Animals that present with an acute abdomen may have a variety of underlying causes. Prompt diagnosis and therapy are key to reducing mortality and morbidity. This lecture used a case-based approach to detail management of animals presenting with an acute abdomen.

**UROABDOMEN**

Immediate surgery is contraindicated in animals with uroabdomen that are hyperkalemic or uremic. They should first be treated medically to normalize electrolytes and acid-base, as well as decrease circulating nitrogenous waste products. Intravenous fluids should be given and abdominal drainage performed. Penrose drains or a peritoneal dialysis catheter (preferred because it can be made into a closed system) can be placed in the ventral abdomen under local anesthesia (sedate if necessary) to allow drainage for 6 to 12 hours. This will stabilize most animals with previously normal renal function.

When urine leaks into the abdominal cavity, some nitrogenous waste products and electrolytes are reabsorbed across the peritoneal membrane and reenter the circulation. Whether molecules are reabsorbed depends on their size. Urea rapidly equilibrates across the peritoneal surface while some larger molecules (e.g., creatinine) cannot pass back into the bloodstream and remain concentrated in the abdominal fluid. Abdominal fluid creatinine concentrations must substantially exceed serum concentrations to diagnose uroabdomen. Because urea rapidly equilibrates across the peritoneum, BUN may be approximately the same in both abdominal fluid and serum, regardless of the cause of the abdominal effusion. Potassium may also help diagnose uroabdomen. A potassium abdominal fluid to blood ratio of greater than 1.4 to 1 is definitive for uroabdomen.

**Medical Management**

If the animal is not hyperkalemic or azotemic (e.g., uroabdomen is diagnosed within 12 to 18 hours after rupture), it should be rehydrated with 0.9% saline and immediate surgical repair should be considered. Occasionally, concurrent trauma (e.g., traumatic myocarditis, pulmonary contusions) will delay surgery. In such patients, abdominal drainage and/or urinary diversion (i.e., urethral catheter and/or tube cystostomy) may be necessary until the animal is stable. With delayed diagnosis, correction of electrolytes, hydration, and acid-base balance should be performed before surgery. Antibiotics may be administered based on culture results or upon bacterial morphology if a urinary tract infection is present, or prophylactically if abdominal drains are placed.
Surgical Treatment

Urethral trauma may be repaired by primary anastomosis (immediate or delayed) or the urethra may be allowed to heal over a urinary catheter if it is not completely transected. Ureteral rupture may be repaired by anastomosis or reimplantation into the bladder, depending on location of the damage. Bladder rupture generally occurs near the apex. Although small ruptures may heal if the bladder is kept decompressed, surgical exploration and repair are indicated in most patients. The entire abdomen should be explored to determine the reason for rupture and/or identify concurrent trauma. If bladder rupture is secondary to severe cystitis, tumor, or obstruction, the bladder may be extremely friable or large areas may be necrotic, making excision and primary closure of the rent difficult. In such cases, prolonged urinary diversion may be beneficial. If cystitis or tumor is present, a biopsy of the bladder mucosa should be submitted for culture and histologic examination. In animals with rupture due to obstruction from calculi, the urethra should be carefully checked for calculi and its patency verified before repairing the bladder defect.

PERITONITIS

Secondary generalized peritonitis is the predominant form of peritonitis in dogs and is usually caused by bacteria. Primary generalized peritonitis occurs in cats associated with feline infectious peritonitis. Generalized peritonitis may result from intestinal or gall-bladder perforation, rupture, or necrosis (e.g., gastric or intestinal foreign bodies, intussusception, mesenteric avulsion, gastric dilatation-volvulus, or necrotizing cholecystitis), pancreatic abscessation, prostatic abscesses, or foreign body penetration.

Medical Management

The goals of management of animals with peritonitis are to treat the cause of the contamination, resolve the infection, and restore normal fluid and electrolyte balances. Food should be withheld if the animal is vomiting. Fluid replacement therapy should be initiated as soon as possible, particularly if the animal is dehydrated or appears shocky (up to 90 ml/kg IV, based on the animal’s condition). Hypokalemia and hyponatremia may be present and require intravenous supplementation. Hypoglycemia is common if the animal has septic shock (systemic inflammatory response syndrome) and glucose may need to be added to the fluids (i.e., 2.5 - 5% dextrose). Standard shock therapy (i.e., fluid replacement, antibiotics, ± soluble corticosteroids) should be initiated. If severe metabolic acidosis is present, bicarbonate therapy may be indicated.

Broad spectrum antibiotic therapy should be initiated as soon as the diagnosis is made. Ampicillin plus enrofloxacin is an effective combination against most bacteria responsible for peritonitis in dogs. However, amikacin plus clindamycin or amikacin plus metronidazole may be necessary if anaerobic infection is present. A second-generation cephalosporin (e.g., cefoxitin sodium may also be used if gram-negative plus anaerobic infection is suspected. If renal compromise is present in an animal with a resistant bacterial infection, imipenem may be considered. Initial antibiotic therapy should be altered based on results of aerobic and anaerobic culture results of lavage fluid (see below) or cultures obtained at surgery.
Low-dose heparin (50-100 units/kg; SC; BID) increases survival and significantly reduces abscess formation in experimental peritonitis. The inflammatory process in peritonitis is associated with an outpouring of fibrous exudate which causes intraabdominal loculation of bacteria. The loculated bacteria are protected from host defense mechanisms and antibiotics which may not be able to penetrate the fibrin clots. Although the exact mechanism of its beneficial effect is still unknown, there does not appear to be any doubt that heparin is indicated in patients with severe peritonitis. Heparin may also be incubated with plasma and given to animals in DIC (incubate 5 - 10 units/kg heparin with 1 unit fresh plasma for 30 minutes; 10 ml/kg IV).

**Surgical Treatment**

Abdominocentesis is the percutaneous removal of fluid from the abdominal cavity, usually for diagnostic purposes, although it may occasionally be therapeutic. Indications include shock without apparent cause, undiagnosed disease with signs involving the abdominal cavity, suspicion of postoperative GI dehiscence, blunt or penetrating abdominal injuries (i.e., gunshot wounds, dog-bites, automobile accidents), and undiagnosed abdominal pain. A multi-fenestrated catheter should be used to enhance fluid collection. Physical and radiographic examinations should precede abdominocentesis to rule out instances where it may not be safe and to guide needle placement. Four-quadrant paracentesis may be performed if simple abdominocentesis is not successful in retrieving fluid. It is similar to simple abdominocentesis except that multiple abdominal sites are assessed by dividing the abdomen into four quadrants through the umbilicus and tapping each of these four areas. Diagnostic peritoneal lavage should be performed in animals with suspected peritonitis if the above methods are unsuccessful in obtaining fluid for analysis.

Exploratory surgery is indicated when the cause of peritonitis cannot be determined or when bowel rupture, intestinal obstruction (e.g., bowel incarceration, neoplasia), or mesenteric avulsion is suspected. Serosal patching and plication are techniques which decrease the incidence of intestinal leakage, dehiscence, or repeated intussusception. Animals requiring surgery that have peritonitis secondary to intestinal trauma (disruption of mesenteric blood supply, bowel perforation, chronic intussusception, or foreign body) are frequently hypoproteinemic. The role that protein levels play in healing of intestinal incisions is not well understood. However, most surgeons are concerned that hypoproteinemic patients may not heal as quickly as patients with normal protein levels, despite one study that showed similar complication rates between these group for animals undergoing intestinal surgery (Harvey, 1990). Most experimental evidence has shown that retardation of wound healing is not seen with moderate protein-depletion, but only with severe deficiencies (<1.5 - 2 g/dl).

Although whether or not one should lavage the abdominal cavity of animals with peritonitis is controversial, lavage is generally indicated with diffuse peritonitis. Lavage should be done with care in animals with localized peritonitis to prevent causing diffuse dissemination of infection. When lavage is performed, as much of the fluid as possible should be removed.
because fluid inhibits the body's ability to fight off infection, probably by inhibiting neutrophil function. Historically, many different agents have been added to lavage fluids, especially antiseptics and antibiotics. Povidone-iodine is the most widely added antiseptic; however, its use may be contraindicated in established peritonitis. Furthermore, no beneficial effect of this agent has been shown in repeated experimental and clinical trials. Although a great many antibiotics have been added to lavage fluids over the years, there is no substantial evidence that their addition is of any benefit to patients who are being treated with appropriate systemic antibiotics. Warmed sterile saline is the most appropriate lavage fluid.

Open abdominal drainage (OAD) is a useful technique for managing animals with peritonitis. Reported advantages are improvement in the patient's metabolic condition secondary to improved drainage, reduced abdominal adhesion and abscess formation, and access for repeated inspection and exploration of the abdomen. With this technique, the abdomen is left open and sterile wraps are placed around the wound. The frequency of the wrap changes is dependent upon the amount of fluid being drained and the amount of external soiling. Experimentally, dogs with peritonitis treated by OAD recover faster than those treated with closed abdomens. Peritoneal bacterial numbers are significantly less in OAD dogs when compared with control dogs and at necropsy there are fewer abdominal adhesions and less peritoneal fluid in the former group. Complications of open abdominal drainage include persistent fluid loss, hypoalbuminemia, weight loss, adhesions of abdominal viscera to the bandage, and contamination of the peritoneal cavity with cutaneous organisms.

After completing the abdominal procedure, leave a portion of the abdominal incision (usually the most dependent portion) open to drain. Close the cranial and caudal aspects of the incision with monofilament suture using a continuous suture pattern. Place a sterile laparotomy pad over the opening, then place a sterile wrap over the laparotomy pad. Change the wrap at least twice daily initially with the animal standing (sedation is seldom necessary). Break down adhesions to the incision that may interfere with drainage. Abdominal lavage may be attempted, but is seldom necessary. Place a diaper over the wrap to decrease contamination from urine. Assess the fluid daily for bacterial numbers and cell morphology. When bacterial numbers have decreased and normal neutrophil morphology is present (non-degenerative), close the incision (generally in 3 to 5 days). If the opening is small it may be left to heal by second intention.

**SPLENIC NEOPLASIA**

The spleen is composed of a variety of tissues, and splenic neoplasia may arise from blood vessels, lymphoid tissues, smooth muscle, or the connective tissue that makes up the fibrous stroma. The most common tumor in dogs is HSA. Other malignant and benign neoplasms may also occur. The most frequently recognized nonneoplastic lesions of the spleen are nodular hyperplasia, hemangioma, and hematoma.

Canine splenic HSA is more common than all other types of malignant splenic tumors; it accounts for approximately half of all splenic malignancies identified. Because HSA arise from blood vessels, they may form in several different sites in the body (e.g., spleen, right
atrium, subcutaneous tissues, and liver). As many as 25% of dogs with splenic HSA may have concurrent right atrial HSA. Splenic HSAs are aggressive tumors that frequently metastasize to the liver, omentum, mesentery, and brain. A majority of dogs with HSA have gross evidence of metastatic disease on initial presentation.

Splenic hematomas vary in size and are encapsulated, blood- and fibrin-filled masses that often are grossly indistinguishable from HSA. Histologically, the cavities are surrounded by congestion, fibrosis, and areas of necrosis. They may result from trauma, may occur spontaneously, or may develop secondary to other diseases (e.g., nodular hyperplasia). Hemangiomas and HSA may be difficult to distinguish histologically, but because the prognosis for these lesions is very different (see below), it is important that they be accurately differentiated. Splenic masses with evidence of malignant neoplastic endothelial cell proliferation can be easily identified as HSA. However, multiple sections of a malignant mass may be studied without obvious malignancy being seen. More important, proliferation of plump endothelial cells that resemble neoplastic endothelium but do not have evidence of mitotic activity may be misdiagnosed as HSA. Splenic hematoma and hemangioma account for 20% to 34% of splenic masses, whereas HSA accounts for 10% to 20% of all splenic samples submitted to veterinary pathology laboratories. However, this 10 to 20% underestimates the true incidence of HSA in dogs with large splenic masses because many such masses are not submitted for pathologic examination, especially if apparent metastasis is seen at surgery. Hyperplastic nodules are an even more common finding at necropsy than HSA.

**Diagnosis**

Total splenectomy is most commonly performed in animals with splenic neoplasia, torsion (stomach or spleen), or severe trauma. Splenectomy has previously been advocated for immune-mediated hematologic disorders refractory to medical therapy (e.g., thrombocytopenia or hemolytic anemia); however, proper use of immunosuppressive drugs and corticosteroids has decreased the need for splenectomy. However, splenectomy may be used if drug therapy is unsuccessful or unacceptable. Although life-threatening sepsis has been associated with total splenectomy in humans, this has not been recognized in dogs.
Thoracoscopy is rapidly becoming a primary means of treating surgical disease of the chest. The procedure provides improved lighting and magnification within the chest and allows for exploration, collection of samples for histopathology and culture, and has been expanded into many modes of treatment of different disease states. The approach with thoracoscopy mimics that used with open thoracotomy and should only be attempted in cases in which the surgeon is comfortable performing the procedure via open thoracotomy. Why? Because if you are unable to visualize the thorax well (often due to extensive adhesions), you cannot achieve your goal due to poor visualization (which may be due to significant adipose, hemorrhage, or adhesions), or significant intraoperative complications occur (hemorrhage) - you convert to open thoracotomy. So the ability to perform lateral thoracotomy or median sternotomy must 1) be prepared for when clipping and scrubbing the patient 2) the equipment must be rapidly available in the operative suite 3) you must be comfortable performing the thoracotomy (sometimes in rapid fashion). Knowledge of thoracic anatomy should be stressed, as you will not have as wide a view to utilize adjacencies during thoracoscopy.

The main reason for changing away from thoracotomy to thoracoscopy is for decreased patient morbidity and hospitalization time. There are certainly drawbacks – the equipment is expensive, the same level of aftercare is required (you still need a thoracostomy tube), and there is a significant learning curve associated with endoscopic surgery. With these in mind, thoracoscopic pericardectomy was one of the earliest endoscopic surgical procedures that proved the benefits to our patients. Thoracoscopic pericardectomy is rapidly gaining use and is the standard of care in some institutions, such as the University of Georgia.

Anesthesia is always a concern with thoracic procedures. Ventilation must be supplied to the patient with open thoracotomy, which is also true of thoroscopic procedures. The thoracic wall is rigid, but the lungs fill the majority of the space. With open surgery we can retract them, rotate them, and even pack them off to gain space. Similar maneuvers can be done thoracoscopically, but it is easier to minimize them by decreasing their volume, usually by at least 50% to allow visualization. The ventilator rate should likewise be at least doubled in an effort to maintain gas exchange. In altering the ventilator parameters, known changes occur. PaO2 increases and PaCO2 decreases due to shunt fraction increasing. Using PEEP at a low level may normalize the situation effectively; however, research experiments determining the affects of thoracoscopy showed minimally significant changes that would not likely be clinical in the normal dogs studied. Patients undergoing thoracoscopy usually aren’t normal!

The indications for thoracoscopy are the same as those for open thoracotomy: pleural effusion of undiagnosed origin, spontaneous pneumothorax, pyothorax, chylothorax,
undified pulmonary disease, pulmonary neoplasia, intrathoracic mass lesions, and PRAA. Most clinicians start any form of endoscopic application in their practice with diagnostic techniques. The same is true for thoracoscopy. You can sample nearly everything safely under visual guidance. Lymph node (sternal or hilar), lung, pleura, pericardium, mediastinum, and mass lesions can be visualized and sampled in a manner similar to that of open surgery. Cup biopsy forceps can be used or graspers and dissectors for excisional biopsy. Lung can be sampled with a guillotine technique similar to that used for the liver, keep in mind that only the peripheral lung can be sampled that way. When exploring for undiagnosed pleural effusion, be certain to take MANY samples. Any abnormality should be sampled. Normal pleural and mediastinum included. Even small abnormalities should not be omitted; the diagnosis of mesothelioma is not easily obtained. Expansion of sampling techniques can lead you to removal of larger pieces, for pyothorax, that is the mediastinum.

For the heart – pericardectomy.

One comfortable with exploration and diagnostic sampling, consider techniques that have been developed with thoracoscopic assistance (similar to laparoscopic assisted gastropexy, tube placement, stone retrieval, etc.). Thoracoscopy can be used to remove discrete, peripheral lung masses.

First explore the entire chest and sample the hilar lymph nodes. If no other pulmonary nodules are encountered, extend one port site over the affected lung and exteriorize if for removal using standard open technique (TA stapling). Test the seal and close the sites routinely. The main benefit to assisted lobectomy is the removal of lesions without rib retraction. Compression of the intercostal nerves against the ribs and tearing of the musculature are avoided, hopefully decreasing morbidity of the procedure. Exploration for spontaneous pneumothorax is similar. The entire chest should be evaluated, and all abnormal segments of lung removed. I commonly perform multiple partial pneumolobectomies for this condition and hopefully can avoid rib retraction. There is fear of missing lesions with this condition – thoracoscopy is quite versatile – you can first evaluate the lung with the patient in dorsal recumbency, and then change to sternal recumbency for that last bit of dorsal lung!

I used to believe that there were limitations to what could be done with therapeutic thoracoscopy, but the development of vessel sealers and expanded endoscopic equipment has helped to maintain its use in veterinary medicine. We regularly perform ligation of the ligamentum arteriosum for PRAA cases thoracoscopically. I also first evaluate the region with esophagoscopy in hopes of avoiding the more rare forms of vascular ring anomaly. The ligamentum can be identified, clipped or sealed, and the remaining fibrous bands dissected easily – the esophageal musculature is easy to see once the bands are removed. We do not perform PDA ligation endoscopically, as there is not a well-defined technique of safe dissection, and currently available endoscopic clips or open clips may not be uniformly large enough.

Lastly – much surgery can be performed endoscopically – we currently do endoscopic thoracic duct ligation, pericardectomy, and cisterna chyli ablation for our cases of chylothorax. Our outcomes are similar to that of open surgery, and we can still turn things
blue with dye injected minimally invasively. Thoracoscopic complete pneumolobectomy is likely the penultimate of thoracoscopic procedures done – it requires the most complex anesthesia (one-lung ventilation) and large, but effective endoscopic stapling devices.
LARYNGEAL PARALYSIS

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Laryngeal paralysis is most often related to no primary disease, but lesions from the myelencephalon to the cranial mediastinum and within the neck should be ruled out. “Idiopathic” laryngeal paralysis is most often diagnosed in large breed dogs over 9 y of age (the exception perhaps being the Brittany Spaniel). The condition is not idiopathic, but has been proven to be part of a polyneuropathy that may also affect the esophagus. The most common clinical signs are those of increased ventilatory noise, exercise intolerance, and inspiratory dyspnea. The condition is progressive and concurrent signs may include coughing and gagging, often associated with drinking. A change in voice is often retrospectively acknowledged by the owner. The choice to pursue surgery is a personal one and should be made upon complete discussion of the condition, the chosen procedure, and complications of the surgery.

Many conditions should be ruled out, including abnormalities of the CNS, congenital polyneuropathy, cervical trauma (beware of concurrent cervical fracture), neoplasia, thymoma, and myasthenia gravis. Polyneuropathy in young dogs (Rottweiler, bouvier des Flandres, bull terrier, Dalmatian, white German Shepherd, and Siberian husky) may have significant neurologic signs including hyporeflexia, decreased postural reactions, and muscle atrophy. Care must be taken to completely evaluate esophageal function in these patients. Dogs with myelencephalic lesions should also show decreased conscious proprioception and postural reactions, hyperreflexia, and may have abnormal swallowing and gag reflexes. Avoid glottic enlargement procedures in any case that shows significant esophageal dysfunction or regurgitation.

The workup for “idiopathic” cases includes CBC, biochemical profile, and urinalysis for detection of concurrent conditions in these older patients. A complete neurologic examination should be done to establish the “starting point” of the polyneuropathy. Progression of the peripheral signs cannot be predicted, but approximately 10% may develop significant deficits and even tetraparesis. EVERY dog with suspect laryngeal paralysis should have thoracic radiographs made. Evaluate the esophagus, heart, diaphragm, and lungs for megaesophagus, cardiomegaly, hiatal hernia or diaphragmatic hernia, and pneumonia. Avoid elective surgery for laryngeal paralysis in dogs with pneumonia unless it is really necessary, and then rapid temporary tracheostomy should alleviate the signs and allow for medical management of pneumonia.

Even dogs presenting for an elective appointment to assess laryngeal function can present as an emergency. Environmental temperature and excitement may change a routine appointment into an emergency. Breaking the cycle of dyspnea, increased breathing efforts (and therefore muscular activity and metabolism), increased body temperature and the
resultant increased oxygen demand can be achieved at many points. Supplemental oxygen via mask, flow by, or oxygen cage may break the cycle. Place an IV catheter if oxygen is not successful and administer fluids as necessary based on physical examination for dehydration and compromised perfusion. If perfusion is adequate, a benzodiazepine or acepromazine are helpful to sedate and relax the patient, decreasing muscle activity and oxygen demand. The author uses small, incremental doses of acepromazine (0.01 mg/kg IV). Butorphanol can be added with care to avoid over sedation (0.2 mg/kg IV). Significant hyperthermia increases oxygen demand, so cooling is essential in those cases with a body temperature > 104 F (40 C). The author prefers cooling with ice and water applied to the axillary and inguinal regions (along the entire trunk if necessary). Water has a higher heat of vaporization, thereby removes more heat than alcohol as it evaporates. Stop cooling at 103 F (39.4 C) to avoid hypothermia. Corticosteroids can be used to combat laryngeal edema (0.1-0.5 mg/kg dexamethasone).

Stable patients can undergo surgery for the upper airway obstruction. First the diagnosis must be confirmed and mass lesions ruled out. Preoxygenate the patient, and administer sedative drugs and induction agents with care to avoid rapid induction and false positive results. Thiopental alone is best; however, it is not readily available. Realize that all sedatives can affect laryngeal function. Lightly sedate the patient (we often use low dose acepromazine and butorphanol) and induce anesthesia. Realize that propofol also can cause rapid, deep planes of anesthesia, so titrate it carefully so that the larynx can be examined for structure and function without being bitten! Doxopram can be used, and the author often uses a dose lower than the recommended (1.1 mg/kg IV). A half dose usually suffices to deepen ventilation, which may result in PARADOXICAL motion of the arytenoids! Have an assistant announce every inhalation (“In”) so that you can correlate any motion, regardless of how small, with the phase of ventilation.

Glottic enlargement is done so long as adequate esophageal function is present. The most commonly performed procedure is unilateral arytenoid lateralization. The lateral approach to the larynx requires knowledge of the cartilages, muscles, vessels, and nerves. Incision of the thyropharyngeus and placing stay sutures allows retraction and identification for closure. Keep the dissection CAUDAL, close to the cricothyroid joint. Separation of inter-cartilaginous joints is not necessary. Avoid the external neural branches on the surface of the thyropharyngeus, and incise the cricoarytenoidus dorsalis to expose the cricoarytenoid joint. Use 2-0 prolene to lateralize the arytenoid, most commonly to the cricoid cartilage at the caudo-dorsal origin of the muscle. Take the cricoid bite first, and then the arytenoid. Do not attempt completely dorsal purchase of the cricoid, which is thick at that point, and mattress the arytenoid purchase if possible, which has been shown to decrease failure/breakage. Close the thyropharyngeus muscle to re-establish pharyngeal function, and ensure no dead space for the rest of closure.

The most common complication is aspiration pneumonia, which is likely 15-20%. Breakage of the suture, or more likely cartilage, results in recurrence of signs. The author has found contralateral arytenoid lateralization unrewarding and often elects for ventral laryngotomy and ventriculocordectomy with mucosal closure. This procedure has been suggested as a
primary means of treating laryngeal paralysis. Intraoral procedures may be associated with more perioperative swelling and resultant dyspnea. Stricture formation would result in fixed obstruction in the later postoperative period.
LAPAROSCOPIC SURGERY IN SMALL ANIMALS

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Minimally invasive procedures like laparoscopy have become more and more popular in veterinary surgery during the last ten years. There are a number of advantages to the patient with having laparoscopic surgery versus an open procedure. These include reduced pain and hemorrhaging, faster recovery periods and excellent viewing due to telescope magnification (McCarthy 2005, Lhermette and Sobel 2008). A relative disadvantage is considered to be the loss of tactile perception, a two dimensional view, and costs associated with training and equipment maintenance (McClaran and Buote 2009).

Laparoscopy is a useful method for diagnostics as well as for surgical procedures. Diagnostic laparoscopy is commonly used as a method for obtaining liver, pancreas, kidney, lymph nodes, splenic, and intestinal biopsies. It is generally accepted that laparoscopy provides better liver biopsy tissues than other traditional percutaneous methods (Monnet and Twedt 2003, Willard at al. 2009, Petre et al. 2012). Commonly performed laparoscopic or laparoscopic-assisted procedures in small animals include: laparoscopic ovariectomy (Thiele et al. 1993) or ovariohysterectomy (Austin et al. 2003, Devidson et al. 2004), laparoscopic-assisted ovariohysterectomy (Devitt et al. 2005), gastropexy and cystoscopy (Rawlings et al. 2001; Rawlings et al. 2003), laparoscopic cryptorchidectomy (Peña et al. 1998) and enteral feeding tube placement (Rawling et al. 2002). Recently more advanced procedures have been described like laparoscopic cholecystectomy, adrenalectomy, splenectomy and insulinoma resection (Mayhew 2009, Collard et al. 2010; Wouters et al. 2011).

Laparoscopy requires special instruments and devices (Fig 1). Laparoscopic surgery is typically facilitated by creating a pneumoperitoneum with CO₂ insufflation to improve the observation of the viscera and to safely insert instruments (Monnet and Twedt 2003). Depending on the surgical procedure, the right lateral and ventral midline approaches are the most commonly used. After the procedure the CO₂ is released and the abdominal port incisions are closed routinely by a suture of the deep fascia, subcutaneous tissue and skin.

Laparoscopy is relatively simple to perform and considered to be safe, having few complications. In a review of 360 diagnostic laparoscopies less than a 2% complication rate was found (Twedt and Monnet 2005). Serious complications include anesthetic or cardiovascular related death, bleeding, or air embolism (Freeman 1999). In a group of 147 laparoscopically or thoracoscopically treated patients, we noticed serious complications; cardiopulmonary related death, only in one case (0,7%) (Crha 2012).

We are sure that a wider spreading of laparoscopic procedures into veterinary practice is beneficial for the patients, because they are safe, and offer many advantages compared to the „open“ surgical approach. We believe that in the Czech Republic laparoscopic surgery will
play a stable role in the near future among standard surgical procedures in many veterinary practices.

Figure 1: Laparoscopic equipment for small animals (modify by Twedt and Monnet 2005)

<table>
<thead>
<tr>
<th>Basic laparoscopic equipment</th>
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<tbody>
<tr>
<td>• 5mm (2.7 mm) telescope</td>
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<tr>
<td>• Video camera and monitor</td>
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<tr>
<td>• 2-4 trocars and cannulas*</td>
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<tr>
<td>• Veress needle**</td>
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<tr>
<td>• Light source and light cable</td>
</tr>
<tr>
<td>• Camera and monitor</td>
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<tr>
<td>• CO₂ insufflator</td>
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<td>• Palpation probe</td>
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<tr>
<td>• Biopsy forceps</td>
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<tr>
<td>• Babcock forceps</td>
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<tr>
<td>• Electrosurgical (e.g. Enseal®, LigaSure®) or ultrasonic (Harmonic Scalpel®) device</td>
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<tr>
<th>Additions for advanced procedures</th>
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<tbody>
<tr>
<td>• Needle holders</td>
</tr>
<tr>
<td>• Dissectors, self-retractor</td>
</tr>
<tr>
<td>• Endoloops, endobags</td>
</tr>
<tr>
<td>• Endostaplers</td>
</tr>
<tr>
<td>• Clip applier</td>
</tr>
<tr>
<td>• Suction and irrigation device</td>
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*number of cannulas depends on the surgical procedure; ** is not needed by the use of Hasson’s technique

References


Nutritional support is indicated in cases of acute weight loss, persistent inappetence, malnutrition, increased metabolic demand, ongoing metabolic loss, or if the animal is physically unable to eat. Enteral nutrition is always favored over parenteral nutrition as it is safer, more physiologic, and more economical. Providing enteral nutrition prevents villous atrophy, stimulates antibody production, and prevents bacterial translocation from the gastrointestinal tract to the systemic circulation. Most feeding tubes are technically simple to place, but there are significant differences between all of the options. The route of administration also dictates feeding tube diameter; tube diameter in turn dictates usable feeding formulas due to varying formula viscosity and particulate matter size. The most common routes of administration for enteral hyperalimentation include oral, nasoesophageal, esophagostomy tubes, gastrostomy tubes, and jejunostomy tubes. Each route has its indications, contraindications, advantages, disadvantages, and complications (Table 1).

The amount of nutrition required is based on calculation of the resting energy requirement (RER): Body Weight (kg) * 30 + 70 = kcal required per day. Once the number of calories necessary to meet the patient's total caloric requirement has been calculated, the rate and volume of feeding are determined based on the route of administration and what the animal will tolerate.

**Nasoesophageal / Nasogastric:** Nasoesophageal or nasogastric feeding tubes are an easy, effective, and efficient means of providing enteral nutritional support. The availability of small bore, soft polyvinyl and silastic feeding tubes and low viscosity, nutritionally complete liquid diet formulations, as well as patient tolerance of tube placement has made nasoesophageal tube placement a popular avenue for feeding patients. Nasoesophageal tube placement is indicated in any patient with malnutrition or inappetance that is not currently vomiting. Tubes can be placed without the need of general anesthesia, which is a big advantage in the critical patient. However, tube diameter is small which limits the types of diets that be fed through the tube. Complications include vomiting, tube clogging, or inadvertent airway placement.

**Esophagostomy Tubes:** Esophagostomy tubes (E-tubes) can be extremely beneficial in inappetant dogs and cats. Clinical scenarios where E-tubes may be indicated include, but are not limited to, severe upper respiratory infection, oropharyngeal tumors, and hepatic lipidosis. E-tubes are not indicated in animals with esophageal disease or in those that are actively vomiting. Advantages of E-tubes tubes over other methods of tube feeding are that
these tubes are relatively simple and inexpensive to place, the animals can be fed once fully recovered from anesthesia, blended canned diets and most medications can be fed through the tube, and there are minimal problems if the tube is removed prematurely. However, general anesthesia is required for placement. Complications associated with E-tubes include vomiting (if the tube is placed such that it crosses the lower esophageal sphincter), stoma irritation or abscessation, and tube clogging.

**Gastrostomy Tubes:** Tube gastrostomy is indicated in anorexic patients with a functional gastrointestinal tract distal to the esophagus or patients undergoing operations of the oral cavity, larynx, pharynx, or esophagus. Gastrostomy tube placement is contraindicated in patients with primary gastric disease (e.g., gastritis, gastric ulceration, gastric neoplasia) or disorders causing vomiting. The advantages of gastrostomy tube feeding include ease of tube placement, patient tolerance, use of large bore feeding tubes, and ease of tube care and feeding by the client. Disadvantages include the need for general anesthesia, the 12 to 24 hours delay in feeding after tube placement, the need for the tube to remain in place for 7 to 14 days even if the animal is meeting its caloric requirements orally. Premature removal can result in life-threatening peritonitis.

**Jejunostomy Tubes:** Jejunostomy tube feeding is indicated in any patient undergoing oral, pharyngeal, esophageal, gastric, pancreatic, duodenal, or biliary tract surgery in which the intestinal tract distal to the surgical site is functional. Patients with preexisting malnutrition or severe inappetance that must undergo major abdominal surgery are considered candidates for early enteral nutritional supplementation via jejunostomy tube. Disadvantages of jejunostomy tube are that general anesthesia and laparotomy are required for placement, tube diameter is small and limits type of diet that can be administered, and that premature removal may result in life-threatening complications.

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<thead>
<tr>
<th>Type</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasoesophageal</td>
<td>Does not require general anesthesia for placement</td>
<td>Small tube diameter</td>
</tr>
<tr>
<td>Nasogastric</td>
<td>Technically simple to place</td>
<td>Prone to clogging</td>
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<tr>
<td></td>
<td></td>
<td>Liquid diets only</td>
</tr>
<tr>
<td>Esophagostomy</td>
<td>Large tube diameter</td>
<td>Requires general anesthesia for placement</td>
</tr>
<tr>
<td></td>
<td>Minimal complications from premature removal</td>
<td>Vomiting will occur if tube crosses lower esophageal sphincter</td>
</tr>
<tr>
<td></td>
<td>Can feed and medicate through tube once animal is recovered from anesthesia</td>
<td></td>
</tr>
<tr>
<td>Gastrostomy</td>
<td>Large tube diameter</td>
<td>Requires general anesthesia for placement</td>
</tr>
<tr>
<td></td>
<td>Feed blenderized normal diets</td>
<td>Need to wait 12-24 hours before feeding</td>
</tr>
<tr>
<td></td>
<td>Can medicate through tube</td>
<td>Tube must stay in place 7-14 days regardless</td>
</tr>
<tr>
<td></td>
<td>Allows for gastric decompression</td>
<td>Premature removal may result in peritonitis</td>
</tr>
<tr>
<td>Jejunostomy</td>
<td>Can be used in the face of vomiting</td>
<td>Requires general anesthesia for placement</td>
</tr>
<tr>
<td></td>
<td>Can use immediately following placement</td>
<td>Requires laparotomy or laparoscopy for placement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small tube diameter; Liquid diets only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Continuous feeding better tolerated than intermittent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tube must stay in place 7-14 days regardless</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Premature removal may result in peritonitis</td>
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GASTRIC DILATATION-VOLVULUS: WHAT’S NEW?

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Classically, the GDV syndrome is an acute condition with a mortality rate of 25% to 45% in treated animals. The gastric enlargement is thought to be associated with a functional or mechanical gastric outflow obstruction. The initiating cause of the outflow obstruction is unknown; however, once the stomach dilates, normal physiologic means of removing air (i.e., eructation, vomiting, and pyloric emptying) are hindered because the esophageal and pyloric portals are obstructed.

Medical Management

Patient stabilization is the initial objective. A large-bore intravenous catheter(s) should be placed in either a jugular or both cephalic veins. Either isotonic fluids (90 ml/kg/hr), hypertonic 7% saline (4–5 ml/kg over 5 to 15 min), or hetastarch (5–10 ml/kg over 10 to 15 min) is administered. If hypertonic saline or hetastarch is given, adjustment of the rate of subsequent crystalloid administration is necessary. Blood should be drawn for blood gas analyses, a CBC, and a biochemical panel. Broad-spectrum antibiotics (e.g., cefazolin, ampicillin plus enrofloxacin) should be administered. If the animal is dyspneic, oxygen therapy may be given by nasal insufflation or mask.

Gastric decompression should be performed while shock therapy is initiated. The stomach may be decompressed percutaneously with several large-bore intravenous catheters or a small trocar, or (preferably) a stomach tube may be passed. The stomach tube should be measured from the point of the nose to the xiphoid process and a piece of tape applied to the tube to mark the correct length. A roll of tape can be placed between the incisors and the tube passed through the center hole. Attempts should be made to pass the tube to the measured point. Placing the animal in different positions (i.e., sitting, reclining on a tilt-table) may help if it is difficult to advance the tube into the stomach. Do not perforate the esophagus with overly rigorous attempts to pass the tube. If these attempts fail, percutaneous decompression of the stomach should be attempted. This may relieve pressure on the cardia and allow the tube to enter the stomach. Once the air has been removed, the stomach can be flushed with warm water if the animal is intubated…(otherwise this is not recommended due to the high risk of aspiration). If blood is seen in the fluid from the stomach, prompt surgical intervention is warranted because this may indicate gastric necrosis. If the stomach tube can still not be passed, and immediate surgical correction is not possible, temporary decompression may be achieved by performing a temporary gastrostomy; however, because this does not relieve the gastric malpositioning it is not recommended. Placement of a Foley catheter into the stomach percutaneously should not be done unless the stomach is simultaneously tacked to the body wall because of the high risk of peritonitis if the stomach pulls away from the tube. Disadvantages of a temporary gastrostomy are that the stomach must be closed when the
permanent gastropexy is performed, and there is a high risk of peritoneal contamination. If immediate surgery is not possible in an animal in which a stomach tube was passed but that dilates rapidly after decompression, the stomach tube can be exteriorized through a pharyngostomy approach. This will prevent the animal from chewing on the tube, until definitive surgery can be performed. After the patient has been decompressed and is stable, radiographs may be taken.

**Surgical Technique**

Decompress the stomach before repositioning, by using a large-bore needle (i.e., 14 or 16 gauge) attached to suction. If the needle becomes occluded with ingesta, have an assistant pass an orogastric stomach tube and perform gastric lavage. Intraoperative manipulation of the cardia will usually allow the tube to be passed into the stomach without difficulty. If adequate decompression is still not achieved, or an assistant is not available, a small gastrotomy incision can be performed to remove the gastric contents, although this should be avoided if possible. For a clockwise rotation, once the stomach has been decompressed, rotate it counterclockwise by grasping the pylorus (usually found below the esophagus) with the right hand and the greater curvature with the left. Push the greater curvature, or fundus, of the stomach towards the table while simultaneously elevating the pylorus (towards the incision). Check to make sure that the spleen is normally positioned in the left abdominal quadrant. If there is splenic necrosis or significant infarction, perform a partial or complete splenectomy. Remove or invaginate necrotic gastric tissues. Avoid entering the gastric lumen, if possible. If you are uncertain whether gastric tissue will remain viable, invaginate the abnormal tissue. Verify that the gastroplenic ligament is not torse, and before closure, palpate the intraabdominal esophagus to ensure that the stomach is derotated. To prevent recurrence of GDV, the stomach must be permanently adhered to the body wall. Gastropexy should always be performed in conjunction with abdominal exploration and derotation of the stomach.

**Permanent Gastropexy**

Gastropexy techniques are designed to permanently adhere the stomach to the body wall. The most common indications are GDV (pyloric antrum to right body wall) and hiatal herniation (fundus to left body wall). Numerous gastropexy techniques have been described. Although the strength and extent of adhesions created by these various techniques differ, all of them (when properly performed) prevent movement of the stomach. To create a permanent adhesion, the gastric muscle must be in contact with the muscle of the body wall; intact gastric serosa will not form permanent adhesions to an intact peritoneal surface.

**Muscular Flap (Incisional) Gastropexy**

Muscular flap (incisional) gastropexy is easier than circumcostal gastropexy and avoids potential complications associated with tube gastropexy. Make an incision in the seromuscular layer of the gastric antrum. Then make an incision in the right ventrolateral abdominal wall by incising the peritoneum and internal fascia of the rectus abdominis or transverse abdominis muscles. Suture the edges of the incisions in a simple continuous
pattern using 2-0 absorbable or nonabsorbable suture. Make sure the muscularis layer of the stomach is in contact with the abdominal wall muscle. Suture the cranial margin first, then the caudal margin. As an alternative, you may raise flaps in the stomach and body wall to increase the extent of muscle contact between these tissues.

**Prognosis**

With timely surgery, the prognosis is fair; however, mortality rates as high as 45% and greater have been reported. A recent study reported a mortality rate of 15% among dogs with GDV; the mortality rate was 0.9% if gastric dilation without volvulus was present (or if GDV could not be verified at surgery). The prognosis is poor if gastric necrosis or perforation occurs or if surgery is delayed. Some dogs with GDV respond to tube decompression and medical stabilization alone. Occasionally, the stomach becomes normally positioned after the air is removed; or, it was only partially rotated (less than 180 degrees) or merely dilated. However, these dogs still have a high likelihood of recurrence. Therefore gastropexy should be recommended, even when conservative management successfully alleviates the gastric malpositioning. The reported recurrence rates of dogs operated on for GDV in which the stomach has been repositioned but gastropexy not performed approaches 80%.
DIAPHRAGMATIC HERNIA REPAIR

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Diaphragmatic hernias are commonly recognized by small animal clinicians and may be congenital or occur secondary to trauma. Congenital pleuroperitoneal hernias are seldom diagnosed in small animals because many affected animals die at birth or shortly thereafter. Most diaphragmatic hernias in dogs and cats are caused by trauma, particularly motor vehicle accidents. The abrupt increase in intraabdominal pressure accompanying forceful blows to the abdominal wall causes the lungs to rapidly deflate (if the glottis is open), producing a large pleuroperitoneal pressure gradient. Alternately, the pressure gradient that occurs between the thorax and the abdomen may cause the diaphragm to tear. The tears occur at the weakest points of the diaphragm, generally the muscular portions. Location and size of the tear or tears depend on the position of the animal at the time of impact and the location of the viscera. Traumatic diaphragmatic hernias are often associated with significant respiratory embarrassment; however, chronic diaphragmatic hernias in asymptomatic animals are not uncommon. Diaphragmatic hernias may also occur in animals with connective tissue disorders.

SURGICAL TREATMENT

Chronic diaphragmatic hernias may have a higher mortality than acute diaphragmatic hernias; however, the prognosis with both groups is good to excellent with surgery (see below under Prognosis). If pulmonary contusions are severe, surgical repair of diaphragmatic hernias should be delayed until the patient’s condition has been stabilized; however, hemiorrhaphy should not be delayed unnecessarily. Animals with gastric herniation should be evaluated carefully for gastric distention and should be operated on as soon as they can safely be anesthetized, because acute gastric distention within the thorax may cause rapid, fatal respiratory impairment.

SURGICAL TECHNIQUE

Make a ventral midline abdominal incision; if greater exposure is needed, extend the incision cranially through the sternum. Replace the abdominal organs in the abdominal cavity (if necessary, enlarge the diaphragmatic defect). If adhesions are present, dissect the tissues gently from the thoracic structures to prevent pneumothorax or bleeding. With chronic hernias, debride the edge of the defect before closure. Close the diaphragmatic defect in a simple continuous suture pattern. If the diaphragm is avulsed from the ribs, incorporate a rib in the continuous suture for added strength. Remove air from the pleural cavity after closing the defect. If continued pneumothorax or effusion is likely, place a chest tube. Explore the entire abdominal cavity for associated injury (i.e., compromise of the vasculature to the intestine or splenic, renal, or bladder trauma) and repair any defects.
NOTE • If the diaphragmatic defect is particularly large, synthetic material such as Silastic sheeting can be used to close it; however, this is seldom necessary.

An abdominal flap graft has been reported for repair of chronic diaphragmatic hernia in dogs. The graft is obtained from the peritoneum and transverse abdominal muscle caudal to the diaphragm. The graft is elevated, placed over the defect, and sutured to the diaphragm.

**Prognosis**

If the animal survives the early postoperative period (i.e., 12 to 24 hours) the prognosis is excellent, and recurrence is uncommon with proper technique. Reported mortality rates for animals with traumatic DH have varied from 12% to 48%. Reported survival rates for animals with traumatic DH who are treated surgically are close to 75%.

**PERITONEOPERICARDIAL DIAPHRAGMATIC HERNIA**

Peritoneopericardial diaphragmatic hernias are less commonly recognized by small animal clinicians than traumatic diaphragmatic hernias. Although PPDH often are associated with respiratory embarrassment, asymptomatic PPDH is common. PPDH may occur as a result of trauma in human beings (in whom the diaphragm forms one wall of the pericardial sac); however, these hernias are always congenital in dogs and cats, in which no direct communication exists between the pericardial and peritoneal cavities after birth. The most widely accepted theory regarding the embryogenesis of this defect is that the hernia occurs because of faulty development or prenatal injury of the septum transversum. This could be a result of a teratogen, genetic defect, or prenatal injury.

Cardiac abnormalities and sternal deformities often occur concomitantly with PPDH. The combination of congenital cranial abdominal wall, caudal sternal, diaphragmatic, and pericardial defects has been reported in dogs, often associated with ventricular septal defects or other intracardiac defects. It is not known if this condition is heritable; however, several breed predispositions have been recognized (see below). Polycystic kidneys have been reported in association with PPDH in cats.

**TABLE 1  Radiographic Signs of Peritoneopericardial Diaphragmatic Hernia**

<table>
<thead>
<tr>
<th>Sign</th>
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<tr>
<td>Enlarged cardiac silhouette</td>
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<tr>
<td>Dorsal elevation of the trachea</td>
</tr>
<tr>
<td>Overlap of the heart and diaphragmatic borders</td>
</tr>
<tr>
<td>Discontinuity of the diaphragm</td>
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<tr>
<td>Gas-filled structures in the pericardial sac</td>
</tr>
<tr>
<td>Sternal defects</td>
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<tr>
<td>Dorsal peritoneopericardial mesothelial remnant</td>
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**SURGICAL TREATMENT**

Surgical repair should be performed as early as possible (generally when the animal is between 8 and 16 weeks of age), when it is unlikely that adhesions will be present and the pliable nature of the skin, muscles, sternum, and rib cage facilitates closure of large defects.
Early correction of PPDH may prevent acute decompensation and the possible development of acute postoperative pulmonary edema. If the hernia is not diagnosed until the animal is older, conservative or surgical management may be used; however, owner satisfaction was higher in operated animals than in animals managed conservatively in a recent study. Some animals that are initially managed medically may have progression of clinical signs necessitating surgical intervention or resulting in death.

**SURGICAL TECHNIQUE**

* Make a ventral midline abdominal incision. If greater exposure is needed, extend the incision cranially through the sternum. Enlarge the diaphragmatic defect if necessary and replace the abdominal organs in the abdominal cavity. If adhesions are present, gently dissect the tissues from the thoracic structures, resecting or debriding necrotic tissue as necessary. Debride the edges of the defect and close in a simple continuous suture pattern. Do not close the pericardial sac. Remove air from the pericardial sac or pleural cavity or both after closing the defect. If continued pneumothorax or effusion is likely, place a chest tube. Repair concomitant sternal or abdominal wall defects.*
Urinary obstruction, specifically urethral obstruction, is a frequent emergency scenario encountered in both dogs and cats. Obstruction most commonly occurs due to lodging of stones, sludge, or plugs within the urethra. Due to significant anatomical differences, obstruction is far more likely to occur in male dogs and cats than in females. The male canine urethra is long, and luminal diameter abruptly changes at the level of the proximal end of the os penis. This is a very common location for stones to become trapped. The male feline urethra also has an abrupt change in diameter as it transitions from the pelvic (membranous) to the penile urethra at the level of the bulbourethral glands. Cystotomy is one of the most common surgical procedures in general veterinary surgery, and it is most often performed for removal of uroliths.

Signs of urethral obstruction include stranguria and pollakiuria. Obstructed animals may display signs of discomfort, anxiety, and abdominal pain, and may vocalize when trying to urinate. If obstruction is unrecognized for greater than 24 hours, animals may present for lack of appetite, vomiting, collapse, stupor, or coma. Animals may be clinically dehydrated and hypothermic. Bradycardia is a notable finding as the animals may have significant electrolyte abnormalities leading to cardiac conduction problems.

Treatment of metabolic and electrolyte abnormalities is best achieved by relieving the obstruction and providing intravenous fluid therapy. Although controversial, cystocentesis may be performed as a transient means of obstruction relief in very unstable animals. More stable animals should be sedated for attempts to relieve urethral obstruction. If initial attempts are unrewarding, general anesthesia may be indicated. When urethral catheterization in unsuccessful, an alternative to cystocentesis for urinary drainage, is placement of a cystostomy tube. This short surgical procedure provides a route for urine diversion, allows stabilization of the animal, and provides access for contrast imaging studies of the urinary tract.

Once the obstruction is relieved, postobstructive diuresis is to be expected and in some cases may be profound. Urine output and IV fluid rates should be monitored closely and adjusted often to maintain adequate hydration. Azotemia and other metabolic abnormalities will normalize in short period of time once the obstruction has been relieved.

For dogs and cats obstructed due to urethral calculi, cystotomy is indicated to remove the stones. In dogs where the stone could not be retropulsed, urethrotomy is indicated. This
most often happens in cases of long-standing partial obstruction where the stone has embedded into the wall of the urethra. Cystotomy is performed from a routine caudal abdominal approach. A ventral incision is made into the bladder in a relatively avascular area. A urethral catheter is passed several times both normograde and retrograde to make sure that no stones remain in the bladder neck or urethra.

For cystotomy closure, monofilament suture is preferred as there is some concern that contact between urine and multifilament suture may lead to an increased rate of absorption or may promote urolith formation. Nonabsorbable suture and staples are contraindicated in urinary bladder closure, as they are associated with the formation of urinary calculi. There are a number of suture patterns that can be used to close the urinary bladder, however a single-layer appositional pattern has been shown to be appropriate. Most textbooks recommend partial-thickness closure incorporating the submucosal layer but not entering the lumen. Urinary calculi formation has been associated with multifilament absorbable suture, nonabsorbable suture, and metal staples, however there have been no studies assessing the lithogenic potential of the newer monofilament rapidly absorbable sutures. Full-thickness purchase of the bladder wall guarantees incorporation of the submucosal holding layer. Single layer partial-thickness closures of the urinary bladder that miss the submucosa may be inadequate for preventing urine leakage.

Alternatively, a cystotomy can be performed using a laparoscopic-assisted method. A two-cannula approach is typically used with the endoscope portal placed near the umbilicus. A urethral catheter is also placed with the catheter hooked up to bag of sterile saline. The instrument portal is placed on midline for female dogs and parapreputial in male dogs. The apex of the bladder is grasped with Babcock forceps and brought to the portal site. The incision is extended and the bladder is sutured into the incision with a temporary simple continuous suture pattern between, securing it to the abdominal wall. A small cystotomy is performed and the endoscope is inserted into the bladder lumen. Calci are visualized and are removed by retrieval forceps, basket retrieval devices, and/or suction. Flushing the bladder lumen with saline pushed through the urethral catheter under pressure facilitates stone removal.

There is no special postoperative care required following cystotomy. Routine postoperative abdominal radiographs can be taken to confirm that all urethral and bladder stones have been removed. Owners should be warned to expect mild hematuria for 3 to 5 days postoperatively. Follow-up medical management should be based on results of stone analysis.

When cats cannot be unobstructed or if a dog or cat suffers from recurrent obstruction, urethrostomy is indicated. Perineal urethrostomy (PU) is performed in cats. In dogs, prescrotal or scrotal urethrostomy is the most common type of permanent urinary diversion. Complications associated with urethrostomy include hemorrhage, stricture, urine scald, urine extravasation into the subcutaneous tissues, incontinence, and chronic infection.

Elizabethan collars should be used in animals postoperatively following urethrostomy to avoid self-trauma. Urethral catheterization is not indicated and is damaging to the freshly
created stoma. Some mild hemorrhage or hematuria is to be expected for several days and any clots at the stoma site should be left undisturbed.

References


GASTROINTESTINAL OBSTRUCTION IN THE DOG AND CAT

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Gastrointestinal obstruction is a common condition encountered in small animal medicine. Obstruction is classically categorized as either mechanical or functional. Mechanical obstruction in the gastrointestinal tract is most often due to entrapped intraluminal foreign material, but can also be caused by intussusception, intestinal entrapment, torsion, mucosal or muscular hypertrophy, or neoplasia. For dogs and cats that present with acute signs of gastrointestinal disease, obstruction is a primary differential.

Focal mechanical gastrointestinal obstruction occurs following indiscriminate ingestion of unusual items. Frequently ingested items include, but are not limited to, rocks, bones, corn cobs, peach pits, balls, toys, plant material, and clothing items. Common locations for focal foreign bodies to become lodged include the pylorus, caudal duodenal flexure, and ileocolic junction, although items may become lodged at any point along the gastrointestinal tract.

Diagnosis can be made from abdominal radiographs, which may show the foreign material if it is radiodense. Otherwise, obstruction is suspected based on the dilation of obstructed intestinal loops with air or fluid. Repeated abdominal radiographs, contrast studies, or ultrasonography may be necessary if the diagnosis is not apparent from the initial radiographic study. Contrast studies should be performed with caution, as barium contrast agents are contraindicated if perforation is suspected, and iodinated contrast agents may exacerbate dehydration.

Gastrointestinal obstruction with linear material is a unique situation most commonly associated with cats. Foreign bodies such as string, thread, or cloth are ingested and become anchored typically at the base of the tongue or at the pylorus. As a result of the anchor, the intestine will gather around the foreign body. This plication of the intestines may cause a complete or, more often, partial obstruction. Intestinal peristalsis continues against the fixed material and may lacerate the mucosa and cause perforations along the mesenteric border.

Diagnosis of linear obstruction can be challenging. Abdominal palpation is frequently painful and may reveal a large mass of bundled intestines. Careful oral examination may reveal the foreign material anchored around the base of the tongue. On abdominal radiographs, the appearance of 3 or more small, eccentrically located, luminal gas bubbles tapered at one or both ends was diagnostic for linear foreign body in one study. If the diagnosis is still uncertain, other imaging techniques such as upper gastrointestinal contrast studies or...
abdominal ultrasonography may be required. Ultrasonographic appearance of a linear foreign body is described as a central hyperechoic line with intestine plicated on either side. Contrast agents should be administered with caution as it has been reported that 16% of cats had intestinal perforation found at surgery.

Linear foreign bodies are considered surgical emergencies. Conservative management of linear foreign bodies has been reported. However, in that study 42% of cats that were initially managed medically ultimately went to surgery. Given that perforated intestine from the linear foreign body carries a 50% mortality rate, early surgical intervention is the treatment of choice. Gastrotomy and multiple enterotomies are typically required for removal for linear foreign bodies. This allows for segmental removal of the material and minimizes the risk of iatrogenic perforation from too much traction. The gastrotomy and simple enterotomies are closed with an appositional simple interrupted or simple continuous pattern using monofilament absorbable suture material. Sutures are placed 2 mm from the incised edge and 2 to 3 mm apart.

Depending on the extent of damage, intestinal resection and anastomosis may be indicated. Intestinal viability is based on assessment of subjective parameters such as color, thickness, arterial pulsation, capillary bleeding, and peristalsis. Due to the mesenteric fat, perforations along the mesenteric border can be difficult to identify and to suture appropriately. This is the most common site for dehiscence following intestinal resection and anastomosis. In this scenario, resection and anastomosis may be preferable to primary closure of the site in the mesenteric border of the intestine. Intestinal anastomosis is most commonly performed using a simple interrupted or a modified simple continuous pattern.

Gastrointestinal obstruction due to intussusception is an uncommon, but notable condition in the dog and cat. Intussusception occurs when a segment of intestine (intussusceptum) moves into the lumen of an adjoining segment (intussuscipiens). Intussusception has been reported at all levels of the gastrointestinal tract with ileocolic intussusceptions being most common. Causes have been attributed to intestinal parasitism, linear foreign bodies, previous abdominal surgery, and gastroenteritis, although often the cause is unknown. Diagnostic imaging is mostly used to confirm what is already suspected from abdominal palpation. The characteristic ultrasonographic appearance of an intussusception is a multilayered target-like image in the transverse plane and alternating hyperechoic and hypoechoic parallel lines in the longitudinal plane.

Surgical intervention is the treatment of choice for intussusception. At surgery, manual reduction of the intussusception should be gently attempted, but it is often not successful. If reduced, the involved intestine (or intussusceptum) is evaluated for perforations and viability. Intestinal resection and anastomosis is indicated when manual reduction fails or if the reduced tissue is devitalized. The resected segment should be submitted for histopathological evaluation to potentially identify the cause of the intussusception. Enteroplication (or enterointeropexy) is recommended to prevent recurrence; however, complications may result from this procedure as well. Both intussusception recurrence and severe postoperative complications associated with enteroplication have been reported in the dog and cat.
REFERENCES:


Tracheal collapse is a progressive, degenerative disease of the cartilage rings in which hypocellularity and decreased glycosaminoglycan content lead to dynamic tracheal collapse during respiration (Nelson 2003). This is quite a common condition of predominantly middle-aged, small and toy breed dogs (e.g. Yorkshire Terriers, Toy poodles, Pomeranians etc.), whereas it is very rare in cats (Hendricks and O’Brien 1985) and larger breed of dogs (Radlinsky and Fossum 2000). It is a complex disease without a known nor completely understood etiology, although it is assumed to likely be a multifactorial disease (Nelson 2003).

Clinical signs may range from a mild, intermittent cough to severe respiratory distress associated with dynamic upper airway obstruction. The cough may be productive or nonproductive with a typical "goose honk" sound; moreover, patients with serious tracheal collapse usually suffer from syncope and hypoxia which may even result in death (Hedlund 1991).

Diagnostics of tracheal collapse is based on history, clinical examination and finding of collapsed trachea by diagnostic imaging, and endoscopy, respectively. Ordinary radiography is only 59% sensitive for the diagnosis of collapsed trachea in dogs (Tangner and Hobson 1982). New non-invasive methods of tracheal diameter examination are being currently described (Eom et al. 2008, Stadler et al. 2011), though endoscopy still remains "the gold standard" in the diagnostics of tracheal collapse (Hertridge and White 2000).

Medical treatment of tracheal collapse is the therapy of choice and surgical repair is considered when patients do not respond well (White and William 1994). The current recommended surgical therapy of tracheal collapse in dogs includes the use of extraluminal prosthetic rings or endoluminal tracheal stents (Payne et al. 2006, Ettinger 2010). The use of extraluminal prostheses is generally limited to cervical tracheal collapse, furthermore it is not without complications. In a one review a permanent tracheostomy was performed in 17/90 dogs (18.9%), and in 10 (11.1%) of these the tracheostomy was undertaken within 24 h of surgery due to postoperative laryngeal paralysis (Buback et al. 1996). Intraluminal stents have provided a promising alternative treatment when addressing collapse of the intrathoracic portion of the trachea and the surgically inaccessible mainstem bronchi (Sura and Krahwinkel 2008). Advantages of intraluminal tracheal stenting include the fact that it is minimally invasive and does not require dissection around the peritracheal neurovascular structures, is associated with shorter anesthesia times, and provides access to the entire length of the trachea. Tracheal stents provide rapid and effective relief of clinical signs and are generally well tolerated in many patients (Payne et al. 2006, Kim et al. 2008). Recently, a few clinical reports have been published; which show encouraging results in the use of self-expanding...
nitinol stents (Fig.1, 2) for the treatment of tracheal collapse in dogs. In one study, overall, 10 of 12 (83%) dogs that underwent placement of self-expanding nitinol stents had long-term (>1 year) improvement of their clinical condition (Sura and Krahwinkel 2008). Comparable results (89%) in long time follow up are described in another clinical study (Durant et al. 2012).

Complications included stent shortening, tracheitis, pneumonia, excessive granulation of tissue, progressive tracheal collapse, and stent fracture (Weisse et al 2008). Also, perineal hernia and rectal prolapse were described (Durant et al. 2012).

Endotracheal stenting is a promising new therapy for tracheal collapse in small animals based on a minimally invasive approach. However, there remain significant challenges to overcoming the potential complications of this surgical method. The search for an ideal intraluminal tracheal stent continues, and long-term studies will be necessary to determine the clinical outcomes of newly developed tracheal stents.

Fig. 1: Bronchoscopic view of the trachea of a dog after placement of self-expanding nitinol stent (Ella-CS, s.r.o, HK, Czech Republic) at the area of collapse

Fig. 2: Bronchoscopic view of the trachea in the same dog 3 months after stent placement (stent is almost covered by granulation tissue)
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TREATMENT OF HYPERTHYROIDISM IN CATS

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University of Georgia

Hyperthyroidism is a commonly diagnosed endocrine disease in cats averaging 12-13 y of age. Hyperfunctioning tissue is usually benign adenoma or hyperplastic tissue rather than carcinoma. Oral medical management can be used definitively or to evaluate response to therapy, which is important, as up to 27% of cats have concurrent renal failure, and treatment of the hyperfunctioning tissue may unmask renal disease in over 1/3 of cats. Another side effect of treatment, hypothyroidism, may result in shorter survival time, and cats that develop hypothyroidism and azotemia have shortened survival times. Predictors of shorter survival included the development of azotemia within 240 d of diagnosis, age, UPC, and hypertension (1) USg and PCV correlated with increased survival time in the same study. Unfortunately, nearly 1 in 5 cats develop side effects that include anorexia, vomiting, lethargy, or facial pruritis, blood dyscrasia, and hepatopathy. Medical therapy requires balancing thyroid levels, monitoring and maintaining adequate renal values and avoiding renal crises, and avoiding the side effects of the chosen medication.

Radioiodine treats primary and ectopic thyroid lesions and spares normal, atrophied tissue. Availability of the treatment and laws regulating the use and quarantine of patients vary widely, requiring weeks of hospitalization. This makes it difficult to treat concurrent diseases, with renal failure being of great concern.

Surgery is a viable option for patients that cannot undergo prolonged isolation required for radioiodine therapy and/or have adverse reactions to medical therapy and may be important for the treatment of thyroid carcinoma in affected cats. Surgery can result in a cure if no ectopic tissue exists; however, hypoparathyroidism, laryngeal paralysis, incomplete response, and recurrence are possible. One study showed that nearly 1 in 5 cats undergoing scintigraphy for hyperthyroidism had multiple sites of uptake and/or ectopic hyperfunctioning tissue. (2) Two or more sites of uptake were present in 12%, with 53% having uptake at the thoracic inlet and 22% having uptake within the thorax. Notably, 8% of cats had uptake only within the chest, and 23% had already had surgery for the problem, 3 having had bilateral thyroidectomy.

Surgery and medical therapy are viable options for treating hyperthyroid cats in primary care situations in which radioiodine is problematic. Due to the common occurrence of elevated liver enzymes, renal disease, and cardiac disease, a thorough preoperative evaluation is required. Cardiac abnormalities consisting of significant tachycardia or ventricular arrhythmias warrant evaluation by a cardiologist, measurement of blood pressure, and perhaps treatment with methimazole to regulate the hyperthyroid condition or propranolol to decrease anesthetic risk.
Anatomy is important to avoid the most significant complications associated with thyroidectomy. First, finding the thyroid glands is important – both should be positively identified. The entire neck should be evaluated for mass lesions during the procedure. A standard ventral midline approach to the neck involves division of the skin, subcutis and sternohyoid muscles on midline. The median raphe is easy to find once the muscles are exposed. Simply compress the musculature and the raphe becomes visible as a small, white separation when the right spot is compressed.

Important structures associated with the thyroid glands include the carotid sheath (containing the carotid arteries, internal jugular veins, and vагосympathetic trunks). Also running lateral to the trachea along its entire length within the neck are the recurrent laryngeal nerves. The left nerve may run more dorsal to the trachea and ventral to the last large structure adjacent to the thyroid glands, the esophagus. The blood supply to the trachea is fine and segmental, so care should be taken to avoid its disruption. Small, yet powerful and important, the parathyroid glands reside on the surface of or within the parenchyma of the thyroid glands. There are 2 sets of paired parathyroid glands. Each thyroid has an associated external parathyroid, which is located rostrally on the external surface of the thyroid, and a caudal parathyroid gland that is within the thyroid parenchyma.

Once all abnormal tissue is identified, removal of hyperfunctioning tissue is the goal. The techniques used include the extracapsular, modified extracapsular, and intracapsular thyroidectomy. Extracapsular excision is simple; the removal involves the entire affected gland and parathyroid glands associated with the side being removed. Clearly this requires a normal, intact contralateral gland. Intracapsular dissection minimizes the potential for damage to the external parathyroid gland, but risks leaving abnormal thyroid lobules behind, increasing the risk of recurrence. Thus, the most commonly performed technique is that of the modified extracapsular thyroidectomy, which resulted in the lowest incidence of hypoparathyroidism after surgery.

Fine forceps (Bishop Harmon) and fine scissors (iris scissors) help with the dissection. The thyroid capsule is incised around the external parathyroid gland, taking great care to preserve its blood supply that enters from rostral and courses caudal to enter the parathyroid. The remaining thyroid gland is removed with its capsule intact. This technique can be used in a staged fashion for bilateral thyroidectomy in cats with bilateral hyperfunctioning tissues. The staging allows for (hopeful) recovery of the blood supply to the parathyroid gland that was freed from the surface of the excised thyroid gland. Three weeks of rest have been suggested between thyroidectomy procedures.

Parathyroid autotransplantation has been suggested for cases of accidental removal of the parathyroid or damage to its blood supply at the time of surgery. The external parathyroid can be minced into small pieces and inserted into a stab incision in the cervical musculature. The author has not had much luck with this procedure.

A study evaluated approximately 100 cats that underwent thyroidectomy for hyperthyroidism(3). Ectopic parathyroid tissue was identified in 9%, none within the thorax,
and approximately 1/3 became azotemic following thyroidectomy. Hypocalcemia developed in 6%, and recurrence in approximately 6% at 3-59 m after surgery, and was greater in cats with ectopic tissue.


ENDOCRINE SURGERY IN DOGS
MaryAnn Radlinsky, DVM, MS, DACVS
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Adrenal gland surgery is important in the treatment of adrenocortical adenoma, adrenocortical adenocarcinoma, and pheochromocytoma. All of these tumors may cause systemic hypertension, coagulopathy, and cardiac arrhythmias. Each gland has a vast blood supply, with numerous branches emanating from the renal, phrenicoabdominal, and cranial abdominal vessels, resulting in many small vessels supplying adrenal mass lesions. Stabilization of secondary conditions may increase the likelihood of positive outcome following surgery. Cortisol secreting tumors may be pretreated with trilostane (1-2 mg/kg q 12) and pheochromocytoma treated with phenoxybenzamine (0.5 mg/kg q 12 h) to minimize complications associated with each condition. For significant tachycardia associated with pheochromocytoma, propranolol may be used (0.2 – 1 mg/kg q 12-24 h). Complications should be anticipated, and heparin added if significant risk of increased coagulation is suspected in dogs with Cushing’s disease; however, a true tendency toward hypercoagulability is difficult to establish. Cortisol should be supplemented in dogs with active cortical tumors to avoid postoperative Addisonian crisis. Dexamethasone (0.05 – 0.1 mg/kg can be administered over 6 h, and tapering (0.02 mg/kg/d) is continued for 3 d. Oral prednisone (0.25-0.5 mg/kg q 12 h) is then administered and should be tapered over 3-4 months thereafter.

Advanced imaging is recommended with contrast CT or MRI to establish whether vascular invasion has occurred prior to surgery. Advanced imaging also allows for complete abdominal exploration, as precise access to the adrenal glands is more beneficial in cases of vascular invasion. Ventral midline laparotomy, allows for evaluation of all abdominal organs. A flank approach or modified intercostal approach is beneficial in cases of vascular invasion; however, decreased complications have not been proven with the flank approach. The approach decreases the need for retraction of the surrounding organs, the most at risk being the liver and pancreas on the right. Laparoscopy also provides a well lit, magnified view of the adrenal glands and can be done from an approach similar to the ventral midline; however, a recent report demonstrated the utility of sternal recumbency for adrenalectomy, which more mimics the flank approach.

The caudal pole of the adrenal gland is closely associated with and dorsal to the renal vein, which can result in hemoabdomen in some patients. Caval invasion may be present in 11-55% of dogs with adrenal tumors. Place Rommel tourniquets around the vena cava cranial and caudal to the adrenal gland, dissect the extravascular portion, then tighten the tourniquets and remove the luminal portion. Once complete removal is verified, use a Satinsky clamp across the cavotomy site and close with 5-0 to 7-0 prolene in a simple continuous pattern. Invasion of the phrenicoabdominal vein is common and does not pose significant increase in difficulty associated with adrenalectomy. The author often frees and ligates the dorsolateral
portion of the phrenicoabdominal vein and uses it as a “handle” with which to manipulate the
gland, as the adrenal capsule is fragile, and trauma to it results in extrusion of tumor cells like
“cottage cheese” into the site. Occurrence does not increase the apparent risk of
postoperative complications.

Prognosis is better for those patients that undergo elective adrenalectomy (6% mortality)
compared to those requiring emergency treatment for acute hemorrhage (50% mortality).
Adrenal tumor size and acute hemorrhage apparently decrease survival time; however, dogs
surviving surgery had very long survival times (up to 1500 d). Complications surrounding
surgery are numerous and increase the risk of death (pulmonary thromboembolism, dyspnea,
pancreatitits, renal failure, hemorrhage, and overall survival is approximately 20%.

Thyroid tumors are usually malignant in dogs. The thyroid gland derives its blood supply
from the cranial and caudal thyroid vessels, which anastomose and form dorsal and ventral
branches with multiple feeding vessels. Thyroid tumors are well known for their associated
intraoperative hemorrhage and invasion of local tissues. Care should be taken to identify the
carotid sheath and recurrent laryngeal nerves to avoid associated complications. Place a
stomach tube in the esophagus to ease identification. Mobility of the mass seems to be the
most reliable indicator of resectability. Use of vessel sealing devices are of GREAT value
for endocrine surgery, because of the large number of small feeding vessels of the glands.
The author uses a vessel-sealing device for minimally invasive adrenalectomy, open
thyroidectomy, and rarely parathyroidectomy. Use of a vessel sealer has also been proven
viable for pancreatic tumors as well.

Hyperparathyroidism related to parathyroid masses should be evaluated with ultrasound to
detect the number of parathyroid masses, and like nearly all ultrasound examinations, it may
be operator dependent. Exposure of the parathyroid or thyroid is via a ventral midline
approach, separating the sternohyoid muscles on midline. Be sure to evaluate BOTH thyroids
and parathyroids in EVERY case of thyroid or parathyroid masses. Enlarged parathyroid
glands should be removed; conservative excision may be warranted to avoid errors if the
glands are not certainly involved. External parathyroidectomy simply involves resection
from the surface of the thyroid with ligation, clip application, or sealing of the main feeding
vessel. Caudal parathyroids are located within the thyroid gland and may necessitate partial
thyroidectomy if they are not visible from the surface. Be certain to preserve the cranial
thyroid vessels feeding the external parathyroids if they are to remain in place and functional.
Hypocalcemia is the most common complication of parathyroidectomy or bilateral thyroid
tumor excisions. Calcium may not fall for 5-7 days, so monitoring for facial pruritis,
weakness, and tremors is important. Increased risk of postoperative hypocalcemia may be
associated with total calcium levels of ≥ 15 mg/dl prior to surgery. Supplementation of
calcitriol for 2-3 d prior to surgery in severely hypercalcemic patients may blunt the drop in
calcium after surgery. Loading with calcitriol consists of 0.02-0.03 mcg/kg/d divided q 12 h.
Maintenance doses of 0.005-0.015 mcg/kg/d divided q 12 h are instituted after 3-4 d. Oral
calcium may be required at 25 mg/kg q 8-12 h; acute hypocalcemia should be treated with
0.5-1.5 ml/kg of 10% calcium gluconate over 20 min while closely monitoring ECG.
Maintenance IV therapy consists of 10 ml of 10% calcium gluconate in 250 ml of 0.9% NaCl
given at 60 ml/kg/24h.
For certain surgical procedures, surgical staples may be an alternative to suturing. Surgical staples are inert and efficient and, when used appropriately, staples and stapling devices minimize tissue handling and contamination, create reliable and secure closures, and provide excellent hemostasis. Disadvantages are that the equipment can be expensive and veterinarians may not be as familiar or comfortable with stapling as they are with suture. The increase in cost may be offset by the reduction in surgical and anesthetic time.

The most common staplers utilized in small animal general surgery are the ligating dividing stapler (LDS), the thoracoabdominal (TA) stapler, and the gastrointestinal anastomosis (GIA) stapler. Less commonly used staplers are the end-to-end anastomosis (EEA) stapler and the intestinal linear anastomosis (ILA) stapler.

The LDS simultaneously places two U-shaped vascular clips across and transects a vascular pedicle. This instrument is typically used during splenectomies for rapid ligation and division of the multiple small splenic vessels. It can also be used to address the vessels in the broad ligament during a large dog ovariohysterectomy or to control mesenteric vessels for a large intestinal resection and anastomosis. The disadvantage of the LDS is that its use is limited to vessels no larger that 2 to 3 mm in diameter. Therefore, larger vessels must still be individually ligated.

An alternative to the LDS is the Ligasure®, a bipolar vessel-sealing device, which permanently seals blood vessels that are up to 7 mm in diameter. This device uses pressure and pulsed low-voltage energy to fuse collagen and elastin of the vessel wall and achieve hemostasis. The amount and duration of energy delivered automatically adjust to the degree of tissue impedance. This device is utilized for hemostasis in laparoscopic (e.g., ovarieotomy) and thoracoscopic (e.g., partial pericardiectomy) surgery, as well as open abdominal procedures (splenectomy, liver lobectomy, partial pancreatetomy).

Thoracoabdominal (TA) staplers place two staggered rows of B-shaped staples. The B-shaped configuration is compressive enough to provide hemostasis, but is noncrushing, which allows for microcirculation to reach the wound edge and prevent tissue necrosis. Cartridge sizes come in lengths of 30, 55, and 90mm. These staplers are commonly utilized for lung lobectomy, liver lobectomy, and partial gastrectomy, although there are multiple other uses. Use of this method for liver lobectomy is associated with less intraoperative hemorrhage.
when compared to conventional techniques of parenchymal dissection and suture ligation, and it is much faster.

A specific vascular cartridge (30 mm – V3) can be used in a TA stapler that places three staggered rows of B-shaped staples. This cartridge is indicated for closure of large vessels or resection of highly vascularized tissue. Specific examples for using a TA stapler with V3 cartridge are lung lobectomy, partial splenectomy, nephrectomy, and right auriculectomy.

Table 1. TA staple characteristics

<table>
<thead>
<tr>
<th>Cartridge Color</th>
<th>Staple Width</th>
<th>Leg length</th>
<th>Closed height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>4.0 mm</td>
<td>4.8 mm</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>Blue</td>
<td>4.0 mm</td>
<td>3.5 mm</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>White</td>
<td>3.0 mm</td>
<td>2.5 mm</td>
<td>1.0 mm</td>
</tr>
</tbody>
</table>

The gastrointestinal anastomosis stapler (GIA) places two double rows of staggered B-shaped stables 3.5 mm apart and then incises in between. This stapler is available in a variety of lengths, but the 50 to 60 mm length is most commonly used in small animal surgery. It is used most often in combination with a TA stapler to create functional end-to-end anastomoses in dogs. Advantages of stapled anastomoses include increased speed, higher tensile strength, and minimal inflammation. Other applications of the GIA include partial gastrectomy and advanced gastrointestinal diversion procedures.

The EEA stapler places a circular double-row of staples. The EEA stapler is ideal for creating inverting end-to-end or end-to-side anastomoses. A circular blade within the cartridge resects the redundant inverted tissue to create a new lumen. This stapler is most commonly utilized in veterinary surgery to perform subtotal colectomy in cats. However, the size availability and somewhat difficult application of the EEA stapler limits its use.

References:


Chlorhexidine gluconate (CHG) is a long-standing agent active against gram + and gram – bacteria, non-spore forming bacteria, yeast, and some viruses. Its efficacy is dependent on skin surface concentration, being bacteriostatic at low and bacteriocidal at high concentration. Concerns have arisen over resistance to the agent, perhaps mediated by the qac gene, encoding for resistance to quaternary ammonium compound, leading to reduced susceptibility to bezalkonium chloride and CHG. Alternatively, iodophores and alcohol additives have been suggested. The main advantage of CHG seems to be its greater residual activity and lack of interference of blood and tissue proteins in its action. Comparison with other agents has yielded the following: greater reduction in flora using CHG/alcohol over 7% iodine/alcohol and 3% parachlorometaxylenol (PCMX). Similar results were obtained when 4% CHG was compared to 10% iodophore preparation. However, another study compared 0.7% iodine/alcohol and 2% CHG/alcohol and found no difference. Studies evaluating postoperative infections seem to favor 0.5-4% CHG over 0.7-10% iodine in clean-contaminated surgery, and cost saving was also documented.

Irrigation with additives to crystalloids has fluctuated; some years it is “en vogue” and others it is not. Research shows that addition of antimicrobial agents to lavage is ineffective due to the need for continued exposure to the agent during logarithmic growth of the bacteria, which is not achieved during lavage. Suggested additives include iodine at < 5%, which is proven to inhibit fibroblasts, usually at 0.35% and 2% CHG. Exposure of implanted devices for 60 s to CHG led to decreased microbial recovery, and irrigation of the surgical site has been associated with decreased infection in some studies. The main complication of CHG contact seems to be skin hypersensitivity, which is rare, and its use on mucus membranes is not uniformly associated with reactions. CHG should not be irrigated into the middle ear or periocular region, as irritation rapidly results and requires immediate irrigation.

Studies have compared 10% hypochlorite, 2% CHG/alcohol, and 10% povidone-iodine showed them to be equal, however, the long residual effect of CHG was suggested for skin preparation for the patient and surgeon. When examining the studies evaluating hand scrub agents, lack of neutralizing agents has been suggested as a flaw to experimental design. Comparison of Avagard and Hibiclens without neutralizing agents added to sample solutions showed both to be effective, while addition demonstrated decreased efficacy of both.

Larger meta-analyses seem to support the use of CHG over iodine. Antimicrobial soaps also were associated with significantly greater reduction in colony forming units on human hands.
compared to non-antimicrobial soaps. Longer wash times (120 s) and larger volume (>1 mL but < 5 mL) may also increase efficacy.

Comparison of the different prep solutions in abdominal surgery, common in general surgery, is also of value. One study compared PCMX, CHG, povidone iodine, and 0.7% iodine/alcohol. 126 patients were enrolled, and 5 developed surgical site infection. All were prepared with povidone iodine (n=2) or iodine/alcohol (n=3).

Expansion into waterless alcohol-based antiseptic scrub for surgeon hand preparation and 1% CHG/alcohol have been introduced. Growth results were equal when staff members were sampled after random assignment of skin preparation of traditional scrub with waterless CHG. The study also suggested that less consumables were required and decreased time of surgeon preparation led to more effective use of capital in surgical cases. Comparisons show addition of CHG/alcohol to be superior at preventing bacterial growth compared to alcohol alone waterless antiseptics as well. Similar results were obtained in all types of antimicrobial soap use. Lastly, the associated skin damage was less with the waterless preparation.

References


Perineal urethrostomy is a commonly employed procedure for the treatment of urethral obstruction in male cats. It is most often recommended for recurrent obstruction, which is as frequent as 35% in cats with FLUTD. We also perform abdominal and pelvic radiography to ensure that urethral calculi are not the cause of the obstruction. Calcium oxalate calculi are becoming more common, and making certain that they are not the cause of the initial obstruction is important for avoiding recurrence in those patients, as cystotomy is required.

Perineal urethrostomy is classically performed with the patient in sternal recumbency with the limbs retracted caudally over the end of the patient table. Be sure that adequate padding is available over the table’s edge and avoid significant cranial traction of the distal limbs. Excise the scrotum, and then perform castration if the cat is intact. Remove the prepuce and scrotal skin so that you are working solely with the urinary structures. Place an allis tissue forceps on the penis after catheterizing it. This will maintain orientation of the tract and will keep the urethral catheter in place. Start the dissection ventrally. Use carmalt forceps ventral to the penis and urethra and advance along the pelvis until the abdomen has been entered. Continue the dissection lateral and ventral until a finger can be inserted under the tract. Free the ischiocavernosus muscles from their pelvic attachments bluntly, do not ligate or transect their bodies, as you will use the muscle bellies later in the procedure. Save the entire ischiocavernosus muscle! The dissection then continues laterally and dorsally along the tract. The retractor penis muscle marks the dorsal midline for you. As you mobilize the tract, look for the bulbourethral glands that sit laterally on the pelvic urethra. Often pelvic fat is encountered first. It subjectively is yellow and lobulated, where the bulbourethral glands are tan, round, smooth and firmer upon palpation. Make sure that the bulbourethral glands are nicely visible prior to opening the urethra. Remove the retractor penis muscle. Open the urethra at its middle on the dorsal midline and extend the incision with iris scissors up to the bulbourethral glands. The urethra at that point should allow a hemostatic forceps into the lumen up to their box locks.

Now you use those ischiocavernosus muscles! Expose the caudal thigh fascia at the ventral aspect of the approach. Use the ischiocavernosus muscles to pull the tract caudally and ventrally. Suture the ischiocavernosus muscles to the fascia with a horizontal mattress suture of 3-0 PDS. This will help to decrease tension on the tract. Emptying the bladder will also help. Then suture periurethral tissue at the proximal most aspect of the surgery site to the underside of the dermis dorsally, this will also reduce interference of the fatty adventitia and subcutis and will decrease the tension dorsally. Start at 12 o’clock, 1 or 2 o’clock and 10 or 11 o’clock and place your initial sutures that anastomose the skin to urethral mucosa. Make sure to take PARTIAL thickness bites of skin and FULL thickness bites of urethra mucosa. Then slowly progress with closure to the ventral aspect of the intended “drain board” of the
urethrostomy. No real dimension of the drain board is required. It likely only changes a circular anastomosis to an elongated one, helping but not avoiding the risk of stricture. Ligate the penis with a MATTRESS suture, and then close the distal aspect of the site. Make sure that you recover the cat in an Elizabethan collar to avoid unnecessary trauma that will cause hemorrhage and second intention healing (leading to stricture).

Complications of the surgery include stricture, dehiscence, urinary incontinence, fecal incontinence, and recurrent signs associated with FLUTD or cystitis. Recent reports showed that approximately 10% will die within 6 m, with reasons related to urinary disease in the majority. Long-term survivors (87%) died mainly of causes not related to the urinary tract and were asymptomatic for urinary tract disease (61%) or were still alive. Cats did not have clinical signs of recurrence (60%) or had 1-2 incidents of FLUTD (30%) or several incidents (11%).

References

When choosing a suture material, the surgeon must be knowledgeable about the healing properties of the particular tissue, the wound healing capability of the patient, and the characteristics of suitable suture materials (particularly tissue reactivity, tensile strength, knot security, and rate of absorption). The type of suture to be used depends on the procedure being performed and the tissue in which it will be placed. The suture material chosen must retain its strength until the wound heals sufficiently (Figure 1). In other words, the tensile strength of suture material must be equal to the normal or uninjured strength of the tissue through which it is passed. The ideal suture would provide strength and apposition until the wound has healed satisfactorily, without causing any secondary complications. Considerations for suture selection include the length of time the suture will be required to help strengthen the wound or tissue, the risk of infection, the effect of the suture material on wound healing, and the dimension and strength of the suture required.

**Figure 1. Rate of tensile strength loss of various suture types**

Several new sutures have become available that present the veterinarian with additional choices when selecting an appropriate material for abdominal surgery. **Synthetic, monofilament, absorbable** suture material is commonly used in gastrointestinal, respiratory, and urinary surgery. Classic options include polydioxanone (PDS®) and polyglyconate (Maxon®). These suture materials maintain their tensile strength for longer than 21 days and are completely absorbed by 6 months following implantation. Although Maxon and PDS are extremely inert and glide easily through tissue, they have a tendency to be stiff and awkward...
to handle. Also, more throws are required to ensure good knot security; therefore other materials may be better for subcutaneous and intradermal suturing. New monofilament absorbable suture materials include poliglecaprone 25 (Monocryl®), glycomer 631 (Biosyn®), and polyglytone 6211 (Caprosyn®). These materials maintain tensile strength for less than 21 days and are completely absorbed between 60 and 120 days. Rapidly absorbable suture materials are ideal for gastrointestinal and urinary suture in that sutures can be placed full-thickness into the lumen ensuring improved suture line integrity. Both the urinary bladder and stomach regain almost 100% of their strength by 14 days following incision and therefore suture should be chosen to match the healing rate of the tissue.

Monocryl was released by Ethicon, Inc., a Johnson & Johnson company, in the mid-1990’s. It is more pliable than other monofilaments leading to improved handling. This suture is indicated in procedures for which high tensile strength is required initially. Monocryl retains 60 to 70% of its original strength 7 days post-implantation, 30 to 40% at 14 days, and 0% by 28 days. Monocryl has been evaluated in cats for use in routine ovariohysterectomy. It was evaluated for pedicle ligation and abdominal closure. No dehiscences were reported and inflammatory response to the suture was mild and short-lived.

Biosyn and Caprosyn are products of Syneture™, part of Covidien, Inc. Biosyn was released in the late 1990’s. Similar to Monocryl, Biosyn offers excellent initial tensile strength with 75% loss of strength occurring by 14 days post-implantation. Biosyn also incites minimal tissue reaction and has improved handling characteristics compared to older monofilament absorbable suture materials.

Caprosyn is the newest rapidly absorbable monofilament suture as it was released in the early 2000’s. Caprosyn is composed of polyglytone 6211, which is a synthetic polyester of glycolide, capralactone, trimethylene carbonate, and lactide. Absorption of this material is essentially complete in 56 days, which is thought to lead to less wound complications and tissue reactions. This suture retains up to 30% knot strength at 10 days post-implantation and has excellent handling characteristics.

Polysorb® is a relatively new synthetic absorbable suture material from Syneture. Polysorb is composed of a glycolide/lactide copolymer. It is another alternative to traditional sutures such as polyglactin 910 (Vicryl®) and polyglycolic acid (Dexon®). Polysorb has good initial tensile strength (maintains 80% of original strength at 14 days, but only 30% at 21 days) and predictable absorption that is complete by 2 months post-implantation. This material also offers excellent handling characteristics and knot security. Indications include closure of subcutaneous tissue and intradermal suture placement. As Polysorb is a braided suture, it is not recommended for visceral placement.

Antimicrobial-impregnated sutures have been recently introduced to veterinary market. These sutures are coated with the antibacterial agent triclosan in order to reduce the bacterial colonization of suture. PDS, Vicryl, and Monocryl are all available in triclosan-coated
varieties. However the only large veterinary study evaluating triclosan-impregnated suture in clinical cases did not show any additional benefit in elective orthopedic cases.

Reference

Primary ligamentous support of the stifle joint is provided by collateral ligaments and the intra-articular cranial and caudal cruciate ligaments. Nutritional support for the intra-articular ligaments arises from small vessels traversing the ligament structure and, as important, through synovial fluid bathing the ligament. Mechanoreceptors and afferent nerve endings have been identified within the interfiber layers of the cranial cruciate ligament. Innervation of the ligament serves as a proprioceptive feedback mechanism to prevent excessive flexion or extension of the stifle joint. This protective action is through stimulation or relaxation of muscle groups which lend support to the joint. The geometry of the CCL femoral attachment is responsible for a reciprocal loosening and tightening of the ligament through a normal range of motion. The CCL arises within the intercondylar fossa of the lateral condyle of the femur and extends diagonally across the joint space to insert onto the craniomedial tibial plateau. (Fig.1) The ligament enters the joint space through the intercondylar notch (INC) and spirals approximately 90° as it crosses the joint between attachment sites. A intercondylar notch width index (ration of the width of the ICN to the width of the distal femur) has been established in the dog. The normal proximal notch index is .32 and normal distal notch width index .41.

The CCL is a mechanical structure that is very important in normal stifle joint function. Because of this role, it is easy to feel that an abnormal mechanical environment is most likely to cause the injury. The CCL prevents cranial displacement of the tibial plateau relative to the femur. This displacement is being induced by the pull of the quadriceps on the tibial crest, pressure of the patella pushing the femur caudally, and the femoral condyles sliding caudally on relative to the slope of the tibial plateau. When considered alone, these forces can be quite large, but antagonist muscles can counter a portion of these cranially directed forces. The CCL also counters internal rotation because it runs from the caudo-lateral to the cranio-medial aspect of the joint. This role is probably most important when the dog changes direction while a hindlimb is bearing weight. The final mechanical role for the CCL is to limit extension of the stifle. The complexity of CCL mechanics increases when it is recognized that specific portions of the ligament are functioning at different times. The ligament is classically divided into two bands – caudolateral and craniomedial – based on the location of their insertion on the tibial plateau. The craniomedial band appears taut through most of the range of motion, and probably is most important in countering cranial drawer and internal rotation. The caudolateral band appears to be the primary restraint against hyperextension. A number of predisposing factors have been proposed that may cause a dog to gradually injure the CCL.

Tibial plateau angle relative to the ground is believed to be a contributing factor to CCL injury in the dog. Ground reaction forces and extensor muscle forces during weight bearing generate compressive forces on the articular surface of the tibia. Because of the caudally-
directed slope of the tibial plateau, tibial compression generates a cranially-oriented shear force that induces cranial tibial translation in CrCL deficient stifles. The shear component of the compressive force on the tibia, called cranial tibial thrust (CTT), is passively constrained by the CrCL and the caudal horn of the medial meniscus. The CTT is proportional to the slope of the tibial plateau. The effect of the tibial plateau on the development of partial CCL injury in the dog continues to be investigated. Presently controversy exists between published reports. One report suggests a difference in tibial plateau slope between dogs having CCL injury and those not having injury (breed and aged matched dogs). Dogs with CCL injury have increased tibial plateau slope and therefore increased CCT. Other reports do not confirm this finding and suggest no difference in tibial plateau slope between dogs having CCL injury and those not having CCL injury. One study showed that in dogs with a normal standing angle of the stifle joint, the tibial plateau slope was within 1-2 degrees of being parallel to the ground. Further, Vezzoni showed that an increased stifle joint standing angle that has been encouraged in some breeds of dogs (Labrador, Rottweiler) to be a risk factor in the development of CCL injury in the dog. Cadaver dissections in our laboratory have shown that hyperextension of the stifle and/or tarsus increases the angle of the tibial plateau slope relative to the ground. This causes the caudolateral band to be overly stressed. Early arthroscopic intervention has shown the caudolateral band to be the initially affected portion of the CCL in dogs with a partial tears.

**Examination:** Perform the initial examination of the stifle with the animal standing. Simultaneously palpate both stifles to detect swelling. A swollen stifle usually indicates degenerative joint disease. The patellar ligament becomes less distinct with joint effusion and the medial aspect of the stifle enlarges because of capsular thickening and osteophyte formation. Palpate the stability of the patella with the hip joint in full extension. Ask the animal to sit; observe the flexion of the stifle and tarsus. The earliest sign of stifle joint pathology is failure to dorsiflex the tarsus fully (compare to the opposite normal side). As effusion and periarticular reaction progresses, the animal will no longer flex the stifle joint fully.
The remainder of the examination is done with the animal in lateral recumbency. Extend and flex the stifle while holding one hand over the cranial aspect of the joint to detect crepitation. Next examine the stability of the patella in relationship to the femur. Extend the stifle, internally rotate the foot, and apply digital pressure in an attempt to displace the patella medially (i.e., medial patellar luxation). Detect lateral patellar luxation by slightly flexing the stifle, externally rotating the foot, and applying digital pressure to attempt to displace the patella laterally. The patella normally moves slightly medially and laterally, but when it leaves the trochlear groove it is considered to be luxating.

Collateral ligaments. Test the integrity of the collateral ligaments by holding the stifle in full extension and attempting to open the stifle on the medial and lateral aspects. Test the medial collateral ligament by using one hand to brace the femur while the other hand abducts the tibia. Normally the medial collateral ligament will not allow joint laxity. Test the lateral collateral ligament by bracing the femur with one hand and using the other hand to adduct the tibia. An intact lateral collateral ligament will prevent joint laxity. If the stifle is allowed to flex while the tibia is adducted, it may feel as though there is lateral laxity of the joint. This is a result of anatomic location of the lateral collateral ligament and internal rotation of the joint and is normal.

Cruciate ligaments. Test the integrity of the cruciate ligaments by trying to elicit a cranial or caudal drawer motion. Drawer movement is caused by the tibia sliding cranially or caudally in relationship to the femur. This motion is not possible when the cruciate ligaments are intact in adult animals. Immature animals may have slight drawer motion, but it stops abruptly as the ligament tightens. To elicit direct drawer motion, place the index finger and thumb of one hand over the patella and lateral fabellar regions, respectively. Place the index finger of the opposite hand on the tibial tuberosity and, with the thumb positioned caudal to the fibular head, slightly flex the stifle. Stabilize the femur, and gently move the tibia cranial and distal to the femur. Do not allow tibial rotation. If the muscles are tense, they may prevent this motion. If this occurs, gently flex and extend the stifle to relax the animal, and repeat the procedure. Test drawer motion with the femur flexed and extended. Usually, the greatest movement is felt with the stifle in flexion. The presence and amount of drawer motion depend on the animal’s age, size, state of relaxation, and the duration and type of cruciate pathology. There is minimal drawer motion in normal dogs and cats, although very young puppies may have a “lax” stifle. Eliciting drawer motion in larger animals or those that are tense is difficult; sedation or general anesthesia may be necessary. Minimal drawer motion may be noted with chronic cruciate pathology (especially in large dogs) because periarticular fibrosis restricts stifle motion. Minimal or partial drawer motion may also occur with incomplete tears or stretching of the cranial cruciate ligament. Drawer motion is evident with a torn caudal cruciate ligament. To identify caudal drawer motion, start with the stifle in a neutral position. Most caudal ligament ruptures are not discovered until exploration because they are mistaken for cranial ligament injuries.

**Imaging:** Early diagnosis is dependent upon radiographic presence of joint effusion. A radiolucent line adjacent to the caudal joint capsule is representative of fatty tissue in the space between the joint capsule and popliteal muscle. Caudal displacement of this line is
representative of joint effusion. This is one of the earliest radiographic indications of partial anterior cruciate ligament injury. As changes progress, typical radiographic signs of DJD will be noted.
METHODS OF SURGICAL MANAGEMENT OF ACL DEFICIENT KNEE/TTA

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Abstract

Techniques in surgical treatment of anterior cruciate ligament rupture in dogs are overviewed. Principles, recent trends and the author’s experiences arthroscopy/arthrotomy in combination with tibial tuberosity advancement are presented. Clinical results of only fascia lata imbrication used for stabilization of the anterior cruciate ligament deficient knee are listed. Repair of cruciate ligament lesion using bone marrow stem cell with novel scaffold in experimental animal model is also mentioned.

Recently, methods of therapy of anterior cruciate ligament (ACL) rupture in dogs are almost always based on surgical intervention. Surgeons’ preferences and their past experience with a technique are usually the main criterion when selecting the type of surgical intervention. Intra-capsular techniques of ACL replacements (Arnoczky et al. 1979; Hulse and Beal 2000) were based on total revascularization of intra-articularly inserted grafts (most often from fascia lata, or ligamentum patellae). Basically, the following options are the most commonly used techniques nowadays:

Primary ACL reconstruction - indicated in cases of avulsion fracture of the site of the ligament’s attachment to the tibia (usually in dogs under 1 year of age). Ideally, arthrotopic/arthroscopic reposition and fixation of one large bone fragment is indicated (Beale et al. 2003; Whitney 1998).

Extra-capsular (EC) stabilization of the knee joint with ACL rupture, which methods and modifications are well described (Tonks et al. 2011). The stabilization efforts focuses on ensuring minimally invasive ways of inserting suture after arthroscopic repair; putting suture into the so-called “isometric position”; anchoring suture in bone rather than soft tissues; or using the “TightRope”® CCL system (Arthrex) (Beale 2000; Cook 2010; Hulse et al. 2010; Hyman et al. 2001; Roe et al. 2008). Since 1995, many of our cases of chronic ACL rupture with secondary osteoarthrosis (i.e., when craniocaudal knee instability is at a minimum level and the joint is therefore relatively firm due to the secondary changes) have been stabilized using only fascia lata imbrication with polypropylene (individual horizontal mattress or inverting continuous sutures) (Necas 2011). As far as we know, no other site uses this technique as an independent method of EC stabilization of knee joints with insufficient ACL. This technique has shown good long term results. We believe that this type of surgery is reliable, quick, technically undemanding, affordable, and less traumatic to tissues. In case of ACL arthroscopy, we use a modified technique of fascia lata imbrication in which the fascia is approached through short skin incisions only (Necas 2011).
Tibial osteotomies adjusting forces acting upon a loaded limb include “Tibial Wedge Osteotomy” (TWO) (Slocum and Devine 1984), “Tibial Plateau Leveling Osteotomy” (Slocum and Slocum 1993), “Tibial Tuberosity Advancement” (TTA) (Montavon et al. 2002), “Modified Maquet technique” (MMT) (Etchepareborde et al. 2011), “Triple Tibial Osteotomy” (TTO) (Bruce et al. 2007) which basically combines TTA with TWO, and CBLO (Hulse et al. 2010; Raske et al. 2013). Currently, TPLO, CBLO and TTA are considered as state-of-the-art methods of surgical solution of ACL rupture in dogs. Of these techniques for ACL insufficiency by tibial osteotomy, TTA will be presented at the WVC 2013 in more detail.

Regardless of the technique used for ACL rupture, intra-articular structures (i.e., anterior cruciate ligament, meniscuses and articular cartilage) can be repaired and treated by arthroscopy. Arthroscopic surgery is a minimally invasive intervention that affords many benefits for patients in the perioperative period (Miller and Presnell 1985; Necas et al. 2002; Pozzi et al. 2008; Siemering 1978; Van Gestel 1985). These benefits include reduced postoperative pain, negligible scarring compared with arthrotomy (which has an appreciable cosmetic effect), earlier restoration of limb function, earlier rehabilitation, shorter post-operation recovery, and shorter hospitalization (Beale and Hulse 2010). Importantly, the less severe injury to the joint during arthroscopy (versus arthrotomy) poses less risk of development of osteoarthritis (Beale and Hulse 2010). Arthroscopic assisted ACL surgeries, performed at Brno since 2001, are currently considered indispensable in therapy of ACL rupture. After this repair and treatment of damaged intra-articular structures, copious joint lavage (which can have a prolonged effect on the suppression of synovitis after arthroscopy as compared with intra-articular application of) is recommended steroids (Muir 2010).

Experimental bone marrow stem cell therapy in combination with novel scaffold for ligament repair in a miniature pig animal model

Results of recent studies hold promise that stem cell therapy will be available for the therapy of orthopedic problems (Barry et al. 2010; Conzemius 2010; Frisbie et al. 2009). Our present experimental study (Fedorova et al., submitted; Necas 2011) with a miniature pig animal model monitors the potential use of scaffold/MSCs for healing of lesions of anterior cruciate ligament. Iatrogenically damaged ligament was treated using the scaffold (developed at our site) and MSCs. In control groups of animals, we monitored healing of this iatrogenic defect without implanting cells, or without both cells and scaffold. The results of this study are currently being evaluated.

Acknowledgements

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UPDATE ON EXTRACAPSULAR STABILIZATION; ISOMETRIC POINTS

Don Hulse DVM, ACVS, ECVS

Surgical Approach

Position the dog in lateral recumbence with the affected limb upward. Make a skin incision adjacent to the lateral edge of the patellar tendon beginning 5 cm proximal to the patella and extending distally 5 cm below the tibial crest. Incise the subcutaneous tissue along the same line. This exposes the lateral edge of the patella, patellar tendon and the fascia lata. With the scalpel blade make an incision at the border of the patellar tendon and fascia lata. Make certain this incision is along the edge of the patellar tendon and not laterally within the fascia lata. This incision is begun 1 cm below the distal pole of the patella and extends distally to the tibial crest. This maneuver creates a tissue plane beneath the tendon/fascia and underlying fat pad. At the proximal extent of the incision/tissue plane beginning just below the distal pole of the patella, use the closed scissors to create a tunnel by forcing the closed scissor blades proximally between the fascia lata and underlying joint capsule. Continue this maneuver proximally the length of the incision. Withdraw the scissors and cut the fascia the length of the incision leaving 2-3mm of tissue adjacent to the patella for future closure. Locate the cut fascia adjacent to the patella tendon at the distal extent of the incision near the tibial crest. At this point, use the closed scissors to create a tunnel from cranial to caudal at the joint line. The tunnel begins at the tibial crest and extends to the fibular head along the tibial plateau. Remove the scissors and cut the fascia from cranial to caudal. **Note do not extend this incision caudal to the fibular head to avoid damage to the peroneal nerve.** This maneuver creates a triangular section of fascia lata which is bluntly separated from the underlying joint capsule. When reflected caudally and proximally, excellent access is created to the lateral collateral ligament, joint capsule and fabella.
Incise the joint capsule. Begin with an incision at the distal pole of the patella; the incision is carried distally to the tibial crest. Next extend the incision proximally. From the distal pole of the patella, cut cranial to caudal along the border of the vastus lateralis (do not incise through the muscle fibers). Reflect the patella medially to expose the cranial face of the joint.

Recommended sites for isometric suture placement:

Anchor Suture Technique (F2T3): When inserting a single anchor/suture (dogs/cats under 35 -40 lbs) the preferred technique is placement of an Arthrex suture anchor loaded with #2 or #5 fiberwire at the femoral F2 site with the free ends of the suture passed through a pre-drilled holes at the T3 site.

Locating the F2 site: The F2 site is located at the level of the distal pole of the fabella. Placement of the anchor is critical. The anchor must be placed in the femoral condyle as far distal and as far caudal as is possible. An anchor placed to far proximal or anterior is at risk for pull out or suture failure. To locate the correct placement site in the femoral condyle, palpate the distal pole of the fabella. Make a vertical incision through the capsular tissue to expose the joint line between the fabella and caudal margin of the femur. Locate the proper position for the anchor just distal to the fabella-femoral joint line and as far caudal as possible. A hole is pre-drilled with a 2mm drill bit (or 1/16 Steinmann pin) at the correct anchor position. The drill hole is angled directed toward the patella to cranial to eliminate the risk of entering the joint. Insert the appropriate size anchor.
Locate the T3 site at the proximal tibia. First locate the protuberances cranial and caudal to the long digital extensor groove. Make a vertical incision through the capsular tissue overlying the extensor groove. Palpate and locate the protuberance just caudal to the extensor groove; this is the site for placement of the first drill hole. At this site beginning as proximal as is possible without entering the joint, insert a .045 k-wire. The K-wire is directed to glide beneath the extensor groove to exit through the medial cortex of the proximal tibia. With the K-wire in place, place a 2mm cannulated drill bit over the wire to create the first drill hole. Drill over the K-wire to exit through the medial cortex. Leave the drill bit in place and remove the K-wire. Through the cannulated hole in the drill bit, place a nytinol Arthrex suture passer such that the loop is lateral. Remove the drill bit and leave the suture passer in the drill hole.

Passing the suture through the drill hole: Place one of the suture ends through the loop in the nytinol suture passer. Only place about 1cm of the suture through the loop to decrease suture drag as it passes though the drill hole. Pull the suture passer medial such that the free end of the suture exits through the medial cortex. Place the free end of the suture through a two hole button such that the button will lie against the medial cortex when the suture is pulled taught. Re-insert the nytinol suture passer through the drill hole such that the loop is positioned medial. Place the free end of the suture through the nytinol loop (1cm of suture end) and pull the suture laterally. Now both free ends of the suture are lateral and ready to be tied.
**Tying the suture:** Place the limb in normal standing position (140 degrees). Place the initial double throw of a surgeon's knot and check cranial drawer. Do not over constrain; there should be 2-3 mm cranial translation. When satisfied with stability, complete the surgeon's knot and place 4 additional half throws. Check range of motion and cranial drawer.

**Advance the fascia lata:** the triangular section of fascia lata created in the initial surgery is advanced and sutured anteriorly, distally, and medially. The free edge is sutured non-absorbable suture.

**Knotless Swivelock**

The 5.5mm PEEK SwiveLock is recommended for dogs weighing 50 lbs or greater. One strand of 2mm Fibertape (2 limbs) is inserted for dogs up to 70 lbs or so; two strands (4 limbs) of 2mm fiberTape is recommended for dogs greater than 70 lbs. The F2 and T3 sites described previously are used in this application.

**Single strand 2mm Fibertape (this is referred to as two limbs since the single strand Fibertape is folded on itself):** The T3 site is located and a .045 guide wire inserted from lateral to medial to exit the medial cortex. The 2mm cannulated drill bit is placed over the guide wire and drilled to exit medially. The guide wire is removed and nytinol suture passer placed through the cannulated drill bit with the loop exiting medially. **The drill bit is removed leaving the suture passer in place.** The Fibertape is passed through the two hole button (making two limbs). The free ends of the FiberTape are loaded into the suture passer and pulled to exit T3 laterally.

The F2 site is located and the spade drill bit used to drill a tunnel to the stop on the shaft of the drill bit. The tunnel is then tapped with the 5.5mm tap. The free ends of the Fibertape are loaded into the eye of the SwiveLock and the Eye placed into the F2 tunnel (3-4 mm into the tunnel). Abnormal craniocaudal laxity is eliminated (leaving 2-3 mm normal laxity) by tensioning each limb of the FiberTape separately. When satisfactory stability is achieved, the limbs of the FiberTape are aligned adjacent to and parallel to the shaft of the Swivelock. A mark is made in the Fibertape where the limbs of the Fibertape are at the same level as the distal end of the interference screw. The Eye of the SwiveLock is retracted from the tunnel and the FiberTape pulled back through the Eye so that the mark is located within the Eye of the Swivelock. The Eye is now re-inserted into the tunnel and a mallet used to drive the Eye into the tunnel until the interference screw is flush with the bone. The square handle on the shaft is held and the knob turned clockwise to engage the interference screw. The interference screw is driven to be flush with the bone surface. The strand of Fiberwire used to hold the Eye in place is unwrapped from the knob and the Swivelock handle removed. One arm of the Fiberwire (used to hold the Eye) is pulled to remove the FiberWire. The FiberTape is now cut.
Two Strands FiberTape (4 limbs): The T3 site is located and a .045 guide wire inserted from lateral to medial to exit the medial cortex. The 2.5mm cannulated drill bit is placed over the guide wire and drilled to exit medially. The guide wire is removed and nytinol suture passer placed through the cannulated drill bit with the loop exiting medially. The drill bit is removed leaving the suture passer in place. Two strands of Fibertape are passed through the two hole button (or 4 hole button). (This makes 4 limbs since each strands of Fibertape is folded on to itself.) The free ends of the FiberTape (all 4 limbs) are loaded into the suture passer and pulled to exit T3 laterally.

The F2 site is located and the spade drill bit used to drill a tunnel to the stop on the shaft of the drill bit. The tunnel is then tapped with the 5.5mm tap. The .045 guide wire is placed into the tunnel and drilled from the depth of the tunnel to exit medially; the guide wire is drilled at the 7 o’clock position of the tunnel. The 2.5 mm cannulated drill bit is placed over the guide wire and drilled to exit medially. The guide wire is removed and the nytinol suture passer placed in the cannulated bit such that the loop is positioned laterally. The cannulated drill bit is removed leaving the nytinol suture passer in place. The lead ends of the Fibertape (4 limbs) are placed into the loop of the suture passer and pulled to exit the 2.5mm tunnel medially. The 4 limbs are tensioned by hand or the Arthrex tensioner to eliminate abnormal craniocaudal laxity (2-3 mm craniocaudal movement remaining). The Eye of the Swivelock is removed by unwrapping the Fiberwire from the knob, removing the Fiberwire by pulling on 1 limb of the fiberwire, and dis-engaging the Eye from the tip of the Swivelock. With the Eye removed, insert the shaft of the Swivelock into the F2 tunnel from lateral to medial. Use a mallet to drive the shaft into the tunnel until the interference screw is flush with the bone surface. Hold the square handle and turn the knob clockwise to engage the interference screw. Continue to engage the interference screw until the screw is flush with the bone. Remove the handle and cut the Fibertape at the exit hole medially and adjacent to the interference screw laterally.
FiberTape pulled through T3; F2 tunnel drilled with spade drill bit; bottom of F2 tunnel drilled with 2.5 drill bit
Partial tears of the cranial cruciate ligament (CrCL) are very common and lead to DJD. These patients respond well to TPLO.

**TPLO PROCEDURE IN DOGS AND CATS**

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Tibial plateau leveling osteotomy (TPLO) is a common procedure used to treat dogs of all sizes suffering from partial and complete tears of the cranial cruciate ligament (CrCL). TPLO can be considered a joint mechanic altering technique. The technique converts cranial tibial thrust to a caudal tibial thrust by rotating the tibial plateau to approximately 6 degrees. After doing so, the caudal cruciate ligament stabilizes the stifle joint against a caudal tibial thrust of low magnitude during the weightbearing phase of the stride. Bone plates to stabilize the osteotomy are available from different manufacturers. The plates vary in appearance and function depending on the manufacturer. No plate has been shown to be clinically superior at this time, but many types of TPLO plates are available. Locking plates are preferred to traditional plates due to increased stability and better limb alignment. TPLO has been found to be an excellent procedure to treat all sizes of dogs and cats with CrCL injury.

**Type of Injury**

Tears of the cranial cruciate ligament (CrCL) typically are categorized as complete or partial. Complete tears are generally easier to diagnose due to the presence of cranial drawer and tibial thrust with the tibial compression test. Partial tears typically have less instability, usually having cranial drawer only when the stifle is positioned in flexion. It is important to visualize the intraarticular structures, particularly the menisci, with either type of tear. Arthrotomy or arthroscopy accomplishes this. Meniscal tears can occur with partial or complete CrCL tears, but are more common with complete tears. The most common type of meniscal injury is a bucket-handle tear of the medial meniscus. It is also interesting to note that partial tears, with little demonstrable instability, may have substantial osteoarthritis at the time of diagnosis. This indicates that gross instability is not the only cause of osteoarthritis- biologic reactions associated with the degenerating CrCL and subsequent micro-instability are likely occurring. TPLO may provide a protective effect for patients with partial CrCL tears. TPLO is thought to decrease stress and strain on the ligament associated with chronic tibial thrust. Patients who were evaluated arthroscopically at long term follow-up following TPLO were found to have no further damage to the remaining CrCL ligament fibers in most patients.
TPLO Procedure using Synthes LCP Plate

Initial inspection of the stifle joint by arthroscopy or arthrotomy, to examine the cruciate ligaments and/or meniscal cartilages is performed. A medial approach to the proximal end of the tibia is performed as described by Slocum, and a TPLO jig (Slocum Enterprises, Eugene, OR) is applied. The size of the bi-radial saw blade to be used, and the location of the tibial osteotomy is determined by preoperative planning from the mediolateral radiograph. The osteotomy is performed with an oscillating saw and bi-radial (Slocum Enterprises, Eugene, OR) or crescentric blade (New Generation Devices, Glen Rock, NJ), with continuous saline lavage to minimize heat necrosis of bone; the tibial plateau segment is rotated and temporarily fixed in position with a 1.6 mm Kirschner-wire. A large bone holding forceps applied across the osteotomy from the proximal jig pin to the tibial tuberosity is used for compression of the osteotomy at the discretion of the surgeon. The TPLO plate is positioned on the medial surface of the tibia in a manner that best fit the bone contour and osteotomy. Plate orientation is such that its caudal margin is preferentially placed parallel to and adjacent to the caudal cortex of the tibial diaphysis whenever possible. The plate is also positioned such that the proximocaudal notch in the TPLO plate is near to, or in abutment to the proximal jig pin. Contouring of the TPLO plate is left to the discretion of the surgeon. If any bending or twisting was required, it is performed at or distal to the junction of the head and shaft of the plate to avoid any damage to the three proximal locking plate holes.

The TPLO plate is attached to the bone using three 3.5 mm locking screws proximally, and three 3.5 mm cortical screws distally. Holes for locking screws are drilled using threaded drill guides and a 2.8 mm drill bit. Holes for cortical screws in the DCP and Combi™ holes are drilled using the universal drill guide and a 2.5 mm drill bit in a neutral or load position as described below. Screws are typically inserted in the following sequence:

- a.) Proximal shaft hole: neutral position, 3.5 cortex screw inserted and tightened or left loose by not more than one-quarter turn. If left loose, the surgeon continues to be push the plate proximally against this screw, before the next screw is placed, ensuring that the proximal end of the plate is not pressed against the bone.
- b.) Distal shaft hole: load position, 3.5 cortex screw inserted and tightened until it nearly touches the bone plate.
- c.) Cranial head hole: 3.5 locking screw to 1.5 N-m tightness.
- d.) Proximal head hole: 3.5 locking screw to 1.5 N-m tightness.
- e.) Tighten the load cortical screw in most distal plate hole, after slight loosening of the neutral cortical screw if necessary. Re-tighten the neutral cortical screw.
- f.) Remove TPLO jig, two jig pins, and Kirschner-wire.
- g.) Confirm compression and correct alignment of osteotomy and limb.
- h.) Caudal head hole: 3.5 locking screw to 1.5 N-m tightness.
- i.) Middle shaft hole (combi-hole): Neutral or load position with a 3.5 mm cortical screw.
- j.) The tightness of all screws was checked and the compression of osteotomy, and alignment of the osteotomy and limb is verified.

The incision is closed routinely in layers.
TPLO Procedure using Fixin Locking Plate

A minimally-invasive medial approach to the proximal tibia and stifle joint is performed and the joint is explored and the meniscus treated at the discretion of the surgeon. The medial collateral ligament is identified, and the TPLO jig is applied medially at the surgeon’s discretion. The popliteus muscle is elevated as little as possible from the caudomedial aspect of the tibia to perform a radial osteotomy and apply the plate.

A radial osteotomy is performed on the proximal tibia such that the proximal extent of the osteotomy exits cranial to the cranial intercondylar area, and the distal extent exits the caudal tibial cortex. The position of the osteotomy has been shown to affect postoperative TPA, as well as the geometric relationship between the structures within the tibial plateau segment and those of the distal tibial segment, namely the patellar tendon insertion. This osteotomy can be centered on the intercondylar tubercles, and thus proximal tibial plateau segment rotation results in accurate tibial plateau leveling without altering the geometric relationship of the patellar tendon insertion to the articular surface of the tibia. The centered cut position has been shown to be geometrically more precise, and biomechanically superior to the distal position.

The osteotomy is performed partially thorough the tibia. Marks corresponding to the magnitude of rotation are made on the tibial cortex, referenced from the TPLO chart. The osteotomy is continued through the bone. The tibial plateau segment is rotated with a pin inserted proximo-cranially, to achieve a postoperative TPA of approximately 6 degrees. The proximal tibial segment is stabilized in the rotated position with a temporary stabilization pin placed into the distal tibial segment. Interfragmentary compression can be achieved by application of pointed bone reduction forceps or applying the bone plate in compression. The osteotomy is stabilized with a FIXIN locking bone plate utilizing standard technique. The plate is temporarily attached to the tibia using pin stoppers, small k-wires or a one clamp. One screw is inserted on each side of the osteotomy. The remaining screw are then inserted. Anatomic contouring of the plate is unnecessary due to the use of locking screws in all of the holes of the plate.

Dogs are restricted to leash walk activity for 8 weeks. Radiographic assessment of healing is performed at 8 weeks. Adequate bony healing of the osteotomy is typically seen at this time.
Once adequate healing I confirmed, the dog is progressively returned to normal activity over the next weeks.

**Outcome**

Although osteoarthritis (OA) can ensue following TPLO, TPLO has been shown to have a decreased chance of developing radiographic signs of OA as compared to extracapsular methods of stabilization of the cruciate-deficient stifle. In addition, radiographic progression of OA is less with minimally-invasive surgical techniques as compared to routine arthrotomy. Some patients appear to develop varying degrees of cartilage erosion. Cartilage erosion can be seen on weightbearing and non-weightbearing areas of the medial and lateral femoral condyles and tibial plateaus. Cartilage erosion appears to affect most patients to some degree, but is very mild in most cases. Severe cartilage erosion has been seen in some TPLO patients, resulting in full thickness loss of cartilage, usually of one of the femoral condyles.

Functional outcome appears to be good following recovery from TPLO. Experimental transaction of the cranial cruciate ligament, followed by TPLO, resulted in near normal function after 18 weeks. Although TPLO is often considered to be the surgical treatment of choice for treatment of cruciate disease in large breed dogs, a superior outcome has not been shown as compared to lateral suture stabilization. Dogs are expected to return to athletic levels of performance following TPLO.

Early treatment of cranial cruciate ligament injury with TPLO may have a better functional outcome and lower chance of postoperative complications. A decreased chance of osteoarthritis and postliminary meniscal tears have been found in patients having partial tears of the cranial cruciate ligament and minimal cranial drawer instability. Early treatment of partial tears with TPLO has also been found to protect the remaining fibers of the ligament. Remaining fibers appear to remain grossly healthy and functional in most patients when assessed arthroscopically at long term follow-up.

**Complications**

The reported complication rate following TPLO was initially very high, 20-25% depending on the study. Currently, complications have become much less common after TPLO due to improvements in the surgical approach, surgical technique, surgical instrumentation, surgical implants and most importantly- surgeon experience. Current complication rate is less than
5%. Complications associated with TPLO can be categorized as intraoperative or postoperative. Intraoperative complications include hemorrhage, intra-articular placement of screws or jig pins, screw breakage and stripping of the screw. Acute postoperative complications include tissue swelling/edema, hematoma/seroma, dehiscence, incisional infection, and irritation from bandaging. Chronic postoperative complications include postliminary meniscal tears, tibial crest fracture, proximal tibial fracture, fixation failure, patellar tendon swelling, and infection. Many complications are minor and easy to resolve. Some complications are severe, difficult to treat and can lead to life long functional deficits. Most complications can be avoided by better preoperative planning, meticulous surgical technique and appropriate postoperative care.

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CORA BASED LEVELING OSTEOTOMY (CBLO) FOR TREATMENT OF THE CCL DEFICIENT STIFLE IN SMALL BREEDS OF DOGS

Don Hulse DVM ACVS and Brian Beale DVM ACVS

Tibial plateau leveling osteotomy (TPLO) is a popular method for treating the CCLD (CCL Deficient) stifle joint in the dog. Recent studies have shown significant joint mechanical alteration which may be contributory to articular cartilage lesions. One explanation for reported abnormal joint mechanics is that the standard Slocum osteotomy is not based on the anatomic CORA. As such, the Axis of Correction (ACA) is not aligned with the anatomic CORA resulting in mal-alignment of the mechanical axis and secondary translation. The result is caudal displacement of the weight bearing axis and a focal increase in joint force. Further, TPLO creates a caudal thrust. When rotated to the recommended 5 degrees, the long-term effect is loss of compliance of cranial supporting structures such as the fat pad and joint capsule. Encroachment of the cranial supporting structures (joint capsule) on the cranial articular surface of the medial/lateral femoral condyles can result in abrasion of the articular cartilage.

The subject of this presentation is to report the concept and technique of a tibial plateau leveling osteotomy based on the anatomic CORA (CBLO). The concept is supported by anatomic dissection, radiographic analysis of treated cadaver specimens, and application in clinical cases having ligament injury to the stifle. Clinical cases include those with multiple ligament injury, acute complete CCL injury with marked craniocaudal and rotational instability, partial stable CCL injury, and partial unstable CCL injury. Dogs with excessive slope (> 34 degrees) and juvenile dogs with active, open proximal tibial physis are also included. Clinical outcome, complications unique to the technique, and strategies to prevent complications will be addressed.

Advantages of the CBLO include preservation of the proximal tibial anatomy which favors application of ancillary stabilization devices (intra-articular reconstruction/Swivelock), extra-articular osteotomy, alignment of the proximal and distal anatomic axes, no secondary translation (balcony effect), TPA/PTA of 90 degrees, ease of correction in dogs having excessive slope, osteotomy distal to the growth plate in juvenile cases, normal appearance of internal joint structures at second look arthroscopy, and excellent, early return to clinical function.

Small breeds of dogs are readily managed allowing easier stabilization because of a larger proximal bone segment (tibial epiphysis). There is no “balcony” effect as a result of secondary translation as seen with a TPLO. Image on left is a beagle with an initial 41 degree slope treated with a CBLO/isometric corkscrew anchor. Image on the
right is a small breed dog managed with a TPLO. Note the secondary translation/balcony effect.

Small and large breeds often present with excessive Tibial Plateau Angle (excessive slope). These cases are easily managed with the CBLO procedure. In case with pre op slope up 40 degrees a single osteotomy is performed. Dogs with slope exceeding 40 degrees are managed with a double coplanar, posterior joining cut. Image on left is that of a small breed dog having an original slope of 39 degrees. Single cut and rotation to 11 degrees. Image on right is that of a Great Dane with an original slope of 50 degrees. Double coplanar cut; PO slope 12 degrees.

Procedure

**Determination of the aCORA:** draw the proximal axis line from the normal intersection point on the tibial plateau at the final Tibial plateau slope (PPTA angle) you wish to have. Intersect this line with the mid-diaphyseal line. The intersection point of these two lines is the CORA. (personal communication Dror Paley 2010).

**Step 1:** Determine the anatomic CORA. Bissect two points (1/4 and 3/4) the length of the tibia in the saggital plane with a line in the long axis (anatomic axis). Draw the tibial plateau angle (slope). Draw the proximal axis line from the center of the tibial spine (this point is where the anatomic axis line intersects the tibial plateau at the desired slope; average is 11 degrees). Where the longitudinal axis line and the proximal axis line intersect is the CORA. There are an infinite number of CORAs along the transverse bisecting line.
Step 2: **Magnitude of the CORA.** The magnitude of the CORA is the angle formed by the intersection of the longitudinal axis and the proximal axis line. Correction of the CORA angle will result in the desired plateau slope (generally 12 degrees). A rotation table based on the magnitude (angle) of the CORA is provided.

Step 3: **Determine saw blade size:** Using digital software, the circle of the appropriate saw blade is positioned at the CORA (point of intersection of the longitudinal axis line and proximal axis line). The desired saw blade diameter (usually 9mm diameter in the small breeds) is slightly larger than the diameter of the bone at the CORA. A slightly larger saw blade will also help achieve anterior translation of the tibial crest achieving a TPA/PTA angle of 90 degrees and allow for cranial stabilization of the osteotomy. Centering the blade on the CORA (Axes of Correction of Angulation; ACA), one achieves translation without axis mal-alignment, ie, the proximal tibial epiphysis will remain centered on the tibial diaphysis.

*Determine the intersection point of the saw blade at the cranial cortex and caudal cortex.*  
**Cranial point:** measure the distance from the insertion of the patella tendon at the tibial crest to the point where the saw blade crosses the anterior cortex (D1). **Caudal point:** measure the distance from the joint line to the point where the saw blade intersects the posterior cortex (D2).

Step 4: **Surgical approach:** Make a medial incision beginning proximally at the joint line and extending distally to accommodate plate size. The caudal satorius muscle insertion is reflected to expose the MCL. Limited reflection of the popliteal muscle and protection of the popliteal artery with gauze packing or Hohmann retractor is recommended. D1 and D2 measurements are marked distal to the insertion of the patella tendon (D1) and distal to the joint line at the MCL (D2).

Step 5: **Osteotomy:** The appropriate saw blade is positioned at D1/D2 and a circular osteotomy begun. **The cranial edge of the blade should intersect D1 at the cranial cortex.** This allows easier rotation and achievement of desired postoperative slope.

Importantly, a full circular motion of the saw is required; if this is not done, the saw blade will bind on the cortex and may break. The osteotomy is stopped when 1/3 to 1/2 complete and appropriate millimeter measurements marked for osteotomy rotation. The osteotomy is completed and rotation achieved. **Note:** 1. **A rotation pin is not required as the distal limb is used a handle for rotation.** Once the marks are aligned, the osteotomy is stabilized with a stabilizing pin. The entry point for the pin is just proximal to the insertion of the patella tendon; the pin is directed across the osteotomy to exit the caudal cortex of the
tibia distal to the osteotomy. Note: The medial cortex of the proximal and distal segments above and below the osteotomy respectively, are not anatomically aligned (the cortex of the proximal segment at the osteotomy lies approximately 1 mm outside (medial) to the distal cortex at the osteotomy)

**Step 6: stabilization of the osteotomy:** The CBLO is a leveling procedure but also simulates a TTA by advancing the tibial crest cranially. Advancing the tibial crest cranially increases the structural moment arm of the tibia and therefore quadriceps force on the osteotomy. Stabilization requires two steps: 1. **Stabilization of the leveling osteotomy:** this is achieved with bone plate and screws. The long axis of the plate is positioned to align with the caudal cortex. 2. **Neutralizing the quadriceps force at the tibial crest:** this is accomplished with a 2mm position screw or K-wire/tension band in the small breed dog.
Anatomy

Cranial Cruciate Ligament

The cranial cruciate ligament (CnCL) originates in the intercondyloid fossa on the caudomedial aspect of the lateral femoral condyle. It courses cranially, medially, and distally oriented in an outward spiral to insert at the cranial intercondyloid area of the tibia. The CnCL is composed of two parts, the craniomedial band and the larger caudo-lateral portion. These two portions blend together, and are made up of hundreds of separate strands, each with its own origin and insertion. Each strand is taut in different positions of stifle joint flexion, extension, and rotation. The cranio-medial band is taut in both flexion and extension, while the caudo-lateral portion is taut in extension and lax in flexion.

Caudal Cruciate Ligament

The caudal cruciate ligament (CdCL) originates in the intercondyloid fossa on the lateral aspect of the medial femoral condyle. It courses caudally and distally, oriented in a slight inward spiral to insert on the lateral aspect of the popliteal notch of the tibia. The caudal cruciate ligament is separated into two functional parts. The larger cranial portion is taut in flexion and lax in extension, while the caudal portion is taut in extension and lax in flexion. The caudal cruciate ligament prevents caudal translation of the tibia relative to the femur (caudal drawer motion), and helps limit internal rotation of the tibia by twisting together with the cranial cruciate ligament.

Collateral Ligaments and Menisci

The medial collateral ligament remains taut in both flexion and extension, while the lateral collateral ligament is taut in extension only. As the stifle is flexed, laxity in the lateral
collateral ligament allows internal rotation of the tibia with caudal displacement of the lateral femoral condyle on the tibial plateau. The lateral meniscus accompanies the lateral femoral condyle in the cranial and caudal excursions, which occur in flexion and extension of the joint. The medial meniscus is limited in its mobility due to a firm attachment to the medial collateral ligament. Tibial rotation in conjunction with cranial and caudal displacement of the lateral femoral condyle on the tibial plateau is known as the “screw-home” mechanism. Since the stifle has primary motion in two planes, flexion and extension in the transverse plane, and internal and external rotation in the sagittal plane, the stifle is a complex hinge joint.

Meniscal Injury

The lateral meniscus is seldom damaged because of its mobility, however the medial meniscus is commonly damaged, in 20-80% of cases of cranial cruciate ligament rupture (Vasseur, 2003), due to its relatively immobile nature resulting from its firm attachment to the medial collateral ligament. Medial meniscal injury results from either crushing or tearing; the types of tears include radial, “bucket-handle”, and caudal peripheral detachment with folding.

Figure 2: Transverse and dorsal view of an inner axial (bucket handle) tear of the medial meniscus.

Figure 3: Transverse and dorsal view of a folding tear of the caudal horn of the medial meniscus.

Figure 4: Transverse and dorsal view of a radial tear of the caudal horn of the medial meniscus.
Clinical Signs

Rupture of the cranial cruciate ligament results in stifle joint instability, which causes synovitis, osteoarthritis, osteophytosis and meniscal damage. Additionally, meniscal injury results in further instability and synovitis. Often, patients with chronic cranial cruciate ligament rupture will have returned to weight bearing. An acute onset lameness typically occurs at the time of meniscal injury.

In cases of acute rupture, stifle joint effusion, positive cranial drawer test, and pain with stifle manipulation are evident. In chronic cases, muscle atrophy, medial buttress formation (peri-articular fibrosis on the medial aspect of the joint), and crepitus with joint flexion and extension may be evident. Cranial drawer may be difficult to demonstrate due to the degree of peri-articular fibrosis. Sedation may allow cranial drawer to be elicited; in some cases, the tibial compression test may be more easily demonstrated.

Medial meniscal injury is seen in over 70% of cases of rupture of the cranial cruciate ligament in dogs (Flo, 1993). Meniscal injury can be detected on physical examination by the presence of a meniscal click that is a pop or soft tissue crepitus that occurs during stifle flexion. Folding tears of the medial meniscus can diminish the magnitude of cranial drawer since the folded horn of the meniscus can become wedged cranial to the femoral condyle. Meniscal injury not associated with rupture of the cranial cruciate ligament is rare in the dog, and if it occurs it is commonly associated with a traumatic overload of the joint, and more frequently involves the lateral meniscus than the medial meniscus.

Treatment

The meniscus has a poor capacity to heal, due to a limited blood supply, which is isolated to its outer one-third. As a result, meniscal treatment in veterinary medicine is primarily centered on preserving the grossly normal, intact meniscus and removal of the damaged portion of the meniscus since they can cause lameness. The two most common types of medial meniscal injury seen in conjunction with cranial cruciate ligament rupture are injury confined to the inner, axial portion of the meniscus (bucket handle tear), and crushing and detachment of the caudal pole. In cases in which an inner axial tear is present, a partial medial meniscectomy can be performed (Figure 5). If the injury is isolated to the caudal pole of the meniscus, a caudal pole hemi-meniscectomy can be performed (Figure 6). In the rare event that the entire medial meniscus is damaged, a complete meniscectomy can be performed.

Prophylactic meniscal treatment

Latent meniscal injury is meniscal damage that is present at the initial surgery, but undetected by the surgeon at the time of joint exploration. A postliminary meniscal tear is one that occurs after the initial surgical procedure. Postliminary meniscal injury has been reported in 17% of dogs with lateral suture stabilization, and 19% of dogs with a modified four-in-one over-the-top stabilization technique, at a median of 6 months following the initial
stabilization procedure. Due to the relatively frequent occurrence of postliminary meniscal tears, several options to reduce this incidence have been suggested.

Some authors suggest that caudal pole hemi-meniscectomy should be routinely performed at the time of joint exploration if the medial meniscus is grossly normal. In this case, removal of the caudal pole of the medial meniscus precludes the possibility of postliminary damage to the caudal pole. Since most stifles have progressive osteoarthritis at the time of stabilization, hemi-meniscectomy seems to result in no worsening of lameness as compared to leaving the meniscus intact.

The TPLO procedure was reported to have a similar incidence of meniscal injury if a complete rupture of the cranial cruciate ligament was present, and the meniscus was normal and left intact. In order to minimize the frequency of postliminary meniscal tears, Dr. Slocum devised the meniscal release procedure. The meniscal release is the incision of the lateral attachment of the caudal horn of the medial meniscus, or an incision of the caudal horn of the medial meniscus. The purpose of the meniscal release is to allow the caudal horn of the medial meniscus to move away from the medial femoral condyle during cranial tibial translation, preventing meniscal impingement. In cases of TPLO with the meniscal release procedure, the incidence of postliminary meniscal tears may be reduced to a rate as low as 1-2%. Although meniscal release appears to be effective in reducing the rate of postliminary meniscal tears, it has the adverse affect of diminishing the load transmission and stability functions of the meniscus (Pozzi A, et al, 2006). Thus, the efficacy of meniscal release at diminishing the rate of postliminary meniscal tears must be weighed against its adverse effects on meniscal function when considering its use on clinical cases.

References


Figure 5: Partial medial meniscectomy

Figure 5: Caudal pole, partial medial meniscectomy

CALCANEAL TENDON INJURY

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Musculotendinous injuries occur infrequently in dogs and cats, but the consequence of such an event can lead to marked dysfunction due to disruption of the muscle-tendon unit (MTU). The MTU is composed of the muscle origin, muscle belly, tendon and tendon insertion. Clinically, MTU disruption causes inability to properly flex or extend the joint served by the affected muscle. Pain, swelling and lameness also are present. Injuries may be acute or chronic. Strain injury is not the result of muscle contraction alone, rather, strains are the result of excessive stretch or stretch while the muscle is being activated. When the muscle tears, the damage is localized very near the muscle-tendon junction. After injury, the muscle is weaker and at risk for further injury. The force output of the muscle returns over the following days as the muscle undertakes a predictable progression toward tissue healing. Current imaging studies have been used clinically to document the site of injury to the muscle-tendon junction. Strains are categorized in a similar manner to sprains: Grade I Strain: This is a mild strain and only some muscle fibers have been damaged. Healing occurs within two to three weeks. Grade II Strain: This is a moderate strain with more extensive damage to muscle fibers, but the muscle is not completely ruptured. Healing occurs within three to six weeks. Grade III Strain: This is a severe injury with a complete rupture of a muscle. This typically requires a surgical repair of the muscle; the healing period can be up to three months. Tendon injuries of the biceps brachii, triceps, patellar tendon, long digital extensor, superficial digital flexor, gastrocnemius, supraspinatis and infraspinatus are most commonly seen. Avulsion of tendons from their bony insertion require reattachment using bone tunnels, screw and washer, bone staple or suture anchors. Muscle belly tears may be treated conservatively or surgically. Conservative therapy may be used with mild injury using cold therapy, laser therapy, and rest initially, followed by heat therapy and rehabilitation exercises. Surgical therapy usually requires debridement of necrotic tissue and primary repair of muscle tissues. Fibrotic contracture of muscle tissues occur secondary to trauma. Fibrotic contractures are generally treated by muscle tendon transaction, Muscle belly resection or tendon elongation.

Tendon Injury

Tendon injury usually results from substantial trauma. An important factor to consider in treatment of tendon injuries is the ability to maintain not only structural strength, but also gliding function. Structural strength will be greatest if the structure can be returned to as near as normal as possible; the tensile strength of scar tissue is inferior to that of normal tendinous tissue. Prompt repair of tendinous injuries increases the chance of optimal healing and decreases the amount of scar tissue formation. Scar tissue formation between the tendinous and surrounding soft tissues also leads to adhesion formation and loss of gliding function. Factors to limit adhesion formation include early surgical intervention, meticulous handling of tissues, anatomical apposition of tendinous tissues, adjunctive postoperative bandaging,
passive range of motion exercise, and appropriate postoperative restriction of activity. Early healing of tendons occurs with formation of immature collagen during the initial four postoperative weeks. Tensile strength of the repair tissue increases as remodeling of the collagen occurs until about 20 weeks postoperatively. Tendon repair is accomplished using a variety of suture materials and suture patterns, depending on the preference of the surgeon. A variety of locking-loop and three-loop suture patterns have been used effectively. Nonabsorbable suture material such as monofilament nylon, polypropylene and braided polyester is preferable to absorbable material due to the long period of time until adequate tensile strength is reached in the repair tissue. After the tendon is repaired, the paratenon or synovial sheath should also be primarily repaired with appositional sutures if possible. Reestablishment of these structures decreases the chance of adhesions and preserves gliding function.

**Repair Guidelines for Tendons**

A tendon surrounded by a sheath will usually not heal spontaneously. The tendon ends will heal in a rounded fashion and function is lost because of loss of continuity of a tendon. A tendon not surrounded by a sheath is thought to regenerate by proliferation and extending a pseudopodial mass to attach to the opposite end that also extends tissue. Regeneration is thought to be a result of haematoma organisation or paratenon proliferation. Paratenon covered tendons are more vascular than synovial sheathed.

1. After the paratenon and tendon have been completely incised the wound fills with inflammatory products (blood cells, nuclear debris, fibrin). During the first week the fibrin is invaded by fibroblasts (from the paratenon) that combine with invading capillary buds to form the granulation tissue that fills the space between the tendon ends. Fibroblasts begin to synthesise collagen by the 3rd day after trauma.
2. During the 2nd wk a dramatic fibroblastic proliferation and collagen production continues. The growth and migration of fibroblasts and the collagen fibres between the stumps are orientated perpendicular to the long axis of the tendon and the vascular reaction reaches its peak.
3. During the 3rd and 4th wk the fibroblasts and collagen fibres near the tendon begin to orient themselves // to the long axis of tendon. This orientation is due to directional stress on scar - the more distant or central scar remains unorganised. The difference in orientation of collagen fibres in the newly synthesised scar tissue is defined as secondary remodelling. Two important factors in secondary remodelling are increase in tensile strength and reduction in mass of scar tissue. It continues for many months. Increase in tensile strength suggests orientation along stress lines. Collagenisation continues until 20 weeks. In animals tensile strength is more important than gliding motion.

Healing of tendons within a tendon sheath should feasibly occur due to intrinsic repair but in clinical practice is usually a combination of intrinsic and extrinsic.
Rupture of Achilles Tendon

Five tendons make up the Achilles tendon – the superficial digital flexor tendon, gastrocnemius, semitendinosus, gracilis and biceps femoris. The gastrocnemius is the most powerful extensor of the hock. It terminates on the proximal lateral surface of calcaneus, while the common tendon (BF, ST, gracilis) terminates on the medial side. Trauma can result in tearing of one or more components of the tendon. Clinical sings include lameness, hyperflexion of the tarsus, and swelling over the tendon. Surgical repair of the tendon is requires using a locking pulley suture and a immobilization of the tarsus using a temporary calcaneotibial screw, fiberglass splint or transarticular external fixator. The prognosis is good following proper repair.
OSTEOCHONDROSIS: CURRENT CONCEPT OF SURGICAL THERAPY

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Abstract

Current techniques of articular cartilage lesions management are listed. Mosaicplasty as a method of surgical treatment of canine stifle osteochondrosis is presented. A role of tissue engineering and transplantation of cells in combination with biomaterial scaffolds in joint resurfacing is mentioned.

Etiology, incidence, breed predisposition, predilection sites, age of clinical manifestation and diagnosis of osteochondrosis in the dog are well described (Carlson et al. 1991; Ekman and Carlson 1998; Johnston 1998; Kincaid et al. 1985; Necas et al. 1999; Olsson 1993; Probst and Johnston 1993; Robins 1978; Rudd et al. 1990; Ubbink et al. 1992). Early diagnosis and minimally-invasive therapy are crucial to ensure successful therapy and reduce the risk of osteoarthrosis (Beale and Hulse 2010; Necas 2011).

Because the natural regeneration of articular cartilage without a vascular supply is very limited, primary healing of the defect is impossible (Edwards 1967; Mankin 1974). The mechanism of cartilage defects healing varies with the degree of damage (superficial versus deep lesions of articular cartilage), however new normal hyaline cartilage is not formed (Edwards 1967; Grande et al. 1995; Mankin 1974; Howel et al. 1990; Mitchel a Shephard 1976; Shapiro et al. 1993; Sokoloff 1974). Therefore the aim is to ensure formation of new cartilaginous tissue whose biochemical composition and mechanic properties are as similar to normal hyaline cartilage as possible. From this perspective, tissue engineering and transplantation of cells (i.e., chondrocytes, mesenchymal stem cells (MSCs)) in combination with the use of appropriate biomaterials play an important role (Brittberg et al. 1994; Butler et al. 2004; Grande et al. 1995; Guo et al. 2004; Hannouche et al. 2007; Chu et al. 1999; Langer et al. 1993; Mičková et al. 2010; Necas et al. 2010).

Surgical techniques for local treatment of cartilage lesions commonly used by clinicians include cartilage debridement (McIlwraith 1990; Rudd et al. 1987), chondroplasty (Hubbard 1996), reattachment of loose cartilage flaps to their original place (Nixon et al. 2004), forage (Pridie 1959), the microfracture (micropicking) method (Frisbie et al. 1999; Frisbie et al. 2003; Rodrigo et al 1994) and abrasion arthroplasty using a motorized shaver (Johnson 1986, Johnson 2001). Current thought favors early intervention with the least invasive method of surgical management. Arthroscopic assisted surgery is the treatment of choice. Recently, it has been routine to manage OCD lesions of the shoulder, elbow, knee and hock joints arthroscopically (Beale et al. 2003; Bertrand et al 1997; Necas 2006; Necas 2011). Osteochondritis dissecans
is managed by removing the cartilage flap (i.e., free fragments and/or adherent cartilage) (Wright et al 2004), and then performing an abrasion chondroplasty, forage, or subchondral bone microfracture/micropicking on the surface of the lesion. At the end of arthroscopic surgery, the joint is inspected and flushed thoroughly to remove all cartilage fragments (Beale et al. 2003; Bertrand et al. 1997; Necas 2006).

Mosaicplasty (osteochondral autografts transplantation) as a method of articular cartilage reconstruction is the treatment of choice in managing large OC defects (especially in stifle joints), where the goal is to restore the cartilage gliding surface with hyaline cartilage by transplantation of osteochondral autografts harvested from a non-weight-bearing area of joint cartilage to the site of weight-bearing cartilage lesion (Feczko et al. 2003; Hangody et al. 1997; Hangody et al. 2008). The method has been successfully used in animals (Bottcher et al. 2009; Cook et al. 2008; Fitzpatrick et al. 2009; Palierne et al. 2011).

Joint resurfacing, such as chondrocyte transplantation and mesenchymal stem cell transplantation, remains a challenge for future research in this field (Conzemius 2010; McIlwraith 2006; Míčková et al. 2010; Necas et al. 2010).

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Management of articular cartilage lesions is based on the concept that providing blood with mesenchymal stem cell precursors access to the lesion encourages healing by formation of fibrocartilage. Several marrow stimulating techniques have been described to achieve this. Abrasion arthroplasty involves uniform removal of subchondral bone until bleeding is achieved. This can be accomplished in the canine elbow by use of either a curette or burr attachment on a small joint shaver. The shaver is usually more rapid and efficient and generally just as accurate. Another marrow stimulating technique is microfracture. In this technique numerous microcracks are created in the subchondral bone plate with a specialized micropick to allow bleeding at the lesion surface.

Indications for abrasion arthroplasty or microfracture vary with the size and degree of cartilage loss. In general, lesions small to moderate size (1-2cm in man) can be treated with resurfacing techniques. Debridement of Grade I lesions with chondromalacia is up to the discretion of the surgeon. Small areas of grade II fibrillation in the absence of other lesions also may be left undisturbed. Larger areas of Grade II cartilage disease can be treated with abrasion arthroplasty or microfracture. Grade III lesions are areas of full thickness fibrillation. Use a curette or burr to remove the diseased cartilage while being careful not to damage any of the surrounding more normal cartilage. Grade IV cartilage damage is full thickness loss of cartilage and exposure and, in some cases, eburnation of the subchondral bone. They are treated with abrasion or microfracture until adequate bleeding occurs. Producing diffuse
effective bleeding varies in difficulty between joints. Combining abrasion and microfracture may help increase subchondral bleeding. In cases of eburnation it may be difficult or impossible to get significant bleeding with these techniques.

To perform abrasion arthroplasty, insert a hand burr or preferentially a power shaver burr through the instrument portal. Either method will produce significant bone debris that can clog the egress portal and impede visualization, therefore it is important to monitor and maintain the flow of fluid through the joint during this procedure. Spin the burr to remove subchondral bone over the area of the lesion. Check for resulting bleeding frequently by stopping inflow of fluid and ensuring adequate outflow to decrease the pressure in the joint. When bleeding is observed diffusely from the lesion bed, lavage the joint to remove the remaining bone debris and close routinely.

To perform microfracture, insert an appropriately angled micropick into the joint and press the tip against the subchondral bone surface. Have an assistant tap the pick handle once or twice. The pick should be held securely to avoid gouging the surface and adjacent healthy cartilage. Apply the micropick diffusely across the diseased area and check for resulting bleeding frequently by stopping inflow of fluid and ensuring adequate outflow. The penetrations should be 2-3 mm apart and 1-2mm in depth. When bleeding is observed diffusely from the lesion bed, lavage the joint to remove the remaining bone debris and close routinely.

Objective evidence documenting the efficiency of abrasion arthroplasty or microfracture is not available in the dog. The figure to the right shows resurfacing of the medial coronoid in a dog 6 months after abrasion arthroplasty. In man microfracture appears to be more effective than abrasion arthroplasty and is the marrow stimulating technique of choice. The technique is highly dependent on appropriate post operative rehabilitation. In man, 4-6 weeks of non-weight bearing activity coupled with active or passive range of motion is necessary for ideal outcome. Overall, the results of abrasion arthroplasty have been unpredictable and symptoms often recur 2-3 years after surgery. Nevertheless, good to excellent results are reported in 50 – 60 % of patients. Microfracture has shown promising results as first line treatment in smaller lesions. Seventy four percent of patients reported significant reduction in pain and swelling and improved function. In another series of patients, the Lysholm and tegner Scores improved significantly.

**Subtotal coronoidectomy:** removal of a section of the medial coronoid is a treatment modality which has been described and has good results. Studies have shown that microfractures are present in the subchondral bone of the medial coronoid distant to a visible fragment. This fact supports the rationale for subtotal choronoidectomy. The procedure is performed through a mini-arthrotomy or arthroscopically guided. The recommended amount of coronoid removed varies but in general removing the coronoid devoid of articular cartilage is a good strategy. Removing excessive coronoid may present long term complications by losing the medial buttress weight bearing area of the elbow. Owner based evaluation studies have demonstrated a significant increase in limb use/function.
Biceps ulnar release procedure;

The biceps/brachialis muscles constitute a large muscular complex. The anatomic origin and insertion of the biceps and brachialis muscles are such that the muscular complex exerts considerable force on the medial compartment of the elbow. The force exerted by the biceps is continuous since it is a pennate muscle with central tendon. More importantly, because the insertion of the biceps/brachialis complex is at the ulnar tuberosity, a large polar (rotational) moment is exerted at the cranial segment of the medial coronoid. The magnitude of the polar moment is a product of the moment arm (distance from the ulnar tuberosity to the tip of the coronoid) multiplied by the force created by the biceps/brachialis muscular complex. The polar moment rotates and compresses the craniolateral segment of the medial coronoid against the radial head. The compressive force is medial to lateral transverse to the long axis of the coronoid. A compressive force generates internal shear stress at an oblique angle to the applied compressive force. In this situation, maximal internal shear stress would be oblique to the long axis of the coronoid. Under the right circumstances, the polar moment and resultant compressive force produced by the biceps/brachialis complex may produce sufficient internal shear stress to exceed the material strength of the cancellous bone in the craniolateral segment of the medial coronoid. The result would be microfracture/fragmentation adjacent to the radial head at an oblique angle to the long axis of the medial coronoid. The surgical technique involves releasing the ulnar insertion of the biceps to unload the medial compartment and prevent the rotational moment rotating the coronoid into the radial head.

Techniques to lateralize the weight bearing axis in the elbow

The cause of mechanical overload can be associated with progressive humeral varus associated with mechanical weight bearing mechanical axis. This process occurs in the human knee and is the most common cause of knee medial compartment OA in man. The normal mechanical axis in the frontal plane in the canine forelimb is a line from the center of the shoulder joint to the center of the radiocarpal joint. The mechanical axis courses through the medial compartment across the medial humeral condyle and medial coronoid. (Fig 3) The anatomic axis in the frontal plane demonstrates the normal varus angulation of the distal humerus and weight bearing axis through the medial compartment of the elbow. (Fig 4) The deviation of the mechanical axis medially and the humeral varus become more apparent with the progression of medial compartment OA similar to the process in the human knee. The result of overload of the medial compartment, collapse to the medial compartment, and OA. (fig. 5) Future treatment strategies are based on lateralization of the mechanical axis.
Sliding humeral Osteotomy (SHO): Sliding humeral osteotomy involves creating a midshaft transverse humeral osteotomy and translating (sliding) the diaphysis distal to the osteotomy medially. Doing so shifts the weight bearing axis through the elbow joint from the medial compartment to the lateral compartment. Owner and vet VAS scores have improved in all cases with a notable decrease in pain upon elbow manipulation.

Elbow replacement is an option in dogs which have end stage elbow OA and conservative/less invasive surgical modalities have not resolved clinical pain. A number of prostheses are available but the most popular one today is the TATE elbow. Clinical outcome studies indicate that a mechanical lameness may persist but that the dogs appear to be less painful. A prosthesis presently in clinical trial is the CUE (canine unicompartmental elbow). The concept is simple and carries little morbidity. Information concerning this technique will be forthcoming in the near future.
Ununited anconeal process (UAP) is a condition where the ossification center of the anconeus does not unit through bone fusion with the proximal ulnar metaphysis. The bone fusion occurs about 6 months of age. The prevailing theory for cause is that the axial length of the ulna is shorter in cases with ununited anconeal process as compared to breed matched cases without UAP. The hypothesis is that as growth proceeds the anconeal process of affected dogs presses against the humeral trochlea. This creates a shear force separating the anconeal process from the ulnar metaphysis. Any breed may be affected but the most common breeds are the German Shepherd, Mastiff, and Bassett Hound. Clinical signs are lameness, increased effusion, pain upon flexion/extension, decrease range of motion (flexion). Most cases show clinical signs early (6 – 9 months) but in some cases the dog may be older. In the latter cases, I believe the anconeal process is stable with fibrous/fibrocartilage union only to be displaced acutely with activity. Diagnosis is confirmed with radiographs taken with the elbow in full flexion; CT of the elbow is recommended as microfracture/fragmentation of the medial coronoid will be present in about 5% of cases.

**Treatment** is dependent upon age and arthroscopic findings. In general, if the dog is greater than 12 months of age, the anconeus is misshapen with sclerosis at the margins. The shape of the anconeus is apparent on radiographs/CT and confirmed with arthroscopy. With these cases, the anconeal process is removed via arthroscopic assisted mini-arthrotomy or lateral arthrotomy. Note the misshapen anconeal process in the figures below secondary to osteophyte formation.

When the dog is 6 - 7 months, a proximal ulnar ostectomy will eliminate the tension secondary to ulnar shortening and may be effective in allowing the anconeal process to proceed to bone fusion. Note arthroscopic examination of the elbow joint is warranted to rule out microfracture/fragmentation of the medial coronoid and to assess the stability of the anconeal process.
If the dog is greater than 7 months of age, my preference for treatment is to arthroscopically examine the joint and treat fragmentation of the medial coronoid if present. Arthroscopic examination is followed by a lateral arthrotomy to expose the ununited anconeal process. The anconeus is aligned anatomically and stabilized with a compression screw and an oblique proximal osteotomy of the ulna. The osteotomy is a critical and necessary component of the procedure; if not performed, tension remains present at the fusion site secondary to the shortened ulna effect. The result is a high incidence of screw failure or persistent incongruence.

Appropriate treatment is arthroscopic exam and treatment as indicated followed by lateral mini-arthrotomy and stabilization with a compression screw and proximal oblique osteotomy. My preference is to stabilize the proximal ulnar osteotomy with a small IM pin.
Comminuted fractures can be especially challenging due to the complexity of the fracture fragments and concomitant soft tissue injury. Careful consideration should be given to decision-making prior to onset of fracture repair. Factors that should be considered include mechanical, biological and postoperative compliance. Complex fractures that are treated with a mechanically sound repair often leave the surgeon pondering what could have possibly gone wrong when a “perfect” repair fails. Often times, the answer lies in the neglect of the biological or postoperative compliance factors. Neurologic function should always be assessed because complex fractures are often associated with high-energy trauma that also can injure the brachial plexus or peripheral nerves of the forelimb. This lecture will focus on presentation of clinical cases involving complex fractures of the forelimb and hindlimb, with an emphasis on the decision-making process. A variety of fracture repair techniques will be discussed including interlocking nails, plate-rod construct and linear external fixators.

Minimally-invasive surgical approaches reduce pain and minimize trauma to the soft tissues. Biological factors important for fracture healing are preserved, enhancing the body’s ability for indirect bone healing. The technique can be used with all fracture types, but is particularly useful for stabilization of comminuted fractures. This type of bone healing is also referred to as secondary bone healing, spontaneous bone healing and callus healing. Stabilization of fractures using the principles of biologic fracture management is performed with the same type of implant systems used with traditional fracture repair, including externally and internally applied devices.

**Fracture Management**

Comminuted fractures of the extremities can be challenging. It is always a race between a fracture healing and an implant failing. Steps can be taken to tip the scale in the direction of early fracture healing. These steps include:

1. minimally invasive surgical approach
2. preservation of soft tissue attachments to bone fragments
3. use of cancellous bone grafts
4. rigid method of fracture stabilization
5. early return to function

It is always important to obtain an accurate history prior to stabilizing fractures. A complete physical exam and appropriate diagnostic tests should performed. Pathologic fractures are more likely to be seen in the geriatric dog and cat and should be identified preoperatively to ensure proper client education and communication.
Indirect Bone Healing

Biological fracture management utilizes indirect fracture reduction to preserve the soft tissue envelope at the expense of anatomic reduction. Indirect bone healing occurs as a result. Indirect bone healing consists of three elements: 1. the formation of granulation tissue at the fracture site 2. fracture gap widening due to resorption of bone ends 3. new bone formation involving formation of a bone callus. Less disruption of the vascular supply to bone fragments is achieved through minimal handling of the fragments, promoting early callus formation.\textsuperscript{2,3,6,7} Indirect bone healing is first associated with the formation of fibrous connective tissue and cartilage callus between the fragments.\textsuperscript{4} Indirect bone healing occurs due to instability at the fracture site and is partially regulated by fragment gap strain.\textsuperscript{4} Interfragmentary strain is a ratio of change in the gap width to the total width prior to physiological loading.\textsuperscript{1,5} A study of the “interfragmentary strain hypothesis” using ovine osteotomy models demonstrated that the initial stages of indirect bone healing occur earlier and more extensively between gaps with lower shear strain.\textsuperscript{1} Management of a non-reducible diaphyseal fracture with an implant system that does not utilize anatomic reconstruction and creation of subsequent small fracture gaps avoids high interfragmentary strain, favoring bone healing.

Implant Systems

External and internal implant systems can be used to achieve bone healing using biological fracture management. Examples of external devices when used in an appropriate manner include casts, splints, linear external fixators and circular fixators. Internal devices commonly used for this application include the plate-rod system, interlocking nail and bone plates. Other implant systems can also be used for biologic fracture management as long as the soft tissue envelope is preserved at the fracture site. Whatever implant system is used, its application must be possible with minimal or no handling of the comminuted fracture fragments.

External Fixator

External fixators provide rigid stabilization and can be used with minimally-invasive technique. Many fractures of the radius and tibia can be reduced closed and stabilized with an external fixator. The main disadvantage is the potential for complications with premature pin loosening and the added care needed in the postoperative period. The use of external fixators for fracture repair is not optimal if the patient or owner is likely to have poor compliance in the postoperative period. External fixators frames can be applied in one of 3 configurations- linear, circular or as a hybrid of linear and circular.

Plate-rod construct

The plate rod system has been found to be an ideal implant system for biological fracture management. Management of a non-reducible diaphyseal fracture with a combination of an IM Steinmann pin and bone plate can be applied without anatomic reconstruction and thus, avoids the development of small fracture gaps with high interfragmentary strain. The addition
The FIXIN locking plate uses a conical head to lock into a matching conical hole in the plate creating fixed-angle stabilization.\(^2\) Mathematical analysis of the plate-rod construct in the canine femur demonstrated that the pin and plate act most like a dual-beam structure, assuming slight motion of the pin in the canal.\(^2\) Addition of an IM pin to a bone plate has been shown by Hulse et al. to decrease strain on the plate two-fold and subsequently increase the fatigue life of the plate-rod construct ten-fold compared to that of the plate alone.\(^1\) In the canine femur, plate strain is reduced by approximately 19%, 44%, and 61% with the addition of an IM pin occupying 30%, 40% and 50% of the marrow cavity, respectively.\(^3\) Stiffness of plate-rod repairs may be as much as 40% and 78% greater when the pin occupies 40% and 50% of the marrow cavity, respectively.\(^2\)

**Locking Plates**

Locking plates have become very popular for minimally-invasive fracture repair. Many locking plate systems are available including the Synthes, FIXIN, SOP and ALPS. Locking plates have the ability to lock the screw into the hole of the plate. The mechanism for locking varies amongst manufactures. The Italian design FIXIN locking plate system has a conical locking mechanism while the Synthes system has a threaded locking mechanism. The FIXIN plate hole is tapered to match the conical nature of the head of the screw. This type of fitting is similar to the Morse taper of the head and neck fitting of the Total Hip Replacement implant. The stability of this design is extremely secure. The Synthes locking plate has threaded holes in the hole of the plate. Corresponding threads in the head of the screw engage the threads of the hole, locking the screw to the plate. The ability to lock the screw to the plate increases pull-out strength of the screw and construct stability.

Traditional plates do not have threaded holes. Screws placed in ordinary plates apply pressure to the plate, pressing it onto the bone surface. The friction between the plate and the bone provides the stability to the bone-implant construct. In contrast, the locking plate achieves stability through the concept of a fixed-angle construct. The locking plate is not pressed firmly against the bone as the screws are tightened. The locking screws and plate function more like an external fixator. Locking plates are essential “internal fixators”. The plate functions as a connecting bar and the screw functions as a threaded fixator pin. The tapered or threaded head of the locking screw engages the hole of the plate, similar to the clamp of an external fixator. The Synthes locking plate also has combi-holes which allow use of traditional or locking screws when desired. Traditional screws should be placed prior to locking screw when using locking plates.
Interlocking nails provide axial, bending and rotational stability due to the ability of the screw to lock the IM pin to the bone.

Interlocking nail

The Deuland interlocking nail system presently available in the U.S. (Innovative Animal Products, Inc., Rochester, MN) is a modified Steinmann pin modified by drilling one or two holes proximally and distally in the pin, which allows the placement of transverse bolts or screws through the bone and nail. The nail, bolts and screws can be applied in closed or open fashion due to the incorporation of a specific guide system that attaches to the nail. The equipment needed to place the nail includes a hand chuck, extension device, aiming device, drill sleeve, drill guide, tap guide, drill bit, tap, depth gauge, and screwdriver. Cost of the system is reasonable and each nail is approximately half the cost of a comparative bone plate. The nails are available in diameters of 4.0, 4.7, 6, 8 and 10 mm and varying lengths and hole configurations. The 4.0 and 4.7 mm nails use 2.0 mm screws or bolts. The 6 mm nail is available in two models and will accommodate either 2.7 or 3.5 mm screws or bolts. The 8 mm nail is also available in two models and will accommodate either 3.5 or 4.5 mm screws or bolts. The 10 mm nail uses 4.5mm screws or bolts. The solid cross locking bolts have a larger diameter compared to a similar diameter screw, thus are less likely to break. Bolts also provide superior mechanical behavior compared to screws.

The interlocking nail is placed along the mechanical axis of the bone. The interlocking nail neutralizes bending, rotational and axial compressive forces due to incorporation of transfixation bolts or screws which pass through the pin and lock into the bone. This is in contrast to a single intramedullary Steinmann pin which is only effective in neutralization of bending forces. The interlocking nail has a similar bending strength compared to bone plates, but is slightly weaker in neutralization of torsional forces. The screws also prevent pin migration, a common complication seen with Steinmann pins.

When using an interlocking nail, the largest diameter nail should be selected that can be accommodated by the medullary cavity at the fracture site. In most large dogs, an 8 mm nail and either 3.5 or 4.5mm screws or bolts can be used in the femur and humerus. In medium-sized dogs, the 6 mm nail and either 2.7 or 3.5 mm screws or bolts are typically used. In small dogs and cats, the 4.7 mm nail and 2.0 mm screws are typically used. The tibia of medium and large - sized dogs will usually accommodate a 6 mm nail, but some large dogs will accept an 8 mm nail. Small dogs and some cats will accept a 4.0 mm nail for repair of tibial fractures.
Dejardin et al. have developed a novel interlocking nail (I-Loc nail, Biomedtrix) that provides an angle stable locking mechanism. The advantage of angle stable locking is the elimination of torsional and bending slack, resulting in reduced interfragmentary motion. This interlocking nail system provided comparable mechanical performance to a plate system.

**Surgical Approach**

Closed reduction and stabilization is the optimal method of treatment when possible. Unfortunately, this method is rarely possible in the senior patient due to the severity of fractures seen, long time until bony union, and the tendency for patients to develop bandage sores. Open surgical approaches can be either traditional or minimally invasive. The minimally invasive approach has also been described as an “open but don’t touch” approach. The acronym, OBDT, is used to describe this technique. The advantages to using an OBDT technique is preservation of vascular supply to the fracture site and thus quicker healing, shorter intraoperative time, less postoperative pain and early return to function. Methods of stabilization that work well with an OBDT approach include the interlocking nail, plate-rod hybrid and external fixation. The key feature of a minimally-invasive approach is the preservation of the soft tissue envelope at the fracture site. Small comminuted fragments will become quickly incorporated into the bony callus if left with a vascular pedicle. Anatomic reduction of small fragments is difficult if vascular supply to the fragment is to remain uncompromised.

**Bone Grafts**

Numerous sites for harvest of cancellous bone graft have been described in the dog, but the most practical are the greater tubercle of the humerus, wing of the ilium and the medial, proximal tibia. The humerus provides the greatest amount of cancellous bone, but the ilium and tibia provide sufficient amounts for most applications. All of these sites are readily accessible, have easily recognizable landmarks, have little soft tissue covering, and provide relatively large amounts of cancellous bone. The greater trochanter can also be used if other sites are not available; however, the yield of cancellous bone is markedly less. Occasionally multiple sites are required to harvest sufficient quantities of bone to fill large bone defects or during arthrodesis.

Minimal instrumentation is required for harvest of cancellous bone graft. Basic surgical instruments are used to approach the site selected for harvest. A hole is drilled through the near cortex using either a drill bit, trephine or trocar-pointed pin. A curette is used to scoop the graft out of the metaphyseal cancellous bone. The cancellous bone should be scooped out in large clumps if possible. Use a curette that can be comfortably manipulated in the medullary cavity; I prefer to use a relatively large curette as this speeds harvest and reduces trauma to the graft. Closure is performed routinely in 2-3 layers. Recently, a technique was described using an acetabular reamer to harvest large amounts of corticocancellous bone graft from the lateral surface of the wing of the ilium.
The graft collected should be handled gently. It is desirable to collect the graft immediately prior to usage. This increases the osteogenic properties of the graft. As graft is harvested, it should be placed on a blood-soaked gauze until transfer to the recipient site. Extreme care should be taken to store the graft properly; do not accidentally discard the graft due to misidentification of the gauze as being used. The graft should be atraumatically packed into the recipient site. Lavage of the site should be avoided after the graft is placed.

Minimally-invasive surgical approach maintains blood supply to comminuted fragments encouraging early healing

Plate-rod repair of a comminuted femur fracture

Gross specimen of application of a plate-rod construct

Comminuted fractures can be managed biologically using an interlocking nail, shortening surgical time and speeding bony union.
References:


ANTEBRACHIAL DEFORMITIES

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Angular limb deformity correction and limb alignment to correct skeletal malalignment are commonly employed in small animal orthopedic surgery. Until recently, a unified system that was applicable to all deformities in all long bones was lacking in veterinary surgery. Recently, the Center of Rotation of Angulation (CORA) methodology has been described for use in deformity planning and correction in people, and several authors have adapted this system for use in dogs. The CORA methodology utilized an axis drawn along the long bone and two joint reference lines drawn across the joint at specific anatomic landmarks to develop reference angles for the proximal and distal joint of each long bone. Two axes exist in each bone; the anatomic axis is drawn from the center of proximal end of the bone to the center of its distal end, while the mechanical axis is drawn from the center of the proximal joint to the center of the distal joint. In bones such as the femur the mechanical and anatomic axes are different, while in other bones, such as the tibia, the axes are identical. The intersection between the joint reference line and the bone axis determine the joint reference angle.

Utilizing radiographs of normal dogs, breed specific joint reference angle ranges have been developed, and these can be used to aid in the planning of deformity correction (Figure 1). Utilizing breed specific normal values, the magnitude and location of multi-planar deformities can be quantified in the frontal and sagittal planes. In the event that breed specific values are not available, the opposite normal limb can be utilized to obtain joint reference angles for the individual patient. If both limbs are affected, the mean joint reference angles from the literature can be used. The joint reference angles are utilized to construct anatomic axis for proximal and distal bone segments. The CORA is located at the intersection of these anatomic axes, and its magnitude can be measured at this intersection (Figure 2). In most deformities, the CORA is uniaxial in both the frontal and sagittal planes, however multiapical deformities do exist. Correction is typically undertaken at the location of the deformity in the frontal plane.

Figure 1: Sagittal and frontal plane alignment determined by the CORA methodology. In the frontal plane, the Medial Proximal Radial Angle (MPRA) and the Lateral Distal Radial angle (LDRA) have been determined. In the sagittal plane, the Proximal Cranial Radial angle (PCRA) and the Distal Caudal Radial Angle (DCRA) have been determined.
A closing wedge, opening wedge, or radial osteotomy can be performed. Each has advantages and disadvantages; for instance, the opening wedge increases limb length at the expense of stability, while the closing wedge provides a more stable construct with bone shortening. The radial osteotomy can be utilized close to joints, as the osteotomy location and angular correction axis (ACA) are at different locations (Figure 3). Stabilization can be performed utilizing bone plates and screws, linear external fixation, or circular external fixation.

The most common congenital elbow subluxation/luxation is Type 1. This is characterized by lateral or caudolateral subluxation/luxation of the radial head with the ulna being in relatively normal position. The inciting cause is relative growth asynchrony of the radius and ulna. The result is deformity and limb dysfunction.

**Pre-operative assessment:** Positioning for precise AP and lateral radiographs of the affected and non-affected limb taken under anesthesia are required for accurate pre-operative measurement. CT with 3D reconstruction and modeling of the limb provides the most detailed CORA and torsional information. If not available orthogonal radiographs will suffice.

**Surgical Intervention:** Open exposure of the elbow joint has given the most consistent clinical results achieving humeral-radial, humeral-ulnar, and radial-ulnar congruence. A caudolateral approach is preferred. The extensor carpi ulnaris, lateral digital and common digital extensor muscles are reflected from the proximal ulna and radial head. The position of the CORA of the proximal radius determined and a closing wedge osteotomy is completed with the ACA and osteotomy centered at the CORA to align the proximal and distal axis and prevent secondary translation. With the radial head subluxated, the coronoid is centered more lateral than normal. The lateral humeral condyle articulates with fibrocartilage that occupies the space normally occupied by the radial head. This redundant fibrocartilage must be excised for the radial head to reduce properly. The radial osteotomy is stabilized with a small bone plate/screws. Next the CORA of the ulna in the frontal plane is identified. It is necessary to correct this CORA to eliminate elbow/carpal translation. If there is subluxation of the semilunar notch, the position of the osteotomy this must be considered when planning the osteotomy. Generally the frontal CORA in the ulna is midshaft so a single osteotomy corrects the frontal CORA and elbow subluxation. One should stabilize this CORA with a small bone plate/screws. Lastly a second ulnar osteotomy is made and a fat graft applied to

Figure 2: A uniaxial deformity has been quantified in the frontal and sagittal planes using the reference angles from Figure 1. The location of the CORA in the frontal and sagittal planes has been identified.
prevent late subluxation of the radial head. If there is significant humeral/ulnar subluxation, the second osteotomy is made proximal to the ulnar plate. If humeral/ulnar subluxation is not an issue, the osteotomy is made distally. Surgical wound is closed using standard methods.
Patellar Luxations
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Patellar luxation is a problem in all breeds and sizes of dogs, but the condition is most common in small breed dogs. Commonly affected breeds include the Yorkshire terrier, maltese, toy poodle, miniature poodle, pomeranian, pekingese and chihuahua. Medial patellar luxation predominates in both small and large breeds, although past literature suggests lateral luxation is much more common in large breeds. Patellar luxation occurs less frequently in cats and medial luxation is most common. Patellar luxation is generally graded from 1-4 based on increasing severity. Grade 1 patellar luxations are generally not repaired, but surgical repair is recommended for grades 2-4, depending on the age and clinical presentation of the patient. Treatment of medial patella luxation may be conservative (small breeds only) or surgical. The decision as to which method is applicable for a patient is dependent upon the clinical history, physical findings and the age of the patient. An older patient in which patella luxation is noted as an incidental finding on physical examination and in which the client reports nonclinical lameness does not warrant surgical intervention. Rather, the client should be informed as to the clinical signs associated with patella luxation. Surgery is advised in the young adult patient even though no clinical problem is apparent since intermittent luxation may prematurely wear the articular cartilage of the patella. Surgery is indicated in any aged patient exhibiting lameness and is strongly advised in a patient with active growth plates since skeletal deformity may worsen rapidly. However surgical techniques used in actively growing animals should be those that will not adversely affect skeletal growth. Surgical options include trochleoplasty, trochlear wedge recession, trochlear block recession, tibial tuberosity transposition, tibial tuberosity transposition, rectus femoris transposition, retinacular imbrication, derotational suture, retinacular releasing incision and corrective osteotomy in cases of femoral or tibial deformity. In severe cases that do not respond to the above treatments, patellectomy and stifle arthrodesis are a possibility; these techniques are fortunately rarely needed (these techniques will not be presented).

Clinical Findings

Pet owners typically report a skipping lameness in affected pets. Typically the pet uses the affected leg normally between skipping episodes. Some owners do not recognize any lameness or gait abnormality in affected patients. Patellar luxation frequently occurs bilaterally, but may one stifle may be more severely affected than the other. Owners often report a slow progression in severity of clinical lameness. The lameness may appear to resolve in some patients over time, but this may be due to the progression of patellar luxation from grade 2 to grade 3. The skipping gait may disappear because the patella is no longer displacing into and out of the trochlear groove. It the patella remains in a luxated position, the patient may not exhibit obvious lameness, but may have a bowlegged gait. Lameness that
acutely worsens in patients with patellar luxation may be associated with a concomitant tear of the cranial cruciate ligament. Cranial cruciate ligament injury occurs in approximately 25% of patients with patellar luxation.

Patellar luxation is generally graded from 1-4 based on increasing severity. Grade 1 luxation is not associated with clinical lameness. The patella can be displaced out of the trochlear groove by applying digital pressure, but spontaneous luxation does not occur. Grade 2 luxation typically presents with an intermittent non-weightbearing lameness, the typical “skipping-gait”. Digital displacement of the patella is possible during examination, but the patella moves back into the trochlear groove when pressure is released or when the stifle is extended. Grade 3 luxation may present with intermittent non-weightbearing lameness or persistent weightbearing lameness. Many of these patients do not have an obvious lameness, but rather display a bowlegged posture when walking. The patella is typically luxated at the time of examination, but can be replaced into the trochlear groove with digital pressure. The patella usually quickly luxates again once pressure is released or the stifle is moved through a range of motion. Grade 4 luxation presents as a persistent weightbearing lameness or bowlegged gait. The patella is fixed in a luxated position and can not be reduced with digital pressure, even in the anesthetized patient.

**Radiographic Findings**

Patients having medial patellar luxation should be evaluated with appropriately positioned orthogonal survey radiographic views of the stifle. Orthogonal views of the entire femur and tibia should also be evaluated if limb deformity is present in small breed dogs and in all medium and large breed dogs with patellar luxation. The patient should be assessed for patella position, distension of the joint capsule, presence of tibial translation, tibial tuberosity position, axial alignment of the femur and tibia, torsional alignment of the femur and tibia, and osteoarthritis. CT imaging is recommended, if available; to more accurately assess hind limb alignment.

Radiographic changes vary from no obvious change to severe limb deformity and marked patellar displacement depending on the grade of luxation, age at onset of patellar luxation and duration of the condition. Minimal radiographic changes are seen in adult patients with uncomplicated grade 1 or 2 medial patellar luxation. Some patients have no abnormal radiographic changes. Radiographic changes that may be seen include patellar displacement, tibial tuberosity displacement, and rarely mild osteoarthritis and mild joint effusion. Grade 3 and grade 4 patellar luxations are more likely to have radiographic patellar displacement, tibial tuberosity displacement, joint effusion and osteoarthritis. These patients are also more commonly affected.
Tears of the cranial cruciate ligament is seen in approximately 25% of dogs with MPL. With axial or torsional abnormalities of the femur or tibia. Patients with severe medial patellar luxation and abnormal limb alignment usually have distal femoral varus, proximal tibial valgus, internal femoral torsion or internal tibial torsion. Radiographic assessment of the depth of the trochlear groove is usually best evaluated by palpation or gross observation, but severely shallow trochlear grooves can be seen radiographically.

Radiographic changes are most severe in puppies where the onset of patellar luxation occurs at an early age when the physis is undergoing rapid growth. Medial luxation of the patella in these dogs causes compression on one side of the distal femoral and proximal tibial physes and compression on the opposite side. As a consequence, the medial aspect of the femoral physis has retarded growth and the lateral aspect has accelerated growth resulting in distal femoral varus. The lateral aspect of the tibial physis has retarded growth and the medial aspect has accelerated growth resulting in proximal tibial valgus. Torsional deformity of the femur and tibia can also occur simultaneously. Correction of the deformity is usually based on comparison of the degree of angulation and torsion found on radiographic examination of the affected patient in comparison to normal reference values. The surgeon should be cautious when interpreting the measured angle of axial deformity as torsional deformity can artificially raise or lower the actual amount of axial malalignment. A CT scan is likely to give the most accurate measurement of axial and torsional deformity.

Patients with medial patellar luxation should also be evaluated for the potential for concomitant cranial cruciate injury. Typical radiographic changes include joint distension and cranial tibial displacement. Osteoarthritic changes are more likely with cranial cruciate ligament injury. If cranial cruciate ligament injury is suspected, measurement of the slope of the tibial plateau may be helpful when deciding on a surgical plan.

Complications associated with medial patellar luxation (MPL) repair can be categorized as intraoperative or postoperative. Complications are fairly common, but fortunately many are easy to resolve or prevent. Most complications can be avoided by better preoperative planning, meticulous surgical technique and appropriate postoperative care.

**Decision-Making for Patellar Luxation Repair**

Many surgical options are available when considering repair of the luxating patella. It is important to consider the underlying problems associated with the particular luxation when choosing a surgical plan. Factors to consider include, depth of the trochlear groove, alignment of the quadriceps mechanism (quadriceps, patella, patellar tendon), and the presence of excessive laxity or tension of the joint capsule and retinacular tissues medially and laterally. The surgical options chosen should alleviate the underlying factor contributing to the luxation. For example, if a dog has good alignment of the quadriceps mechanism, but a shallow trochlear groove- the surgical plan should include a technique to deepen the femoral trochlea, but not a tibial tuberosity transposition.
Methods to Deepen the Trochlea

Three methods are commonly used to deepen a shallow trochlear groove. These methods are described below. A head-to-head comparison as not been performed to document superior efficacy of one technique compared to the others. Usually trochleoplasty is reserved for toy-breed dogs and cats. Trochlear wedge recession and trochlear block recession are preferred for small, medium and large breed dogs, but also can be performed effectively in toy-breed dogs and cats with a slight increase in technical difficulty.

Trochleoplasty - Trochleoplasty is a traditional technique that involves removal of articular cartilage and subchondral bone from the trochlear sulcus, thereby deepening the sulcus. Fibrocartilage repair is generally seen. This technique is considered less desirable to cartilage-sparing techniques described below, although it is sometimes used in toy breeds very successfully. Trochleoplasty is technically easy to perform. A deepened groove can be quickly formed using appropriate sized rongeurs. Attention should be paid to ensuring adequate depth of the groove proximally.

Trochlear Wedge Recession - Trochlear wedge recession provides a means of adequately deepening the trochlear sulcus, while preserving most of the articular cartilage. This technique is described elsewhere, but basically involves removal of a v-shaped wedge of bone and cartilage from the trochlear sulcus, removal of underlying bone, followed by replacement of the original wedge in a recessed position. This is an excellent technique, but technically more demanding than trochleoplasty. The technique is performed using a fine-tooth hand saw-blade. Care should be taken when beginning the saw cut, not to excoriate the adjacent cartilage due to slippage. The cut is initiated perpendicular to the cartilage surface adjacent to the peak of the trochlear ridge. Once the saw blade has engaged the subchondral bone, the blade is gradually redirected in the proper direction, parallel to the v-shaped trochlear groove. A cut is made from the lateral and medial ridge, meeting deep to the central sulcus of the groove. The wedge is removed and carefully stored to avoid accidental discard. The groove is further deepened by removing a block of bone from one side of the groove by making a parallel cut with the handsaw. A modification of this technique is to broaden and deepen the proximal aspect of the new, deepened groove by performing a partial trochleoplasty in the proximal aspect of the groove only, as described above using rongeurs. A portion of bone can also be removed from the underside of the trochlear wedge to further deepen the groove. The wedge is replaced and the adequate
depth of the groove is documented. Fixation of the wedge is usually not needed due to pressure applied from the patella lying above and the congruency between the groove and wedge geometry.

**Trochlear Block Recession** - Trochlear block recession is similar to trochlear wedge recession except that a block-shaped wedge is removed from the trochlear sulcus rather than a v-shaped wedge. This technique allows a deeper groove to be produced, which may provide better biomechanical stability of the patella when the stifle is in an extended position. This is an excellent technique, but technically more demanding than trochleoplasty. The technique is performed using a fine-tooth hand saw-blade, a small osteotome and mallet. Care should be taken when beginning the saw cut, not to excoriate the adjacent cartilage due to slippage. The cut is initiated perpendicular to the cartilage surface adjacent to the peak of the trochlear ridge. Once the saw blade has engaged the subchondral bone, the blade is gradually redirected in the proper direction, perpendicular to the long axis of the bone. A cut is made from the lateral and medial ridge and each cut is carried to an adequate depth deep to the central sulcus of the groove. The block of cartilage and bone is removed gently using an osteotome and mallet. The osteotome is positioned just proximal to the intercondylar notch beginning at the depth of the trochlear cuts. The osteotome is directed towards the proximal extent to the trochlear groove. Gentle raps with the mallet will advance the osteotome, dislodging the trochlear block. The trochlear block is removed and carefully stored to avoid accidental discard. The groove is further deepened by removing a complimentary block of bone from the deep portion of the groove by making a parallel cut with the osteotome or by deepening with a rongeur. A portion of bone can also be removed from the underside of the trochlear block to further deepen the groove. The block is replaced and the adequate depth of the groove is documented. Fixation of the block is not needed due to pressure applied from the patella lying above and the congruency between the groove and block geometry.

**Alignment of the Quadriceps Mechanism**

**Tibial Tuberosity Transposition** - Tibial tuberosity transposition is an excellent method of improving alignment of the patellar mechanism in patients having an abaxially displaced tibial tuberosity. If the tuberosity is displaced medially, luxation occurs medially; therefore, the tuberosity must be transposed laterally and secured. Lateral luxations
require medial tibial tuberosity transposition. An osteotomy is performed as previously described; the tuberosity is transposed then secured with a single or multiple k-wires. An attempt is made when performing the osteotomy to leave the distal cortical bone intact to act as a tension band against the pull of the quadriceps mechanism. If the tuberosity is freed completely, it is prudent to secure the transposed bone with either a pin and tension band or a lag screw. The tuberosity should be transposed to a position that restores axial alignment to the quadriceps mechanism.

**Rectus Femoris Transposition** - This is a technique described by Dr. Barclay Slocum for use in bow-legged dogs having medial patellar luxation. This technique is done in combination with a medial releasing incision. A trochlear deepening technique should also be performed as needed. The rectus femoris is transected from its pelvic origin with a small piece of attached bone, then laterally transposed by tunneling under the vastus lateralis and reattaching it to the cervical tubercle or third trochanter of the proximal femur with wire or heavy suture. This realigns the quadriceps mechanism, restoring a straight-line pull.

**Corrective Osteotomy of the Femur** - Varus deformity of the distal femur is a contributing factor to medial patellar luxation particularly in large breed dogs. Accurate radiographic assessment of the distal femur is needed to measure angulation. If the distal femur has a varus deviation of greater than 10° a varus corrective osteotomy may be needed. A closing wedge osteotomy using a bone plate is commonly used for this procedure.

**Corrective Osteotomy of the Tibia** - Valgus deformity of the proximal tibia may require corrective osteotomy using a closing wedge osteotomy. This typically is only needed in dogs having severe medial patellar luxation when they were puppies. Unequal pressure on the growth plate leads to incongruent growth and angulation of the proximal tibia.

**Retinacular Imbrication**

Lateral imbrication is usually performed with correction of a medial patellar luxation as a means of creating lateral restraint. The stretching of the lateral joint capsule and retinaculum occurs chronically with longstanding patellar luxation. Occasionally a traumatic luxation may result in rupture of these tissues; imbrication is also a good technique for repair in this case. Imbrication is usually performed using heavy, absorbable, monofilament suture placed in a vest-over-pants- or horizontal mattress pattern. Care must be taken not to tighten the retinaculum excessively (especially if a retinacular releasing incision has been performed on the opposite side), because it is possible to create an iatrogenic luxation in the opposite direction. An alternative method of supplying lateral restraint is placement of a lateral derotational suture from the lateral fabella to a bone tunnel in the tibial tuberosity.

**Retinacular Releasing Incision**

A medial releasing incision is performed if fibrous hyperplasia has occurred medially following prolonged or severe medial patellar luxation. An incision is made through the retinacular tissues in a medial parapatellar location. The incision should extend proximally beside the medial edge of the quadriceps tendon. Placement of the incision in this location
will release the insertion of the sartorius muscle, decreasing pull on the patella. The incision occasionally has to be carried deeper to include the joint capsule if marked joint capsular fibrosis has occurred creating excessive medial restraint. The incision is left open and not sutured. Arthroscopic medial releasing incisions can be performed. This technique is quick, easy to perform and has low morbidity. Long-term follow-up is presently unavailable. In addition, the clinical indications with this technique are presently unknown.

**Patellar Sling Suture Technique**

The patellar sling suture is a simple procedure that provides lateral support to the patella in patients undergoing surgical stabilization of MPL. The sling is created using a suture anchor and heavy suture material. The author currently prefers the use of a Fastak anchor and #2 Fiberwire (Arthrex VetSystems, Naples, FL) in small dogs and cats or a Corkscrew anchor and #5 Fiberwire (Arthrex VetSystems, Naples, FL) in medium and large dogs. The suture anchor is inserted in routine fashion in the center of the lateral surface of the femoral condyle, perpendicular to the sagittal plane of the femur. The anchor can be directed slightly cranio-lateral to caudomedial to avoid inadvertent contact with the trochlear block created with the TBR. One arm of the suture is passed from lateral to medial through the insertion of the quadriceps tendon at the proximal pole of the patella. The suture can be passed using an 18-gauge needle and a nytinol wire passer. The needle is inserted from medial to lateral in the quadriceps tendon. The wire passer is inserted from lateral to medial through the lumen of the needle, exiting the hub of the needle medial to the patella. The needle is then removed by sliding it over the passing wire. The arm of the Fiberwire (FW) is threaded through the loop of the wire passer and the FW is pulled from lateral to medial through the quadriceps insertion by pulling the wire passer through the tissue. The FW is then passed from medial to lateral through the origin of the patellar tendon at the distal pole of the patella in similar fashion.
The patellar sling suture encircles the patella, providing a secure method of fixation. The suture is tensioned, removing all the slack. It is important to emphasize proper tensioning of the suture. The goal is to tension the suture sufficiently to prevent any future medial displacement of the patella, but not to over-tension the suture, which could result in excessive lateral tension and subsequent lateral patellar luxation. The suture is secured by tying 2-3 routine square knots to the opposing arm of the suture. The patellar sling moves like a pendulum with the patella as the stifle moves through its normal range of motion.

The author emphasizes the need for strict aseptic technique when using FW for the patellar sling suture. A Dura Prep skin preparation and use of a Ioban drape (3 M Products) are recommended to prevent contact of the braided suture material with the skin.

The advantages of the patellar sling compared to a derotational suture or lateral retinacular imbrication is the bone to bone attachment and the lack of elongation of the suture over time.
THE HEADLESS COMPRESSION SCREW

Don Hulse DVM, Dip ACVS, ECVS

The headless compression screw is an ideal implant to achieve compression of a fracture plane or an osteotomy where tension force would separate the osteotomy. Fractures which would be ideal for this method of stabilization include positions where a tension band would be utilized. Examples are olecranon fractures, tibial crest fractures, and greater trochanter fractures. HCS are also ideal when osteotomy of the above sites are used to facilitate fracture reduction/stabilization. Examples would be an olecranon osteotomy for exposure of an elbow fracture and greater trochanter osteotomy for exposure of an acetabular fracture.

Most common use for the HCS is with a CORA based leveling osteotomy. With this technique, the quadriceps tension will displace the cranial aspect of the osteotomy is not resisted. The HCS has been very effective in eliminating the tension produced by the quadriceps. The two examples below demonstrate primary union of the osteotomy 7 weeks following surgery achieved with a Synthes LCP and HCS.
HOW I TREAT FRACTURES OF THE RADIUS IN DOGS AND CATS

Brian S. Beale, DVM, Diplomate ACVS

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Radial fractures can be challenging to repair in toy breed and cats due to the small bone size and suboptimal blood supply to the region. Most of these fractures occur secondary to substantial trauma, which can lead to increased complexity of the fracture in some patients and concomitant soft tissue injury. Careful consideration should be given to decision-making prior to onset of fracture repair. Factors that should be considered include mechanical, biological and postoperative care. Minimally-invasive surgical approaches reduce pain and minimize trauma to the soft tissues. Biological factors important for fracture healing are preserved, enhancing the body’s ability for direct or indirect bone healing. Stabilization of fractures using the principles of biologic fracture management is performed with the same type of implant systems used with traditional fracture repair, including externally and internally applied devices.

Implant Systems

External and internal implant systems can be used to stabilize radial fractures in toy breeds and cats. Examples of external devices when used in an appropriate manner include casts, splints, linear external fixators and circular fixators. Internal devices commonly used for this application include the plate-rod system and bone plates.

External Fixator

External fixators provide rigid stabilization and can be used with minimally-invasive technique. Many fractures of the radius can be reduced closed and stabilized with an external fixator. The external fixator is a reasonable choice when substantial soft tissue compromise has occurred. The main disadvantage is the potential for complications with premature pin loosening and the added care needed in the postoperative period. Another problem is the need to use small diameter fixator pins due to the small size of the bone. Pins diameter should not exceed 30% of the width of the bone. If pins prematurely loosen, bone resorption around the pin may occur and lead to larger holes, increasing the risk of fracture through the pin holes. The use of external fixators for fracture repair is not optimal if the patient or owner is likely to have poor compliance in the postoperative period.

Plate-rod construct

The plate rod system has been found to be an ideal implant system for biological fracture management. Management of a non-reducible diaphyseal fracture with a combination of an IM Steinmann pin and bone plate can be applied without anatomical reconstruction and thus, avoids the development of small fracture gaps with high interfragmentary strain. The addition of the IM pin to the plate also significantly increases the construct stiffness and estimated
Distal radial fractures are common in toy breed dogs and cats. Locking plates are ideal for these type of fractures due to the small size of the distal fragment that may only allow use of 2 screws. Low profile plates are desirable number of cycles to fatigue failure when compared to a plate only construct. An IM pin serves to replace any transcortical defect in the bone column and acts in concert with the eccentrically positioned plate to resist bending. Addition of an IM pin to a bone plate has been shown by Hulse et al. to decrease strain on the plate two-fold and subsequently increase the fatigue life of the plate-rod construct ten-fold compared to that of the plate alone. Stiffness of plate-rod repairs may be as much as 40% and 78% greater when the pin occupies 40% and 50% of the marrow cavity, respectively. When using a plate-rod construct in toy breed and cat radius fractures, the pin is first placed in the ulna through a caudolateral approach. This helps to reduce the radial fracture and provide some stability, making plate placement easier. The plate is placed on the radius through a craniomedial approach.

**Locking Plates**

Locking plates have become very popular for traditional and minimally-invasive fracture repair and work very well for fractures of the radius in toy breeds and cats. The most common fracture is a distal radius fracture. The distal fragment is very small, often allowing use of 2 screws only. Locking screws are advisable when only 2 screws can be used. Some locking plates are also low profile (FIXIN, Synthes, PAX and ALPS), which is ideal due to the presence of the extensor tendons and the difficulty of closing the incision due to the tension of the soft tissue in the region. Many locking plate systems are available including the Synthes, FIXIN, PAX, SOP and ALPS. Locking plates have the ability to lock the screw into the hole of the plate. The ability to lock the screw to the plate increases pull-out strength of the screw and construct stability. Traditional plates do not have threaded holes. Screws placed in ordinary plates apply pressure to the plate, pressing it onto the bone surface. The friction between the plate and the bone provides the stability to the bone-implant construct. In contrast, the locking plate achieves stability through the concept of a fixed-angle construct. The locking plate is not pressed firmly against the bone as the screws are tightened. The locking screws and plate function more like an external fixator. Locking plates are essential “internal fixators”. The plate functions as a connecting bar and the screw
functions as a threaded fixator pin. The tapered or threaded head of the locking screw engages the hole of the plate, similar to the clamp of an external fixator. Traditional screws should be placed prior to locking screw when using locking plates.

Locking plates are ideal for minimally-invasive fracture repair for several reasons. Blood supply to the bone is preserved because the plate is not pressed tightly against the bone. The plate does not require perfect anatomic contouring because the displacement of the plate will not occur as the screw is tightened into the hole of the plate. Accurate contouring is difficult with a minimally-invasive approach due to the minimal exposure to the shaft of the bone. Lastly, locking screws give fixed angle support to the non-reduced fracture, increasing stability and less chance of collapse and instability at the fracture gap.

The size of traditional or locking plates used for toy breed dog and cat radius fractures typically use screws that are 1.5-2.0 mm diameter. Straight plates or T-plates are most commonly used.

Distal radius fractures are often stabilized using a straight or t-shaped plate. The small distal fragment typically only allows use of 2 screws. The fracture on the left is stabilized with a 1.9 FIXIN straight plate. The fracture on the right is stabilized with a 1.5 mm Synthes notched t-plate.
HOW I PERFORM PANCARPAL ARTHRODESIS

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Arthrodesis – the indications

Arthrodesis is used to treat joints having severe instability, severe osteoarthritis, or cancer. It is often referred to as a salvage procedure, but if done correctly, arthrodesis can give a good to excellent functional outcome. Essentially any diarthrodial joint can be arthrodesed, but the carpus, tarsus, digits and shoulder have the best outcome. Carpal and shoulder arthrodesis provides the best functional outcome.

Arthrodesis – the basic principles

Arthrodesis is much more complicated than repairing a fracture. The surgical goal is similar - bony fusion - but with arthrodesis, the implant system must counteract extensive distractive forces. The implant system is being placed across a joint that is designed to have motion – a highly negative factor for implant survivability and bone healing. There are 4 fundamental principles that must be respected to have a successful arthrodesis: adequate cartilage debridement, proper bone alignment, rigid stability and bone graft augmentation. Practical tips that can be used to address each principle are described below.

Principle 1: Articular cartilage debridement - The articular cartilage must be removed from the ends of the bone over the majority of the weightbearing surfaces. Cartilage that is left behind increases the chance of inadequate bony fusion between the two bones. The cartilage can be removed using a curette, motorized burr or by performing a juxta-articular osteotomy. A hand curette will adequately remove cartilage when using a scooping or scraping action. When using a curette, an attempt should be made to invade the subchondral bone plate, ensuring access to a source of mesenchymal stem cells and vascular invasion. If the bone ends are sclerotic, a motorized burr may be superior to a hand curette. A motorized burr removes articular cartilage much more quickly than a hand curette, but generates extraordinary heat. Copious lavage should be used when using a motorized burr to reduce
the risk of thermal necrosis. Necrotic bone cells will need to be removed and replaced, increasing the time to reach bony union. The Burr should be used to remove articular cartilage and superficial bone. Some bleeding of bone is desirable, but over-aggressive bone removal may make alignment of the joint more difficult reduce stability of the articulation to be arthrodesed. After removal of articular cartilage the joint should be copiously flushed to remove cartilage debris. Small holes can be drilled in the ends of the bone articulations using a k-wire or small drill bit. This is often referred to as forage and enhances neovascularization and provides a source for mesenchymal stem cells. Another method that can be used to prepare the bone surfaces is a juxta-articular osteotomy of the ends of each bone. Copious lavage should be used during the cutting process to avoid thermal necrosis. The line of the osteotomy should be planned carefully to achieve the proper joint angle after the stabilization.

**Principle 2: Bone alignment** – A good functional outcome following arthrodesis requires adequate alignment of the limb. Care should be taken to ensure proper axial and rotational alignment. Malalignment leads to gait abnormalities, reduced willingness to use the limb and abnormal forces placed across adjacent joints which may predispose them to osteoarthritis or instability. The arthrodesis should be positioned at a functional angle. A proper functional angle is best chosen by measuring the opposite normal joint using a goniometer. This is best performed while the patient is in a standing position. Alternatively, the angle can be selected from known joint angles from various surgical text and journal articles.

**Principle 3: Stabilization and implant system** – Rigid stability is a must. The implant system must be able to withstand tremendous distractive forces for a prolonged period of time. The most commonly used implant systems for arthrodesis are bone plates, plate-rod construct, pin and tension band, and external fixators. Cross pins or lag screws can also be used to achieve arthrodesis, but these methods are less secure and should be reluctantly used in only very young, small patients. Once the joint is properly aligned one or two appropriately sized pins can be placed across the ends of the bones to provide temporary stabilization while the primary implant system is applied. The pins can be removed if desired after applying a bone plate, or if desired. The pins can be left in place if they were initially placed such that they do not interfere with the bone plate or plate screws. If the pins are left in place, a plate-rod construct has been created. The advantage of leaving the pins in place is the ability for them to absorb some of the load, reducing plate strain and risk of failure. Compression should be placed across the site of arthrodesis to give improved stability when possible. Greater stability reduces the chance of implant cycling and failure and enhances bone healing. Application of bone plates should ideally be placed on the tension surface of
the bones to reduce the chance of implant failure. Unfortunately this is not always possible due to poor access due to overlying soft tissues and the lack of a true contiguous tension surface along the course of the conjoined bones. If a bone plate is applied to the compressive surface of the bones, the implant should be sized accordingly to handle the additional load. Addition of adjunctive implants such as pins or an external fixator to share loads can help protect the plate and screws. External fixators can also be used effectively as the sole means of stabilization for arthrodesis. They are particularly useful in patients having open wounds requiring arthrodesis. Following bony union, the external fixator is easily removed. In contrast, the use of internal fixation in these patients predisposes them to infection. If infection occurs, the bone plate, screw and any pins may have to be surgically removed to resolve the infection. Arthrodesis techniques have been described in detail in multiple surgical texts and a through discussion for each joint is beyond the scope of this presentation.

**Principle 4: Bone augmentation** – Autogenous bone grafts are easy and quick to harvest and speed bony union of the arthrodesis. Bone grafts can be harvested typically in 10-15 minutes. Autogenous cancellous bone grafts have osteoconductive, osteoproducive and osteogenic properties. The most productive harvest sites are the greater tubercle of the humerus and the ilial wing. Other sites that can be used include the proximal tibia, the proximal femur and the sternum, but these sites are not recommended unless the shoulder and ilium are not available for some reason (usually because of poor presurgical planning!) Bone graft is harvested from the humerus by drilling a hole with a large pin and harvesting cancellous bone using a curette. The same technique can be used for the ilial wing; however an alternative technique that provides a large volume of corticocancellous graft makes use of the acetabular reamer. The reamer is used to harvest bone from the lateral cortex an medullary of the ilial wing. Following graft harvest from either site, the collected bone is stored in a stainless steel bowl or on a blood-soaked gauze (do not accidentally discard the sponge!). The graft should be harvested immediately prior to placing it at the site of arthrodesis to increase viability of osteoblasts, growth factors and the bone scaffold. Other products are available “off the shelf” for use to enhance bone production, including various synthetic bone substitute compounds, lyophilized and frozen bone products.

**Pancarpal Arthrodesis** - Pancarpal arthrodesis is most commonly performed using a bone plate applied to the cranial or medial surface of the radius, carpus and metacarpus. The advantage of applying the plate to the cranial surface is ease of application of the plate and screws. Cranial plate placement may also allow more accurate alignment of the limb for novice surgeons. The disadvantage of cranial plate placement is interference with the extensor tendons of the digits. Another disadvantage is the compressive forces experienced by the plate during weightbearing place large cyclic bending forces on the plate that can lead to breakage of the plate. The plate should be positioned such that screw holes are positioned away from the radiocarpal joint. Many surgeons use external coaptation of 2-4 weeks post-op to decrease the cyclic forces experienced by the plate. Medial plate placement is more difficult, but does lessen interference with extensor tendons. Medial placed plates also allow longer screw purchase and it positions the thickest portion of the plate in an optimal position to counteract the compressive forces that occur during extension of the carpus. The size of
plate used should be optimized- the plate should be large to counteract the tremendous forces placed across the carpus with weightbearing, but the size of the plate is limited by the size of the small carpal bones and width of the metacarpal bones. Hybrid plates are available that allow placement of larger screws in the radius and smaller screws in the carpal and metacarpal bones.