Interventional Endoscopy (IE) involves the use of endoscopic equipment with other contemporary imaging modalities, such as fluoroscopy and/or ultrasound, to perform diagnostic and therapeutic procedures in virtually any part of the body accessed endoscopically (gastrointestinal, biliary, respiratory, urinary tract, etc).

Currently, an expanding investigation of the use of some novel techniques in veterinary medicine has been undertaken. The combination of endoscopy and fluoroscopy allows for one to visualize and gain access into small orifices that would otherwise require more invasive surgical techniques. A good example of this is the placement of a biliary stent into the common bile duct via the major duodenal papilla with endoscopic and fluoroscopic guidance. Many of these interventional procedures are considered the standard-of-care in human medicine, and are currently being investigated in veterinary medicine. The use of these techniques are expanding in our veterinary patients as these modalities are becoming more widely available.

The invasiveness and morbidity associated with some traditional surgical techniques (i.e. ureterotomy for ureteral obstructions or strictures, biliary re-routing surgery, nasopharyngeal surgery for nasopharyngeal stenosis, etc) makes the use of minimally invasive alternatives using IE appealing. The advantages of such procedures are not only their minimally invasive nature but the lower morbidity, shorter hospital stays, and most importantly the lack of alternative options our patients have. The limitations are that these procedures are technically challenging, require specialized equipment, and extra training.

This talk is a brief overview of some of the minimally invasive interventional endoscopic procedures actively being performed in veterinary medicine as well as some promising future applications currently under investigation.

**Equipment**

A C-arm fluoroscopy unit is ideal for most of the IE procedures we are currently performing. This unit has the advantage of image intensifier mobility, permitting various tangential views without moving the patient, and positioning of the patient where endoscopy is easiest (i.e. at the end of the table for rigid cystoscopy). Ultrasonography is useful for percutaneous needle access into structures (gall bladder, renal pelvis, etc) making portable ultrasound very valuable. Guidewires of various size, shape, length, and stiffness, as well as catheters and stents of various materials, shapes, and sizes are needed for each procedure (see below).

Endoscopes are used to guide the operator toward the orifice where visualization and access is needed (i.e. common bile duct, ureteral orifice, nasopharyngeal stenosis). Various flexible and rigid endoscopes are used for interventional endosurgical techniques. Flexible gastroduodenoscopes (6 mm and 8 mm), bronchoscopes, and ureteroscopes (7.5-8.2 french) are classically used for various body system interventions. Rigid endoscopes (1.9-7.5 mm) are also useful for cystoscopy and rhinoscopy. An adult (11 mm) or pediatric (9mm) side-view duodenoscope is necessary for endoscopic retrograde cholangiopancreatography (ERCP) and biliary stenting, though this is not yet commonly performed in our clinical patients. Other specialized catheters and guidewires are needed for each particular procedure which will be expanded more upon during the presentation.

**Respiratory Interventions**

**Nasopharyngeal stenosis**

Nasopharyngeal stenosis (NPS) is a pathologic narrowing within the nasopharynx caudal to the choanae resulting in a variable degree of inspiratory stertor. This can occur as a congenital anomaly or be secondary to an inflammatory condition (aspiration rhinitis), surgery, trauma, or a space-occupying lesion. Traditional therapy involves surgery or serial balloon dilatation procedures. Balloon dilatation is minimally invasive and utilizes interventional technique via fluoroscopy and endoscopy, but can result in re-striction in a few days to a few weeks. We have found that stenting of this nasopharyngeal region allows for a more permanent fixation and results in both dogs and cats have been extremely promising.
Under both fluoroscopic and rhinoscopic guidance a hydrophilic guidewire is advanced caudally from the nares through the ventral nasal meatus, through the stenotic opening, and down the esophagus. This is viewed inside the nasopharynx with retroflex rhinoscopy, and from the outside with fluoroscopy. Once the stenotic lesion is identified a percutaneous transluminal angioplasty (PTA) balloon, preloaded with a metallic stent (balloon expanded metallic stent—BEMS) is advanced over the guidewire and centered over the stenotic lesion. Using both fluoroscopic and endoscopic viewing the balloon is inflated (with a 50:50 mixture of contrast and saline) and the waist of the stenosis is subsequently broken with the balloon. As the balloon expands, the stent deploys. Once the stenosis is open, the balloon is deflated and removed over the wire, and the stent is left to remain in place. More recently the authors are infusing 2-5 ml of topical Mitomycin C (0.1%) onto the stenotic lesion after the stent is deployed to prevent aggressive fibrosis. The stent will re-epithelialize in a few days-weeks (approximately 2-6 weeks). The size (length and width) of the stent and balloon are typically chosen based on Computed Tomography (CT), which is done prior to the procedure. The patients usually go home the same day as the procedure with anti-fibrotic doses of glucocorticoids (prednisone 0.5 mg/kg BID) tapered over 6-8 weeks, 2 weeks of antibiotics and Tramadol as needed for any discomfort. The author’s recommend feeding moist food for the first 2 months as well.

Tracheal Stricture balloon dilatation

For tracheal strictures, balloon dilatation prior to considering stent placement is often ideal. In order to avoid tearing the trachea a hot-knife can be used to pre-determine where the stricture should tear, preventing a longitudinal tear in the normal tracheal tissue.

Tracheal Tumor/Polyp Polypectomy or Laser ablation

Tracheal tumors can be treated in various different ways depending on the location, type and extent. Many tumors are found in the intrathoracic trachea and surgical removal via resection and anastomosis are associated with a significant morbidity, particularly when a diagnosis is not yet made, or there is evidence of concurrent metastasis. With the use of electrocautery snares, polypoid mass (tracheal polyp, extramedullary plasmacytoma or leiomyoma/leiomyosarcoma) can be effectively resected during the biopsy procedure, providing both a diagnosis and treatment concurrently. If the mass is broad based and not amenable to polypectomy then either a laser (diode or CO2) or stent can be use to open the airway. For non-resectable masses the author prefers a tracheal stent, as this is fast, safe and seemingly highly effective.

GASTROINTESTINAL INTERVENTIONS

Esophageal balloon dilation and esophageal stenting

Esophageal strictures are frustrating to treat for both veterinarians and physicians. Patients classically present with signs of regurgitation. Strictures in the esophagus can be secondary to reflex esophagitis (commonly post-anesthesia), caustic substance ingestion, medications sitting on the esophageal mucosa for lengths of time (i.e. doxycycline tablets in cats), from esophageal foreign bodies, etc. Many alternative therapies have been tried because recurrence is very common. Balloon dilation or bougienage procedures using endoscopic guidance is currently the treatment of choice in veterinary medicine. Regardless of the intervention chosen, many of these strictures recur and present as a monetary and clinical dilemma for our feline and canine patients. In human medicine, fluoroscopy, in conjunction with endoscopy, is used for dilation of esophageal strictures, allowing better visualization that the waist of the stricture is not just stretched, but completely broken. With a similar theory to the NPS cases, esophageal strictures would ideally be balloon dilated with a stent left in place to keep the stenotic lesion open for the time it would take the tissue to re-stenose. The biggest concern about doing this in the esophagus is that this area is very motile (vs the nasopharynx) and food will need to pass through the area. The risk of the stent migrating into the stomach, or proliferative tissue growth around the ends of the stent material, makes permanent stenting for benign disease less than ideal. In order to circumvent these concerns pliable stents with a shape that would ideally hold up again peristalsis (dumb-bell and self expanding) have been tried. Knowing that the stenotic tissue will heal over 14 or more days, having a stent that can be removed or resorbed (polylactic acid or PDS stents) in a few months are being investigated. This has been studied in
humans for some time and in a small handful of clinical veterinary cases. The technique holds a more clear indication for non-resectable esophageal malignancies, and this has been performed with success.

Using both fluoroscopic and endoscopic guidance, the stent is placed over a guidewire and centered over the esophageal stenosis or tumor inside its delivery system. Once deployed the stent is expanded across the stenosis. For benign lesions it is recommended that the stent be tacked with a suture (either endoscopically or manually placed suture) to prevent stent migration into the stomach. The preliminary results thus far have been variable. In the future this may be a consideration at the time of 2nd or 3rd balloon dilation to avoid serial anesthetic procedures and high costs but the ideal stent needs to be investigated before this is routinely recommended.

**Esophageal-jejunal feeding tubes**

Enteral methods of feeding are preferred over parenteral nutrition in humans due to the benefits on gut mucosal integrity, barrier function, and lower complication rates. Jejunal feeding in small animal patients is controversial. In animals that are intolerant of gastric feedings, have intractable vomiting, have pancreatitis where pancreatic exocrine duct by-pass is desired, or are unconscious and regurgitation or reflux is a concern (ventiled animals), feeding directly into the jejunum is often considered. Classically this has been done via surgical or laparoscopic techniques with a high complication and oral dislodgement rates. More recently there has been investigation of PEG-Jejunal feeding tube placement using endoscopy, and this has been met with success.

Due to the ease of placing a nasal feeding tube or an esophagostomy feeding tube, tubes have been able to be placed into the jejunum from the nares (NJ) or esophagus (EJ) with fluoroscopy +/- endoscopy, eliminating the complications associated with enterotomy or gastrotomy (septic peritonitis or unnecessary gastric or jejunal orifices). NJ and EJ tube placement is aided with fluoroscopy visualizing the guidewire and cathether placement into the duodenum and into the jejunum. If an upper GI endoscopic procedure is being performed at the same time than wire placement across the pylorus can be done through the endoscope. This technique is fast, effective and fairly inexpensive when compared to surgical placement and parenteral access with intensive care monitoring of TPN. These tubes have been left in place in clinical patients for over 2 weeks, and once the J-feedings are unnecessary an E-tube remains for convenience.

**Colonic stenting**

Colonic obstructions are rare in small animal patients. They can be due to neoplastic lesions, strictures, or granulomatous lesions. In humans, colonic stents have been available for over a decade and are most commonly placed for people with neoplasia who are a prohibitive surgical risk or resection holds little chance of surgical cure. They have been used as a mechanism to help de-obstipate for bowel preparation prior to resection and anastomosis. In humans, colonic stents can either be placed through the endoscope for direct visualization while they are deployed, or they can be placed over a guidewire under fluoroscopy alone. They are preferred to be placed through the scope for precise stricture localization, for proximal tumor locations and to guide the stent across acute angulations in the colon. In humans, clinical success is seen in up to 95% of patients. At the University of Pennsylvania 4 colonic stents have been placed in cats; 3 for tumors and 1 for a stricture. In all cases colonoscopy was done to visualize the lesion and help localize the lesion fluoroscopically. A guidewire was then advanced through the stenotic lesion. Under fluoroscopic guidance a self-expanding metallic stent (SEMS) was placed across the stenotic lesion or tumor and the stent was deployed in that position. Patency was re-established immediately in all cases and subsequent de-obstipation was achieved. All cats were fecally continent, and no stent migrations were seen. The stent was visualized to be incorportated into the colonic mucosa within 4 days in one cat that was re-scoped.

**BILIARY INTERVENTIONS**

Extrahepatic biliary obstructions present a great dilemma as they induce life-threatening metabolic derangements, causing excessive morbidity and mortality. Surgical treatment is often indicated, but the outcome with biliary re-routing surgery holds such a high risk, with the mortality rate ranging from 25-70% in dogs and over 75% in cats. If the metabolic derangements can be relieved by a fast and effective decompressive
procedure than future surgical interventions for a more definitive fixation may be safer for the patient. We will discuss two options that can be performed in veterinary patients 1) endoscopic drainage through the common bile duct (ERCP) and 2) laparoscopic assisted biliary drainage by cholecystostomy tube placement.

**Endoscopic retrograde cholangiopancreatography (ERCP) and biliary stent placement**

Endoscopic retrograde cholangiopancreatography (ERCP) is an IE technique used for the diagnosis, and potential treatment, of biliary tract disease, pancreatitis, or pancreatic obstructive lesions. To date biliary stents have been successfully placed in a small handful of normal purpose-bred dogs, and clinical investigation is underway. Using a side-view duodenoscope the major duodenal papilla is visualized and cannulated with a sphinctertome catheter. Once a retrograde cholangiogram and pancreatogram are performed a guidewire is advanced into the common bile duct under fluoroscopic guidance. Then, through the endoscope, a polyurethane stent is advanced over the wire. With fluoroscopic and endoscopic guidance the stent is advanced into the common bile duct, transverses the major duodenal papilla and exits into the duodenum. This can be left in place until the obstructive lesion resolves (ie pancreatitis), or a permanent metallic stent can be used in the case of neoplasia. This bypasses the need for re-routing biliary surgery for EHBDO.

**Laparoscopic cholecystostomy tubes**

Laparoscopic cholecystostomy tubes have been reported in a small number of clinical veterinary patients. They can be accomplished with very short anesthesia times. An 8 or 10 french locking-loop pigtail catheter can be advanced through a right paracostal approach being visualized with laparoscopy. With transhepatic penetration of the catheter, the gallbladder is accessed. Once the trocar is into the lumen of the gallbladder, as visualized via laparoscopy, the trocar and stylet are slowly removed and the locking loop mechanism is set in place. The catheter can drain the gallbladder and can be sutured securely to the body wall. This can remain in place until the patient is a better anesthetic candidate for surgery, or for 4—6 weeks while a seal is achieved and a more benign lesion resolves (pancreatitis), bypassing the need for surgical intervention. In the clinical reports, most patients needed to have the rent in the gallbladder closed surgically once stabilized, as a seal did not form very quickly.

**URINARY INTERVENTIONS**

**Ureteral stenting** is performed for a variety of disorders to divert urine from the renal pelvis into the urinary bladder. This technique can be useful in patients with ureteral obstruction due to ureterolithiasis, ureteral or trigonal obstructive neoplasia, ureteral stenosis/strictures or following ureteroscopy, percutaneous nephrolithotomy, ureteral stone retrieval (basket retrieval or via laser lithotripsy), for post-operative ureteral anastomosis, ureteral tears, ureteral spasm, or ureteritis. In addition, the presence of the ureteral stent may result in subsequent passive ureteral dilation to permit passage of previously obstructive ureteroliths, or allow passage of the flexible ureteroscope for appropriate ureteral intervention. This technique has been performed in the authors practice in over 170 patients (dogs and cats) for various causes.

**Cystoscopic-Guided Laser Ablation (CLA) of Ectopic Ureters**

Ectopic ureters are a common congenital anatomic deformity in dogs with the ureteral orifice being positioned distal to the bladder trigone within the ureter, vagina, vestibule or uterus. Over 95% of dogs with ectopic ureters transverse intramurally and are candidates for this minimally invasive IE procedure. Endoscopic repair of ectopic ureters has been performed in over 70 dogs (males and females) in the United States. This is done with the use of fluoroscopy, cystoscopy and a diode or holmium:YAG laser. This procedure is performed on an out-patient basis at the time of cystoscopic ectopic ureter diagnosis avoiding the need for more than one anesthetic procedure for fixation. This will be discussed in more detail in the incontinence section.

**Ureteroscopy** is possible in dogs larger than approximately 20 kg. This is performed for various reasons, mainly for evaluation of idiopathic renal hematuria. This procedure is difficult to perform in dogs though a normal ureteral orifice, as the ureter in a normal dog is less than 2 mm and the smallest ureteroscope is approximately
2.5 mm. Ureteral access is obtained via cystoscopic access, with a guidewire being advanced up the ureter into the renal pelvis and the endoscope being advanced over the guidewire under fluoroscopic and endoscopic guidance. This procedure is ideally performed for evaluation of the ureteral and renal pelvic mucosa in the case of idiopathic renal hematuria, for ureteral stone disease and laser lithotripsy if ESWL is not effective, or for evaluation of ureteral obstruction and hydroureter when other imaging modalities are not diagnostic (ureteral stricture/stenosis or neoplasia).

**Essential (Idiopathic) renal hematuria** is a rare condition in which a focal area of bleeding in the upper urinary tract results in long term hematuria, iron deficient anemia (chronically) and the potential for clot formation, or calculi due to blood clots, resulting in ureteral colic or signs of lower urinary tract disease. In people, the presence of a hemangioma or vascular malformations have been visualized ureteroscopically, which is cauterized through the working channel of a ureteroscope. This has been performed in a small number of dogs to date.

**Ureteral infusions for essential renal hematuria** has been recently performed in a number of canine patients in which the ureter is too small to allow for ureteroscopic access. This is done with cystoscopic and fluoroscopic guidance in which a cauterizing agent is carefully infused into the renal pelvis to stop the bleeding.

**Treatment of Nephrolithiasis**

The treatment of problematic nephroliths is a rare necessity. Less then 10% of all nephroliths in dogs and cats become a clinical problem and should be monitored carefully, but not necessarily treated unless one of the following occur: recurrent urinary tract infections (with appropriate term antibiotic therapy [over 8-12 weeks]), any degree of hydronephrosis, worsening renal function, pain/discomfort (not associated with a pyelonephritis). When this occurs the use of traditional surgical options like nephrostomy is met with complications and long-term morbidity. In studies looking at clinical dogs ~ 43% had stone fragments remaining and 23% had procedure related complications. Additionally, 67% of dogs had evidence of renal azotemia that developed following nephrostomy. In a feline study looking at normal cats there was a 10-20% decrease in the GFR of the kidney that had a nephrostomy performed. It is important to realize that in normal animals the renal hypertrophic mechanisms are not exhausted, but in clinically affected dogs and cats this process has already occurred, making the change in renal function more dramatic. With the use of less invasive approaches, like extracorporeal shockwave lithotripsy (ESWL) (<1.5-2 cm) or percutaneous nephrolithotomy (PCNL) (>1.5-2 cm) the preservation of renal function has been shown in humans to be dramatically improved. PCNL is highly effective in removing all stone fragments in the calices and does not requiring cutting of the nephrons. The nephrons instead are spread apart with the use of a balloon dilation kit to allow a scope and intracorporeal lithotrite to remove the stone debris effectively.

**Laser lithotripsy** is an innovative technique involving the intracorporeal fragmentation of uroliths, which is assessed using a rigid or flexible cystoscope or ureteroscope. The holmium:YAG (yttrium, aluminum, garnet) laser combines both tissue cutting and coagulation properties, as well as the ability to fragment stones upon contact. The laser energy is focused on the urolith surface, directed via cystoscopy. This process is useful for ureteral, cystic and urethral calculi. All stone types are able to be fragmented using laser lithotripsy.

Other urologic applications for laser lithotripsy include incision of urethral and ureteral strictures; ablation of superficial transitional cell carcinoma within the urethral lumen (using a diode laser), and laser ablation of urinary polyps. Bladder polyps are common findings in dogs and can be associated with chronic, recurrent urinary tract infections, cystolith formation, and are often misinterpreted for cystic neoplasia. Using cystoscopy and baskets or laser lithotripsy the polyps can be removed without surgical intervention by cauterizing the stalk.

**Percutaneous cystolithotomy (PCCL)** is a technique where a rigid and flexible cystoscope are used to remove stones in the bladder and urethra of male and female cats and dogs. This is done via a small incision in the abdomen at the level of the bladder apex. Then a small sheath is advanced into the bladder lumen to allow for
antegrade cystoscopy and stone retrieval via stone basketing. This technique is fast and effective and does not require laparoscopy.

**Urethral Stenting for Malignant Obstructions**

Malignant obstructions of the urethra can cause severe discomfort, dysuria and life-threatening azotemia. Greater than 80% of animals with transitional cell carcinoma (TCC) of the urethra, and/or prostatic carcinoma experience dysuria and approximately 10% developing complete urinary tract obstruction. Chemotherapy and radiation therapy has been successful in slowing tumor growth but complete cure is uncommon. When signs of obstruction occur, more aggressive therapy is indicated. Placement of cystostomy tubes, transurethral resections, ureteral laser procedures, and surgical diversionary procedures have been described few hold long-term promise, most are very expensive, and many are potentially associated with an undesirable outcome due to manual urine drainage, associated morbidity, frequent urination, and chronic infection. Placement of self-expanding metallic stents using fluoroscopic guidance through a transurethral approach can be a fast, reliable, and safe alternative to establish urethral patency in both males and females with a greater than 90% good to excellent palliative outcome. Most procedures can be done on an out-patient basis. Urethral stenting has also been useful in patients with benign urethral strictures, granulomatous/proliferative urethritis or reflex dysynnergia, when traditional therapies have failed.

**Transurethral Submucosal Collagen Implantation** via urethroscopic guidance has been performed for USMI at many institutions. This procedure is indicated if medical management for SMI has failed, is contraindicated, or not tolerated. Overall success of the procedure is good (>80%), though the average maintenance of continence rates following this procedure is reported to be 68% at 17 months, with re-injections potentially being necessary thereafter. Different materials have been tried with variable success.

**FUTURE**

**Intra-arterial stem cell delivery for chronic kidney disease**

Currently under investigation is the use of autologous mesenchymal stem cells (MSC) for the treatment of feline chronic kidney disease. We are currently have a fully funded, randomized placebo controlled study investigating the use of stems cells in feline patient with IRIS stage 3 chronic kidney disease and compare the delivery of these cells intravenously and intra-arterially to a placebo. This study is following the patients out over 3 years assessing systemic signs, blood pressure, GFR, biochemical parameters, ultrasonographic and radiographic parameters. This same study is also being investigated in canine patients with glomerulonephritis (GN)/protein losing nephropathy (PLN).

In conclusion, IE provides new alternatives to the treatment of certain conditions that are traditionally very difficult to manage, or when minimally invasive palliation is desired.