal body weight can be maintained with appropriate diet and exercise. Because ovarian hormones are required for vulvar development, dogs spayed at a very young age may retain infantile vulvas. Affected dogs are predisposed to vaginitis, dermatitis, and urine pooling.

Ovariohysterectomy has also been associated with an increased risk for development of transitional cell carcinoma, osteosarcoma, and hemangiosarcoma, although an exact cause-effect relationship has not been established. Risk of hemangiosarcoma in female golden retrievers spayed after 12 months of age is 4 times that of intact female golden retrievers or those spayed before 12 months of age. Early reports that classified dogs as spayed or intact indicated that spayed dogs lived longer. However, reanalysis of the data shows that length of survival is related to how long a dog has its ovaries. In that study it was shown that the longer the duration of ovary exposure, the greater the likelihood that a Rottweiler would have extreme longevity (living at least 13 years). In fact, in that paper, there was a 3 fold increase in extreme longevity for Rottweiler dogs that remained intact longer.

Ovariectomy without hysterectomy is becoming more common, particularly with laparoscopic spays. Ovariectomy alone does not increase the risk of pyometra, since endometritis, pyometra, and stump pyometra require progestagens to develop. Ovariectomy may be less traumatic because incision size is smaller and tissues are handled less; the only increased risk compared to OHE is future development of uterine tumors, which are rare in dogs (0.3%). Most of these tumors (90%) are benign leiomyomas; therefore, the true overall incidence of malignant uterine tumors is 0.03%. In a recent study comparing dogs undergoing ovariectomy or ovariohysterectomy, there was no significant difference in surgical time, pain scores, or wound scores.

**Castration**

Castration is performed to prevent insemination of female dogs, alter behavioral development, and prevent testicular cancer and benign prostatic hypertrophy. Based on short and long term studies, gonadectomy at early ages (e.g., 3 months or less) does not increase the risk of musculoskeletal or genitourinary disorders or physical behavioral problems as compared to castration at older ages (e.g., 7 months of age). Early castration does not affect urethral size or risk of urinary tract infections. Castration increases the risk of obesity.

Castrated dogs have been shown to have an increased risk of bladder and prostate cancer compared with intact dogs. Rottweiler dogs neutered before one year of age had increased risk of osteosarcoma, while golden retrievers had an increased risk of lymphosarcoma and joint disease. One study noted incidence of joint disease was doubled in dogs castrated at less than 6 months versus intact males. These studies may not reflect the normal population since they were drawn from referral populations.

**Greyhound**

Greyhounds have an unusually high risk of subcutaneous hemorrhage after ovariohysterectomy and castration. In fact, 26% of retired racing greyhounds had significant subcutaneous hemorrhage. Potential bleeding tendencies are not identifiable on preoperative blood work or coagulation panels. Administration of fresh frozen plasma decreases the prevalence of hemorrhage, but not all dogs respond. While the cause of the bleeding disorder has not been identified, it is thought to be a result of
abnormal fibrinolysis. Administration of aminocaproic acid on the day of surgery and for 4 days thereafter may decrease the risk.

**Bibliography**


INTRODUCTION

Wounds may fail to heal because tension, infection, hematoma or seroma formation, ischemia, molestation, pressure, motion, foreign materials, neoplasia, drugs (corticosteroids, neoplasia), radiation, severe malnutrition, or underlying metabolic disease. When wounds fail to heal, the veterinarian should examine and treat the animal for underlying disease, culture a punch biopsy of the wound to evaluate for infection and determine sensitivity, and apply local wound management techniques to encourage development of a healthy wound bed that can either be left to heal by second intention or closed primarily.

REVIEW OF DRESSINGS AND BANDAGES

DRESSINGS

Dressings are used on wound surfaces to prevent infection, maintain moisture, enhance healing, or facilitate debridement. Some dressings such as triple antibiotic ointment and silver sulfadiazine will speed wound healing, likely because of their broad spectrum antibacterial activity and ability to keep wound surfaces moist. Spray or foam topical dressings containing debriding agents are useful when an animal cannot be anesthetized or when all viable tissue must be spared (such as in burn wounds). One example is a salt-lysosyme foam (VetAid Spray). Hexamethyldisiloxane acrylate copolymer (No-Sting Barrier Film) produces a nontoxic film on the skin that protects the skin from fecal, urine, or serum scald. It is applied to clean dry skin every third day and allows underlying skin inflammation to resolve.

Antiseptic-impregnated dressings may reduce the amount of contamination through and under the dressing. Bandage materials impregnated with silver products have a great spectrum of activity but are expensive. Alternative options include biguanide impregnated bandages (e.g., Kerlix AMD, Tyco/Kendall), which are less expensive and can come in a variety of materials such as roll gauze.

Hydrocolloids

Hydrocolloids are usually made of pectin, gelatin, or carboxymethylcellulose attached to a film or adhesive backing. Hydrocolloid bandages absorb 67-75% of their weight in wound fluid or exudates while maintaining a moist environment. They are used for partial or full thickness wounds and can be used on granulating and necrotic wounds. They enhance healing, protect wounds from contamination, and aid in autolytic debridement, and may reduce infection rates compared to gauze, film, foam, or hydrogel coverings. They can be left on wounds up to seven days but should be changed any time strike-through occurs. They may cause exuberant granulation tissue; therefore, wounds should be checked frequently. The gel formed may have an unusual odor and texture like purulent material but washes off easily. Dressings that form gel should be cut to fit inside the wound (on the wound bed only) so they don’t cause maceration of the skin.

Hydrogels

Hydrogels are 80-90% water- or glycerin-based wound dressings that come as sheets, amorphous gels, or impregnated gauze. They absorb minimal amount of fluid but provide large
amounts of moisture to dry wound beds, facilitating autolytic debridement, reducing pain, and enhancing healing. They can be applied as often as twice daily or left on the wound for up to five days. They are used for minimal to moderately draining wounds (scrapes, burns, ulcers, blisters) and on wounds in the late stages of healing that have healthy granulation tissue, decreased drainage, and evidence of epithelialization. They can cause maceration to surrounding healthy skin and therefore should only cover the wound bed.

**Alginates (e.g. Curasorb, C-stat, Kalginate, Tegagen)**

These polysaccharide dressings are produced from kelp, and are available as twisted fibers or mats that are held in place with an overlying bandage. Alginates form a soluble gel when they come in contact with sodium from wound exudates, providing a nonadherent moist wound environment that promotes autolytic debridement and enhances wound healing. They are used on moderately heavy exuding wounds in the early stages of healing. They also aid in hemostasis. If used on dry wounds, they must be moistened with saline to avoid dessicating the wound. They can be left on moist wounds for up to seven days, as long as there is no strike-through of the overlying bandage. The gel formed may have an unusual odor and texture like purulent material but washes off easily.

**Collagen (e.g. Collamend, Fas Cure, Collasate, HyCure)**

Processed collagen comes in sheets, powders, gels, or sponges. It enhances inflammation and hemostasis and provides a scaffold for cellular colonization, thus accelerating fibroplasias and epithelialization. In dogs (but not horses) it increases the rate of epithelialization, probably because it maintains a most environment.

**Tripeptide-copper Complex (e.g. Iamin-Vet)**

Tripeptide-copper complex is a hydrogel that acts as a growth factor, chemotactic agent, and wound activator. It stimulates wound neovascularization, epithelialization, collagen deposition, and wound contraction to enhance wound healing. It is used for partial and full thickness wounds that have been debrided and thoroughly cleansed. It is applied under a nonadherent dressing that is changed daily, or can be applied to unbandaged wounds up to four times a day. It has been shown to speed healing of diabetic ulcers in people, ischemic wounds in rats, and open wounds in dogs.

**Acemannan (e.g. Carravet, Carrasorb)**

Acemannan is derived from the aloe vera plant. It acts as a synthetic growth factor that stimulates macrophages, resulting in release of interleukin-1 and tumor necrosis factor alpha secretion, cytokines that stimulate wound healing. Interleukin-1 stimulates fibroblast proliferation, neovascularization, epidermal growth and migration, and collagen deposition. Tumor necrosis factor alpha induces wound angiogenesis. Acemannan increases granulation tissue formation, speeds the rate of healing of foot pad wounds, and stimulated non healing wounds to begin to heal. The freeze-dried form attracts water and reduces tissue edema and inflammation. Acemannan is used for partial and full-thickness burns, lacerations, ulcers, abrasions, and slow-healing wounds. Its greatest effect is within the first week of injury. Wounds should debrided and lavaged as needed before application, and acemannan should be reapplied during daily bandage changes.

**Maltodextrin (i.e. Intracell Multidex)**

Maltodextrin is a hydrophilic powder made of D-glucose polysaccharide with 1% ascorbic acid that pulls fluids from the wound, keeping the wound moist while helping to remove exudates. It also attracts white blood cells to the wound to increase growth factor concentration and, when hydrolyzed to glucose, provides an energy source for the wound to speed healing. It works in infected and non-infected wounds, but should be applied after the wound is debrided and lavaged. The powder form is used on exudating wounds, while the gel form is used for drier
wounds. Wounds treated with maltodextrin should be lavaged before each application and rebandaged daily. In horses maltodextrin decreases pain and stimulates granulation tissue.

**Honey**

Honey decreases inflammatory edema, stimulates macrophage migration, accelerates sloughing of dead tissue, provides an energy source, and forms a protective protein layer over the wound bed. It stimulates development of healthy granulation tissue and has some antibacterial properties because of its hydrogen peroxide contents, which also stimulates angiogenesis. It is effective against a wide variety of gram positive and gram negative organisms, including E. coli, Pseudomonas, Serratia, Salmonella, Staphylococcus, Streptococcus, and Candida. Honey used on wounds should be unpasteurized and not heated above 37°C. Surgical gauze soaked in honey is laid directly on the lavaged and debrided wound, and covered with an absorbent secondary bandage. The bandages are changed one to three times daily as needed for strike through. Because honey absorbs a large amount of fluid, it could exacerbate fluid and electrolyte imbalances is used on large wounds.

**Sugar**

Because of its high osmolality, granulated sugar decreases edema, attracts macrophages, accelerates sloughing of necrotic tissues, provides energy, promotes development of a protective protein layer, and stimulates development of healthy granulation tissue. Before use, wounds are thoroughly lavaged. A deep layer (at least 1 cm) of sugar is placed over the wound and covered with absorbent bandages. Bandages and sugar are changed at least twice a day, and as soon as strike through occurs. Sugar is discontinued once a healthy granulation bed forms. Wounds infected with Staphylococcus, Streptococcus, Enterobacter, E. coli, Klebsiella, Pseudomonas, and Serratia respond to sugar treatment. Like honey, it can also cause metabolic imbalances when used on large wounds.

**Silver**

Silver has broad spectrum antimicrobial properties. It can be found in wound ointments and creams or bound in foam sponges and nonadherent dressings. Although expensive, some of these dressings can be reused for several days because of continual release of silver ions into the wound fluid.

**Polyurethane foam (e.g. Hydrasorb)**

Polyurethane foam absorbs exudates and keeps wounds moist. It is used in the early inflammatory stage and through the repair stage. Polyurethane foam can be used to deliver medications, but will not be absorptive if saturated with medicinal fluids. Bandages are usually changed daily. If exudation is minimal, it may be left on for more than a day.

**SELECTION OF BANDAGE MATERIALS**

Bandage material selection should be based on the stage of wound healing and character of the wound. Moisture increases the rate of healing of wounds; the wound itself should be kept moist; however, the adjacent skin edge should be kept dry.

For wounds with minimal debris or necrosis, use a smooth, nonadherent contact layer in the first 24-48 hours to avoid disturbing blood clots, and apply an absorptive second layer. A thin coating of antimicrobial dressing may be placed on the contact layer after debridement and flushing. The outer layer is applied with pressure if there is bleeding. Distribute pressure evenly throughout the bandage and leave the central toes exposed so they can be evaluated for swelling, excessive coolness, and abnormal color. Remove pressure bandages within 24-48 hours, or earlier if the animal is actively traumatizing the bandage.
If the wound needs debridement, adherent contact material such as wide mesh gauze is applied wet or dry to the wound surface. Dry gauze may be used as a contact layer when the wound produces large amounts of thin fluid and loose necrotic tissue or debris. The wider the mesh, the more debridement the wound undergoes. Gauze moistened with sterile saline or dilute antiseptic solution (0.05% chlorhexidine) is more effective at dissolving and removing thick wound drainage and debris. The bandages may need to be changed 2-3 times a day until the debris or excess lessens. Opioids may be necessary to limit pain and sedate the animals during bandage changes.

When the wound is beginning to “heal”, some drainage is still present and new granulation tissue is forming. Blood vessels in the granulation tissue give the wound a pink, cobblestone appearance. Use nonadherent semiocclusive bandages for the contact layer and cover with a thick, absorptive second layer.

Once new skin begins to form and drainage is decreased, the contact layer may be composed of semiocclusive or occlusive, nonadherent material. Petroleum based products should be avoided at this time since they slow new skin formation. The intermediate and outer layers should allow some wound mobility to allow wound contraction.

After 3 weeks the wound begins to mature. Bandages are usually not required during this stage but may help to protect the wound.

**SUMMARY OF WOUND MANAGEMENT FOR CHALLENGING WOUNDS**

**Punch biopsy for culture**

Swabs of wounds are not sufficient for culture in most cases because of local contamination. The wound surface should be prepped as for surgery and a punch biopsy of deep tissue obtained for culture. Antimicrobials will be selected based on sensitivity results. In some instances, resistant bacteria are best treated by topical antimicrobials. Animals with swelling, inflammation, redness, CBC changes, or other indicators of systemic effects should receive systemic antibiotics. Systemic antibiotics are also administered when healing does not progress with topical therapy.

**Moist wound healing:**

Moist wound healing is preferred over wet-to-dry techniques. Wet-to-dry bandages traumatize healthy tissue with debridement, are detrimental to cellular healing, disperse bacteria during bandage changes, leave fibers in the wound bed, and are painful to change.

**Topical antimicrobials**

High local antimicrobial concentrations will reduce bacterial numbers without causing systemic effects. For soupy infected wounds, use an antimicrobial impregnated gauze within the wound. For drier infected wounds, use a gauze or sponge impregnated with antibacterial ointment, silver sulfadiazine solution, or a silver/alginate/dextran combination. Once the infection has cleared, use a topical that keeps the wound slightly moist.

**Occlusive or semiocclusive dressings**

Occlusive and semiocclusive dressings promote moist wound healing. Incidence of infection rate is 63% lower in wounds treated with occlusive dressings because they serve as a barrier to bacteria, prevent dessication, lower oxygen tension, increase angiogenesis, and encourage white blood cell viability and activity.

**Appropriate bandages**

Tie over bandages help secure the dressing to the wound and reduce tension on wound edges. A sterile adhesive drape (e.g. Ioban) acts as an occlusive barrier; it works great for preventing strike through and retaining fluid.
WOUND COOKBOOK

Practices should consider developing a consistent plan for management of challenging wounds so that their staff can assist with client education and wound management. Of course, plans may need to be changed for financial reasons, and should be changed if the wound is not healing appropriately. An example of wound-based planning using dressings combined with tie-over bandage or Ioban adhesive drape is as follows:
- Soupy wounds: Kerlix AMD with Ioban covering; change daily.
- Nasty, nonsoupy wound: Honey on Kerlix AMD or gauze and Ioban covering; change daily.
- Necrotic wounds: Medical maggots. Change bandage 2-3 times daily.
- Infected nonsoupy wound: Algidex with Ioban covering; change every 2-7 days.
- Granulating wound: Telfa pad with triple antibiotic and VetWrap; change every 2-7 days.
- Superficial scrape: Adaptic or Telfa pad with thin layer of triple antibiotic.

Maggots

Like honey, maggot therapy has been used for thousands of years to treat wounds. Popularity of maggot therapy waned with introduction of antibiotics in the 1940’s but rose once more with the advent of antibiotic-resistant bacteria, such as MRSA. Maggot therapy is recognized by the US Food and Drug Administration and the UK Prescription Pricing Authority and thus can be officially prescribed. Sterile maggots are currently used in human patients for treatment of bed sores, leg ulcers, diabetic foot wounds, primary burns, osteomyelitis, and postoperative incisional infections. They are particularly useful for chronic wounds that have not responded to conventional therapy. Lucilia sericata, the green-bottle blowfly larvae, prefer necrotic over live tissue and therefore are well suited for clinical use. Since maggot secretions are effective against vancomycin-resistant MRSA, they are important complement to current wound therapy.

Maggot therapy provides three advantageous processes in wounds: wound debridement, acceleration of wound healing, and wound disinfection. Maggots clean necrotic tissue from a wound to an extent matched only by microsurgery. This removes material that would otherwise serve as a nidus for infection and inflammation. During debridement, the green-bottle fly larvae secrete proteolytic enzymes, including serine- and metallo-proteinases, which digest bacterial byproducts and necrotic tissue. These enzymes also breakdown components of the extracellular matrix within the wound, such as collagen and fibrin, which allows initiation of healing, and they disrupt biofilms that form around devices and necrotic tissue. Dissolution of these biofilms permits bactericidal activity by antimicrobials and the host’s immune system. Maggots also secrete ammonia, which increases wound pH and optimizes protease activity. Interestingly, maggot excretions that are incorporated into hydrogel wound dressings will also stimulate debridement and wound healing.

Although not reported in every study, maggot therapy can accelerate wound healing in some cases. Factors implicated in this effect include the physical movement of the maggots within the wound, excreted chemicals that increase wound pH, and stimulation of fibroblast growth. Maggots also modulate mammalian immune system by inhibiting migration, activation, and pro-inflammatory responses of certain white blood cells, which reduces tissue damage caused by these cells.

Maggots secrete or excrete a variety of substances with antimicrobial properties. Factors within these products are active against Gram-positive, Gram-negative, and methicillin-resistant bacteria; viruses; fungi; and even cancer cells. Some of the factors, such as alloferon, stimulate human natural killer lymphocytes in vitro and induce interferon production in vivo. Alloferon has been shown to be clinically active against herpes simplex and human papilloma viruses and is sold as the product Allomedin, which is used to treat cold sores, genital herpes, and gingivitis. Other factors, such as 5-S-GAD, generate hydrogen peroxide and are active against bacteria, inhibit angiogenesis in some cancers, protect retinal ganglial cells from apoptosis associated with glaucoma, and prevent cataract formation.
Several descriptive clinical studies of maggot therapy have been published in people. In one study, use of maggots in 30 patients with chronic wounds (arterial or venous stasis ulcers, diabetic or pressure ulcers, or chronic surgical wounds) resulted in decrease in wound bacterial counts and healing of 83.2% of the wounds. In a case series of 34 chronic leg wounds (>12 weeks duration), 85% of wounds healed, usually within 7-10 days. In another study of 70 patients with chronic leg wounds, 86% had 66% to 100% reduction in wound size. About a third of these patients perceived an increase in pain during the treatment period. Outcomes for larval therapy are worse in patients with greater wound depth, old age, or septic arthritis. A randomized, controlled comparisons of patients with venous or arterial ulcers treated with maggots or conventional hydrogel dressing found no difference in rate of healing; however, maggot treatment resulted in complete wound debridement 2.3 days faster than hydrogel treatment. Again, the patients receiving maggot therapy significantly reported higher pain scores.

In veterinary medicine, most reports of maggot therapy are either experimental or case series; controlled studies of large numbers of animals are still lacking. Maggot therapy has been used in horses for treatment of septic navicular bursitis, hoof infections, complicated laminitis, supraspinous bursitis, ulcers, cartilage necrosis, septic joints, and rattlesnake bites. In donkeys, sheep, dogs, cats, and rabbits, it has been used for wound debridement and infection control.

**Leeches**

Within their saliva, leeches secrete pure anti-coagulating substances hirudin and calin, along with hyaluronidase, which facilitates spread of the anticoagulant through the wound, and a variety of chemicals that stimulate vasodilation and prolong bleeding. Other secretions inhibit proteolysis, dissolve fibrin, and reduce or prevent inflammation. Plastic surgeons use medicinal leeches to salvage flaps, microvascular free-tissue flaps, digit reimplantations, and facial reconstruction sites that suffer from postoperative venous congestion. Leeches have also been used to treat osteoarthritis, tenosynovitis, sialadenitis, and other inflammatory conditions.

The site is prepped with warm, heparinized saline to encourage vasodilation. Alcohol and iodine may potentially interfere with attachment. A barrier, such as a moist gauze with a hole in it, is placed over the wound to limit leech migration. The leeches are carefully placed on the wound and left there until they are fully distended, usually 30 to 60 minutes. The leeches will detach themselves when full; alternatively, common salt can be sprinkled on their heads. Forcible removal is avoided because it may cause regurgitation. If the wound bleeds persistently, place pressure over the site. Leeches are disposed of as clinical waste.

Potential complications associated with leech application include infection, often evidenced by local cellulitis or abscess formation. In people, the incidence of leech associated infection ranges from 2 to 20% and can result in extensive tissue loss and sepsis. The most common pathogen is Aeromonas, a resident flora of leeches. Aeromonas produces beta-lactamases, so first generation cephalosporins and penicillins are likely to be ineffective. Options for prophylactic treatment include fluoroquinolones or aminoglycosides. Sites should not be prepped with alcohol or hypertonic saline, either of which could cause the leech to regurgitate into the wound and possibly infect the site. Leeches may also result in persistent bleeding, anemia, and local or systemic allergic reactions. Leeches may also migrate (e.g., under flaps, into airways) and therefore should be watched while they are in place. Leeches have the potential to transmit viral infections and should therefore not be reused in people. Most patients require multiple treatments to reduce venous congestion; since leeches can consume 10 times their weight in blood, transfusions may be necessary over the course of the treatment.

As with other adjunctive therapies, controlled clinical trials for leech therapy in people are lacking. In one study, leech therapy resulted in survival of 8 free tissue transfers considered unsalvageable; most patients required 6 or 7 days of treatment with 215 leeches used per patient. At least half of patients receiving leech therapy for chronic sialadenitis/sialadenosis. In 113 patients with advanced osteoarthritis of the stifle, leech application resulted in statistically significant reduction of pain scores, long term reduction in joint stiffness, and improved mobility. In another randomized control trial, a single course of leech therapy effective relieved pain and improved function and quality of life for
at least 2 months in women with carpometacarpal thumb osteoarthritis. The reason for the response in patients with osteoarthritis is not known.

Leech therapy has anecdotally been used in veterinary medicine for treatment of congested flaps, grafts, penis, and paws; drainage of auricular hematomas; treatment of cats with saddle thrombus; relief of pressure or pain in horses with tenosynovitis, tendinitis, and acute laminitis; and reduction of red cells in cats with polycythemia vera. Leech sellers claim it treats joint malformation, arthritis, disc disease, neuritis, muscle stiffness, eczema, abscesses, mastitis, and lymphagitis. All of these claims are unproven in animals.

**Negative Pressure Wound Therapy**

Open wound management is frequently used for treatment of wounds with extensive tissue injury or infection or those that are chronic and nonhealing. Negative pressure wound therapy stimulates wound healing by a variety of mechanisms, including removal of fluid, reduction of edema, and stimulation of granulation tissue formation. One major advantage of NPWT is the ability to delay bandage changes to every 2 to 3 days. NPWT has also been used to enhance skin graft attachment, decrease seroma formation after primary wound closure, and treat peritonitis and myofascial compartment syndrome. NPWT should not be used in sites that have neoplasia, active bleeding, or exposed vessels or in patients with coagulopathies.

In a prospective, controlled, experimental study of dogs with open wounds NPWT stimulated early appearance of high quality granulation tissue but delayed wound contraction and epithelialization and did not enhance bacterial clearance from the wounds. NPWT results in extensive loss of fluid and protein, and a large amount of bacteria is trapped in the dressing, so it is important to keep the negative pressure working. In some experimental studies it provides no additional benefits over traditional bandages. We find it works well to stimulate wound healing in wounds that are not dry or necrotic. Dry, necrotic wounds are better treated with medical maggots, while wounds with a large amount of debris are better treated with honey bandages changed daily or twice daily or with surgical debridement.

**Laser Therapy**

Low level laser therapy (LLLT) affects various aspects of the healing process, including minimizing inflammation, formation of edema, improvement of skin regeneration and enhancement of collagen synthesis. Like HBOT and other modalities, there are few randomized, blinded, controlled studies in companion animals and people. Additionally, studies report a variety of dose ranges, wavelengths, and duration and frequency of treatment. In general doses ranging from 3 to 6 J/cm2 appear to be more effective in promoting wound healing, and doses 10 above J/cm2 are associated with deleterious effects. The wavelengths ranging from 632.8 to 1000 nm seem to provide more satisfactory results in the wound healing process. Experimentally pulsed LLLT with 11.7 J/cm(2)/890 nm of a deep second-degree burn model in rat significantly increased the rate of wound closure compared with control burns. In mice, reepithelialization of wounds being treated with LLLT was the same as those in mice receiving an NSAID. In a rat operative wound model (incisional healing), LLLT with a He-Ne laser was found to promote the healing of operative wounds when used at 17.0 mW setting of 15 seconds a day with a frequency of every other day. In horses and mice, LLLT had no significant effect on second intention healing of full thickness wounds. In dogs, healing of full thickness wounds was delayed with LLLT treatment. In a rat Achilles tendon blunt injury model, LLLT resulted in increased edema of the tendon. In another rat model, LLLT reduced the number of bacteria in the wound. In a dog model of palatal surgery, LLLT had no effect on palatal healing.

**Lavage Systems**

Interestingly, in people infection rates of wounds lavaged with tap water are similar to those lavaged with sterile saline. So, a cheap lavage system is a hose or sprayer. Specific lavage systems are useful for cleaning wounds focally but they must be used properly. Wound irrigation is most effective when performed at pressures between 5 and 10 psi; pressures above 10 PSI cause tissue trauma. Benefits of pulsed lavage over a bulb syringe or whirlpool bath are the need for less fluid.
Previously clinicians used a 35 cc syringe with an 18 gauge needle for flushing, but that actually generates pressures of 25-40 PSI. A more effective method is to put a bag of fluids in a pressure cuff, attach a fluid set and needle (18 or 20 gauge), and pump up the pressure cuff to 300 mmHg to drive fluid through the needle. DeRoyal has a JetOx unit that uses pressurized oxygen from an anesthesia canister to produce an aerated lavage. A wound can be easily cleaned with 50 mls of saline using this system. The PSI depends on the oxygen flow: 11 L/min will provide 6 PSI, and 13 L/min will provide 9 PSI.

TENSION RELIEVING TECHNIQUES FOR WOUNDS
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Tension on wound will delay healing and increase the risk of infection and dehiscence. Techniques for reducing wound tension include undermining, stent sutures, pretensioning sutures, walking sutures, skin expanders, relaxing incisions, Z-plasty, and tie-over bandages. In areas where tension cannot be easily relieved, other closure methods such as flaps and grafts should be considered.

Pretensioning sutures
These sutures are basically intradermal or full thickness skin closures that have not been initially tightened. They are used postoperatively for gradual closure of open wounds or intraoperatively during placement of multiple relaxing incisions. If a skin suture is used, large gauge (e.g. 0), nonabsorbable monofilament (e.g., nylon or polypropylene) is placed in a simple continuous pattern full thickness (big, wide bites) through the skin edge. Each day, the suture is elevated with a hemostat and tightened; a fishing sinker is used to keep it tightened. In about 3 days, the skin edges usually meet each other. At that point, the animal is fully anesthetized, and the suture is removed and replaced with appropriate subcutaneous and skin closures.

For an intradermal closure, a continuous intradermal pattern of monofilament absorbable material (usually 3-0) is placed; instead of knots, however, each end of the suture is passed through a button and secured with a lead sinker or some other fastener. The suture can be tightened a little each day and a new sinker placed so that the wound edges are eventually apposed.

Tie-over bandages
Open wounds may take weeks to months to heal by second intention, depending on wound size, infection, blood supply, and patient's health. In some patients, tie-over bandages are used until the wound is no longer infected and can be closed without tension. Tie-over bandages provide a method for stretching and lengthening the local skin to facilitate wound closure. The amount of skin relaxation obtained depends on the location of the wound and the local skin character. Maximal stretch is usually noted within 2 to 3 days after placement of tension on the skin. Tie-over bandages are also useful for securing bandages in areas that are difficult to incorporate into a regular bandage, or to reduce tension on primarily closed wounds (e.g. mast cell tumors).

For maximal stretch, local skin should be undermined around the wound before placement of suture loops. Individual suture loops of large gauge monofilament nylon are placed at least 2-3 cm away from the skin edge. Spacing of loops depends on the size of the wound (usually 2-3 cm apart; more on big wounds); extra loops should be placed in case loops are accidentally cut or pulled out. Usually each wound will have between 6 and 12 loops. Nonabsorbable 0 monofilament material is often used to make suture loops for tie-over bandages. This type of suture is difficult to tie because it tends to hitch. If hitching is a problem, the suture loop can be formed over the narrow end of a syringe case,
which is slid out of the loop once the final knots are secured. Because suture loops may pull through skin or be accidentally cut during bandage changes, extra loops should be placed.

With a tie-over bandage, the contact layer can be cut to shape so that it remains within wound bed. Frequency of bandage changes depends on the amount of wound drainage. If skin stretching is desired, umbilical tape laces on tie-over bandages should be tied in a bow or secured with an adjustable fastener. The laces are tightened 2 to 3 times a day to gradually increase tension on the skin. Most animals require sedation and analgesics during bandages changes for the first 3 to 5 days. If wounds are effusive or the laces are tight, the lacing material usually must be cut to change the bandage.

Complications include suture loop failure or skin necrosis. Suture loops may pull out if they are placed too close to the edge of the tissues. Loops can turn into slip knots under tension. If the knots closest to the skin hitch, the underlying skin may necrose when the laces are tightened. Skin may also necrose if placed under too much tension.

**Stents**

Stent sutures incorporate an object within the suture to spread tension over a larger area. Common stents include buttons at the commissure of the lips after cheiloplasty, pieces of red rubber tubing on either side of incision lines, or roll gauze of the top of an incision. Incorporation of these objects requires placement of mattress sutures. Stent sutures can did into swollen skin and cause further damage, so they are often removed within 2-3 days of placement.

**BASIC PRINCIPLES OF WOUND RECONSTRUCTION**

The area around the recipient site should be evaluated for skin laxity, which will determine whether the donor site can be closed once the flap has been elevated and moved. The skin adjacent to the defect is picked up with thumb and forefingers; if a ridge of skin can be created, then the donor site can most likely be closed. If there is tension on the wound, alternative methods of closure must be considered, since tension on wound will delay healing and increase the risk of infection and dehiscence.

**Basic flaps**

Before the animal undergoes a final prep for surgery, template of the flap can be cut from cloth, manually held in place at the proposed flap base, and rotated to recipient site to estimate the amount of coverage available. Animals should be prepped widely and positioned on the surgery table so extra skin is pulled up near the surgery site.

Because blood supply varies, a specific ratio of flap length to width cannot be determined. In general, flaps should be just long enough to cover the wound without tension and have a base that is slightly wider than the remaining flap width. Flaps that are too wide, however, lose mobility, so clinical judgment is important for determining flap size. Occasionally a flap with a length at least twice the width will survive if the blood supply is adequate. Flaps must be handled gently to prevent damage to the subdermal plexus.

Local skin flaps (“random pedicle flaps”) rely on the blood supply within the subdermal plexus, the extent of which varies with body location. Flaps can either be advanced so the direction of the skin is relatively unchanged, or they can be pivoted up to 90˚ to cover an adjacent defect. Advancement or “sliding” flaps are easiest to perform because they do not produce a second wound. Flaps can be advanced unilaterally to produce a “U” shaped closure or bilaterally to produce an “H” shaped closure. Alternatively, a relaxing incision can be made parallel to the long axis of the wound to produce a bipedicle advancement flap that is slid across the wound. The resultant wound at the donor site is either closed primarily or left to granulate in. Because closure of wounds with advancement flaps depend on stretching the skin, local structures such as eyelids and lips can be distorted with wound closure. A rotational flap, which pivots local skin into the region, will reduce this distortion. Transposition flaps are the most common type of rotational flap. Rectangular flaps of skin can be rotated up to 90˚ to close an
adjacent defect. Triangular shaped wound beds can also be closed with unilateral or bilateral semicircular rotational flaps. Although semicircular rotational flaps do not produce a secondary defect, they are used less commonly than transposition and advancement flaps.

In general, mean skin flap survival for random pedicle flaps is 83% to 89% of the flap length. Flap necrosis is more likely when flaps are excessively long or narrow; experience tension or excessive motion; or are traumatized during tissue elevation, surgical manipulation, or after surgery. Necrotic portions of the flap should be resected and the remaining wound allowed to heal by second intention or managed by delayed primary closure with additional flaps or grafts. Other complications include dehiscence, infection, hematoma formation, and distortion of local tissues. Complication rates are higher in patients that receive radiation therapy, particularly when it is administered prior to wound reconstruction.

**Axial pattern flaps**

Axial pattern flaps are developed from skin that contains a direct cutaneous artery and vein. Because these flaps have better perfusion than random pedicle flaps, the transposed skin has a much better chance of surviving. Axial pattern flaps are often used to close extensive defects from tumor removal or trauma. Most flaps are rectangular; however, size and shape depend on the species of animal and the extent of the blood supply. Axial pattern flaps are usually left attached to local skin at their base; however, they can be freed on all sides as an island of tissue to make rotation easier.

The most common axial pattern flap is the caudal superficial epigastric axial pattern flap. This flap can be used for reconstruction of wounds to the upper rear legs, lateral abdominal wall, and perineum. In cats and short legged dogs, these flaps can often reach the tarsus. Development of a caudal superficial epigastric axial pattern flap is similar to unilateral chain mastectomy, except that the major blood supply is left intact caudally. Mammary glands remain functional after flap rotation. On animals with chronic wounds, axial pattern flaps can be performed once the recipient site is healthy and free of infection, as confirmed with culture and sensitivity of a punch biopsy from the wound bed. In trauma patients, presence of flow within caudal superficial epigastric vessels should be verified with a Doppler flow probe or color flow Doppler ultrasonographic imaging. In most animals, the donor site has enough laxity to allow for immediate primary closure. Once incised, however, the surrounding skin retracts, making the wound at the donor site appear much larger. Animals should be clipped widely around the donor site and positioned and prepped so that the surgeon can take full advantage of lateral thoracic, abdominal, and flank skin for closure.

Caudal superficial epigastric flaps in female dogs can extend to a point midway between the first and second mammary gland. In some cats and male dogs, necrosis may occur if the flap extends to the second nipple. To determine the appropriate flap length for wound coverage, a pattern of the flap can be constructed from sterile paper, gauze, pads, or drapes, manually secured to the proposed flap base, and rotated to recipient site. If the wound is on the rear leg, flap length and wound coverage should be evaluated with the leg in extension. Before the flap is developed, the recipient site should be debrided as needed. Thin epithelial edges are excised, and the wound is covered with moistened gauze sponges until the flap is elevated. Before the flap is incised, the skin at the donor site should be grasped, lifted, and released to make sure it is normally positioned.

Flaps are elevated below the mammary vessels to preserve the blood supply. Dissection continues caudally to the level of the caudal superficial epigastric artery and vein. The caudal superficial epigastric artery and vein are branches external pudendal vessels, which exits from the superficial inguinal ring just medial to the last nipple and 2 to 4 cm lateral to the midline. Elevated flaps will appear narrower and shorter from contraction. Once elevated, flaps can be rotated up to 180°; however, sharp turns or kinks in the flap base can cause lymphatic or vascular obstruction and subsequent swelling and necrosis. If further mobility is needed, the flap can be turned into an “island” by incising the skin across the base. The subcutaneous tissues are left intact to prevent damage to the caudal superficial epigastric artery and vein. If the recipient bed is not directly adjacent to the donor site, a bridging incision is made between the donor and recipient beds. After elevating the surrounding tissues, the flap is laid within the new gap and over the recipient bed. Although the subcutaneous
tissues along the flap edge can be apposed to the recipient site, the center of the flap should not be tacked down to the recipient bed, since this could damage blood supply. Instead, a continuous suction drain should be placed to reduce dead space.

Other flaps that commonly have successful outcomes include the superficial temporal and caudal auricular flaps. These flaps have great collateral blood supply and are very useful for reconstruction of the head and neck. Thoracodorsal and omocervical flaps can be used for front limb reconstruction, but are not always as hardy as they are described in the literature. Flank and axillary fold flaps sometimes have a direct cutaneous vessel and therefore may be used similar to axillary pattern flaps.