Intestinal surgery in small animals – how to prevent it leaking?

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Intestinal surgery is required on a reasonably frequent basis in veterinary practice, whether to remove a foreign body, obtain biopsies for diagnosis or to deal with an intussusception. Where a skin wound is sutured and subsequently breaks down, although inconvenient, the result is rarely life-threatening.

If an intestinal wound breaks down, however, there can be significant morbidity and also, potentially, mortality associated with the resulting septic peritonitis. Surgery of the gastrointestinal tract (GIT) can be considered clean contaminated at best, with the bacterial load increasing as you progress distally along the tract. For this reason, the severity of the complications associated with dehiscence of an ileal or colonic incision will typically be more severe than for a more proximal leak (see Figure 1).

Figure 1: An enterotomy was made in the ileum of this Labrador to remove a foreign body 36 hours prior to this photo being taken; the dog was referred for management of septic generalised peritonitis secondary to leakage and dehiscence, but unfortunately despite aggressive management he progressed rapidly to systemic inflammatory response syndrome and multiple organ failure.

INTESTINAL SURGERY – A SHORT HISTORY

Intestinal surgery has, somewhat surprisingly, been around for a long time; it pre-dates anaesthetics, antibiotics and analgesics. There are written records of 12th century surgeons in London and Paris performing intestinal surgery, using "…elder pypes in the guttes under the seame…", the seame being the incision site; segments of dried intestine, bone, wax, tallow and dried tracheal segments from dead animals have also been described for support of intestinal incisions (Robinson, 1891). In 1812, Travers reported the importance of getting 'complete' apposition of both intestinal segments during anastomosis, identifying that leaving big gaps between sutures led inevitably to leakage although he incorrectly described the peritoneum as the crucial layer (Travers, 1812). In 1826, Lembert introduced an inverting vertical mattress suture, based on the belief that healing was dependent on full and complete apposition of the serosa/peritoneal layer, and Czerny then modified this into a two-layer inverting closure to reduce the risk of leakage further. Halstead correctly identified the submucosa as the crucial layer for suture-line integrity in 1887, with his preference being a single layer of interrupted horizontal mattress sutures, modified into a continuous inverting suture by Connell a few years later (Connell, 1892).

These historical developments and recommendations for intestinal surgery were predominantly based on extensive, and often barbaric, animal experimentation but relatively limited experience in people. The attitude towards intestinal surgery in human patients is nicely summarised in a paper regarding circular enterorrhaphy from 1891, which opens with the statement that intestinal surgery was, until recently, recognised as 'quite fatal' to the patient (Frank, 1891). This is, perhaps, not so surprising given the anaesthetic, analgesic and surgical protocols at the time coupled with the absence of antibiotics. Anaesthesia meant (at best) chloroform and/or ether, and sutures commonly reported for intestinal surgery in the late 19th and early 20th century included silk, linen and catgut. By convention, suture material was typically boiled in either a 5% carboxylic acid solution or phenol solution for at least 30 minutes prior to surgery to sterilise it (Bull, 1886). Following closure of intestinal incisions or perforations it was not uncommon to lavage the intestines with warm carboxylic acid solution, dilute formaldehyde and/or flush the intestinal tract through with salt solutions to remove toxins. Peri-operative management often included multiple enemas in the post-operative period to maintain this 'cleansing'.

Intestinal anastomosis was an even more problematic issue, and many patients with intestinal obstruction ended up with an 'artificial anus', meaning the intestine was transected proximal to the obstruction and marsupialised to the skin to relieve the obstruction, rather than attempting to resect and anastomose (Wagstaffe, 1885). At the time, many surgeons felt that suture closure of anastomoses was highly risky due to the risk of stenosis, prolonged surgical time leading to shock and leakage through needle tracks. A two-piece metal coupling device called the Murphy button was developed for sutureless anastomosis in the late 19th and early 20th centuries but was associated with reasonably high complication rates from intestinal necrosis, displacement

and the fact that it was, itself, a foreign body (Murphy, 1892; Frank, 1902). In the first years of the 20th century, mortality rates were stated in one report as 10.5-16% with Murphy button anastomoses, but 58-100% with hand sutured (Frank, 1902). The first 'surgical stapler' was described in by a Hungarian surgeon called Hültl in 1906, with modern-day surgical stapling devices evolving from extensive work carried out in Russia in the wake of World War II (Ballantyne, 1984).
In terms of hand-sutured intestinal wounds, true progress only followed the discoveries of Lister and the application of principles of aseptic surgery, combined with the development of more sophisticated surgical equipment and consumables, in tandem with progress in anaesthetic, analgesic and antibiotic medications in the 20th century.

INTESTINAL SURGERY – CURRENT RECOMMENDATIONS FOR BEST PRACTICE

1. PATIENT FACTORS

Thorough patient assessment is required prior to any surgery, to ensure that the patient is genuinely an appropriate candidate for surgery, and also to identify any negative or positive prognostic indicators.
Pre-operative assessment also allows accurate identification of the patient's fluid balance/imbalance and acid-base status including electrolyte derangements, eg. hypochloraemia, hypokalaemia and hyponatraemia with intestinal obstruction (Brown, 2012).
A retrospective case series in 2003 suggested that presence of two or more of the following factors meant an increased risk of leakage at anastomotic sites: pre-existing peritonitis, obstruction from intestinal foreign body (as opposed to other causes), and serum albumin less than 2.5g/dL (Ralphs et al, 2003; [see Figure 2]).
Studies in both people and animals have previously identified many other factors potentially associated with leakage of intestinal wounds, including sex (males are more likely to develop leakage than females in some studies), trauma, an intra-abdominal abscess, concurrent infection, malignancy, preoperative use of corticosteroids, increased age, chronic obstructive pulmonary disease, sepsis, hypertension, diabetes mellitus, and congestive heart failure (Allen et al, 1992; Ralphs et al, 2003).
Although a direct causative link has not been clearly shown, it is recognised that chronic weight loss of 15-20% is linked to poor visceral wound healing in general, and that certain medications (glucocorticoids, chemotherapeutics) have the potential to disrupt intestinal wound healing (Ellison, 2011). Delayed enteral feeding after surgery has also been implicated in an increased risk of leakage, hence the move towards early resumption of oral feeding.

2. GENERAL PRINCIPLES

Gentle tissue handling and atraumatic surgical technique are both very important to minimise trauma and therefore the risk of complications.
Steps should be taken to avoid desiccation of tissues under surgery lights, for example through regular lavage with warmed sterile fluids. It is also advisable to keep as much of the intestinal tract as possible within the abdomen and covered by soaked swabs.
Strict adherence to aseptic technique reduces the risk of infection, as does the use of antibiotics where indicated.
Soaked sterile swabs should be used to isolate those segments of the GIT that are to be opened, to minimise contamination from spillage of contents (see Figure 3).
Aseptic technique for intestinal surgery includes changing gloves after the contaminated portion of the procedure is complete, and using clean instruments and suture material for closure of the body wall.
Atraumatic surgical instruments that are fit for purpose should be used, for example Debakey and Adson-Brown thumb forceps are both acceptable for use on intestinal tissues, but so-called 'smooth' tissue forceps still found in many veterinary surgical packs are not appropriate. These are designed to hold swabs, not living tissue, and therefore if you hold intestinal tissue tight enough to stop it slipping out of the grip, it will cause patchy necrosis and damage. Babcock forceps may be used with care, but Allis tissue forceps should

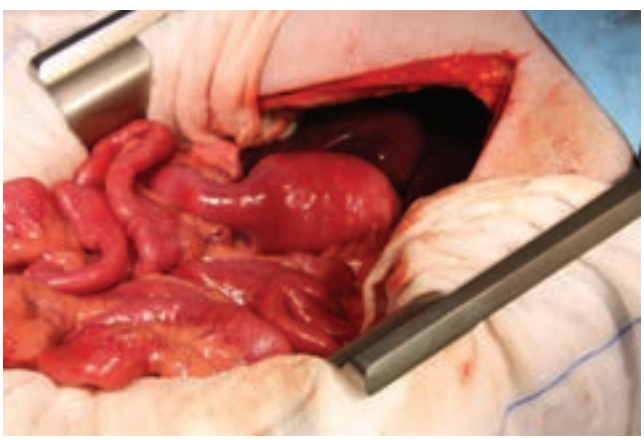

Figure 2: Foreign body obstruction of the small intestine was identified as a potential risk factor for anastomotic leakage in the study by Ralphs et al, 2003. This may reflect the potential difficulty in judging intestinal viability in the region of the foreign body and along the dilated proximal intestine, and how far to take the enterectomy in order to ensure good wound healing.

Figure 3: The surgical site should be isolated from the rest of the abdomen using sterile swabs to minimise the adverse effects of any leakage or spillage during surgery. This principle can be seen in this image taken during surgery to resect an ileocolic tumour.

never be used to hold intestine unless that segment is to be removed. Artery forceps should be placed with care to avoid causing collateral damage to neurovascular structures that might compromise intestinal viability. Doyen forceps can be very useful when operating single-handed, but care should be taken not to over-tighten and cause tissue damage.

3. PROPHYLACTIC ANTIBIOTICS

Antibiotic prophylaxis is the idea of giving pre-emptive antibiotics to prevent an anticipated infection, as opposed to therapeutic antibiotics where the drugs are being used to treat a confirmed infection.

A general rule of thumb is that prophylactic antibiotics should be used if there is a significant risk of contamination during surgery, or if a post-operative infection would be potentially catastrophic. As mentioned previously, the small intestine contains both gram-positive and gram-negative organisms; if the mucous membrane barrier of the intestine is disrupted for any reason then bacteria may move into surrounding tissues and lead to infection. This factor makes prophylactic antibiotics appealing for intestinal surgery, although the true need for antibiotic prophylaxis in every intestinal procedure is still debated (Brown, 2012).

If prophylactic antibiotics are going to be used, then they must be effective against the bacteria likely to be encountered (eg. proximal versus distal small intestine, small intestine versus colon). Also, the antibiotic must be in the tissues at the time of surgery, which means that giving antibiotics subcutaneously or intramuscularly around the time of surgery is both inappropriate and ineffective. Prophylactic antibiotics, by definition, should be given intravenously, typically one to two doses, but no more unless there is a compelling reason to continue therapeutic antibiotics (Brown, 2012).

4. SUTURE PATTERN

Two-layer closure of intestinal incisions was popular through much of the 19th and early 20th century, as most surgeons believed this gave greater security against leakage and would best restore anatomy. However, this belief was convincingly disproved in the mid-20th century, with several experimental studies showing that two-layer intestinal closure in fact gives significantly greater inflammation, more tissue necrosis, tissue microabscesses and reduced tensile strength; as such it is associated with a far higher risk of stenosis (Sako and Wangensteen, 1951; Ballantyne, 1984). It also gives poorer submucosal apposition, which is the crucial factor for primary intestinal wound healing (Brown, 2012).

Although there have been many studies of intestinal surgery that have utilised animals, few studies exist that address the question of what is best for outcome in dogs and cats, as opposed to what is going to be best in humans but can be tested for safety on dogs, cats and other animals. One of the few studies to directly evaluate the specifics of suture patterns in veterinary patients was published in 2003 (Kirpensteijn et al, 2003). These authors compared single-layer appositional with single-layer crushing and two-layer closure. This study identified that the single-layer appositional closure gave the best result with best histological restoration and least fibrosis; the crushing version induced more inflammation and necrosis, and problems with two-layer closure were as previously documented.

Figure 4: Serosal patching can be used to provide physical support to an enterotomy or enterectomy site. This technique is only required occasionally, but there are situations where it can be invaluable in bolstering a surgical site.

Single-layer closure provides consistently better results and is the recommended option in small animals, with the choice of interrupted versus continuous sutures being largely dictated by personal preference.

Everting suture patterns are generally not recommended, as they offer no benefit over appositional closure, but they do increase contamination and inflammation at the serosal surface that can delay healing and increase the risk of adhesions (Bellenger, 1982). Inversion causes compression of the blood supply in the inverted cuff; in smaller veterinary patients in particular this can predispose to reduced luminal diameter and stenosis (Bennett and Zydeck, 1970; Bellenger, 1982). Approximating patterns should avoid these potential complications.

5. SUTURE MATERIAL

The suture of choice for intestinal closure is monofilament synthetic absorbable, such as polydioxanone (PDS) or polyglyconate (Maxon), although there are some situations where non-absorbable materials such as polypropylene might be considered.

Shorter-acting monofilament suture such as poliglecaprone and glycomer 631 can also be used for intestinal surgery. They have similar handling properties to PDS but are degraded more quickly so there may be situations where they are better avoided, eg. where delayed wound healing may be encountered.

The newer 'plus' versions of suture material are impregnated with the antibacterial agent triclosan, which is suggested to reduce infection in skin and body-wall wounds; this may encourage use in intestinal surgery, although there is no

proof of efficacy for intestinal incisions and opinion remains divided on the subject of impact on surgical-site infection rate (Sandini et al, 2016).
Multifilament sutures in general cause more tissue drag and in the presence of contamination they can potentiate infection. They also tend to produce a greater inflammatory reaction in the tissues than monofilament sutures, and this can prolong the lag phase of wound healing, which in turns delays the return of strength (Brown, 2012).
Chromic gut is not suitable for enteric incisions as proteolytic enzymes found in GIT secretions degrade it, and it will stimulate a marked inflammatory reaction during dissolution (Ballantyne, 1984).

6. OMENTALISATION AND SEROSAL PATCHING

The omentum has an extensive vascular and lymphatic supply, and provides angiogenic and immunogenic stimuli that are beneficial in intestinal wound healing.
Once omentum is wrapped around an intestinal surgical site, it is often not necessary to physically suture it in place other than perhaps one or two strategic anchoring sutures.
It's important to remember that the omentum does not provide physical support, so if this is required, eg. to reinforce an intestinal repair where the strength of the wall is questionable, then serosal patching may be preferable (see Figure 4 [Jones et al, 1972; Crowe, 1984]).

ASSESSMENT OF INTESTINAL VIABILITY

This may be difficult but is clearly very important in terms of identifying situations that increase the risk of dehiscence, whether through tissue necrosis or suture pull-out from weakened tissue. The standard clinical criteria used to assess viability are colour, visible pulsation in the mesenteric vessels, and active, ordered peristalsis. These are all subjective criteria that require familiarity with what is normal to assess whether abnormality is present.
Subjective criteria always carry the potential to either over or underestimate viability, the key concern being underestimating how much of a compromised intestine needs to be resected. However, these are the only realistic criteria available for general use in practice. Surface oximetry has been suggested for assessment of perfusion, but this requires a specialised surface oxygen tension electrode, and only a few millimetres of intestine can be checked at a time.
Fluorescein-dye infusion has been recommended in many surgical textbooks, combined with Woods lamp illumination, but in dogs this assesses predominantly mucosal viability, not the full thickness of the wall. The other complicating factor is that fluorescein only tells you that there are vessels physically there or not; the important question is whether there is active efficient perfusion through those vessels.

LEAK-TESTING INTESTINAL INCISIONS

This is a surprisingly popular way of testing intestinal suture lines, frequently taught at undergraduate level, despite the limited information regarding reliability. Saline-leak testing as a concept comes from human surgery, but there it is almost exclusively used to evaluate colorectal anastomotic sites, not for general enterotomy or intestinal anastomosis (Saile et al, 2010). There is still only one *in vivo* veterinary study in the English language veterinary journals that evaluated saline leak testing for biopsy sites. This study used 38 experimental use hounds, ie. with no underlying intestinal abnormality, which automatically introduces a difference compared to clinical cases (Saile et al, 2010). The authors' conclusion from this study was as follows: "For canine jejunum, saline volumes of 16.3-19ml (digital occlusion) and 12.1-14.8ml (Doyen occlusion) can be used to achieve intraluminal pressures of 34cm water during leak testing of a 10cm segment containing a closed biopsy site."
This is very specific in terms of what was being tested, and whether the data can be generalised for use on all intestinal surgical sites in clinical patients of all sizes and species is far from clear. There are many anecdotal reports of apparently 'good' leak tests that developed septic peritonitis from leakage shortly following surgery, and it seems prudent not to rely too heavily on this single method of assessment.

SUTURES OR STAPLES?

This is an interesting question, and not one that necessarily has a quick and simple answer. Stapled anastomoses have comparable safety to hand sewn (where the surgeon is experienced in intestinal surgery) with similar leakage rates, but staples have the advantage of greater speed (Toyomasu et al, 2010; Jardel et al, 2011).
In hand-sewn anastomoses, work in the human surgical field confirms a higher complication rate in those with less experience, and in those doing fewer than 15 anastomoses per annum (Byrne et al, 2006). Where a surgeon is relatively inexperienced but is trained specifically in how to use stapling equipment to perform functional end-to-end anastomosis, a study from 2011 showed that the outcome can be good, although all the inexperienced surgeons in this particular study were working under direct supervision of a senior surgeon rather than on their own, which may skew the results (Jardel et al, 2011).
There are some situations where surgical stapling devices can be very useful, and can reduce surgical time, but in the author's opinion veterinary surgeons should not use staplers as a shortcut to doing a procedure that they would not be able to do if working by hand. If the staple cartridge misfires, the stapler breaks, something gets dropped, or the tissues are too oedematous to holds staples securely – you need to be able to complete the procedure by hand.
The stapled version of small intestinal anastomosis – functional end-to-end anastomosis – somewhat counter-intuitively does not actually mean joining the intestinal segments end-to-end in line with each other, as is familiar from hand-sewn anastomosis. The intestinal segments are laid side by side, and a GIA stapler used to create what is technically a side-to-side anastomosis, and this means cutting through the circular muscle layer (Brown, 2012).
This translates into reduced inter-digestive migratory muscle contractions for up to four weeks after surgery compared to hand-sewn end-to-end anastomosis, although the clinical impact of this in patients has not been specifically reported

(Toyomsau et al, 2010).

The other issue with stapling equipment is of course the added expense; three packets of suture material are significantly cheaper than investing in either single-use staplers or reusable stainless steel hand pieces with individual-use staple cartridges. The cost to the client will potentially be several hundred euro different, depending on what is required.

The use of a cheaper option, namely a skin stapler, for both enterotomy incisions and intestinal anastomoses has been reported (Coolman et al, 2000a and b) but these reports evaluated only a single type of skin stapler, and anyone who has ever used skin staplers will be aware that not all skin staplers are created equal. This may explain why, despite being a quick and reasonably cheap option, the use of skin staples for intestinal closure has not become routine in veterinary practice.

SUMMARY

As with any surgical procedure, it is important to take the time to properly assess the patient prior to surgery, to identify any risk factors that may be corrected, but also to be aware of risk factors that cannot be corrected in advance. Knowledge of surgical anatomy, and adhering to good basic principles of intestinal surgery is key to avoiding complications, together with making informed choices about the most appropriate suture patterns and types, or surgical stapling equipment where appropriate.

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