DEVELOPMENT OF A NOVEL TECHNIQUE FOR CONTINUOUS GASTRIC DECOMPRESSION IN DOGS WITH GASTRIC DILATATION AND VOLVULUS SYNDROME: TEMPORARY PERCUTANEOUS T-FASTENER GASTROPEXY AND CONTINUOUS DECOMPRESSIVE GASTROSTOMY

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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To my mother and to Stacey
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Abstract of Thesis Presented to the Graduate School
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DEVELOPMENT OF A NOVEL TECHNIQUE FOR CONTINUOUS GASTRIC
DECOMPRESSION IN DOGS WITH GASTRIC DILATATION AND VOLVULUS
SYNDROME: TEMPORARY PERCUTANEOUS T-FASTENER GASTROPEXY AND
CONTINUOUS DECOMPRESSIVE GASTROSTOMY

By

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Gastric dilatation-volvulus (GDV) is a life-threatening condition characterized by
gastric distention and malposition. Rapid decompensation in GDV patients occurs
secondary to massive gastric distention, and effective decompression is critical for
preoperative stabilization. Currently employed techniques provide only temporary
decompression, and gastric dilatation will return as long as gastric volvulus remains.
The purpose of this research was to develop a minimally invasive technique to provide
sustained gastric decompression in dogs with GDV. We proposed a novel
decompression method employing a temporary T-fastener gastropexy (TTG) and
continuous decompressive gastrostomy catheter (G-cath). This technique was
evaluated in a fresh canine cadaver model, followed by a live canine gastric dilatation
model. These studies revealed that the novel technique was able to be performed
rapidly and provide successful, effective continuous gastric decompression without
causing a significant gastric wound. Following this, the novel decompression technique
was employed for use in clinical cases of GDV and compared to standard trocarization.
In this clinical study, the TTG and G-cath was found to be safe, effective, quickly performed, and provided sustained gastric decompression in dogs with naturally-occurring GDV. The novel technique did not differ significantly compared to trocarization, except for providing sustained decompression. G-cath placement did not induce any clinically significant gastric trauma and was well tolerated in the awake patient. This novel decompression method is the first safe, effective, image-guided technique to provide sustained gastric decompression in dogs with GDV. This technique has the potential for wide application in a common canine emergency
Overview

Gastric dilatation-volvulus (GDV) is a life-threatening emergency that most commonly affects large- to giant-breed, deep-chested dogs and is characterized by rapid accumulation of gas within the stomach, rotation of the stomach on its long axis, and an associated increase in intragastric pressure (IGP).\(^1\)–\(^4\) The acute medical crisis in GDV patients is largely due to the massive gastric distention which compresses critical abdominal vasculature, causing impaired blood flow to and from vital organs, leading to hypovolemic shock, cardiac arrhythmias, electrolyte imbalance, and visceral necrosis among other detriments.\(^5\)–\(^8\) Gastric volvulus in the absence of dilatation has been demonstrated to result in minimal visceral pathology after 12 hours,\(^9\) highlighting the devastating role that gastric dilatation plays in the disease process. As such, rapid gastric decompression and stabilization is critical in the treatment of dogs with GDV in order to restore venous return and halt progression of systemic decompensation.\(^8,\)\(^10\) Often, dogs have gastric dilatation for an extended period of time due to transport from a general practice to an emergency facility, or while awaiting corrective surgery at a specialty center. The most commonly employed techniques for gastric decompression, trocarization and orogastric tube placement, achieve successful decompression 86% and 75.5% of the time, respectively.\(^11\) Unfortunately, decompression is only temporary and gastric distention can recur in minutes along with the associated untoward sequelae. Ideally, a minimally invasive technique to provide sustained decompression in GDV patients should be used, however there is currently no such technique described.
Anatomy

The canine stomach is a highly distensible J-shaped dilation of the alimentary tract that primarily stores and digests ingesta received from the esophagus before emptying into the duodenum.\textsuperscript{12} Its size is variable amongst breeds and capacity has been reported to be between 0.5-6L.\textsuperscript{13} It has been estimated that an “average sized” dog is comfortably full at around 700mL.\textsuperscript{14} The stomach is grossly divided into several segments (Figure 1-1). The area in which the esophagus enters the stomach is called the cardia. The fundus is a blind expansive sac, dorsal and to the left of the cardia. As the fundus moves right, it transitions into the body of the stomach which represents roughly the middle 1/3 of the stomach. Between the body of the stomach and the exit into the duodenum is the pyloric region. The pyloric region begins at the angular incisure of the lesser curvature.\textsuperscript{12} The first portion is made up of a thick-walled, muscular, funnel-shaped region called the pyloric antrum, which leads to a narrow pyloric canal, and finally to the pylorus, a muscular sphincter at the opening to the duodenum, the ostium pyloricum.\textsuperscript{12} The stomach has a characteristic bend, and each surface of the bend is named. The larger, wider, leftward facing angle spanning the cardia, fundus, body, and pyloric region is called the greater curvature. The greater curvature is the attachment point for the greater omentum. The smaller, 50-70 degree acute angle spanning the cardia, body, and pyloric region is the called the lesser curvature.\textsuperscript{12} The lesser curvature is the attachment point for the lesser omentum, and the papillary process of the caudate liver lobe rests in this area at the angular incisure.\textsuperscript{12}

The stomach is held in place by 4 main ligamentous bands within the greater and lesser omentum\textsuperscript{12,15} (Figure 1-2). Within the greater omentum, the gastrosplenic and gastrophrenic ligaments help maintain the location of the left side of the stomach. The
gastrosplenic ligament extends from the splenic hilus to the greater curvature of the stomach. The gastrophrenic ligament connects the left diaphragmatic crus to the fundus. Within the lesser omentum, the hepatogastric and gastroduodenal ligaments help maintain the location of the right side of the stomach. A majority of the lesser omentum makes up the hepatogastric ligament connecting the lesser curvature of the stomach to the liver. The right border of the lesser omentum makes up the hepatoduodenal ligament, attaching the liver to the duodenum.

The gastric wall is made up of four layers: the serosal, muscular, submucosal and mucosal layers (Figure 1-1). The serosa makes up the external surface of the stomach, tightly adhered to the muscular layer via the tela subserosa. The muscular layer accounts for one third of the stomach’s weight.\textsuperscript{16} It is made up of three smooth muscle layers: an outer longitudinal layer, middle circular layer and internal oblique layer. The longitudinal layer passes longitudinally over the curvatures, but in a more oblique orientation over the surfaces, and is essentially absent adjacent to the angular incisure.\textsuperscript{12,16,17} Deep to this, the circular layer has two distinctly thickened areas at the cardiac sphincter and pyloric sphincter, and is thickest as it crosses the greater curvature.\textsuperscript{12,15} The deepest muscular layer is the oblique layer (Gavard’s muscle) which is primarily over the body and fundic areas and runs distally and outwardly toward the pylorus and the greater curvature.\textsuperscript{12,18} The submucosa lies deep to the muscular layer and consists of a thin, dense layer of areolar tissue intimately associated with the mucosal layer. It is the strongest layer of the stomach, and contains fine gastric vessels and nerves.\textsuperscript{12,18} Like the muscular layer, the mucosa is divided into three distinct layers: a columnar surface epithelium, a glandular lamina propria and a lamina muscularis
mucosae. This layer accounts for half of the weight of the stomach,\textsuperscript{16} is the most metabolically active, and receives more than 50\% of the total blood flow to the stomach.\textsuperscript{19} Within the mucosa there are three types of glands: cardiac glands, pyloric glands, and gastric glands proper, each with specific function. Cardiac glands produce a serous secretion and are found primarily in the cardia with some present along the lesser curvature.\textsuperscript{12,13,18} Pyloric glands primarily secrete mucus and are found in the pylorus and body. The gastric glands proper are made up of parietal, chief, mucous neck, and endocrine cells.\textsuperscript{12,13,18} They are located mainly in the fundus and body and occupy roughly 2/3 of the gastric mucosa.\textsuperscript{12,13,18} Parietal cells release hydrochloric acid which maintains an acidic gastric pH, and a mucoprotein that binds to, and allows for B12 absorption in the distal small intestine. Chief cells secrete pepsinogen, which breaks down proteins after being converted to its active form, pepsin, in the acidic environment. Neck mucous cells secrete mucus that is protective to other glandular cells. Gastric endocrine cells produce gastrin, histamine, and serotonin.\textsuperscript{12,13,18}

Arterial blood to the stomach comes from all three branches of the celiac artery: the splenic, hepatic, and left gastric (Figure 1-3).\textsuperscript{12,13,17,18} The splenic becomes the left gastroepiploic artery which anastomoses with the right gastroepiploic and together supply the greater curvature. The splenic branch of the splenic artery also anastomoses with the gastric branches of the left gastric artery to form the short gastric arteries. The hepatic artery gives off the right gastric artery, which supplies the pyloric region before anastomosing with the left gastric artery and supplying the lesser curvature. The hepatic artery then continues as the gastroduodenal artery, from the right gastroepiploic
branches. The left gastric comes directly off of the celiac artery, supplying the fundus before joining the right gastric artery.\textsuperscript{12,13,17,18}

All blood flow to the stomach drains into the portal vein. The left gastric and left gastroepiploic veins drain to the splenic vein and then to the portal vein. The right gastric and right gastroepiploic veins drain to the gastroduodenal and then the portal vein. (Figure\textsuperscript{1-4}).\textsuperscript{12,13,17,18} Gastric lymph drains to the hepatic lymph nodes after passing through the splenic, duodenal or gastric nodes.\textsuperscript{20} The stomach receives sympathetic innervation from fibers off of the celiac plexus, and parasympathetic innervation from fibers off of the dorsal and ventral vagal trunks.\textsuperscript{12,18}

**Etiology and Pathogenesis**

A definitive etiology for GDV has not been determined and remains a topic of debate in veterinary medicine. Many theories have been proposed, and many risk factors in dogs have been identified. It is likely that several factors are responsible for the development of GDV, and that causes may vary from case to case.

The two main components of GDV are a gas distended stomach and gastric torsion. It is unclear which precedes the other, and evidence exists for each theory. It is generally believe that GDV is initiated by gas accumulation in the stomach and a functional or mechanical obstruction of the cardia or pylorus and that volvulus follows secondarily.\textsuperscript{21–23} Contrary to this belief, volvulus has been diagnosed without the presence of gastric dilatation.\textsuperscript{24–26} However, gastric dilatation without volvulus is reported even after gastropexy, suggesting that gastric dilatation does not occur secondary to gastric volvulus.\textsuperscript{27–29}

The mechanics of gastric malpositioning in GDV is relatively conserved in the clinical literature, and the degree of gastric volvulus generally ranges from 90 to 360
degrees. Rotation begins with displacement of the pylorus from its normal position in the right cranial abdomen to ventral midline; the pylorus then continues cranially to the left cranial abdomen, dorsal to the esophagus, adjacent to the cardia and abdominal wall. The gastric body and fundus are simultaneously displaced dorsally to the right cranial abdomen, and become wrapped in the greater omentum. If standing at the rear of a patient, this is a clockwise rotation. Normally, the canine stomach is held in place by four ligaments: the gastrocolic, gastrohepatic, gastrophrenic, and gastrosplenic ligaments. What allows this abnormal rotation in dogs remains unclear. In humans, gastric volvulus occurs primarily, due to failure of these supportive structures due to elongation, disruption, or agenesis or the gastric ligaments, or secondarily due to other intra-abdominal maladies such as paraoesophageal hiatal hernias, traumatic diaphragmatic hernias, or post-traumatic adhesions. These lead to similar clinical signs as in dogs, and mortality rates between 30-50% due to gastric strangulation, necrosis, perforation and shock. It had been suggested that GDV in dogs may also be due to abnormal or longer gastric ligaments, facilitating gastric rotation. One veterinary study comparing the hepatogastric ligaments in normal dogs and dogs that had an episode of GDV found the ligaments to be similar histologically, however dogs with GDV had significantly longer hepatogastric ligaments than the unaffected dogs. It is unclear, however, whether this elongated hepatogastric ligament was present prior to GDV, or developed as a result of GDV.

The source of gas in GDV has also been a topic of debate with some claiming swallowed air to be the predominate source while others believe that bacterial fermentation is responsible for the gas. The composition of gastric gas in GDV patients
has been analyzed in patients with GDV. Initial reports in the 1970s suggested the gas was produced by bacteria due to detection of H$_2$ gas, a product of bacterial fermentation, and CO$_2$ levels much higher than those of atmospheric gas found in post-mortem GDV gastric gas samples.$^{34,35}$ Additionally, they documented the presence of the gas forming bacteria, *Clostridium perfringens*, in post-mortem gastric contents.$^{34,36}$ A study in the late 1990s performed gas analysis in seven live clinical GDV patients and concluded their findings to be consistent with atmospheric gas, suggesting aerophagia to be the source.$^{37}$ However, CO$_2$ was higher than atmospheric levels in this study as well, which the authors suggested may be due to salivary bicarbonate reacting with gastric acids rather than bacterial fermentation. Most recently, a report in 2013 analyzed gas contents in 10 clinical GDV patients and again, CO$_2$ levels were far greater than that in atmospheric air and the presence of H$_2$ was documented in 2/10 dogs.$^{38}$ These authors concluded that the gas within the stomach of GDV patients was the product of bacterial fermentation. It is plausible that duodenal reflux could inoculate the stomach with bacteria capable of rapidly producing gas. One study reported canine fecal bacteria to be capable of producing between 675 mL and 18,000 mL of gas per 450 g of fruit and vegetable fiber substrate within 4 hours.$^{39}$ Both aerophagia and bacterial fermentation can lead to rapid gastric dilatation. As such, it is possible that the underlying source of gas in cases of acute gastric dilatation varies between dogs or that each plays a role in pathogenesis.

A paucity of data exists on intra-gastric pressures (IGP) reached as a result of the extreme gas distention in GDV patients. One study reported the mean IGP in 20 patients with naturally occurring GDV to be 22.9 mmHg and ranging from 9 to 62
mmHg. Another study suggested that IGP in GDV patients reaches as high as 80 mmHg.\textsuperscript{40} Experimental studies evaluating various effects of GDV have used 80 mmHg,\textsuperscript{41} 50 mmHg,\textsuperscript{40,42} 30 mmHg,\textsuperscript{8} 25 mmHg,\textsuperscript{43} and 20 mmHg\textsuperscript{44} as intra-gastric pressures to simulate GDV in research dogs. The lowest known IGP to cause complete occlusion of the caudal vena cava, inhibiting venous return to the heart is 20 mmHg.\textsuperscript{44} In this angiographic study, venous blood in the abdomen was found to be diverted to the intervertebral veins, the vertebral sinus and then to the azygous vein to return to the heart. However, this collateral route of venous drainage was clearly insufficient as evidenced by the reflux of venous blood caudally into the iliac and renal veins. Compression of the great abdominal vessels leads to a dramatic decrease in venous return and subsequently decreased cardiac output. Experimental GDV with an IGP of 30 mmHg led to a 64\% decrease in cardiac output in one study\textsuperscript{8} and in another study, 50 mmHg IGP led to an 89\% decrease, suggesting that the higher the IGP the greater the decrease in cardiac output.\textsuperscript{40} Decreased cardiac output can rapidly lead to hypovolemic shock, and give rise to a cascade of events contributing to the overall instability of the patient.

Of the two main components of GDV, gastric dilatation is the primary instigating factor leading to patient decompensation. Studies evaluating gastric dilatation in the absence of volvulus have produced clinical signs, cardiopulmonary values, and biochemical changes consistent with clinical gastric dilatation and volvulus.\textsuperscript{41,42,45–47} In contrast, gastric volvulus alone causes pathology limited to the stomach. One study evaluating the effect of 360° gastric volvulus in the absence of gastric dilatation found that even after a 12 hour non-distended volvulus, all other tissues drained by the portal
vein were histologically normal and only mild to moderate pathologic changes were found in the stomach. This same study found these changes to be reversible, as gastric tissue was grossly and histologically normal when evaluated 7 days after a 12 hour non-distended volvulus. Additionally, dogs have sustained chronic gastric torsion without developing the urgent clinical signs associated with GDV.

The effects of massive gastric dilatation are widespread and devastating (Figure 1-5). As the stomach expands, it places cranial pressure on the diaphragm, limiting motion during inspiration. Experimental models of GDV have shown this leads to decreased lung compliance, reduction in tidal volume, subsequent increase in PaCO2, atelectasis and overall reduction in arterial oxygen saturation, contributing to widespread tissue hypoxia. Simultaneously, the distended stomach compresses critical vasculature in the abdomen, most notably the caudal vena cava and portal vein. Caval and portal compression leads to regional hypertension, poor venous return to the heart, and causes edema and congestion of the gastrointestinal tract. Poor venous return leads to tachycardia and reduced preload, reducing cardiac output by as much as 89%, ultimately resulting in severe hypovolemic and obstructive shock. Additional experimental findings have included significant decreases in mean arterial pressure, venous oxygen desaturation, metabolic acidosis and a 50% reduction in coronary blood flow with associated subendocardial necrosis. Ventricular arrhythmias in the perioperative period occur in 40–70% of dogs with GDV, and have been associated with an increased mortality rate. The exact cause of these arrhythmias in dogs with GDV is unknown, but it is believed that both the reduction in coronary blood flow and subendocardial necrosis play a role. This
would be consistent with the experimental finding that dogs developed similar ventricular arrhythmias after acute ligation of the coronary arteries causing myocardial ischemia.\textsuperscript{53} Another speculated cause of arrhythmias is the release of myocardial depressant factors from the hypoxic pancreas of GDV patients, creating a pro-arrhythmogenic state, as has been documented in experimental studies.\textsuperscript{54} Other potential contributing factors include acid–base and electrolyte abnormalities, and reperfusion injury.\textsuperscript{50,51} Realistically, all of these factors may contribute to the development of perioperative arrhythmias, which exacerbate the state of cardiorespiratory stress and widespread hypoxia in GDV patients. These alterations in normal cardiovascular function, in combination with the obstruction of venous return also have significant effects on the remainder of the abdominal organs. There is mechanical obstruction of blood flow to the stomach due to torsion of gastric vessels and compression of the capillaries in the gastric wall from the extreme gastric distension.\textsuperscript{9,49} With no major outlet for venous blood, the remainder of the gastrointestinal tract becomes congested and tissue oxygenation is impaired.\textsuperscript{6,55} This leads to tissue death beginning with the mucosal layers. Loss of mucosal integrity allows bacterial translocation from the intestinal lumen as has been described in patients with hemorrhagic shock,\textsuperscript{56} and subsequent endotoxemia documented in dogs with experimental GDV.\textsuperscript{57} Compression of the portal vein and portal hypertension also exacerbate the effect of bacterial translocation by causing reticuloendothelial dysfunction, decreased phagocytic activity against translocated bacteria, and reduced hepatic clearance of endotoxin.\textsuperscript{58} Despite the great risk for bacterial translocation, bacteremia has been seldom documented in GDV patients, with one study finding only
1 out of 5 GDV patients to have a positive blood culture. Another study found no difference in blood culture results between 21 dogs with GDV and 5 control dogs. Additionally, bacterial translocation was not proven to be the source of a positive blood culture in any GDV patient. Regardless, GDV creates a physiologic scenario lending itself to bacterial translocation and endotoxemia that can result in septic shock, fever, cellular membrane damage, complement and coagulation activation, increased vascular permeability, and can induce renal and hepatic damage. Renal congestion and hypoxia occur secondary to venous compression in the abdomen as well, and experimental studies have shown a significant increase in blood urea nitrogen, creatinine, and phosphorus in GDV patients. The state of cardiovascular collapse and tissue hypoperfusion in GDV patients has been found to lead to hemostatic abnormalities and disseminated intravascular coagulopathy. Patients with longer periods of hypoperfusion are also at a greater risk for ischemic reperfusion injury once treatment is instituted and circulation is restored.

**Emergency Gastric Decompression**

When considering the cascade of events that can follow, it becomes clear that rapid gastric decompression and stabilization is critical in the treatment of dogs with GDV in order to restore venous return and halt progression of systemic decompensation. Studies have demonstrated that cardiopulmonary parameters improve rapidly following gastric decompression, especially in those studies where shock is treated simultaneously, as is the case with clinical patients. The two most commonly employed gastric decompression techniques are percutaneous trocarization using a large bore needle or intravenous catheter, and orogastric tube
placement.\textsuperscript{11,55,65} A temporary surgical gastrostomy has also been described in the literature as a means for sustained decompression.\textsuperscript{66,67}

Percutaneous trocarization is a commonly employed decompression technique as it is technically easy, does not require sedation or much restraint, and is repeatable.\textsuperscript{11,68} To perform percutaneous trocarization, typically the right side of the abdomen is percussed with a finger until an area of distinct tympany is identified by a sharp pinging sound.\textsuperscript{65} If a dull thud is appreciated instead of a ping, the spleen may be displaced, and ultrasound guidance can be used to avoid splenic laceration. The selected area is clipped and aseptically prepared, then an over-the-needle catheter or needle, up to 10 gauge in size, is briskly placed through the skin into the gastric lumen.\textsuperscript{49,65} Placement is confirmed by the presence of odorous gas, bubbling, and detectable air outflow.\textsuperscript{65} The needle or catheter is held in place as the stomach decompresses and removed once the stomach falls away from the length of the needle and signs of gas outflow are absent.\textsuperscript{65} It is unknown at what IGP this occurs, and the effect is temporary, with gas distention recurring sometimes as rapidly as minutes.

Risks associated with percutaneous gastric decompression are splenic laceration, and gastric perforation if placed in necrotic stomach. In one study of 85 trocarized GDV patients, the only complication of trocarization was a single case of splenic laceration, which did not require treatment.\textsuperscript{11} Should these complications arise, they would be identified and treated during surgical correction of GDV.

Orogastric tube placement provides a more rapid decompression, but is more time consuming to perform, invasive, stressful to the patient than percutaneous trocarization and requires several individuals to aid in patient restraint.\textsuperscript{49} Its use often
requires sedation, which is not ideal in a compromised patient, or is used in animals that are recumbent and so severely affected that they do not require sedation.\textsuperscript{11,67} Passage of an orogastric tube is achieved as follows:\textsuperscript{65} the distance from the nose to the caudal edge of the 13th rib is measured and marked on a smooth, stiff, large-bore tube. Next, a mouth gag which can either be a roll of tape or a specialized mouth gag is placed to keep the mouth open during intubation and to protect the orogastric tube. A water based lubricant is applied to the pre-measured tube and the tube is passed through the mouth gag, into the esophagus until the premeasured mark on the tube reaches the nose. Vigilant airway monitoring and protection should take place during orogastric intubation, and in some cases concurrent endotracheal intubation should be considered. The tube enters the stomach, just through the lower esophageal sphincter and a characteristic odorous air is expressed through the tube. If resistance is encountered, it is sometimes recommended to stand the patient on their hind limbs during placement to bring the stomach caudal and reduce tension on the cardia, or alternatively trocarization can be performed concurrently to reduce IGP and facilitate tube placement. Once the tube is passed, the stomach is lavaged with 5-10ml/kg of tepid water until the water retrieved is clear. Diagnostic information can be gleaned from the characteristics of the material retrieved from the orogastric tube. For example, the presence of black or dark red material may suggest gastric necrosis. Additionally, if lavage fluid is not returned through the tube after administration, this suggests a gastric perforation.\textsuperscript{49}

While each of these techniques has strengths and weaknesses, both trocarization and orogastric tube placement only provide temporary decompression. Gas distention can reoccur rapidly, and sometimes, repeated orogastric intubation or
trocarization is required to maintain decompression. In some cases, patients have an extended period of gastric dilatation due to travel from a general practice to a surgical practice, or while awaiting emergency surgery. Neither technique provides lasting decompression suitable for transit or an extended period of surgical delay. During this time period the patient would continue to decompensate due to the return of the gastric dilatation. The only technique described to have a continued decompressive effect is a temporary surgical gastrostomy described in the early 1970’s.66,67

The temporary gastrostomy as a method for GDV decompression was first described by Pass and Johnston in 1973.66 The gastrostomy was performed with the patient sedated and administered local anesthesia at the surgical site. A 5cm incision was made in the right paracostal region after decompression via trocarization. The stomach was initially sutured to the body wall, then the stoma incision was made into the gastric lumen. The gastrostomy was then left to drain gas and fluid until corrective surgery was performed 6-12 hours later. In 1976, Walshaw and Johnston reported outcomes from the technique used in 30 clinical patients and stated that since the introduction of the technique, mortality rates in GDV patients had dropped to 33%.67 At the time, this was an improvement; however this is a higher mortality rate than compared to current literature.4,67 Although this method does achieve continuous decompression, it is also much more invasive, facilitates the continuous loss of gastric fluids, and requires an additional closure at corrective surgery. The ideal gastric decompression method would have the less traumatic nature of trocarization, and facilitate continuous gastric decompression like a surgical gastrostomy without requiring
sedation or increasing the risk of aspiration. These characteristics are similar to those considered for placement of percutaneous gastrostomy tubes in humans.

**Percutaneously Placed Gastrostomy Tubes**

The use of percutaneously placed gastrostomy tubes in human medicine began in 1980 with the first description of percutaneous endoscopic gastrostomy (PEG) tubes in pediatric patients.\(^6^9\) Due to the ease and safety of placement, the technique has been adapted for use in patients of any age and for multiple disease processes since its introduction. The technique and variants were developed, and are most commonly used for feeding tube placement, however they have been described more recently for use in patients with obstructive esophageal disease to achieve gastric decompression.\(^7^0\),\(^7^1\) Advanced variations in the technique such as the “introducer method” of PEG and the percutaneous radiologic gastrostomy (PRG) rely on the placement of T-fasteners, which are used to achieve temporary gastropexy and controlled access for the gastrostomy procedure (Figure 1-6).\(^7^2\) Across techniques, complications are similar and acute complications include gastrostomy site bleeding and visceral injury.\(^7^3\)–\(^7^7\) Complications associated with long term use include wound infection, early tube dislodgement and as a sequelae, gastric leakage or accidental intra-abdominal food spillage.\(^7^3\)–\(^7^7\) Gastrostomy tubes have been used in veterinary medicine as well, typically as feeding tubes rather than for decompression. Surgical, percutaneous non-endoscopic, and endoscopic gastrostomy tube placement techniques have been described.\(^7^8\)–\(^8^0\) Percutaneous endoscopic gastrostomy tubes were adapted relatively quickly from human to veterinary medicine; first described in dogs in 1986.\(^7^9\) This has since become the most commonly used method of placing gastric feeding tubes in cats and dogs, and has been found to have a similar complication rate as surgically placed tubes.\(^8^0\)
Use of the T-fasteners

The first description of T-fastener use in human medicine was in 1986, and fasteners were used to achieve temporary gastropexy to allow for gastrostomy tube placement.\textsuperscript{81} While minor changes to the materials of the system have been made since introduction, the system and technique have remained relatively unchanged due to its efficacy. The T-fastener system is an apparatus that includes a needle and an anchor bar housed within the needle that is deployed coaxially by the user.\textsuperscript{82} The anchor bar is attached to a suture device and is delivered into a desired lumen providing an anchor point for manipulation. When used to achieve a temporary gastropexy for gastrostomy tube placement, the hollow needle is passed through the abdominal wall and into the distended gastric lumen (Figure 1-7). The preloaded suture with the T-fastener is then deployed through the needle. The fasteners are then secured up to the abdominal wall using external bumpers that maintain suture traction but reduce tension on the skin externally.\textsuperscript{82,83} T-fastener gastropexy improves the safety of gastrostomy tube placement by allowing controlled dilation of a stoma tract and direct percutaneous insertion of a tube into lumen.\textsuperscript{83,84} The temporary gastropexy prevents early leakage at the tube site, reduces the risk of tube dislodgment, and allows easy tube replacement.\textsuperscript{83,84} A clinical study comparing percutaneous radiologic gastrostomy tubes placed with or without T-fasteners revealed that T-fasteners greatly reduce the chance of serious technical complications.\textsuperscript{85} Complications related to the T-fasteners themselves are seldom reported and are typically limited to skin irritation with rare cases of infection and fistula formation.\textsuperscript{86} These complications are associated with T-fasteners in place for 1-2 weeks, while complications are seldom reported when used for short periods of time.\textsuperscript{87}
T-fasteners have now been used to gain minimally invasive percutaneous access to multiple areas of the gastrointestinal tract in patients of all ages, for many purposes. The use of T-fasteners to achieve temporary organopexy in veterinary medicine has not been reported, although the use of an experimental endoscopic prototype has been described for gastrotomy closure in natural orifice transluminal endoscopic surgery.
Figure 1-1. Illustration depicting the gross divisions and layers of the canine stomach.

Figure 1-2. The stomach is held in place by 4 main ligamentous bands within the greater and lesser omentum. Source: https://s3.amazonaws.com/classconnection/295/flashcards/3765295/png/screen_shot_2015-01-29_at_104354_am-14B36B1364E1488EAF5.png, © 2007 Lippincott Williams & Wilkins.
Figure 1-3. Illustration depicting the arterial supply to the canine stomach. Source: Evans HE, De Lahunta A. Miller's Anatomy of the Dog. Elsevier Health Sciences; 2013.

Figure 1-4. Illustration depicting the venous drainage of the canine stomach. Source: Evans HE, De Lahunta A. Miller's Anatomy of the Dog. Elsevier Health Sciences; 2013.
Figure 1-5. Illustration depicting the cascading pathophysiology of gastric dilatation-volvulus syndrome in dogs. Source: Broome CJ, Walsh VP. Gastric dilatation-volvulus in dogs. N Z Vet J 2003;51:275–283.

CHAPTER 2
RATIONALE OF MATERIAL SELECTION FOR PLACEMENT OF A PERCUTANEOUS T-FASTENER GASTROPEXY AND DECOMPRESSIVE GASTROSTOMY: CADAVERIC TRIAL

Rationale for Selected Materials and Methods

Patients with gastric dilatation-volvulus syndrome (GDV) present in an acute medical crisis, in which they are systemically unstable and require immediate intervention for survival. To successfully develop and evaluate a novel technique to provide continuous gastric decompression in clinical patients with an urgent disease, careful selection of the materials used for both the decompression technique and measurement of efficacy is critical. The unstable nature of the GDV patient and abnormal gastric anatomy are particular factors that make standard approaches for percutaneous organ decompression and intraluminal data collection challenging.

Decompression Method: Catheter Selection

The ideal percutaneous decompression device for patients with gastric dilatation-volvulus would be placed quickly, provide continuous decompression without obstructing, have self-retaining properties to prevent premature dislodgement, and cause minimal iatrogenic trauma to the gastric wall. Standard trocarization with a 14-gauge over-the-needle catheter is performed quickly and reported to cause minimal trauma to the gastric wall.\textsuperscript{11,91} However, these catheters have no self-retaining properties and as the stomach decompresses and falls from the body wall, the catheter dislodges from the gastric lumen after which, gas distention can return. Pigtail catheters have an advantage over standard catheters as their tips are straight for initial insertion into the intended lumen, but can then be formed into a coiled, pig-tail shape to prevent the catheter tip from sliding out with outward traction (Figure 2-1).
Pigtail catheters are most commonly inserted percutaneously using one of two methods: the trocar method, or the Seldinger technique. The trocar technique uses a sharp, stiff metal trocar within the catheter to gain access to the desired lumen. A rapid force applied to the base of the trocar-catheter assembly allow it to cut through the body wall and into the desired lumen in one motion. While the trocar technique is fast and easy to perform, its entry is often blind, forceful, and provides less control and haptic feedback to the operator than with the Seldinger technique. Serious complications, such as bowel perforation, and mesenteric artery laceration, have been reported secondary to the trocar method used for peritoneal catheter access in human medicine. While uncommonly reported, splenic laceration has been reported after trocar decompression for gastric decompression in GDV patients as well.

The Seldinger technique was initially described by Sven Ivar Seldinger in 1953 as a novel means for placing IV catheters. This method allows a more gradual, controlled coaxial dilation of the intended catheter tract (Figure 2-2). A small gauge needle is initially placed, into which a guidewire is fed to maintain the tract. The initial needle is removed over the guidewire, and a catheter is then placed over the guidewire. Prior to catheter placement, the tract can be serially dilated if desired to increase the tract diameter gradually and facilitate placement of a larger catheter.

This technique creates a catheter tract with a small initial entry site that is then dilated in a very controlled fashion. This provides tactile feedback to the operator and allows intra-procedural decisions to be made—such as early recognition of misplacement, or alterations in final catheter size. In contrast, the trocar method creates the catheter tract in one rapid puncture through the tissues, which is less amenable to
alteration based on feedback, and is traumatic in nature. Studies have demonstrated that both techniques are viable options for catheter placement in a variety of scenarios. Very few studies directly compare the outcomes of each technique. One study comparing the two techniques with a peritoneal dialysis catheter model, found the Seldinger method possessed a significantly lower catheter leak rate (16.3 vs 3 %, \( p = 0.03 \)) and outflow failure due secondary to migration of the catheter tip (22.6 vs 10.1 %, \( p = 0.04 \)), with higher long-term catheter survival.

A preliminary test was performed by a single operator in two canine cadavers to evaluate the introduction techniques in a gastric dilatation model. The canine cadavers were from dogs that had been euthanized less than 24 hours prior and for reasons unrelated to the study. The goals of this trial were to determine the speed of placement, handling, and effect on the gastric wall of each technique in order to choose the best entry method for the novel catheter decompression technique. The thoracic esophagus was approached through a right lateral thoracotomy, and a 2cm esophagotomy was made to facilitate placement of insufflation tubing into the stomach. The esophagus proximal to the tubing was ligated to prevent backflow, and a purse string suture was placed around the tube entering the esophagus to prevent air leakage around the tube. An insufflation unit was used to provide outward gas distention of the stomach with 30 mmHg of pressure, and trial catheters were placed in the right abdominal wall caudal to the 13\(^{th}\) rib in an area of obvious gastric tympany. For the trocar method evaluation, a 5 Fr. Yueh Pigtail Centesis Catheter-Trocar assembly\(^1\) (Figure 2-3) was blindly placed percutaneously into the distended gastric lumen.

\(^1\) Yueh Pigtail Centesis Catheter-Trocar assembly, Cooke Medical, Bloomington, Ind.
For the Seldinger method evaluation, a 21ga needle was placed into the gastric lumen, through which a 0.018in, 60cm guidewire was introduced into the gastric lumen. The needle was removed over the guidewire and a 5fr introducer\(^2\) was placed over the guidewire to dilate the tract to its final size and then was removed over the guidewire. Finally, a 5fr Dawson-Mueller Multipurpose Drainage Catheter\(^3\) (Figure 2-4) was placed over the guidewire into the gastric lumen. The guidewire was removed and the pigtail coil was formed, locked in place and retracted to the body wall.

The Yueh catheter inserted using the trocar method was placed in under 20 seconds, however the wound in the gastric wall had a cuff of traumatized tissue visible grossly around the catheter hole, presumably from the trocar (Figure 2-5).

The Daswon-Mueller catheter inserted using the Seldinger method was placed in under 80 seconds, the wound it generated did not appear to have the same collateral damage (Figure 2-6) as the catheter placed using the trocar method.

Subjectively, the operator also felt that the use of the Seldinger technique provided greater precision and control of catheter placement than the trocar method. The lack of apparent collateral trauma around the Seldinger site compared to the trocar site is likely explained by the controlled dilation of the tract site from the 0.032in diameter of the initial 21ga needle placed, to the 0.66in diameter of the final 5fr catheter vs the acute cutting of the 5fr sized gastrostomy with the trocar method.

A catheter size of 5fr was chosen with the goal of allowing adequate gastric decompression without creating a significant gastric wound. Use of up to a 14ga needle

\(^2\) Mallinckrodt modification micropuncture introducer set, Cooke Medical, Bloomington, Ind.

\(^3\) Dawson-Mueller multipurpose drainage catheter, Cooke Medical, Bloomington, Ind.
or catheter has been recommended for trocarization and decompression in GDV cases without any reported leakage of gastric contents.\textsuperscript{11,91} A 14ga needle and 5fr catheter have outer diameters of 0.83 inches and 0.66 inches, respectively. Because of this, we believed that leakage at the gastrostomy catheter site upon removal would be unlikely.

**Intra-gastric Measurement Method**

Intragastric pressure has been measured experimentally in both human and veterinary medicine to evaluate a variety of disease processes.\textsuperscript{99–102} Most methods of measuring intra-gastric pressure experimentally require normograde access to the gastric lumen via the oral\textsuperscript{99,100} or nasal\textsuperscript{101,102} route. Due to the abnormal gastric anatomy in dogs with GDV, access to the gastric lumen via the esophagus is unreliable.\textsuperscript{11} For this reason, it was decided that measurements would be taken via the decompression catheter itself. This approach also allows for measurement of catheter outflow to monitor for changes in flow that may indicate catheter obstruction. In a critical GDV patient, the measurement of intra-gastric pressure and flow must be achieved in a way that does not encumber the patient or clinician, and is possible to employ in clinical cases without causing delay. The patient is often moved around the hospital for stabilization, diagnostic imaging, anesthesia, and surgery. With these considerations in mind, the ideal data capture device would be small, mobile, and easily follow the patient while keeping clear of the emergency clinician. The Labquest 2\textsuperscript{4} (Figure 2-7A), is a small, modular, portable data collection computer made by Vernier Software and Technology intended to collect, analyze, and share experimental data from over 60 different sensor unit modules. It is equipped with an 800 MHz application processor.

\textsuperscript{4} Labquest 2 with gas pressure sensor and spirometer, Vernier Software & Technology, Beaverton, Ore.
capable of acquiring up to 100,000 data samples per second from any sensor module connected to the unit. For the purposes of this study, the gas pressure sensor module (Figure 2-7B), and the spirometer module (Figure 2-7C) were used to collect intragastric pressure and catheter efferent gas flow measurements. The gas pressure module functions using a flexible membrane that moves in response to changes in absolute pressure, creating a voltage output proportional to the change in pressure. One side of the membrane is exposed to a vacuum chamber while the other side is open to the source connected to the sensor, in our case, the pressure in the gastric lumen. The voltage output at the pressure sensor membrane has a linear relationship with absolute pressure. This relation allows for calculation of the absolute pressure exposed to the unit based on the voltage produced at the membrane. The spirometer module was augmented to allow for measurement of gas outflow though the catheter. As air is forced out of the stomach due to the pressure gradient, the flow heads measure the difference in pressure that occurs between the two intake tubes. The intake tubes transmit the pressures to a differential pressure transducer in order to extrapolate the flow rate. The greater the pressure differential measured, the greater the gas outflow from the stomach. This allows for the direct measurement of airflow rate in liters per second. From this, the total efferent gas volume can be calculated in liters and expressed as a percent to normalize the data between different sized dogs with different gastric volumes.
Figure 2-1. Pigtail catheter formed in gastric lumen resisting outward traction. The loop formed inside the gastric lumen is lightly outlined to highlight its shape. (arrow). Photo courtesy of W. Alexander Fox-Alvarez, DVM.


Figure 2-5. Gastrostomy wound from catheter placement via the trocar method. Note the appearance of traumatized tissue below the stoma site. Photo courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 2-6. Gastrostomy wound from catheter placement via the Seldinger method. Minimal collateral trauma is appreciated. Photo courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 2-7. The Labquest 2 computer (A), with Gas Pressure Sensor (B) and Modified Spirometer (C). This data collection unit was used to collect intragastric pressure and outward flow rates from the gastric catheter. Photo courtesy of W. Alexander Fox-Alvarez, DVM.
CHAPTER 3
DESCRIPTION OF A NOVEL TECHNIQUE FOR GASTRIC DECOMPRESSION IN DOGS USING AN IATROGENIC GASTRIC DILATATION MODEL: TEMPORARY PERCUTANEOUS T-FASTENER GASTROPEXY AND CONTINUOUS DECOMPRESSIVE GASTROSTOMY

Introduction

Gastric dilatation-volvulus (GDV) is a life-threatening medical and surgical emergency that most commonly affects large to giant breed, deep-chested dogs.\textsuperscript{1–4} The acute medical crisis in GDV patients is largely due to massive gastric distention which compresses critical abdominal vasculature, causing impaired blood flow to and from vital organs, leading to hypovolemic shock, cardiac arrhythmias, electrolyte imbalance, and visceral necrosis among other detriments.\textsuperscript{5–8} Gastric volvulus in the absence of dilatation has been demonstrated to result in minimal visceral pathology after 12 hours.\textsuperscript{9}

Rapid gastric decompression and stabilization is critical in the treatment of dogs with GDV in order to restore venous return and halt progression of systemic decompensation.\textsuperscript{8,10} Often, dogs have gastric dilatation for an extended period of time due to transport from a general practice to an emergency facility, or while awaiting corrective surgery at a specialty center. Trocarization and orogastric tube placement achieve successful decompression 86\% and 75.5\% of the time, respectively.\textsuperscript{11} However, this effect is only temporary and clinically, gastric distention can recur in minutes along with the associated untoward sequelae. A gastrostomy performed under local anesthesia via a 5cm incision in the right paracostal region has been reported to provide lasting gastric decompression,\textsuperscript{66} Although this method facilitates continuous decompression, it is also invasive and requires an additional closure at corrective surgery.
Time of onset of clinical signs to presentation to a surgical facility has been shown to be associated with a poor prognosis in some studies,\textsuperscript{103,104} while having no effect in others.\textsuperscript{68,105} This conflicting evidence may be challenging to interpret as limitations and confounding factors are common in many veterinary studies involving owner recall. More likely, prognosis is related to the time and severity of cardiopulmonary and vascular compromise, which may be directly related to the degree and duration of gastric dilatation. It is therefore logical that reducing the duration and severity of gastric dilatation should improve gastric perfusion, cardiopulmonary homeostasis and facilitate pre-operative stabilization. Employing a minimally-invasive technique to provide rapid, effective, continuous gastric decompression at presentation in dogs with GDV would accomplish this and may improve clinical outcome in some dogs.

The T-fastener is a device used in human interventional radiology and minimally invasive surgery to allow temporary –pexy of an organ, most often to facilitate tube placement into the stomach or small intestine, either for feeding,\textsuperscript{106,107} or decompression.\textsuperscript{71} T-fasteners consist of a suture attached to a metal T-bar, loaded into a slotted needle which is introduced percutaneously inside the organ lumen and deployed. The deployment needle is removed and the suture and attached intraluminal T-bar remain and are used to -pexy the organ to the body wall. The temporary T-fastener –pexy allows for: immediate dilation of a stoma tract, direct percutaneous insertion of a catheter or tube into a lumen, prevents early leakage at the -ostomy site, reduces risk of tube dislodgment, and facilitates tube replacement.\textsuperscript{83,84} To the authors’ knowledge, the use of T-fasteners in veterinary medicine has not been described,
although the use of an experimental endoscopic prototype has been described for gastrotomy closure in natural orifice transluminal endoscopic surgery.\textsuperscript{89} The aims of this study are to 1) describe a novel means of gastric decompression in an iatrogenic gastric dilatation model, using a percutaneously placed temporary T-fastener gastropexy (TTG) and self-retaining gastrostomy catheter (G-cath), 2) evaluate its efficacy, and 3) determine whether the resulting gastrostomy wound would leak following acute removal. We hypothesize that the technique will be feasible and performed in a clinically appropriate amount of time, will effectively and continuously decompress the stomach, and will not result in a gastrostomy wound leakage.

\textbf{Materials and Methods}

\textbf{Dogs.} Six clinically normal male intact dogs, weighing at least 15kg, were included in the study. Breeds at-risk for GDV were represented. Dogs were obtained from a local rescue group, and enrolled after informed consent. Preoperative physical examination, packed cell volume, total protein, and blood gas analysis were performed in all dogs. The study protocol was approved by the UF Veterinary Hospitals Research Review Committee, and the Institutional Animal Care and Use Committee, protocol #201408449.

\textbf{Experimental Procedure.} All dogs were premedicated with 5µg/kg of dexmedetomidine, and 0.1mg/kg of hydromorphone administered IV or IM. Anesthesia was induced with up to 4mg/kg of propofol IV to effect, and maintained with isoflurane in 100 % oxygen administered via endotracheal tube. A ventilator was used to maintain capnometry within 35 and 45 mmHg. Dogs were monitored with continuous electrocardiography, capnography and direct blood pressure assessment; and were administered 10ml/kg/hr IV crystalloid fluids for the duration of anesthesia. Dogs were
placed in dorsal recumbency with slight leftward obliquity and the abdomen and caudal thorax clipped and steriley prepared routinely using chlorhexidine and sterile saline.

Dogs were draped for an abdominal surgical approach. The stomach was approached endoscopically, insufflated with room air, and evaluated for any abnormalities. Following initial gastroscopy, gastric insufflation was continued until moderate outward tympany was present and rugal folds were absent endoscopically. Once this was achieved, the TTG and G-cath supplies were readied (Figure 3-1) procedure was performed as follows (Figure 3-2). Three \text{T-fasteners} were placed percutaneously roughly 1.5cm apart in a triangular orientation, into the gastric lumen via the right lateral abdomen; 1-3 cm caudal to the 13th rib and lateral to the rectus abdominis muscle. The exact location of placement within this region was determined by the degree of palpable tympany and confirmed via endoscopic visualization. During placement, all \text{T-fasteners} were attached to a 6cc syringe with 2cc sterile saline. After placement into the gastric lumen; the syringe plunger was drawn back until bubbles were present, indicating intragastric positioning. In the center of the triangle formed by the \text{T-fasteners}, a 21ga needle was placed into the gastric lumen, into which a 0.018in, 60cm guidewire was fed. The needle was removed over the guidewire and a 5fr introducer\textsuperscript{2} was placed over the guidewire to dilate the tract and then was removed. A 5fr locking pigtail catheter\textsuperscript{3} was placed over the guidewire into the gastric lumen, the guidewire was removed and the pigtail coil was formed, locked in place and retracted to

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\textsuperscript{1} SAF-T-PEXY, Kimberly Clark Medical, Roswell, Ga.
\textsuperscript{2} Mallinckrodt modification micropuncture introducer set, Cooke Medical, Bloomington, Ind.
\textsuperscript{3} Dawson-Mueller multipurpose drainage catheter, Cooke Medical, Bloomington, Ind.
\end{flushleft}
the body wall. The catheter was attached to a device\textsuperscript{4} to measure and record gas outflow from the catheter (L/s) and intra-gastric pressure (IGP) (mmHg), which was calibrated according to manufacture protocol. The endoscopic unit was then used to insufflate the stomach to 23mmHg. Once 23mmHg was reached, insufflation was discontinued and the stomach was allowed to passively drain from the catheter until intraluminal pressure reached 5mmHg. Time and flow were measured continuously, and intraluminal pressure measurements were taken every 30 seconds. This process was performed three times, consecutively, in each dog. Upon completion of the third round, the pigtail catheter was unlocked and removed, and each T-fastener had its anchor suture cut externally, allowing the fastener bar to remain in the gastric lumen.

A multitrocar laparoscopy port\textsuperscript{5} was placed 1cm caudal to the umbilicus on midline. Capnoperitoneum to a pressure of 8-10mmHg was achieved using an insufflation unit and a 5mm 0˚ laparoscope was introduced into the abdomen via the port. A laparoscopic blunt probe was used to manipulate the stomach and to facilitate evaluation of the catheter and T-fastener gastric wounds both laparoscopically and endoscopically. The stomach was insufflated until rugae were absent and the gastrostomy site could be observed endoscopically. Concurrently, the serosal surface was observed laparoscopically to document any evidence of leakage (gas bubbles or fluid egress). Following the study procedure, a second 5 mm laparoscopic port was placed midway between the xiphoid and umbilicus and all dogs underwent laparoscopic,

\textsuperscript{4} Labquest 2 with gas pressure sensor and spirometer, Vernier Software & Technology, Beaverton, Ore.
\textsuperscript{5} SILS Port, Covidien, Minneapolis, Minn.
intracorporeal gastropexy, using 2-0 knotless barbed suture\(^6\), and were castrated routinely. Upon completion of the gastropexy, the –pexy site was evaluated endoscopically to document the presence of any intraluminal suture material. Dogs were hospitalized and monitored for 72 hours to monitor for complications related to the procedure.

**Data Analysis**

Continuous, parametric, numeric data were presented as mean ± SD and range. Statistical software\(^7\) was used for all data analysis.

**Results**

Breeds enrolled included one of each of the following: Great Dane, Golden Retriever, German Shepherd, Doberman Pinscher, Hound mix, and Pitbull mix. Mean age was 25.5 ± 18.17 months (range, 9 to 48 months) and mean body weight was 27.73 ± 16.51 kg (range, 16.2 to 60 kg) among dogs. Physical examination, packed cell volume, total protein, and preoperative blood gas analysis were unremarkable in all dogs.

Mean catheter placement time was 3.3 ± 0.47 minutes (range, 2.55 to 3.88 min). The mean time to reach ≥ 50% reduction in IGP and ≤ 6mmHg was 2.1 ± 1.3 (range, 1 to 6 min) and 8.4 ± 5.1 minutes (range, 3.5 to 19.5 min), respectively (Figure 3-3). Total intra-gastric volume (IGV) was defined as the total gas outflow between 23mmHg and 5mmHg and was recorded via a transducer device\(^d\). The mean percent decrease in IGV after 1 minute of decompression was 28 ± 12 percent (range, 8 to 43 percent). The

\(^6\) VLOC 90, Covidien, Minneapolis, Minn.

\(^7\) JMP, version 9.0.2, SAS Institute Inc, Cary, NC.
mean time to achieve a ≥ 50% decrease in IGV was 3.24 ± 2.27 minutes (range, 1.5 to 8 minutes) (Figure 3-4).

In one dog, the gastric mucosa was endoscopically observed to be cyanotic after insufflation to an unknown pressure during the initial creation of outward tympany. The first round of decompression testing was aborted in this patient due to concern for the dog after an approximate 60% decrease in IGP with only mild to moderate improvement of the mucosa was observed. The stomach was manually evacuated through the catheter using a 35cc syringe and monitored endoscopically. Once normal mucosal appearance returned, the second and third insufflation/decompression treatments were performed routinely.

After catheter removal, no evidence of gas or fluid leakage at the catheter site was visible laparoscopically or endoscopically in any dog. The T-fastener and catheter entry sites were found to be in the parietal surface of the stomach, at the margin of the fundus and body, close to the greater curvature in 5/6 dogs. In one dog, the sites were just dorsal to greater curvature. In 3 cases, a short (~2mm) portion of the T-fastener anchor sutures was visible laparoscopically after removal (Figure 3-5). In a few instances, flow and pressure readings acutely decreased and this was interpreted as partial obstruction of the catheter. When this occurred, 6mL of sterile saline followed by 6mL of air were flushed through the catheter. This resolved the issue in all cases. No other technical complications associated with TTG or G-cath placement occurred.

Endoscopic evaluation of the intracorporeal laparoscopic gastropexy sites revealed no suture luminal penetration in any dog. There was no evidence of excessive
inflammation or infection at the catheter and T-fastener sites in the skin post-operatively. At the 72 hour post-operative point, all dogs were clinically normal.

Discussion

The results of this study suggest that a temporary T-fastener gastropexy and decompressive gastric catheter can be placed rapidly and provide effective continuous gastric decompression with no evidence of post-operative catheter site leakage in normal dogs with iatrogenic gastric dilatation. The dogs in this study represented breeds, sizes and body conformations at risk for developing GDV. Published data on the intra-gastric pressure of naturally occurring GDV is limited, however one study reported a mean of 22.9 mmHg in 20 naturally occurring GDVs. The maximum intra-gastric pressure of 23 mmHg in our study was chosen based on this data, and subjectively did provide the outward dilatation and tympany seen in clinical cases of GDV. The reported range for normal intra-abdominal pressure in dogs is variable between studies, likely due to differences in methods (i.e. sedate vs anesthetized, healthy vs ill, stress/pain levels etc.). A recent study comparing a standardized method of indirect, intravesicular intra-abdominal pressure measurements to direct measurements using a laparoscopic insufflator reported the mean resting intra-abdominal pressure to be between 5.81 and 7.06 mmHg in their population of normal dogs. Thus, our end-point for IGP of 5 mmHg and analysis cut-off point of <6 mmHg were chosen. In other words, there should be no pressure gradient between the gastric lumen and peritoneal cavity and therefore no clinical significance to IGP at or below 6mmHg.

The TTG and G-cath were placed in all dogs without complication and in a clinically reasonable amount of time (~3 minutes). In a clinical GDV patient this time
would likely be longer considering clipping, sterile preparation and administration of local anesthesia in addition to T-fastener and catheter placement. However, this would still likely be faster than placing an orogastric tube, and would provide sustained decompression that cannot be achieved via standard trocarization. Potential complications of the T-fastener and catheter placement are expected to be the same as those considered for trocarization in GDV patients and mainly consist of splenic laceration, inaccurate placement, and gastric perforation. In one study, out of 85 trocarized GDV patients, the only complication of trocarization was a single case of splenic laceration, which did not require treatment. The TTG and G-cath require a total of 4 blind needle placements into the gastric lumen within a 2cm² area of tympany. Theoretically, this may increase the chance of lacerating viscera (e.g. spleen), although this would seem unlikely in practice since all 4 needles are inserted into a relatively small area. Ultrasound-guided insertion could be considered and may eliminate this risk.

T-fasteners were designed to allow for percutaneous gastrostomy in human medicine and are currently used in interventional radiology and minimally invasive surgery to achieve temporary gastropexy to facilitate gastrostomy tube placement for feeding, or decompression. T-fastener gastropexy improves the safety of gastrostomy tube placement by allowing for controlled dilation of a stoma tract, direct percutaneous insertion of a tube into lumen, preventing early leakage at the tube site, reducing the risk of tube dislodgment, and allowing easy tube replacement. A clinical study comparing percutaneous radiologic gastrostomy tubes placed with or without T-fasteners revealed that T-fasteners greatly reduce the chance of serious technical complications. Complications related to the T-fasteners themselves are seldom
reported and are typically limited to skin irritation with rare cases of infection and fistula formation.\textsuperscript{86} These complications are associated with T-fasteners in place for 1-2 weeks, and are unlikely to occur with the short duration of use expected with the investigated application.\textsuperscript{87} To the authors’ knowledge, this is the first report of T-fastener use in veterinary medicine to achieve temporary gastropexy. This technique could be adapted in veterinary medicine to place larger, permanent gastrostomy or jejunostomy feeding tubes as is performed in humans.\textsuperscript{107,112,113}

In addition to the TTG, the in vitro success of the technique was due in part to the properties of the decompressive catheter\textsuperscript{c}. The catheter chosen was a 5fr Ultrathane\textsuperscript{®} catheter with a locking 10 mm pigtail containing 5 drainage holes within the pigtail loop. The orientation of the fenestrations within the loop, prevents/limits the chance of obstruction of the catheter from contact with the mucosa or intraluminal material. Additionally, the self-locking pigtail aids in preventing catheter pull-out and obviates the need for a finger-trap suture. The size of the catheter was chosen with the goal of allowing adequate gastric decompression without creating a significant gastric wound. Use of up to a 14ga needle or catheter has been recommended for trocarization and decompression in GDV cases without any reported leakage of gastric contents.\textsuperscript{11,91} A 14ga needle and 5fr catheter have outer diameters of 2.1 mm and 1.7 mm, respectively, but the catheter used in our study is placed by dilation of tissue in contrast to cutting which is typical of a hypodermic needle. Consequently, leakage at the catheter site was thought to be unlikely and was not observed in any dogs.

The 5fr catheter used would be unable to remove solid contents from the gastric lumen. With the exception of a food bloat progressing to volvulus, this would be
unimportant as gas is responsible for a majority of the dilatation in most clinical GDV cases. In a dog with GDV in sternal or left lateral recumbency, the catheter placement we used would facilitate removal of gas, as gas would rise to the site of the catheter as is seen with typical intermittent trocarization. The dogs in our study were fasted and so we are unable comment on how well the catheter would function with gastric fluid obstructing its lumen, however a few times, the catheter appeared (endoscopically) to be covered with mucous and flow rates declined. This problem was easily remediated with a 6mL saline flush followed by 6mL air flush. In clinical GDV dogs, it may be beneficial to flush the catheter intermittently, or whenever obstruction is suspected.

The evidence suggests that the most devastating component of GDV is the gastric dilatation, which causes portal and caval compression, decreased venous return and cardiac output, hypoxemia, gastrointestinal edema, gastric hypertension and ischemia, the release of myocardial depressant factors and systemic inflammatory mediators. Without gastric dilatation and associated vascular compression, gastric pathology appears to be limited as evidenced in a study in which dogs underwent an experimental 360° gastric volvulus while maintaining gastric decompression. In this study, all other viscera drained via the portal system were histologically normal even after a 12-hour volvulus. Additionally, only mild to moderate changes to the stomach were noted after the decompressed 12-hour volvulus, and appeared to be reversible as gastric tissue was reported to be histologically normal 7 days post-operatively. Other studies have demonstrated that cardiopulmonary parameters improve rapidly following gastric decompression. Thus, achieving and maintaining decompression in clinical
dogs with GDV should reduce the negative impact of extreme gastric dilatation, improving patient stabilization, and possibly overall outcome.

Measurements of IGP were standardized among dogs, starting at 23mmHg and ending at 5mmHg, while total IGV was variable between dogs due to their differing sizes. For this reason, IGP was analyzed and reported in mmHg as it could be compared directly, and IGV was analyzed and reported as a percent change, in order to directly compare volume data between dogs. The change in IGP was rapid with a 50% drop (to 11.5mmHg) occurring in the first 2 minutes (Figure 3-3). As expected, changes in IGV followed the same pattern as changes in IGP (Figure 3-4), with more rapid gas outflow from the catheter occurring with higher IGPs. The mean time for 50% reduction of IGV was about 3.5 minutes. The remaining 50% IGV exited the catheter at a much slower rate. It is important to consider that the gas exiting was passive and, as done in one case, when the gas efflux slows down the remainder of the IGV removal can be facilitated manually using a large syringe, or potentially suction unit. It is possible that a small amount of gas escaped via the lower esophageal sphincter and/or the pylorus into the duodenum during the procedure, confounding interpretation of changes in IGP and IGV. If this occurred, we believe it was of minimal significance for the following reasons: the pressure was able to be held at 23mm Hg when the catheter was occluded which would not be possible if gas was exiting the stomach, no audible gas outflow was appreciated from the esophagus during data collection, gas flow was documented continuously through the catheter, and lastly, the small intestine did not appear gas distended during laparoscopic evaluation.
There were no major complications associated with the placement of the TTG and G-cath either intra-operatively or in the 72 hour post-operative period. One minor complication that occurred in three cases was that a 1-2 mm tag of the T-fastener suture was visible laparoscopically coming through gastric serosa (Figure 3-5). This would likely not cause a long-term problem, as the suture is absorbable 3-0 Glycomer 631, and when removed in humans after 1-2 weeks, complications are seldom reported. In one case, during initial insufflation to achieve outward tympany at an unknown pressure, the gastric mucosa appeared cyanotic. Some intraluminal gas was removed endoscopically, and the TTG and G-cath were placed routinely before bringing the IGP up to the 23mmHg starting point. The decompression went routinely, however after ~ 60% decrease in IGP, the mucosa still appeared cyanotic. Out of concern for the dog, the remaining IGV was removed quickly using a 35cc syringe attached to the catheter. Decompression was maintained until the mucosa appeared grossly normal again. Since the pressure transducer could not be attached prior to catheter placement, we are unsure what the total IGP was in this dog. However this example demonstrated that after the initial rapid passive decompression occurs, the remainder of the IGV can be removed manually if desired. Interestingly, while all catheters were placed in the right side, all catheter entry sites in the stomach were at the margin of the fundus and gastric body, in the ventral surface in 5/6 dogs. This suggests that with dilatation alone, the body and fundus are displaced ventrally and to the right, which is counter to what would be expected with clinical GDV. This may have been due to the rapid rate of gastric dilatation, or perhaps because dilatation occurred with the dogs in dorsal recumbency.
In the present study, placement of a temporary T-fastener gastropexy and decompressive gastric catheter was achieved rapidly and successfully provided effective continuous gastric decompression in an iatrogenic gastric dilatation model without causing a significant gastric wound. This technique may be an effective method for sustained gastric decompression in clinical GDV patients, however clinical investigation is required.
Figure 3-1. Supplies for temporary T-fastener gastropexy and decompressive gastrostomy catheter placement. Photo courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 3-2. Synced endoscopic and external procedural images depicting introduction of the initial T-fastener(A), deployment of the second T-fastener bar(B), introduction of the 21ga needle centered in the temporary gastropexy(C), placement of the 0.018in, 60cm guidewire through the needle and removal of the needle(D), dilation of the stoma tract over the guidewire(E), and finally, placement of the 5fr pigtail decompression catheter over the guidewire and removal of the guidewire(F). Photos courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 3-3. Mean Intra-gastric Pressure (mmHg) vs Time (seconds).
Figure 3-4. Percent Change in Intra-gastric Volume vs Time (seconds).

Figure 3-5. T-fastener Suture Visible Laparoscopically. Photo courtesy of W. Alexander Fox-Alvarez, DVM.
CHAPTER 4
THE USE A NOVEL GASTRIC DECOMPRESSION TECHNIQUE IN DOGS WITH GASTRIC DILATION-VOLVULUS SYNDROME: TEMPORARY PERCUTANEOUS T-FASTENER GASTROPEXY AND CONTINUOUS DECOMPRESSIVE GASTROSTOMY

Introduction

Gastric dilatation-volvulus syndrome (GDV) is a life-threatening emergency characterized by gastric distention and malposition, most commonly affecting deep-chested large- to giant-breed dogs.\textsuperscript{1–4} The rapid clinical decompensation of GDV patients occurs secondary to massive gastric distention, which impinges upon normal diaphragmatic movement, compresses vital abdominal vasculature, and leads to a cascade of negative sequelae including hypovolemic shock, arrhythmias, electrolyte disturbances, visceral necrosis, and death.\textsuperscript{5–8} For this reason, rapid gastric decompression is a key component of preoperative stabilization in dogs with GDV.\textsuperscript{9,10} Most GDV patients are decompressed on presentation via either orogastric intubation or percutaneous trocarization, which have reported success rates of 76\% and 86\%, respectively.\textsuperscript{11} However, these techniques provide only temporary decompression, and gastric dilatation can return as long as the volvulus is present in the patient. Any patient with a delay in surgery may require second attempts of decompression or only benefit from temporary relief of clinical signs.

Some studies have demonstrated that prolonged distention and delays in surgery are associated with a worse outcome,\textsuperscript{103,104} and as such, surgery should never be purposefully delayed. However, in several clinical scenarios there are unavoidable delays in surgery, such as transit from a general practice to an emergency facility, while calling in emergency staff, or while owners weigh the financial and emotional demands of pursuing treatment. In cases where surgical delay is expected, a technique that
provides lasting gastric decompression would be ideal. The authors in this study recently published an in vivo pilot study evaluating the use of a percutaneously placed temporary T-fastener gastropexy (TTG) and self-retaining gastrostomy catheter as a means of continuous gastric decompression in dogs with experimentally induced gastric dilatation. The technique was found to be minimally invasive, quick to perform (under 4 minutes), and successfully provided effective continuous gastric decompression, without creating a gastric wound that required closure. The next logical progression in the investigation of this technique was to evaluate its performance and efficacy in clinical GDV patients.

The purpose of this study was to evaluate and describe the use of a novel means of gastric decompression in dogs with naturally-occurring GDV by use of a percutaneously placed TTG and self-retaining gastrostomy catheter (G-cath) and to compare findings to standard gastric trocarization. We hypothesized that the novel decompression technique would be safe, effective, and would not differ significantly when compared to trocarization, with the exception of taking longer to perform and providing sustained gastric decompression.

**Materials and Methods**

**Dogs.** Fourteen dogs, presenting with untreated, naturally occurring gastric dilatation-volvulus (GDV) were included in the study. Dogs were privately owned and enrolled after informed owner consent. All dogs presented to the emergency and critical care service at the University of Florida College Of Veterinary Medicine and were diagnosed with GDV based on consistent clinical signs and abdominal radiography. Prior to presentation, dogs were randomly assigned to one of two gastric decompression groups: the “trocar group”, in which standard trocarization performed
(n=7) or the “G-cath group”, in which a temporary T-fastener gastropexy (TTG) and decompressive gastric catheter (G-cath) were performed (n=7). The study protocol was approved by the UF Veterinary Hospitals Research Review Committee, and the Institutional Animal Care and Use Committee, protocol #201508909.

**Experimental Procedure.** Upon presentation to the emergency service and diagnosis with GDV, all dogs had telemetry connected for continuously recorded EKG output, and an IV catheter was placed in the cephalic vein(s). Aggressive intravenous fluid therapy was instituted and tailored to the individual patient based on cardiopulmonary parameters, aiming for treatment endpoints of <140 bpm for heart rate, and >100 mmHg for systolic blood pressure. Blood was collected from the catheter site for venous blood gas with lactate measurement. These values represented the baseline values on presentation, or $T_0$. All dogs were administered 0.2mg/kg of methadone IV to alleviate discomfort. Lactate measurements were repeated every 15 minutes for the following hour of decompression and stabilization, and a final blood gas was drawn at 60 minutes. Immediately following initial blood collection, gastric decompression was achieved in one of two ways. Patients in both groups had the site of decompression clipped, steriley prepared, confirmed via ultrasound, and locally anesthetized with 1mL of lidocaine infused around the intended entry sites.

The trocar group had gastric decompression performed by the emergency clinician on staff via standard gastric trocarization performed using a 14ga over-the-needle catheter placed in an area of outward tympany 1-3 cm caudal to the right 13th rib in the dorso-lateral abdomen. The site was visualized using ultrasound prior to trocarization. The trocar was held in place by the operator while decompression
occurred. Upon initial placement, the catheter was attached to a device\(^1\) to measure and record intra-gastric pressure (IGP) (mmHg) at \(T_0\). This device was calibrated according to manufacture protocol prior to use. Intra-gastric pressure measurements were recorded every 5 minutes until trocar catheter removal. The clinician operating the trocar catheter was blinded to IGP readings. Removal of the trocar catheter was performed at the operator’s discretion based on their subjective assessment of flow through the trocar catheter, the level of decompression, and improvement of cardiopulmonary parameters. An IGP reading was taken immediately prior to trocar removal. Repeat trocarization was performed at the clinician’s discretion, based on their subjective assessment of returned gastric dilatation, increase in patient discomfort and an associated decrease in cardiopulmonary parameters. Procedural timing began at initiation of local anesthesia, and ended upon the removal of the trocarization catheter. Corrective surgery and gastropexy were performed routinely upon the completion of data collection. Partial gastrectomy and splenectomy were performed when necessary as determined by the primary surgeon. The trocar sites were evaluated for trauma at the serosal surface during corrective surgery if able to be identified.

The G-cath group had gastric decompression performed by a single operator via temporary TTG and G-cath (Figure 4-1). With the operator wearing sterile gloves, three T-fasteners\(^2\) were placed percutaneously about 1.5cm apart in a triangular orientation, into the gastric lumen via the right dorso-lateral abdomen, in the same area as described for the trocar group. The exact location of placement within this region was

\(^1\) Labquest 2 with Gas Pressure Sensor, Vernier Software & Technology, Beaverton, Ore.

\(^2\) SAF-T-PEXY, Kimberly Clark Medical, Roswell, Ga.
determined by ultrasound guidance and the degree of palpable tympany. Prior to placement, all T-fasteners were attached to a 6cc syringe with 2cc sterile saline. After introduction into the gastric lumen, the syringe plunger was drawn back to evaluate for the presence of air bubbles, indicating appropriate intra-gastric positioning, and the T-fasteners were deployed from the needle. In the center of the temporary gastropexy, a 21ga needle was placed into the gastric lumen, into which a 0.018in, 60cm guidewire was fed. The needle was removed over the guidewire and a 5Fr introducer\(^3\) was placed over the guidewire to dilate the tract and then was removed. Finally, a 5fr locking pigtail catheter\(^4\) was placed over the guidewire into the gastric lumen; the guidewire was removed and the pigtail coil was formed, locked in place and retracted to the gastric wall. Procedural timing began at initiation of local anesthesia, and ended upon the completion of the procedure as indicated by locking the pigtail catheter. As with the trocar group, an immediate IGP measurement was recorded, followed by readings every 5 minutes. If fluid was present at the catheter, or gas efflux was unable to be detected subjectively, the catheter was flushed with 3 mL of water followed by 3mL of room air prior to the IGP reading. The TTG and G-cath remained in place and passively decompressed the stomach for 60 minutes, or until the time of surgical correction of the GDV. No patient had surgery delayed in order to collect 60 minutes of data. The TTG and G-cath were draped out of the surgical site, and prior to abdominal explore a non-sterile surgical assistant unlocked and removed the pigtail catheter, and cut the T-fastener anchor sutures, releasing the temporary gastropexy prior to derotation.

\(^3\) Mallinckrodt modification micropuncture introducer set, Cooke Medical, Bloomington, Ind.

\(^4\) Dawson-Mueller multipurpose drainage catheter, Cooke Medical, Bloomington, Ind.
Corrective surgery and gastropexy was performed routinely following removal. Partial gastrectomy and splenectomy were performed when necessary as determined by the surgeon. The TTG and G-cath locations were evaluated for trauma at the serosal surface during corrective surgery.

Duration of clinical signs prior to decompression, decompressive procedural time, IGP readings, lactate readings every 15 minutes, and success rates were recorded and compared between groups. Successful decompression was defined as lowering IGP to ≤ 7 mmHg. Complications associated with the decompression procedure noted during placement and/or abdominal explore for GDV corrective surgery were recorded.

**Data Analysis**

Continuous, numeric data were presented as median and interquartile range following assessment of normality by the Shapiro-Wilk method. The Wilcoxon Signed Rank Test was used for repeated nonparametric measures, and the Wilcoxon Rank Sums method was used for non-repeated measures. The Pearson Chi square test was used to compare categorical measures. For all comparisons, values of P < 0.05 were considered significant.

A priori power calculation was performed based on our previously published literature demonstrating an average of 2.3 mins +/- 1.3 mins to reach a 50% drop in IGP. The recommended sample size was 13 dogs total, with an alpha of 0.05 and beta of 0.80. JMP Statistical software\(^5\) was used for all data analysis.

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\(^5\) JMP, version 9.0.2, SAS Institute Inc, Cary, NC.
Results

Animals.

Breeds included German Shepherd (7), Doberman Pinscher (1), Giant Schnauzer (1), Golden Retriever (1), Greyhound (1), Great Dane (1), Standard Poodle (1), and Weimaraner (1). The overall median age was 7.9 years (IQR, 5.7 to 10.1) and median body weight was 33 kg (IQR, 29 to 46.5). Weight and age were not significantly different between groups (p = 0.11, and 0.08 respectively). The duration of clinical signs prior to presentation ranged from 0.5 to 17 hours with a median of 4.5 hours (IQR, 1.2 to 6.5) and 2.5 hours (IQR, 1.3 to 6.0) for the trocar and G-cath groups, respectively. These findings were not significantly different between groups (p = 0.75).

Procedure.

The median time to perform the decompression procedure was 3.0 minutes (IQR, 2.4 to 5.1) and 3.9 min (IQR, 3.4 to 4.5) in the trocar and TTG groups, respectively. Times to perform decompression procedures were not significantly different between groups (p = 0.28). The mean and median initial IGP reading on presentation for the 11 dogs with successful gastric access was 13.4 and 12.6 mmHg (StD. 5.0, IQR 10.0 to 18.6, range: 4.2 to 20.2), and was not significantly different between groups (p = 0.78). Lactate concentration on presentation for all 14 dogs had a median value of 3.5 mmol/L (IQR 1.8 to 6.0), and was not significantly different between groups (p = 0.75). Longer duration of clinical signs prior to presentation was associated with higher lactate on presentation when evaluated using a bivariate analysis (r-squared – 0.29, P = 0.05). No relationship was found between higher IGP on presentation and initial lactate (r-squared 0.003, P = 0.86). All patients had significant drop from initial to final IGP (P = 0.0001) and there was no difference between groups (P = 0.55). The decrease in IGP from the
initial reading (T0 min) to the second reading (T≤ 5 min) was significant in all cases (p = 0.0007), and was not different between groups (P = 0.07).

Successful gastric decompression (lowering IGP to ≤ 7 mmHg) was achieved in 71.4% (5/7) of cases in the G-cath group and in 85.7% (6/7) of the trocar cases overall. These findings were not significantly different between groups (P = 0.511). The trocar group reached and IGP of ≤ 7 mmHg faster than the G-cath group (Figure 4-2). There was no difference in IGP between 5 and 60 minutes for dogs in the G-cath group (P = 0.13) demonstrating continuous decompression efficacy after catheter insertion (Figure 4-2).

One trocar case did fail on the first attempt to decompress the stomach (inadvertent abdominocentesis), but was successful on the second attempt and was considered a successful decompression overall. The one case that was considered a failure in the trocar group also had a failed first attempt to trocarize the stomach (inadvertent abdominocentesis), however, while the second attempt did enter the gastric lumen, it failed to reduce the IGP to ≤ 7 mmHg prior to withdrawal. In these cases, recorded procedural time encompassed both attempts. Upon abdominal exploration, no evidence trauma from the failed trocar was identified in either case. The two failures in the G-cath group occurred in the 2nd and 3rd cases that had this procedure. One of failed due to splenic laceration with the T-fasteners and 21ga needle. The T-fasteners went through the spleen and into the gastric lumen, as indicated by the presence of air bubbles in the syringe attached to the T-fasteners, the guidewire was unable to be fed through the central 21ga needle due to the presence of the spleen. The procedure was abandoned, and the T-fastener anchor sutures were cut externally to release the spleen. Surgical
evaluation of the spleen revealed 4 small punctures, 3cm from the margin, in the head of the spleen (Figure 4-3A).

Hemorrhage was minor and controlled with hemostatic foam. Splenectomy was not performed. The procedural data was incomplete in this case due to the failure and was excluded from data analysis. In the second failure in the G-cath group, the TTG and G-cath were placed without issue externally, however, they were placed into a loop of jejunum that was trapped between the distended stomach and body wall. Upon surgical exploration, the catheter and T-fasteners were found to be placed 5mm away from the anti-mesenteric border of the loop of jejunum. The T-fasteners anchor sutures were cut, and the catheter was removed in order to free the segment of bowel. There was no evidence of leakage from either of the three T-fastener, nor G-cath sites and the bowel was healthy in appearance (Figure 4-3B). The area was wrapped in omentum and the remainder of the surgery proceeded routinely. In the first 3 cases in the G-cath group, including these two failures, ultrasound was used to determine the location of the intended TTG and G-cath site and marked with local anesthesia. The T-fasteners were then placed blindly based on the site of local anesthetic blebs. In the remainder of cases, the initial T-fasteners was placed under direct ultrasonic visualization to ensure appropriate intra-gastric placement. All cases after this alteration in technique were placed successfully.

The site of the TTG and G-cath on the stomach was evaluated in all successful cases and none were found to require closure or treatment (Figure 4-4C). In all cases, the TTG and G-cath sites were located in the gastric mid-body, either 1-3cm dorsal or ventral to the greater curvature (Figure 4-5). Splenectomy was performed in 2 of the
trocar cases due to splenic thrombi secondary to torsion. Partial gastrectomy was performed in 1 case in the G-cath group in which a 7x5cm portion of the fundus displayed full thickness necrosis. The TTG and G-cath sites were approximately 10cm away from this location in a healthy area of the gastric body, 2cm ventral to the greater curvature. In both groups, all dogs survived to discharge and were doing well when examined 2 weeks post-operatively for suture removal.

**Discussion**

The results of this study support the use of a percutaneously placed temporary T-fastener gastropexy (TTG) and self-retaining gastrostomy catheter (G-cath) for gastric decompression in dogs with naturally occurring GDV. Both trocarization and G-cath achieved successful gastric decompression in most of the GDV patients in this study, with the G-cath having the added advantage of sustained decompression. The use of T-fasteners and a pigtail catheter in the G-cath technique prevented premature dislodgement and provided a continuous patent avenue for gas outflow. T-fasteners consist of a suture attached to a metal T-bar, preloaded into a slotted 18ga needle that is introduced percutaneously into the organ lumen and deployed. The needle is removed, and the suture and attached intraluminal T-bar remain and are used to affix the organ to the body wall. T-fasteners are used in human medicine to allow temporary fixation of an organ to the body wall, most often to facilitate safe tube placement into the gastrointestinal tract for feeding or decompression. The use of 3 T-fasteners for TTG created a tented area around the catheter tip to prevent the gastric wall from folding onto the catheter as the stomach decompressed. The TTG also provides a means to replace the catheter in the event of early dislodgement, although the locked pigtail catheter tip is intended to resist premature removal.
The population of dogs in the study did not differ between groups and was consistent with previous GDV studies with respect to age, size, and breed. Consistent with many other GDV case series, the German Shepherd breed was over-represented, making up 50% of the dogs in this study population. There was a wide range in duration of clinical signs prior to presentation (0.5 to 17 hours). Literature has been inconsistent on whether a longer duration of clinical signs prior to treatment in GDV patients is associated with a worse prognosis. This inconsistency is likely due to the variability in the degree of gastric distention between patients and the associated cardiopulmonary and vascular compromise. The degree of gastric distention and IGP also had a wide range in our study population (IGP 4.2 to 20.2 mmHg). It is reasonable to consider that a higher IGP for a longer duration would lead to greater cardiovascular decompensation, hypoperfusion, and greater increase in blood lactate concentration. Although, longer duration of clinical signs showed a trend towards higher blood lactate concentration, neither a higher initial IGP, nor a longer duration of clinical signs correlated statistically with elevated blood lactate on presentation in this study. While a longer duration of clinical signs did not correlate to a higher mortality in our population, the only dog that required partial gastrectomy had the longest duration of clinical signs (17 hours).

Both the standard trocar and G-cath procedures were performed in a clinically reasonable amount of time which did not differ between groups. The G-cath group had less variability in procedure time compared to the trocar group (IQR 1.1 vs 2.7 min respectively). The time measured to perform the procedure reflected the amount of time the operator was physically performing each procedure, rather than the amount of time
required to achieve successful decompression. In the trocar group, this was made up of the initial trocar time, any subsequent attempts in those with an initial failure, and the duration of time the operator held the trocar in place for decompression. In the G-cath group, it was the duration of time required to place the TTG and G-cath, as once placed, the operator is no longer necessary to provide decompression. When evaluating the decompression speed of the techniques themselves, both had a significant decrease from initial IGP in ≤ 5 min which was not different between groups.

Data on the IGP in naturally occurring GDV is limited to a footnote in a single study in which the mean IGP was 22.9 +/- 13.7 mmHg in 20 dogs. The mean IGP in our study was lower than this at 13.4 +/- 5.0 mmHg but within the same range of values. The lowest documented IGP shown to demonstrate complete caval compression leading to diversion of venous return via the azygous vein was 20 mmHg in an experimental angiographic study. The low mortality rate in our study may be related to the fact that only 1 dog had an initial IGP greater than 20 mmHg, and therefore most dogs likely retained at least some normal abdominal venous return. The physiologic range of IGP in normal dogs is unknown, however several studies have evaluated the normal intra-abdominal pressure (IAP) in dogs. While the results of these studies have varied based on technique, one study found IAP measurement in dogs using 1 mL/kg of instilled saline to correlate well to IAP measured via laparoscopic insufflator pressure measurements. In this study, the mean resting intra-abdominal pressure in clinically normal dogs had a range of 5.81 to 7.06 mm Hg. Based on this, we defined a successful decompression as lowering IGP to ≤ 7 mm Hg, as an IGP within the normal range of intra-abdominal pressure would likely be of no consequence to abdominal
structures. The trocar group reached an IGP of ≤ 7 mmHg faster than the G-cath group (≤ 5min vs ≤ 10min, respectively). This finding is not surprising, as Poiseuille's Law would predict the flow through a 14ga catheter with an outer diameter of 2.1 mm and a length of 4.5cm to be faster than a 5fr catheter which has an outer diameter of 1.7 mm and a length of 25cm. However, the benefit of the G-cath is its ability to maintain the decompression for an extended period of time. Two dogs in the G-cath group and 1 in the trocar group had IGP values which read slightly increased from the previous reading. This may have been due to contraction of abdominal musculature, change in positioning during transport, or partial occlusion of the catheter. In both G-cath cases, the elevated IGP readings decreased once more after the catheter was flushed with 3mL of saline followed by 3mL of air. In clinical cases, the authors would recommend this be performed every 15 minutes while the G-cath is in place or any time where the catheter subjectively seems to be occluded to ensure continued patency.

A retrospective study by Goodrich et al., evaluating gastric decompression methods in GDV patients found orogastric intubation and trocarization to have success rates of 75.5% and 86% respectively. The success rates in our study were similar to these findings and were not different between groups. Both the trocar group and the G-cath group had 2 cases fail on initial attempt, however one of the two failed trocar cases was successful on a second attempt. G-cath cases were only attempted once and if failure was suspected, the procedure was abandoned out of concern for the unknown degree of trauma caused by misplacement. Based on the two cases of misplaced TTG/G-cath units, we now expect this trauma to be minor. The TTG/G-cath that was misplaced into the spleen had mild hemorrhage from the sites which was controlled by
direct pressure and a hemostatic sponge. The second misplaced TTG/G-cath was placed into a loop of jejunum which also had mild trauma, and was treated with an omental wrap. Neither misplaced TTG/G-cath unit lead to damage requiring major surgical intervention. The two G-cath failures occurred early in the study (2\textsuperscript{nd} and 3\textsuperscript{rd} cases). In the first 3 cases in the G-cath group, ultrasound was used to determine the location of the intended TTG and G-cath site and marked with local anesthetic blebs. The T-fasteners were then placed blindly at these sites. In the 2 failed cases, the patient reacted to the local anesthesia and moved which may have altered the regional anatomy in the abdomen from when it was ultrasounded. In the remainder of cases, the initial T-fastener was placed under direct ultrasonic visualization to ensure appropriate intra-gastric placement. This small alteration to the ultrasound guidance technique seemed to prevent further incorrect misplacement in the remaining 4 cases and is recommended for this technique. Goodrich et al reported that only 1/85 dogs trocared in their study had evidence of inadvertent trauma to abdominal organs on explore.\textsuperscript{11} In the present study, 2 cases had trocars misplaced into the abdomen and in neither of these cases was the location of the aberrant puncture identified upon abdominal explore despite purposeful investigation into their locations. Based on this, the retrospective nature of the Goodrich study, and the infrequency of secondary clinical problems, we believe that the inadvertent trauma from misplaced trocars occurs more frequently, but is likely underreported and inconsequential. Although there is some inherent risk to both decompression techniques, a thorough exploratory laparotomy should allow for correction if any damage to internal organs via decompression occurs.
As in the pilot study describing and evaluating the TTG and G-cath procedure,\textsuperscript{115} none of the placement sites in the stomach were found to have caused clinically significant trauma or a wound that required closure (Figure 4-5). One concern we had moving from pilot cases to clinically affected dogs was whether the location of TTG and G-cath placement would be in areas known to be at higher risk for gastric necrosis. While gastric necrosis can occur anywhere in the stomach, it is most commonly reported in the fundus and cardia,\textsuperscript{9,119,120} which coincides with the clinical experience of the authors. In all cases, the site of the TTG and G-cath was located in the gastric mid-body, either 1-3cm dorsal or ventral to the greater curvature, away from some of the more common locations of gastric necrosis. In the one patient where partial gastrectomy was performed the TTG and G-cath sites were in a healthy area of the gastric body, about 10cm away from the 7x5cm portion of the full-thickness fundic necrosis which was removed. While the degree of gastric torsion can be variable in GDV patients, the TTG/G-cath seemed to be consistently placed in this area in all dogs, suggesting it is unlikely to be placed in areas known to be higher risk for gastric necrosis.

Limitations of the study are related to the variable nature of GDV patients upon presentation and inability to compare the techniques in homogenous clinical groups. In awake dogs, IGP values may fluctuate due to changes in abdominal musculature tone and positioning. Surgery was not delayed in any patient, and patients were under anesthesia at variable times within the hour of data collection which may have had an effect on IGP readings. Ideally, an IGP measurement in the trocar group 1 hour after decompression would have been performed, however by this time, a majority of dogs
were in the operating room. Greater case numbers may have detected differences between groups and reduced the risk of Type II error.

In conclusion, the use of a percutaneously placed temporary T-fastener gastropexy and self-retaining gastrostomy catheter was found to be safe, effective, and provide sustained gastric decompression in dogs with naturally occurring GDV. These findings confirm our hypothesis, as the novel technique did not differ significantly when compared to standard trocarization, and additionally did not differ in time to perform. The continuous decompression afforded by the G-cath makes it an ideal for cases in which surgical delays are unavoidable.
Figure 4-1. Procedural images from a pilot study dog with experimentally induced gastric dilatation. Synchronized endoscopic and external images depict placement of temporary T-fastener gastropexy and decompressive gastrostomy catheter. Images show the introduction of an initial T-fastener (A), deployment of a second T-fastener bar (B), introduction of a 21-gauge needle centered in the temporary gastropexy site (C), placement of an 0.018-inch, 60-cm guidewire through the needle and removal of the needle (D), dilatation of the stoma tract over the guidewire (E), and finally, placement of a 5F pigtail decompression catheter over the guidewire and removal of the guidewire (F). Photo courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 4-2. Median (solid line) and interquartile range (shaded) of intra-gastric pressure (IGP) readings over time in all successful cases. The trocar (blue) depicts IGP values at T0 and T ≤ 5min and G-cath (orange) groups depicts the IGP values in 5 minute intervals. The green line represents the defined successful gastric decompression at 7 mm Hg. The G-cath provided sustained gastric decompression for the 60 minutes of data collection.
Figure 4-3. Images depicting sites of misplaced T-fasteners and gastric decompression catheter. A) Site of inadvertent splenic damage after minor bleeding was controlled. Small white arrows represent sites of T-fastener placement, large white arrow represents site where gastric decompression catheter placement was attempted. B) Site of inadvertent jejuna placement. Small black arrows represent sites of T-fastener placement, large black arrow represents site where gastric decompression catheter was placed. One T-fastener suture is visible exiting the jejunal placement site on the right. Photos courtesy of W. Alexander Fox-Alvarez, DVM.
Figure 4-4. Photos depicting the external(A) and internal(B) appearance of the completed temporary T-fastener gastropexy and decompressive gastrostomy catheter marked by a large white arrow, as well as the sites of entry in the gastric wall after removal of the T-fasteners and catheter (C), Small black arrows represent sites of T-fastener placement, large black arrow represents site where gastric decompression catheter placement was attempted). Note only mild serosal damage. Photo courtesy of W. Alexander Fox-Alvarez, DVM.

Figure 4-5. Locations of temporary T-fastener gastropexy and decompressive gastrostomy catheter. Black Xs represent sites on the ventral gastric surface, while white Xs represent sites on the dorsal gastric surface. Illustration courtesy of W. Alexander Fox-Alvarez, DVM.
CHAPTER 5
CONCLUSION

Gastric dilatation-volvulus (GDV) is a devastating canine emergency characterized by rapid accumulation of gas within the stomach, rotation of the stomach on its long axis, and an associated increase in intragastric pressure (IGP). A massively gas-distended stomach compresses critical abdominal vasculature, causing a cascade of negative physiologic impacts. Rapid gastric decompression and stabilization is critical in the treatment of dogs with GDV in order to restore venous return and halt progression of systemic decompensation. The most commonly employed techniques for gastric decompression, trocarization and orogastric tube placement are effective techniques, however, they only provide temporary decompression. In several clinical scenarios, definitive surgical correction can have unavoidable delays and the stomach can re-distend with gas. An ideal decompression technique would be minimally invasive, quick to perform, and provide sustained gastric decompression on the patient without creating any major additional trauma to the patient.

Techniques used in human medicine to gain minimally invasive gastric access were evaluated and discussed in Chapter 2, with the goal of developing the ideal gastric decompression method for dogs with GDV. The T-fastener and the pigtail catheter were the two key devices borrowed from human medicine to be adapted for use in the novel gastric decompression technique. Additionally, the use of the Seldinger entry method and image-guided placement were incorporated into the proposed procedure as they are also employed in human gastric access techniques to improve safety and control. With many similarities to how gastric feeding tubes are placed in human medicine, the
proposed technique included first creating a temporary gastropexy using T-fasteners in
order to maintain the placement of the gastric wall against the body wall, followed by
placement of a 5Fr pigtail catheter into the gastric lumen via the Seldinger method in the
middle of the T-fastener gastropexy to provide decompression. The novel technique,
called the “G-cath” technique, was first evaluated in a fresh cadaver model and found to
be quickly placed and cause minimal trauma to the gastric wall. After promising results
in the cadaveric trial, the technique was evaluated in a live animal model.

In Chapter 3, we evaluated the G-cath technique using a gastric dilatation model
in 6 clinically healthy large breed dogs. The procedure was completed in under 4
minutes in all dogs. The catheter provided rapid decompression, lowering the IGP by
50% in 2.1 minutes on average, and down to 6 mm Hg in 8.4 minutes on average. The
catheter and T-fasteners did not create clinically significant gastric wounds upon
removal. It was determined that the placement of a temporary T-fastener gastropexy
and decompressive gastric catheter was able to be performed rapidly and provide
successful, effective continuous gastric decompression in an iatrogenic gastric dilatation
model without causing a significant gastric wound. These findings suggest that the
novel decompression technique may be effective in clinical cases of GDV.

Finally, the novel decompression technique was employed for use in clinical
cases of GDV and compared to standard trocarization. The G-cath was found to be
safe, effective, quickly performed, and provide sustained gastric decompression in dogs
with naturally-occurring GDV. The novel technique did not differ significantly compared
to trocarization, except for providing sustained decompression. G-cath placement did
not induce any clinically significant gastric trauma and was well tolerated in the awake
patient. Even in cases where the G-cath was misplaced, the trauma was minor, did not require additional surgery, and did not affect patient morbidity or case outcome.

This novel decompression method is the first safe, effective, image-guided technique to provide sustained gastric decompression in dogs with GDV. This technique has the potential for wide application in a common canine emergency. Delays in surgery may be due to transport from general practices to an emergency surgical facility especially in rural areas or in military/working dog deployments, while awaiting emergency call-in staff, and/or while owners weigh the financial and emotional demands of treatment. In these cases, sustained gastric decompression may reduce or prevent the myriad of negative impacts of significant gastric distention, enhance preoperative stability, and ultimately improve outcomes.

Interesting future research may include comparing clinical outcome in a larger group of dogs undergoing trocarization or G-cath placement prior to surgery, development of an economical kit for commercial use in veterinary medicine, and adapting the technique methods to facilitate tube placement for feeding, rather than decompression.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

William Alexander Fox-Alvarez, or “Alex”, was born and raised in south Florida. His interest in veterinary medicine stemmed from his love of nature and wildlife at a young age. Alex completed his undergraduate studies at Florida State University and the University of Florida before attending veterinary school at the University of Florida. After graduating, he pursued his passion for exotic and zoo animal medicine and completed a rotating emergency small animal and zoo animal internship at Valley Animal Hospital and the Reid Park Zoo in Tucson, Arizona. During his internship, he found surgery to be the most rewarding facet of veterinary medicine and decided to pursue a residency in small animal surgery. He then returned to the University of Florida to complete a surgical internship, and stayed on the following year as a surgical resident. During this surgical residency, Alex also attained a Master of Science degree, graduating in the summer of 2017. Alex is scheduled to finish his surgical residency and become board eligible in 2018. His research interests include soft tissue surgery, surgery of zoo and exotic animals, minimally invasive surgery, and gastric dilatation-volvulus syndrome.