BSAVA

ORIGINAL ARTICLE

Stapled functional end-to-end intestinal anastomosis with endovascular gastrointestinal anastomosis staplers in cats and small dogs

S. Genoni [*,1], F. Cinti [†], M. Pilot [‡], M. Rossanese [§], D. McCready[*] and M. Cantatore[¶]

[*]Department of Surgery, The Ralph Veterinary Referral Centre, Marlow, UK
[†]Department of Surgery, San Marco Veterinary Clinic and Laboratory, Padova, Italy
[‡]Langford Small Animal Hospital, Langford House, University of Bristol, Bristol, UK
[§]Queen Mother Hospital for Animals, Royal Veterinary College, Hatfield, UK
[¶]Department of Surgery, Anderson Moores Veterinary Specialists, Winchester, UK

[1]Corresponding author email: stefano.genoni@gmail.com

Objectives: To investigate the use of endovascular gastrointestinal stapling devices to perform intestinal functional end-to-end stapled anastomosis in small dogs and cats.

Materials and Methods: Medical records of dogs (≤10 kg) and cats that underwent intestinal resection and functional end-to-end stapled anastomosis with an endovascular gastrointestinal anastomosis (endovascular-GIA) stapling device at five small animal referral centres between April 2014 and September 2023 were retrospectively reviewed. Data including clinical findings, surgical technique, histopathology and complications were collected. A minimum follow-up of 10 days was required. Patients with follow-up of less than 10 days were included if they developed a major complication. Outcome was obtained from assessing the clinical records and contacting the referring veterinarians or owners. Estimated survival was generated according to the Kaplan–Meier method. Differences between survival curves were tested by log-rank test.

Results: Twenty-five patients (10 dogs and 15 cats) were included. The median bodyweight was 4.6 kg (range 2.6 to 10 kg). Nine patients were diagnosed with intestinal neoplasia, 16 with non-neoplastic intestinal disease. The median follow-up was 126 days (range 18 to 896 days). Five patients developed minor postoperative complications, including three superficial surgical site infections. No major postoperative complications were reported. Eighteen patients were alive at the end of the study, one patient was lost to follow-up. Kaplan–Meier estimated median survival time was not reached. Survival was significantly longer for patients with non-neoplastic versus neoplastic intestinal.

Clinical Significance: The study suggests that the use of endovascular gastrointestinal anastomosis staplers is safe and effective to perform intestinal functional end-to-end stapled anastomosis in dogs ≤10 kg and cats.

Journal of Small Animal Practice (2024); **65**, 799–806
DOI: 10.1111/jsap.13756

Accepted: 27 May 2024; Published online: 10 July 2024

JSAP JOURNAL OF SMALL ANIMAL PRACTICE

INTRODUCTION

Intestinal resection and anastomosis is a commonly performed procedure in dogs and cats (Giuffrida & Brown, 2017). Different surgical techniques have been reported for intestinal anastomosis, including hand-sewing, end-to-end circular stapling devices and skin staplers (Schwartz & Coolman, 2018). In addition, gastrointestinal anastomosis (GIA) stapling devices have been used for functional end-to-end intestinal anastomosis (Giuffrida & Brown, 2017).

Intestinal functional end-to-end stapled anastomoses (FEESA) using GIA staplers were first reported in the veterinary literature in 1991 – an open lumen technique was described and closure of the transverse intestinal lumen was performed using a thoracoabdominal (TA) stapler (Ullman et al., 1991). A modified technique using a GIA stapler for the transverse intestinal lumen closure was described in 2008 (White, 2008). In 2001, a one-stage technique to perform intestinal FEESA was reported (Jardel et al., 2011). Resection of the affected intestine before the completion of the stapled anastomosis was not required (Jardel et al., 2011).

Short surgical time, reduced bowel manipulation and ease of application of the GIA staplers are reported advantages of stapled, in comparison to hand-sewn, intestinal anastomoses (White, 2008). Another significant advantage of stapled anastomoses is simplicity in performing the anastomosis of two portions of intestine with marked differences in lumen diameter (Ullman et al., 1991; White, 2008). More recent publications suggest that stapled intestinal anastomoses might lead to lower complication rates when compared to hand-sewn intestinal anastomoses in dogs (Davis et al., 2018; DePompeo et al., 2018).

Whilst intestinal FEESA with standard GIA staplers was reported in four cats, all patients had significant pathologic dilation of the intestine or underwent colonic resection and anastomosis (Ullman et al., 1991). The small size of the intestinal lumen in small dogs and cats makes the passage of the limb of a standard GIA stapler impossible (Ullman et al., 1991; White, 2008).

Endovascular GIA staplers are smaller devices compared to standard GIA staplers and have been extensively reported in the human literature to perform a wide range of gastrointestinal, thoracic and vascular procedures (Chan et al., 2000; Kimura et al., 2015; Liu et al., 2006; Naito, Miura, et al., 2017a; Perinjelil et al., 2018; Powell, 1995).

Medline (Pubmed), Google Scholar and Science Direct databases were searched in December 2023 with the following keywords: "functional end-to-end anastomosis," "FEESA," "intestinal resection and anastomosis," "*endo*-GIA," "endovascular-GIA," "stapled intestinal anastomosis" and "enterectomy." When filtered for veterinary patients, our literature search documented only one cadaveric study in feline patients (Sanders et al., 2023).

The objective of this study was to describe the clinical use of endovascular-GIA stapling devices to perform functional end-to-end intestinal anastomosis in small dogs (≤10 kg) and cats.

MATERIALS AND METHODS

Data extraction

This retrospective study was approved by the Royal College of Veterinary Surgeons Ethics Review Panel (approval number 2022-144). The medical record databases of five small animal referral hospitals from the United Kingdom and Italy were searched in the period of May to September 2023 for patients that underwent an intestinal FEESA using an endovascular-GIA stapler. The databases including ezyVet (Idexx), RxWorks (Covetrus Software Services), easyVET (VetZ, Antech), CRIS™ and POA (POA Systems) were searched by the leading investigator from each hospital using the keywords "enterectomy," "intestinal anastomosis," "stapled anastomosis," "FEESA," "*endo*-GIA anastomosis" and "functional end-to-end anastomosis." Dogs with a bodyweight ≤10 kg and cats were included in the study. Patients with a minimum of 10 days follow-up were included. Patients were excluded if the available follow-up was less than 10 days; however, patients with a follow-up of less than 10 days were included in the study if a major complication developed.

Medical record review

The following data were retrieved from the medical records: signalment, bodyweight, body condition score, presenting clinical signs, presence of septic peritonitis at presentation, diagnostic imaging, surgical findings, site of affected intestinal tract, surgical technique for intestinal resection and anastomosis, stapler type, staple size, surgical time, anaesthetic time, final diagnosis, histopathological results, duration of hospitalisation, intra- and postoperative complications, follow-up time, survival time and cause of death. Postoperative complications were classified as minor if resolved spontaneously or required medical treatment, and major if required revision surgery or resulted in death.

Surgical technique

All patients underwent an exploratory celiotomy as well as an intestinal resection and FEESA. The procedure was performed via an open lumen technique (Ullman, 1994; White, 2008) or a one-stage technique (Jardel et al., 2011). The endovascular-GIA staplers used included the Ethicon Echelon/Echelon flex (Johnson & Johnson Medical Limited, New Brunswick, New Jersey, USA) or the Covidien Medtronic Endo GIA™ (Medtronic Limited, Dublin, Ireland) stapler. Transverse stapling of the anastomosis was performed with an endovascular-GIA or a TA stapler. A suture was placed at the base of the longitudinal staple line (crotch suture). Oversewing of the transverse staple line was performed according to surgeon's preference. In addition, leak testing of the anastomosis site was performed according to surgeon's preference.

Data analysis

Outcomes of interest for each patient included diagnosis, intra- and postoperative complications as well as survival time. The time to complication and follow-up were calculated from the date of surgery. Survival time was calculated from the date of surgery to the date of death. The cause of death was classified as either related to a surgical complication of the stapled anastomosis, related to the progression of the underlying intestinal pathology or unrelated. For patients with incomplete follow-up information, referring veterinarians were contacted and the clinical records from the referring first-opinion practice were obtained. When information could not be obtained from the referring veterinarian or referring practice records, the owner was directly contacted using a standardised telephone questionnaire (Appendix S1). Referring veterinarians and/or owners were contacted, if necessary, in the period between May 2023 and September 2023. Data analysis was performed using Microsoft Excel 2020. The Kaplan–Meier method was used to estimate survival. Differences between survival curves were tested by log-rank test. For all tests, a p value ≤0.05 was considered statistically significant.

RESULTS

Patients

Thirty-two patients that underwent intestinal resection and FEESA were identified in the examined databases. Five patients (all cats) were excluded because a standard GIA stapler was used. Of the remaining 27 patients that underwent surgery with an endovascular-GIA stapling device, two cats were excluded due to follow-up time of less than 10 days (2 and 4 days, respectively). Neither cat had a known complication at the time they were lost to follow-up. Twenty-five patients that underwent surgery between April 2014 and September 2023 matched the inclusion criteria and were enrolled in the study. Each referral centre contributed between one and eight cases. A total of 10 dogs and 15 cats were included. The dog breeds included cross breed (five), miniature Pinscher (one), Lagotto Romagnolo (one), Chihuahua (one), dachshund (one) and Lancashire Heeler (one). The cat breeds included domestic shorthair (five), Maine Coon (five), domestic longhair (one), Oriental (one), Siamese (one), Bengal (one) and Munchkin (one). Of the 10 dogs, seven were female (six neutered) and three were male (two neutered). Of the 15 cats, nine were male and six were female. All cats were neutered. The median bodyweight was 4.6 kg (range 2.6 to 10 kg): 5.8 kg in dogs (range 3.2 to 10 kg) and 4.18 kg in cats (range 2.6 to 7.4 kg). The body condition score was recorded for 18 of the 25 patients, with a median score of 5/9 (range 3/9 to 6/9). The median age was 8 years (range 5 months to 16 years): 5 years in dogs (range 5 months to 12 years) and 8 years in cats (range 6 months to 16 years) (Table 1).

Presurgical clinical findings

The most common clinical signs at presentation were vomiting [n = 16 (64%)], hyporexia or dysorexia [n = 13 (52%)], weight loss [n = 6 (24%)], lethargy [n = 6 (24%)], anorexia [n = 5 (20%)], diarrhoea [n = 5 (20%)], polyphagia [n = 2 (8%)], polydipsia [n = 1 (4%)] and melaena [n = 1 (4%)] (Table 2). Two dogs and one cat [n = 3 (12%)] were diagnosed with preoperative septic peritonitis – due to intestinal perforation in two patients and dehiscence of a jejunal enterotomy, performed to remove a foreign body 3 days before referral, in one patient. Abdominal ultrasonography was performed in 23 patients (92%) and an abdominal CT scan in two patients (8%). Twenty-three patients (92%) were diagnosed with jejunal disease. Two patients (8%) had jejunal disease with ileocecocolic junction involvement. A jejunal mass was identified in four dogs and six cats [n = 10 (40%)]. Jejunal intussusception was diagnosed in seven cats and one dog [n = 8 (32%)]. Two cats and one dog [n = 3 (12%)] were diagnosed with a jejunal foreign body. One dog was diagnosed with jejunal volvulus, one dog with a jejunal perforation, one dog with a jejunal diverticulum and one dog with dehiscence of a jejunal enterotomy (4% each).

Surgical procedures and complications

Fifteen patients (60%) had an open lumen, whereas 10 patients (40%) had a one-stage, intestinal FEESA. Partial jejunectomy was performed in 23 patients (92%), with resection of the ileocaecocolic junction, ileum and part of the jejunum performed in two patients (8%). In 14 patients (56%), a Medtronic Endo GIA™ (Medtronic Limited, Dublin, Ireland) stapler was used. A Covidien Echelon™ or Echelon Flex™ (Johnson & Johnson Medical Limited, New Brunswick, New Jersey, USA) stapler was used in 11 patients (44%). The length of the endovascular-GIA stapler cartridge was 60 mm in 18 patients (72%), 45 mm in five patients (20%) and not reported in two patients (8%). The height of the staples was 3.5 mm (colour coding = blue) in 15 patients (60%) and variable height from 3.0 to 4.0 mm

Table 1. Patient demographics

	n	Breeds (n)	Female, n	Male, n	Median age (range)	Median bodyweight, kg (range)
Dogs	10	Cross Breed (5), Miniature Pinscher (1), Lagotto Romagnolo (1), Chihuahua (1), dachshund (1), Lancashire Heeler (1)	7 (6 neutered)	3 (2 neutered)	5 years (5 months to 12 years)	5.8 (3.2 to 10)
Cats	15	Domestic Shorthair (5), Maine Coon (5), Domestic Longhair (1), Oriental (1), Siamese (1), Bengal (1), Munchkin (1)	6 (all neutered)	9 (all neutered)	8 years (6 months to 16 years)	4.18 (2.6 to 7.4)

n Number of affected patients

Table 2. Clinical signs at presentation

Clinical sign	Number of patients (%)
Vomiting	16 (64)
Hyporexia/dysorexia	13 (52)
Weight loss	6 (24)
Lethargy	6 (24)
Anorexia	5 (20)
Diarrhoea	5 (20)
Polyphagia	2 (8)
Polydipsia	1 (4)
Melaena	1 (4)

Table 3. Surgical technique

Surgical technique	Number of patients (%)
Partial jejunectomy	23 (92)
Resection of ileocaecocolic junction	2 (8)
Open lumen intestinal anastomosis	15 (60)
One-stage intestinal anastomosis	10 (40)
Medtronic Endo-GIA™ stapler	14 (56)
Covidien Echelon™ Flex™ stapler	11 (44)
Transverse stapling with TA stapler	20 (80)
Transverse stapling with *endo*-GIA stapler	5 (20)
Oversewing of transverse staple line	19 (76)

(Tri-Staple™ technology, Medtronic Limited, Dublin, Ireland – colour coding = purple) in eight patients (32%). No detail on staple height was reported in two patients (8%). In all patients, the longitudinal staple lines were offset before transverse stapling was performed. The transverse stapling of the anastomosis was performed using a TA stapler in 20 patients (80%). The length of the TA stapler cartridge was 30 mm in 10 patients (40%), 60 mm in six patients (24%) and not reported in four patients (16%). The height of the staples in these patients was 3.5 mm (colour coding = blue). In five patients (20%), a Medtronic Endo GIA™ stapler was used for the transverse stapling. Of these, staples of variable height from 3.0 to 4.0 mm (Tri-Staple™ technology, Medtronic Limited, Dublin, Ireland – colour coding = purple cartridge) were used in four patients (80%) and a staple height of 3.5 mm (colour coding = blue) were used in one (20%) patient. A summary of the surgical procedures and equipment used can be found in Table 3.

Oversewing of the transverse staple line was performed in 19 of 25 patients (76%). In 25 patients, a suture was placed at the base of the longitudinal staple line (crotch suture). Leak testing was performed in 17 patients (68%). Leaking was identified in one patient and a simple interrupted suture of polydioxanone was placed.

The surgical time for the completion of the anastomosis was reported for six patients, with a median of 10 minutes (range 8 to 20 minutes). The total surgical time was reported for 17 patients, with a median of 58 minutes (range 30 to 95 minutes). The total anaesthetic time was reported for 24 patients, with a median of 117 minutes (range 60 to 260 minutes).

No intraoperative surgical complications were reported. Two patients experienced intraoperative hypotension and required a constant rate infusion of noradrenaline (noradrenaline 1 mg/mL solution for infusion – Hospira UK Ltd. – 0.1 μg/kg/min). One patient experienced transient low oxygen saturation. Minor postoperative complications were reported in two dogs and three cats [$n = 5$ (20%)]. One patient developed marked ileus which responded to medical management within 2 days. One patient developed regurgitation that resolved within 4 days with medical management. Three patients (12%) developed a superficial surgical site infection (SSI). In two of these patients, the SSI was suspected to be secondary to self-trauma and was managed with topical disinfection and application of a protection collar, without administration of antibiotics. No major postoperative complications were reported. The median duration of hospitalisation was 4 days (range 1 to 8 days).

Histopathological diagnosis

Histopathological examination of the resected intestinal tract was performed in 21 patients (84%). Ten patients (40%) were diagnosed with inflammatory changes, nine patients (36%) with neoplasia, one patient (4%) with an intestinal diverticulum and one patient (4%) with no abnormalities. Of the nine patients with a diagnosis of neoplasia, adenocarcinoma was reported in two dogs and two cats [$n = 4$ (44%)], lymphoma in four cats (44%), and a gastrointestinal stromal tumour in one dog (11%) (Table 4).

Follow-up and postoperative outcome

The median follow-up time was 126 days (range 18 to 896 days). Eighteen patients (72%) were alive at the time of the last follow-up (nine dogs and nine cats). One cat was lost to follow-up after 19 days. Follow-up information until death was available for five cats and one dog [$n = 6$ (24%)]. Five of the six patients were diagnosed with neoplasia [lymphoma ($n = 3$) and adenocarcinoma ($n = 2$)], and one patient with jejunal intussusception. Three of the six patients died due to the progression of the neoplastic disease. Three patients died of unrelated causes [acute renal failure ($n = 1$), haemolytic anaemia ($n = 1$) and cardio-respiratory arrest during investigations of upper airway disease ($n = 1$)], 60, 285 and 149 days postoperatively, respectively. No patient died due to postoperative surgical complications. One cat required an enterotomy for the removal of a small intestinal foreign body 9 months following jejunal resection and FEESA. The foreign body was not associated with the previous anastomosis site; however, upon surgical exploration, the anastomosis site was found to be moderately dilated (Fig 1). The Kaplan–Meier estimated survival was not reached. Survival was significantly longer for patients with non-neoplastic versus neoplastic disease ($p = 0.005$).

DISCUSSION

The findings of this study suggest the use of 45 to 60 mm endovascular-GIA staplers with blue or purple cartridges is safe and effective in performing intestinal FEESA in dogs (≤10 kg) and cats. The advantages of FEESA are well reported and include reduced surgical time, bowel manipulation and rate of intestinal dehiscence as well as simpler anastomosis of two segments

Table 4. Histopathological diagnosis

Histopathological diagnosis	Number of patients (%)
Inflammatory changes	10 (40)
Neoplastic disease	9 (36)
Adenocarcinoma	4 (16)
Lymphoma	4 (16)
Gastrointestinal stromal tumour	1 (4)
Intestinal diverticulum	1 (4)
No abnormalities	1 (4)

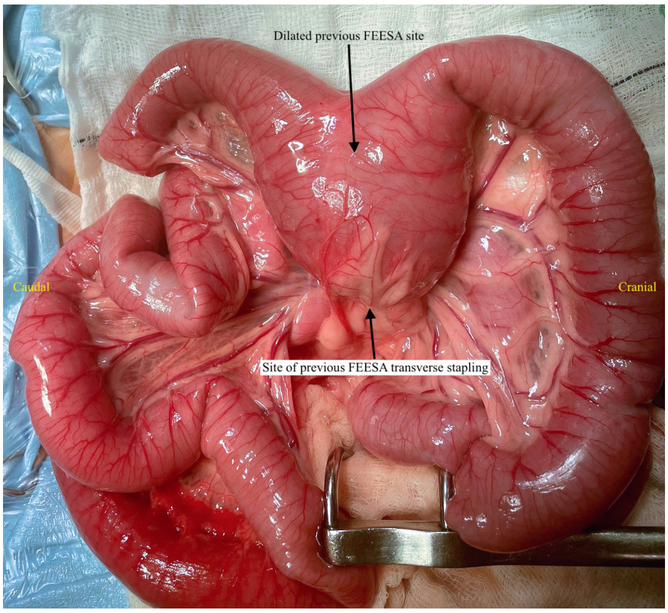

FIG 1. Intraoperative photograph showing a dilated jejunal tract 9 months following *endo*-GIA FEESA.

of intestine with marked differences in luminal diameter (Davis et al., 2018; DePompeo et al., 2018; Ullman et al., 1991; White, 2008). The use of the smaller sized endovascular-GIA stapler could therefore facilitate FEESA in patients that, historically, were not considered suitable candidates (Ullman et al., 1991; White, 2008).

Stapled intestinal anastomoses have been associated with a reduced risk of postoperative dehiscence in dogs, with a 5% dehiscence rate for stapled anastomoses *versus* 13% for hand-sewn anastomoses (DePompeo et al., 2018). The presence of preoperative septic peritonitis has been identified as a risk factor for postoperative intestinal dehiscence (Ralphs et al., 2003; Snowdon et al., 2016). In dogs presenting with septic peritonitis, the difference in the reduced risk of postoperative intestinal dehiscence was even greater, with a dehiscence rate of 9.7% for stapled anastomoses versus 28.9% for hand-sewn anastomoses (Davis et al., 2018). The possibility to perform intestinal FEESA in smaller patients could extend the reduced risk of intestinal dehiscence to small dogs. Incisional dehiscence following intestinal surgery is reported to be significantly lower in cats than dogs, with less than 1% of cats developing dehiscence of an intestinal anastomosis in 126 patients (Hiebert et al., 2022). In our study, no patients developed intestinal dehiscence including three patients with preoperative peritonitis. While our study's sample size limits the statistical power, the observed absence of intestinal dehiscence was similar to a report of low dehiscence rate following intestinal anastomoses in cats (Hiebert et al., 2022).

Endovascular-GIA staplers may also provide a distinct mechanical advantage compared to staplers employing a two-row configuration for intestinal anastomosis. All endovascular-GIA staplers have three rows of staples on each side of the central cutting blade, instead of the two rows of most GIA staplers. Increased resistance and burst pressure of three-row stapling devices, in comparison with two-row stapling devices, have been reported (Kimura et al., 2015). The longitudinal staple line and the crotch of the staple line have been described as potential weak points of the anastomosis performed with two-row stapling devices, however, only the crotch has been reported as the critical area for three-row stapling devices (Kimura et al., 2015). In a recent human clinical trial, the use of triple-row stapling devices was associated with a lower complication rate compared to double-row stapling devices in patients undergoing ileocolic anastomosis (Foo et al., 2018).

The transverse staple line has been identified as a weak point of intestinal FEESA (Ellison et al., 2019; Jardel et al., 2011; Snowdon et al., 2016; Ullman et al., 1991). This is due to the inherent everting pattern of the transverse staple line (Ullman et al., 1991) as well as the presence of a cross-stapling site where the transverse staples are fired over the longitudinal staple line (Jardel et al., 2011; Naito, Sato, et al., 2017b). In most of the dogs with dehiscence of the anastomosis at the transverse staple line, a standard TA stapler with two rows of staples was used (Sumner et al., 2019). In our study, 20 of 25 of the transverse staple lines were performed using a TA stapler (two rows of staples) and five of 25 were performed using an endovascular-GIA stapler (three rows of staples). Based on biomechanical and clinical studies in humans, transverse stapling with a three-row stapling device should be a consideration (Foo et al., 2018; Kimura et al., 2015).

Oversewing of the transverse staple line has been reported to increase the maximum leakage pressure and reduce the risk of postoperative dehiscence and anastomosis leakage in dogs (Duffy & Moore, 2020; Sumner et al., 2019). In our study, 19 of 25 transverse staple lines were oversewn, while no oversewing was performed in six of 25. Given that none of the cases in our series developed dehiscence, we cannot draw conclusions and provide firm recommendations regarding the best technique. However, based on previous studies in dogs, oversewing is advisable (Duffy & Moore, 2020; Sumner et al., 2019).

In our study, the height of the staples used was either 3.5 mm (1.5 mm when closed, blue cartridge) or variable height (Medtronic Tri-Staple™ technology) with the height of the internal row, intermediate row and external row of staples 3, 3.5 and 4 mm, respectively (purple cartridge). The use of 1.5 mm high (blue cartridge) staples is reported as the standard in human surgery and the choice in staple height in veterinary science has been guided by this data (DePompeo et al., 2018; Duffy & Moore, 2020; Sumner et al., 2019; Tobias, 2007;

Ullman et al., 1991; White, 2008). Optimal staple height should be guided by the thickness of the target tissue and, recently, data on small intestinal thickness in dogs and cats has become available and compared to human data (Mullen et al., 2020; Sanders et al., 2023). An ex-vivo study examined the small intestinal wall thickness in healthy dogs and reported 2.49 mm ± 0.28 mm for the jejunum, while the average thickness of the human small intestine was reported to be 1.5 mm (Mullen et al., 2020). When a FEESA performed with blue cartridges was compared to green cartridges in dogs, leak pressure exceeded maximum intraluminal peristaltic pressure in all anastomoses (Mullen et al., 2020). A recent ex-vivo study on healthy cats' intestine reported an average jejunal thickness of 2.28 mm ± 0.30 mm (Sanders et al., 2023), similar to dogs, which supports the use of comparable cartridge recommendations in both species, despite the body size difference. Intestinal FEESA were performed with a Medtronic Endo GIA™ stapler with Tri-Staple™ technology (purple cartridge) for the longitudinal staple line and TA staplers (blue cartridge), for the transverse staple line (Sanders et al., 2023). Again, the leak pressure measured was higher than the physiological peristaltic pressure in all cases (Sanders et al., 2023). Based on the comparable small intestinal thickness in dogs and cats, cadaveric (Mullen et al., 2020; Sanders et al., 2023) and clinical studies (Ullman et al., 1991; White, 2008), as well as the results of our study, the use of blue and purple cartridges appears appropriate in dogs and cats. Both Mullen et al. (2020) and Sanders et al. (2023) claimed green and black cartridges may be a more appropriate choice in dogs and cats based on the higher intestinal mural thickness compared to humans. These studies raised concerns including the possible compromise of the intestinal wall microvasculature, adequate engagement of the submucosa and correct staple conformation when using blue cartridges (Mullen et al., 2020; Sanders et al., 2023). However, based on our literature search, no clinical data assessing the small intestinal microvasculature response to different staple sizes is available in the veterinary literature currently. More importantly, it would be difficult to recommend performing intestinal FEESA with green cartridges in dogs and cats until more compelling clinical evidence becomes available. A better distribution of the forces along the staple line and improved perfusion of the stapled tissue are claimed advantages of the variable height staple technology according to the manufacturer [Medtronic Limited, https://www.medtronic.com/covidien/en-us/products/surgical-stapling/tri-staple-technology.html (Accessed December 2023)], however, definitive evidence that the variable height Tri-Staple™ technology leads to better clinical outcomes in intestinal surgery is lacking at this stage.

A crotch suture was placed at the base of the longitudinal endovascular-GIA staple line in all 25 patients enrolled in our study. The use of a reinforcing suture at the crotch of the anastomosis has been recommended to reduce the risk of complications related to staple pull-out and leakage (Goto et al., 2007; Tobias, 2007; Ullman, 1994). Different suture patterns have been described for the crotch suture, including simple interrupted and cruciate pattern sutures (Sumner et al., 2019). However, a higher complication rate was not reported when a crotch suture was not used (Jardel et al., 2011; Sumner et al., 2019).

The length of the stapler jaw may have implications in altering the local anatomy and function. The original reports describing FEESA in dogs suggested the use of a 50 to 60 mm long stapler jaw (Jardel et al., 2011; Ullman et al., 1991; White, 2008). This is considered adequate for patients large enough to accommodate a standard GIA stapler. However, objective data providing recommendations on optimal stapler jaw length in small dogs and cats are lacking. It would appear reasonable to consider shorter jaw length in small patients. White (2008) anecdotally suggested an endovascular-GIA stapler with a 30 mm long jaw could be considered to perform FEESA in small dogs. Similarly, Sanders et al. (2023) described the use of a 30-mm long endovascular-GIA stapler with variable height staples (purple cartridge) in a feline cadaveric study to assess the resistance to leakage in five different intestinal anastomosis techniques. Normal small intestinal diameter in cats is reported to be less than 12 mm (Adams et al., 2010), which could indicate that a 30-mm long endovascular-GIA might be sufficient. However, several factors will affect the final size of the anastomosis, including the healing process, positioning of the transverse staple line as well as the use of an inverting suture pattern for oversewing. It is currently unknown if this could lead to a stenotic lumen. None of the intestinal FEESA in our study was performed with a 30-mm long endovascular-GIA; therefore, no conclusions on the safety of a 30-mm stapler jaw length can be drawn. Stapled anastomoses in this study were performed with 45- to 60-mm long endovascular-GIA staplers and this length was deemed safe given that no major complications were encountered. However, one of the patients in our study developed a moderate dilation of the anastomosis site, identified 9 months after the original FEESA during an exploratory celiotomy for an intestinal foreign body located distant to the original FEESA site. Although the clinical significance of this finding was unknown, it is possible that a 60-mm long stapler jaw might be unnecessary in small dogs and cats and could lead to an excessively long anastomotic site that may impact peristaltic function, resulting in accumulation of intestinal content at the anastomosis site. In fact, one of the five cats that were excluded from the study because a standard GIA 60-mm stapling device was used, developed a severe sacciform dilation of the anastomosis site with subsequent coprostasis. No evidence of underlying intestinal pathology was present in this patient. Surgical resection and sutured end-to-end intestinal anastomosis resolved the clinical signs. The absence of specific investigations into the remodelling of the anastomotic site in 24 of 25 patients in this study prevented conclusions being drawn into the incidence and clinical relevance of this finding. Further investigations into the optimal stapler jaw length for FEESA in small dogs and cats are however warranted.

Fifteen out of 25 of our patients underwent intestinal resection and FEESA using an open lumen technique, whereas 10 of

25 underwent a one-stage technique. In the authors' experience, the use of endovascular-GIA stapling devices has a slight disadvantage compared to the use of standard GIA stapling devices, especially when a one-stage technique is chosen. Manipulating the intestine to manoeuvre the endovascular-GIA stapler jaws within the lumen is subjectively more difficult given the jaws cannot be separated. The procedure was, however, successfully completed in all the cases included in our study.

Our study included patients with a minimum of 10 days follow-up. This decision was based on a study that reported intestinal anastomosis dehiscence and subsequent septic peritonitis was identified within 3 to 10 days of surgery in 115 dogs and cats (Ralphs et al., 2003). In addition, a similar minimum follow-up period was selected in a study comparing the incidence of complications following FEESA in dogs (DePompeo et al., 2018). The authors concluded this minimum follow-up period was appropriate in identifying patients with a major surgical complication.

The retrospective nature of our manuscript and the small sample size are limitations of our study. Additionally, the inclusion of both canine and feline patients might limit the assessment of the outcomes. The presence of patients with underlying intestinal disease makes interpretation of some of our findings difficult. However, in conclusion, this study suggests that the use of endovascular-GIA stapling devices was safe and effective in performing FEESA in small dogs and cats. Further studies regarding the ideal height of the staples and the length of the stapler cartridge used are warranted.

Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Author contributions

S. Genoni: Data curation (equal); formal analysis (equal); investigation (equal); project administration (equal); writing – original draft (lead); writing – review and editing (equal). **F. Cinti:** Data curation (equal); writing – review and editing (equal). **M. Pilot:** Data curation (equal); writing – review and editing (equal). **M. Rossanese:** Data curation (equal); formal analysis (lead); methodology (equal); writing – review and editing (equal). **D. McCready:** Data curation (equal); writing – review and editing (equal). **M. Cantatore:** Conceptualization (lead); data curation (equal); formal analysis (equal); investigation (equal); project administration (equal); supervision (equal); writing – review and editing (equal).

Data availability statement

No data are available. All the relevant data have been included in the publication. Existing datasets are not publicly available due to privacy concerns.

References

Adams, W.M., Sisterman, L.A., Klauer, J.M., Kirby, B.M. & Lin, T.-L. (2010) Association of intestinal disorders in cats with findings of abdominal radiography. *Journal of the American Veterinary Medical Association*, **236**, 880–886. Available from: https://doi.org/10.2460/javma.236.8.880

Chan, D., Bishoff, J.T., Ratner, L., Kavoussi, L.R. & Jarrett, T.W. (2000) Endovascular gastrointestinal stapler device malfunction during laparoscopic nephrectomy: early recognition and management. *The Journal of Urology*, **164**, 319–321. Available from: https://doi.org/10.1016/s0022-5347(05)67349-1

Davis, D.J., Demianiuk, R.M., Musser, J., Podsiedlik, M. & Hauptman, J. (2018) Influence of preoperative septic peritonitis and anastomotic technique on the dehiscence of enterectomy sites in dogs: a retrospective review of 210 anastomoses. *Veterinary Surgery*, **47**, 125–129. Available from: https://doi.org/10.1111/vsu.12704

DePompeo, C.M., Bond, L., George, Y.E., Mezzles, M.J., Brourman, J.D., Chandler, J.C. et al. (2018) Intra-abdominal complications following intestinal anastomoses by suture and staple techniques in dogs. *Journal of the American Veterinary Medical Association*, **253**, 437–443. Available from: https://doi.org/10.2460/javma.253.4.437

Duffy, D.J. & Moore, G.E. (2020) Influence of oversewing the transverse staple line during functional end-to-end stapled intestinal anastomoses in dogs. *Veterinary Surgery*, **49**, 1221–1229. Available from: https://doi.org/10.1111/vsu.13451

Ellison, G.W., Case, J.B. & Regier, P.J. (2019) Intestinal surgery in small animals: historical foundations, current thinking, and future horizons. *Veterinary Surgery*, **48**, 1171–1180. Available from: https://doi.org/10.1111/vsu.13275

Foo, C.C., Chiu, A.H.O., Yip, J. & Law, W.L. (2018) Does advancement in stapling technology with triple-row and enhanced staple configurations confer additional safety? A matched comparison of 340 stapled ileocolic anastomoses. *Surgical Endoscopy*, **32**, 3122–3130. Available from: https://doi.org/10.1007/s00464-018-6027-1

Giuffrida, M.A. & Brown, C. (2017) Small intestine. In: Veterinary surgery: small animal, Vol. **2**. St. Louis, Missouri, USA: Elsevier, pp. 1730–1761.

Goto, T., Kawasaki, K., Fujino, Y., Kanemitsu, K., Kamigaki, T., Kuroda, D. et al. (2007) Evaluation of the mechanical strength and patency of functional end-to-end anastomoses. *Surgical Endoscopy*, **21**, 1508–1511. Available from: https://doi.org/10.1007/s00464-006-9131-6

Hiebert, E.C., Barry, S.L., Sawyere, D.M., DeMonaco, S.M. & Muro, N.M. (2022) Intestinal dehiscence and mortality in cats undergoing gastrointestinal surgery. *Journal of Feline Medicine and Surgery*, **24**, 779–786. Available from: https://doi.org/10.1177/1098612X211048454

Jardel, N., Hidalgo, A., Leperlier, D., Manassero, M., Gomes, A., Bedu, A.S. et al. (2011) One stage functional end-to-end stapled intestinal anastomosis and resection performed by nonexpert surgeons for the treatment of small intestinal obstruction in 30 dogs. *Veterinary Surgery*, **40**, 216–222. Available from: https://doi.org/10.1111/j.1532-950x.2010.00784.x

Kimura, M., Takahashi, H., Tanaka, T., Sagawa, H. & Takeyama, H. (2015) Weak points of a stapled side-to-side anastomosis. *Hepato-Gastroenterology*, **62**, 924–926.

Liu, C., Tsai, H.-L., Loong, C.-C., Hsia, C.-Y., Chin, T. & Wei, C. (2006) ENDO-GIA staplers for side-to-side anastomosis of veins. *European Journal of Vascular and Endovascular Surgery*, **32**, 584–588. Available from: https://doi.org/10.1016/j.ejvs.2006.04.037

Mullen, K.M., Regier, P.J., Waln, M., Fox-Alvarez, W.A. & Colee, J. (2020) Gastrointestinal thickness, duration, and leak pressure of six intestinal anastomoses in dogs. *Veterinary Surgery*, **49**, 1315–1325. Available from: https://doi.org/10.1111/vsu.13490

Naito, M., Miura, H., Nakamura, T., Sato, T., Yamanashi, T., Tsutsui, A. et al. (2017a) Sutureless functional end-to-end anastomosis using a linear stapler with polyglycolic acid felt for intestinal anastomoses. *Annals of Medicine and Surgery*, **17**, 50–53. Available from: https://doi.org/10.1016/j.amsu.2017.03.037

Naito, M., Sato, T., Nakamura, T., Yamanashi, T., Miura, H., Tsutsui, A. et al. (2017b) Secure overlap stapling using a linear stapler with bioabsorbable polyglycolic acid felt. *Asian Journal of Endoscopic Surgery*, **10**, 308–312. Available from: https://doi.org/10.1111/ases.12364

Perinjelil, V., Nkansah-Amankra, K., Maraqa, T., Mercer, L. & Sachwani-Daswani, G. (2018) Endo GIA stapler malfunction in a small bowel loop resection. *Journal of Surgical Case Reports*, **2018**, rjy281. Available from: https://doi.org/10.1093/jscr/rjy281

Powell, R.W. (1995) Stapled intestinal anastomosis in neonates and infants: use of the endoscopic intestinal stapler. *Journal of Pediatric Surgery*, **30**, 195–197. Available from: https://doi.org/10.1016/0022-3468(95)90559-6

Ralphs, S.C., Jessen, C.R. & Lipowitz, A.J. (2003) Risk factors for leakage following intestinal anastomosis in dogs and cats: 115 cases (1991–2000). *Journal of the American Veterinary Medical Association*, **223**, 73–77. Available from: https://doi.org/10.2460/javma.2003.223.73

Sanders, J.E., Regier, P.J., Waln, M. & Colee, J. (2023) Gastrointestinal thickness, duration, and leak pressure of five intestinal anastomosis techniques in cats. *Veterinary Surgery*, **53**, 384–394. Available from: https://doi.org/10.1111/vsu.14043

Schwartz, Z. & Coolman, B.R. (2018) Disposable skin staplers for closure of linear gastrointestinal incisions in dogs. *Veterinary Surgery*, **47**, 285–292. Available from: https://doi.org/10.1111/vsu.12759

Snowdon, K.A., Smeak, D.D. & Chiang, S. (2016) Risk factors for dehiscence of stapled functional end-to-end intestinal anastomoses in dogs: 53 cases (2001-2012). *Veterinary Surgery*, **45**, 91–99. Available from: https://doi.org/10.1111/vsu.12413

Sumner, S.M., Regier, P.J., Case, J.B. & Ellison, G.W. (2019) Evaluation of suture reinforcement for stapled intestinal anastomoses: 77 dogs (2008-2018). *Veterinary Surgery*, **48**, 1188–1193. Available from: https://doi.org/10.1111/vsu.13274

Tobias, K.M. (2007) Surgical stapling devices in veterinary medicine: a review. *Veterinary Surgery*, **36**, 341–349. Available from: https://doi.org/10.1111/j.1532-950x.2007.00275.x

Ullman, S.L. (1994) Surgical stapling of the small intestine. *The Veterinary Clinics of North America. Small Animal Practice*, **24**, 305–322. Available from: https://doi.org/10.1016/s0195-5616(94)50154-2

Ullman, S.L., Pavletic, M.M. & Clark, G.N. (1991) Open intestinal anastomosis with surgical stapling equipment in 24 dogs and cats. *Veterinary Surgery*, **20**, 385–391. Available from: https://doi.org/10.1111/j.1532-950x.1991.tb00344.x

White, R.N. (2008) Modified functional end-to-end stapled intestinal anastomosis: technique and clinical results in 15 dogs. *Journal of Small Animal Practice*, **49**, 274–281. Available from: https://doi.org/10.1111/j.1748-5827.2007.00499.x

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Owners' questionnaire.