Evaluation of the Effect of Onlay Mesenteric Flaps on End-To-End Jejunojejunostomy Healing in Horses

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Objective: To evaluate the effect of onlay mesenteric flaps (MFs) with end-to-end jejunojejunostomy on stomal diameter, length of jejunum with reduced stomal diameter, abdominal adhesion formation, and healing.
Study Design: Experimental study.
Animals: Healthy adult horses (n = 6).
Methods: Two hand sewn end-to-end jejunal anastomoses using a 1 layer simple continuous serosubmucosal suture pattern were performed in each horse ~2 and 5 m oral to the ileocecal fold. Using a random design for selection anastomosis location (oral or aboral), 1 anastomosis was covered with 2 adjacent onlay MFs secured with interrupted sutures and cyanoacrylate glue. Two weeks later, adhesion formation, stomal diameter, length of reduced jejunal stomal diameter, and healing were evaluated.
Results: Use of onlay MFs decreased stomal diameter ($P = .05$), increased length of reduced peristomal jejunal diameter ($P = .05$), surgical time ($P = .003$), and serosal fibrosis ($P = .05$). No difference was evident for adhesion formation, and degree of inflammation between techniques.
Conclusion: End-to-end jejunojejunostomy covered with 2 onlay MFs is not recommended because this technique results in luminal reduction.

Ideally an anastomosis technique should maintain normal tissue orientation, promote first intention healing with minimal fibrosis through apposition of layers, form an impervious seal with complete mucosal coverage and minimal exposure of sutured edges, maintain adequate stomal diameter, and result in a rapid return of normal intestinal function.[1,2] Hand sewn end-to-end single layer anastomosis techniques result in larger stomal diameter than double layer end-to-end techniques.[3,4] An appositional single layer using a simple continuous pattern results in greater stomal diameter and more accurate tissue alignment; however, these techniques have been associated with increased incidence of abdominal adhesions compared to double layer inverting anastomosis and appositional single layer anastomosis covered with a hyaluronate membrane.[1,4]

Intra-abdominal adhesions develop during healing after abdominal surgery when there is damage to the visceral and parietal peritoneum.[5] In horses, adhesion formation is reportedly the most common cause of repeated episodes of colic after small intestinal surgery and the second most common cause for repeat celiotomy,[6–8] with an incidence of clinically consequential postoperative abdominal adhesions ranging from 9% to 28% confirmed at repeat celiotomy or at necropsy.[9,10] The true incidence of adhesions is likely higher; affected horses may not show associated clinical signs or may not have surgery again or be necropsied.[10,11]

Prevention is the most viable strategy for minimizing complications associated with intra-abdominal adhesion formation.[5] Preventive therapeutic modalities evaluated in horses include intra- and postoperative heparin,[12] postoperative peritoneal lavage,[13] omentectomy,[14] and intraperitoneal 1% sodium carboxymethylcellulose (SCMC) administration.[15] In people and rats barriers techniques, whereby surgically traumatized surfaces are protected during mesothelial regeneration have to prevent formation of fibrinous adhesions (i.e., the precursors of fibrous and permanent adhesions) between adjacent structures.[16,17] In horses application of SCMC and hyaluronate (HA) membrane to a single layer anastomosis[4] or in a serosal abrasion model[18] provided protection against perianastomotic adhesions. Covering a single layer Lembert pattern anastomosis with a SCMC and HA membrane improved outcome and decreased mortality.[19] Although use of SCMC and HA membranes appears to have a positive effect, they are not commercially available or are expensive. Alternatively, the mesentery can potentially be used as an affordable, protective membrane because it has most of the characteristics of an ideal barrier: high biocompatibility, adherence to traumatized surfaces, effective on oozing surface, and cost effective.[17] Furthermore, the mesentery can help to seal and provide vascular supply to the anastomosis.

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Jejunal anastomosis covered with a pedunculated mesenteric flap (MF) preserved from one end of the resected jejunal segment has been described,[20] but not evaluated in living horses. Furthermore the use of a single long MF may predispose to potential complications such as scarring and subsequent shortening of the mesentery and/or distortion of the jejunum compared to the use of 2 shorter MFs. We hypothesized that covering an end-to-end jejunal anastomosis with 2 MFs preserved from the supporting mesentery of the resected jejunal segment would prevent adhesion formation, and have no effect on stomal diameter compared with an uncovered single layer, simple continuous end-to-end anastomosis. Thus our purpose was to evaluate a barrier technique whereby segments of the supporting mesentery from the resected jejunal segment were used as onlay flaps to cover a single layer appositional end-end jejunojejunostomy during healing.

MATERIALS AND METHODS

Horses

Healthy small mixed breed (Manga Larga Marchador cross) horses (n = 6 [3 geldings, 3 mares]; mean age, 5.2 years [range, 2.5–17 years]; mean weight, 212 kg [range, 190–260 kg]) in good body condition were studied. All experimental procedures and animal care were approved by the institutional Animal Care and Use Committee. Two weeks before study, horses were administered ivermectin and tetanus toxoid and housed in individual (4 m × 4 m) stalls, fed 3 kg grain daily, and ad-libitum timothy hay and water.

Preoperative Management

The day before surgery, horses were weighed and complete physical examination, hematologic, and serum biochemical analyses performed. Food, but not water, was withheld for 12 hours before surgery. One hour before induction of general anesthesia, potassium penicillin (22,000 U/kg intramuscularly [IM]) and gentamicin sulfate (6.6 mg/kg intravenously [IV]) were administered. After premedication with xylazine hydrochloride (0.5 mg/kg IV), general anesthesia was induced with guaifenesin (120 mg/kg IV) and sodium thiopental (5 mg/kg IV) and maintained with halothane in oxygen in a semi closed system (spontaneous/assisted breathing). Lactated Ringer's solution (5 mL/kg/h) was administered during the surgical procedure. Dobutamine (0.002 mg/kg/min IV) was administered as needed to maintain mean arterial pressure >70 mmHg.

Surgical Procedure

Horses were positioned in dorsal recumbency and the ventral abdomen was clipped and surgically prepared for a 30 cm ventral median celiotomy. A standardized systematic exploration of the abdominal and pelvic cavities (~30 minutes) was performed to rule out any preexisting adhesions or other abnormalities. Warm sterile saline (0.9% NaCl) solution was used to prevent desiccation of the intestines during manipulation. The jejunum was exteriorized and examined from the ileocecal fold to the duodenocolic ligament.

Two end-to-end jejunojejunostomies were performed in each horse with the anastomotic technique location randomized by using an online randomization tool (www.random.org). Two ~40 cm jejunal segments, corresponding to 2 mesenteric arches, were selected for resection and anastomosis: 1 site was located 2 m oral to the beginning of the ileocecal fold and the 2nd site was 2 m oral to the 1st anastomosis.

The jejunal segment was resected obliquely (65° to the long axis of the jejunum), and end-to-end jejunojejunostomy completed using a single layer, simple continuous serosubmucosal appositional technique (SA) using 2-0 polyglactin 910. One anastomosis in each horse was randomly selected for protection with 2 onlay MFs developed from the supporting mesentery of the resected jejunal segment (Fig 1). To allow complete coverage of the anastomosis without tension or traction on the bowel by the MFs, a transverse cut in the mesentery was made to advance and increase flap length (Fig 1C). One MF was placed as an onlay graft over the anastomosis on 1 side of the jejunum (covering ~50% of the jejunal circumference) and the other flap was placed similarly on the other side so that the leading edge of each flap was in contact on the antimesenteric border (Fig 1D). Flaps were anchored to the serosal surface of the jejunum with 3–5 simple interrupted serosubmuscular sutures distributed along the edge of the MF. Small drops of *n*-butyl cyanoacrylate (Vetbond, 3M Corporation, St. Paul, MN) were interspersed along the MF edges between the simple interrupted sutures to adhere the mesentery to the serosal surface. The mesentery dorsal to mesenteric border was then sutured with 2-0 polyglactin 910 to its adjacent mesentery using a simple continuous pattern and then the remaining mesenteric defect closed (Fig 2).

Surgical time was recorded for each anastomosis. Start time was defined as the beginning of mesenteric vessel ligation and finish time was completion of closure of the mesenteric defect after anastomosis. The celiotomy was closed in layers: linea alba (3 nylon simple continuous pattern), subcutaneous tissue (2-0 chromic catgut simple continuous pattern); skin (*n*-butyl cyanoacrylate without sutures). A stent was sutured over the incision for the anesthetic recovery.

Postoperative Management

Immediately after anesthetic recovery, the stent was removed and an abdominal bandage was placed and changed daily for 4 days. Horses had free access to water, salt, and hay when returned to the stall. Grain was offered 12 hours after surgery. Non-steroidal anti-inflammatory drugs were not administered for analgesia because of their potential influence on adhesion formation; however xylazine (0.5–1 mg/kg IV) and butorphanol (0.005–0.01 mg/kg IV) were administered when necessary to alleviate discomfort. Using a small bore nasogastric catheter (nasogastric feeding tube 24 Fr × 240 cm, Mila International, Inc., Erlanger, KY) all horses were administered 25 L of balanced electrolyte solution containing NaCl (5.27 g/L), KCl

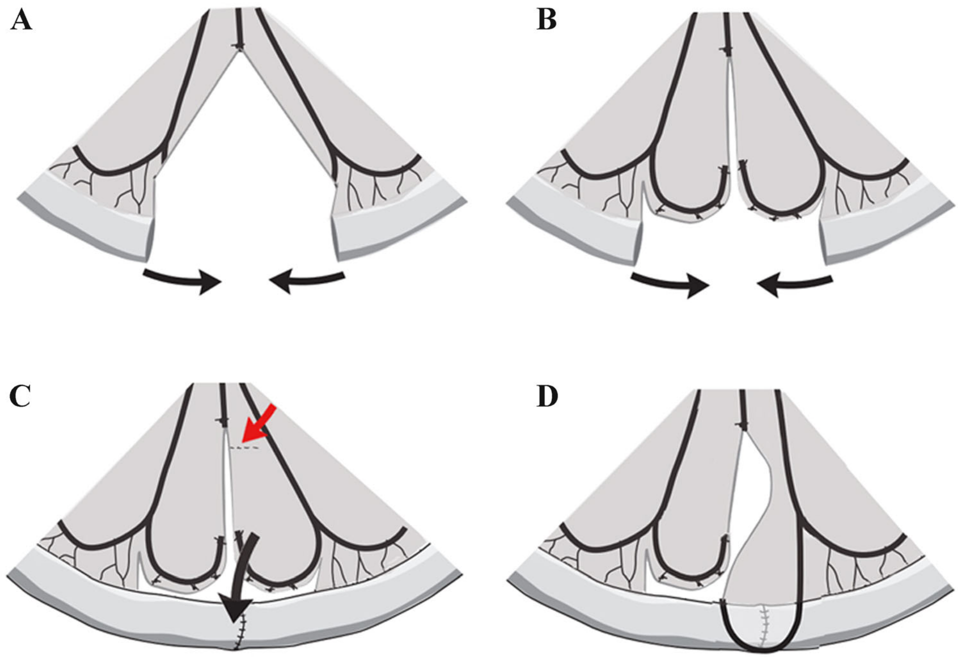

Figure 1 Jejunal resection without (A) or with (B) preservation of mesenteric flaps. (C) A transverse cut in the mesenteric flap was performed (red arrow) to increase the flap's length. (D) The flap has been advanced and placed over the anastomosis site covering ~50% of the jejunal circumference; the other flap was positioned similarly on the other side so that the leading edge of each flap was in contact on the antimesenteric border (not shown).

(0.37 g/L) and $NaHCO_3$ (3.78 g/L)[21] by continuous infusion (25 mL/kg/h) as the sole postoperative fluid therapy. Horses were monitored during and after enteral fluid therapy to identify sign of intolerance to the fluid therapy such as gastric reflux or other postoperative complication.

A complete physical examination was performed every 6 hours for the initial 48 hours and every 12 hours thereafter. Horses were monitored closely for colic, fever, appetite, water consumption, and fecal production. A modification of a numerical rating scale (NRS)[22] was used to evaluate pain before and every 4 hours after surgery. Horses were graded on gross pain behavior score (pawing, sweating, looking at the flanks, flehmen, and lying down/standing up repeatedly); from 1 to 4; where 1 = none, 2 = single time, 3 = occasional, and 4 = continuous. Any horse that had occasional or continuous pain behavior (NRS $\geq$ 3) was closely monitored, and treated with additional doses of xylazine and butorphanol. Horses were housed in individual stalls for 14 days, after which they were anesthetized using thiopental and ketamine, and euthanatized with potassium chloride (25 g in 1 L Ringer's lactate, IV). Necropsy was performed immediately after euthanasia.

Necropsy

Each anastomosis site was evaluated grossly for adhesions, impaction, distention of the small intestine oral to the anastomosis, and anastomotic distortion. The number and location of peritoneal adhesions were recorded. Peritoneal adhesions were classified using the following scale: 0 = no adhesions; 1 = omental adhesions only; 2 = localized fibrous adhesions to either bowel or mesentery, without significant distortion of the mesentery or bowel; 3 = several fibrous adhesions resulting in gross distortion of the bowel or adherence of multiple bowel loops; 4 = massive adhesions, with small bowel loops adhered to each other or to other parts of the intestinal tract.[23] Only adhesions involving the anastomosis sites and/or surgical incision were used for statistical analysis.

Stomal Diameter

Each anastomosis and 20 cm of jejunum oral and aboral to the anastomosis was removed and feed material rinsed from the lumen with isotonic saline solution. Using a modification of the technique described by Baxter et al.,[24] a silicone tube (inner diameter, 5 mm) was placed into 1 end of the jejunal segment, secured with umbilical tape, and attached to a sphygmomanometer to record intraluminal pressure. A 5 mm internal diameter propylene tube was secured with umbilical tape in the other end and used to infuse a 0.1% solution of barium sulfate in Ringer's lactate at a rate of 100 mL/min to an intraluminal pressure of 20 mmHg. The distended jejunal segment was placed over a 30 cm × 40 cm radiographic cassette and radiographed with the beam perpendicular to the mesentery. Using the radiographs, the width (stomal diameter) and length of the barium column were measured. Five width measurements were made: at the anastomosis, and at points located 5 and 10 cm on each side (oral, aboral) of the anastomosis. The relative stomal diameter at the anastomosis site was calculated by a modification of a previously described formula.[1]

$$\text{Stomal diameter} = \frac{100 \times (\text{mean size barium column outside anastomosis} - \text{barium column size at anastomosis})}{\text{Mean size barium column outside anastomosis}}$$

The peristomal length of reduced jejunal diameter was measured in the following manner. A tangent line to the antimesenteric border was drawn perpendicular to the transverse axis at the site of anastomosis. The contact points of this line with the column of barium on the anti-mesenteric border segments oral and aboral to the anastomosis determined the peristomal length of reduced jejunal diameter (Fig 3).

Histologic Evaluation

Immediately after radiographic examination, the barium solution was drained, and the segments rinsed with saline solution. Four full thickness jejunal samples were taken for histologic evaluation: at the anastomosis site (between mesenteric and anti-mesenteric border), at a segment where the mesentery had been anchored to the intestinal serosa with the *n*-butyl cyanoacrylate and sutures, at a segment between the 2 anastomosis sites (between mesenteric and anti-mesenteric border) and a full thickness sample of the abdominal incision including peritoneum and skin. All specimens were fixed in buffered 10% formalin, sectioned at 3 μm, and stained with hematoxylin and eosin.

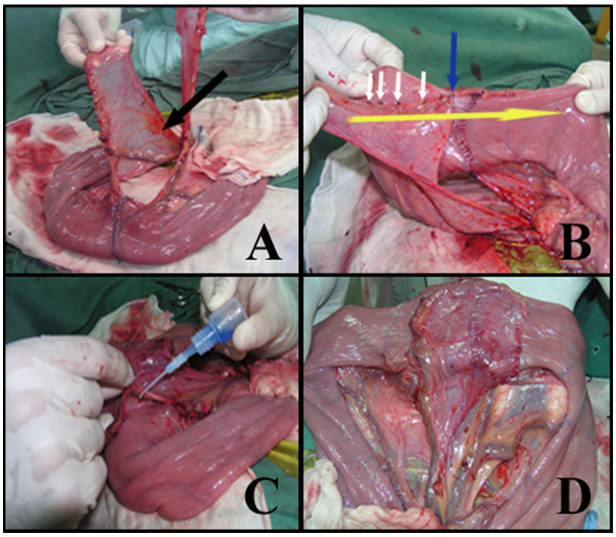

Figure 2 Photographs taken during construction of a simple continuous single layer end-to-end jejunojejunostomy covered with mesenteric flap. (A) Mesenteric flaps preserved from the supporting mesentery of the resected bowel. Notice the difference in length of the flaps before (left side) and after the transverse cut was performed (right). The arrow indicates the approximate place were the transverse cut was performed. (B) The mesenteric flap is now anchored to antimesenteric border by a simple interrupted suture (blue arrow) and ready to be placed over the anastomosis site (yellow arrow). White arrows indicate the ligatures of the jejunal vessels on the flap. (C) Application of *n*-butyl-cyanoacrylate glue drops between the simple interrupted sutures to adhere the mesenteric flap edge to the serosal surface of the jejunum. (D) Completed jejunojejunal end-to-end anastomosis covered with mesenteric flaps.

Sections were evaluated (light microscopy) by a pathologist unaware of the surgical procedures who graded 3 variables: inflammation (defined by leukocyte infiltration), serosal fibrosis, and serosal healing. For inflammation and serosal fibrosis a 0–3 scale was used: 0 = none, 1 = mild, 2 = moderate, 3 = severe. For serosal healing a 0–2 scale was used: 0 = none, 1 = incomplete, 2 = complete.[24] In the specimens from the abdominal incision inflammation and epithelial regeneration were evaluated.

Statistical Analyses

Software (SAS, version 8.2, SAS Institute, Inc., 2002; Cary, NC) was used for all statistical analyses. Continuous variables were analyzed with a mixed-model ANOVA to test for the effects of treatment while controlling for horse, age, and gender. Binary variables were analyzed with a generalized linear model. Initial analyses were performed by use of models that tested for treatment (MF vs. SA), horse, age, gender and period effects. There were no significant ($P < .05$) horse, age, gender, and location and order effects; therefore, the effects of these variables were removed from the models for the final analyses. Values of $P \leq .05$ were considered significant.

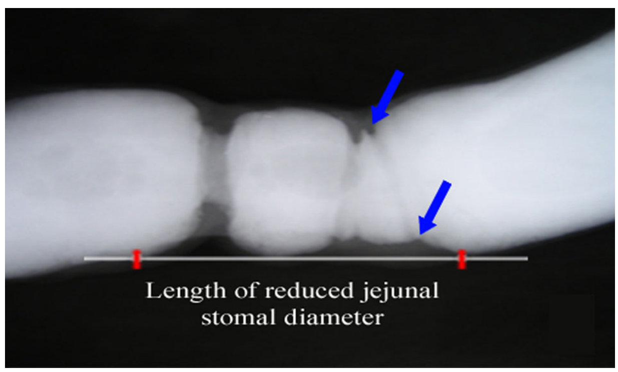

Figure 3 Contrast radiograph of an end-to-end jejunojejunostomy covered with 2 onlay mesenteric flaps. The intestinal segment was infused with a 0.1% solution of barium sulfate. Notice the cuff-like effect of the mesentery over the anastomosis site (blue arrows). To measure the peristomal length of reduced jejunal diameter, a line tangent to the antimesenteric border was drawn perpendicular to the transverse axis at the site of anastomosis. The contact points of this line with the column of barium on the anti-mesenteric border segments oral and aboral to the anastomosis (red bars) determined the peristomal length of reduced jejunal diameter.

RESULTS

Mean anesthesia time was 373 minutes (range, 327–378 minutes); time from anesthetic induction to start of surgery was 28 minutes (range, 15–50 minutes) and surgery time was 345 minutes (range, 310–363 minutes). Mean arterial pressure and O_2 saturation were >70 mmHg and >96%, respectively, in all horses during the entire length of the procedure.

No abdominal adhesions or abnormalities were identified during the initial abdominal exploration. MF (mean ± SD, 130 ± 8.7 minutes) took significantly longer to perform than SA (mean, 85 ± 17.7 minutes; $P = .003$).

All horses recovered from anesthesia without complications. Two horses had mild signs of abdominal discomfort (NRS score, 3) for 1–3 hours after recovery. Both horses responded well to a single dose of xylazine (1 mg/kg IV) and butorphanol (0.01 mg/kg IV). Two horses developed mild edema and mucopurulent discharge from the caudal aspect of the surgical incision that were treated with daily cleaning with topical antiseptic.

Necropsy Findings

There was evidence of focal incisional infection (dehiscence of the skin and subcutaneous inflammation) in the 2 horses that had clinical signs of surgical site infection. Those 2 horses also had peritoneal adhesions at the surgical incision involving the cecal apex and the large colon in 1 horse and the cecal apex and omentum in the other horse. One of those horses had signs of colic during the immediate postoperative period.

All anastomosis healed well and signs of dehiscence or leakage were not observed in any horse. Four horses had adhesions involving the anastomosis sites: horse 1—adhesion of the mesentery to the antimesenteric border on both MF and SA sites; horse 2—adhesion of the mesentery to the antimesenteric border of the MF site; horse 3—the site where a mesenteric vessel was ligated and transected was adhered to the mesenteric border of the SA site; and horse 4—adhesion of the large colon mesocolon to the MF site was observed. There was no significant difference in adhesion formation between MF and SA ($P = .4$; power 0.1).

Although not measured, evidence of shortening of the suspending mesentery at the anastomosis site was apparent in 4 horses at the MF site when compared with the SA site (Fig 4). In the MF group it was also noted that the mesentery had created a cuff-like effect around the anastomosis site resulting in greater reduction of stomal diameter (42.6 ± 8.78%) than SA (33.3 ± 2.59%; $P = .05$). There was also a longer peristomal segment of constricted jejunum in MF anastomoses (8.97 ± 2.52 cm) than in SA (6.25 ± 1.29 cm; $P = .05$; Fig 5).

Histologic Findings

Anastomotic healing was consistent with expectations at 2 weeks. The inflammatory response and inflammatory infiltrate was similar for anastomotic techniques ($P = 1.0$); however, serosal fibrosis was more pronounced for MF than SA ($P = .05$). A more intense serosal inflammatory response (foreign body-type) was noted where cyanoacrylate was used compared with sites where sutures were used (Fig 6). A mild to moderate inflammatory response with mobilization of mononuclear cells and macrophages was noted in the surgical incision especially in the deepest subcutaneous tissues.

DISCUSSION

We found that protecting an end-to-end jejunojejunostomy with MFs offered no apparent advantage because it took longer to perform, resulted in more serosal fibrosis and luminal stenosis and failed to prevent adhesion formation. The use of inert barriers to cover an intestinal anastomosis prevents intestinal adhesions in people,[16] rats,[17] and horses.[4,18,19] likely by preventing contact between damaged peritoneal surfaces during the early postoperative period when peritoneal adhesions typically form.[25] Covering the anastomosis site

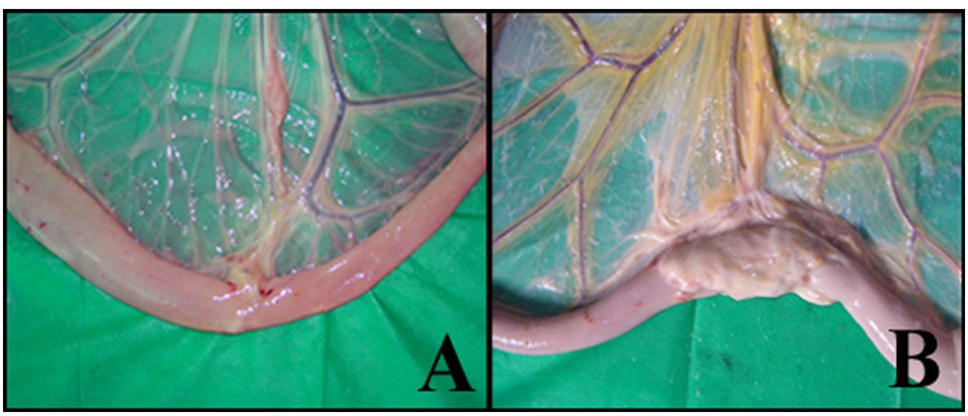

Figure 4 Necropsy photographs taken 14 days after surgery. (A) Simple continuous single layer end-to-end jejunojejunostomy not covered with mesenteric flaps; (B) simple continuous single layer end-to-end jejunojejunostomy covered with 2 mesenteric flaps. Notice the marked shortening of the mesentery on the MF anastomosis (B).

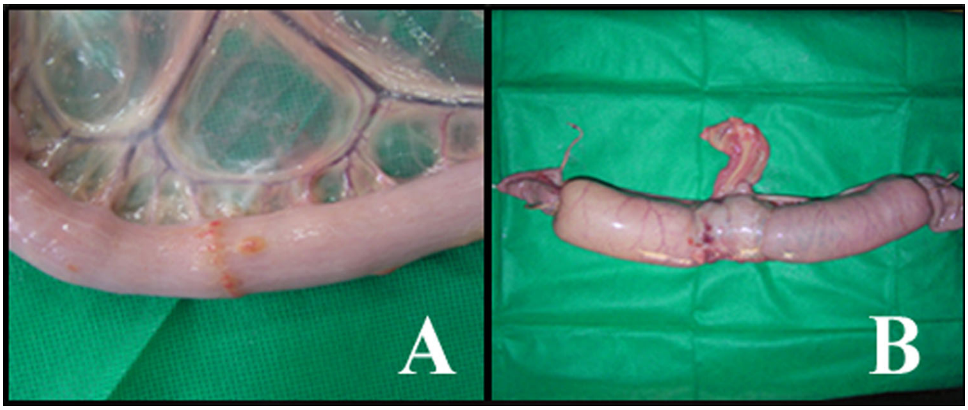

Figure 5 Photographs (immediately after euthanasia) of a simple continuous single layer end-to-end jejunojejunostomy not covered (A) or covered with 2 mesenteric flaps (B).

with vascularized MFs was expected to provide a vascular graft and patch to the anastomosis and prevent direct contact of the intestine traumatized by the suture with free serosal surfaces. In our study, it is possible that surgical trauma to the MFs may have induced excessive fibrosis and scarring making anastomosis more prone to peritoneal adhesions, and may have also accounted for the significant reduction in stomal diameter observed in the MF group.

We modified a reported single flap *ex vivo* technique[20] by constructing 2 MFs to cover the anastomosis site in an attempt to minimize the likelihood of intestinal distortion and stenosis from mesenteric traction because less flap length would be required to cover the jejunum. Secondly we reasoned that using *n*-butyl cyanoacrylate would decrease suture use to anchor the flaps, decrease surgical time, and avoid local ischemia from the sutures.

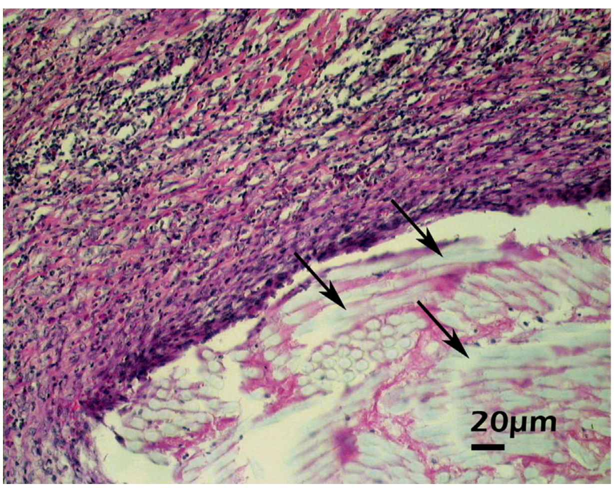

Figure 6 Histologic section in a region where the mesentery was anchored to the jejunal serosa with *n*-butyl cyanoacrylate. Notice the inflammatory infiltrate surrounding the fragments of *n*-butyl cyanoacrylate (arrows; H&E staining, 20×).

The cuff like effect noted in the MF anastomoses that resulted in significantly smaller stomal diameter and a longer peristomal segment of constricted jejunum was most likely because of mesenteric contraction during the tissue healing process. Despite the fact that we modified the flaps to increase mesenteric length and decrease tension at the MF anastomosis site, an evident shortening of the suspending mesentery was observed in 4 horses in the MF group. It has been reported that mesenteric tension and scarring has the potential to cause distortion and contracture resulting on kinking of the intestine, predisposing to obstruction.[24]

Although performing 2 anastomoses in the same horse increased the power of the study, this approach likely had disadvantages. Firstly, it resulted in longer surgical time, subsequently peritoneal and systemic inflammation were likely increased because of the increased tissue handling. Consequently this experimental approach may have countered any potential benefits of the MF technique. Further, lumen size reduction in MF anastomoses was more pronounced (42.6%) than when a hyaluronate membrane was used to cover an end-to-end jejunal anastomosis (28%)[4] constructed with the same suture pattern we used. Lumen reduction could be explained by MF tension and contraction during healing and the effects of significantly longer time to construct the MF anastomosis and increased tissue manipulation. It is known that regardless of how gently intestinal tissue is handled, mesothelial damage, peritoneal inflammation, and extravascular fibrin deposition can occur resulting in fibrosis as reported by Baxter et al.[24] who noted that mesenteric and serosal fibrosis and scarring had the potential to cause contracture and distortion that can predispose to obstruction.

Appropriate anastomotic healing and alignment of tissue layers was observed in all anastomosis samples of both types, supporting other observations that a single layer appositional anastomotic technique results in more accurate tissue alignment and improved healing.[1] Although no recent studies evaluating the effects of a single layer simple continuous end-to-end jejunojejunostomy are available, an earlier study reported this technique to be associated with a >50% incidence of intra-abdominal adhesion formation caused by exposed mucosa and suture,[1] observations similar to our findings where 4 horses had adhesions involving the anastomosis site (3 MF, 2 SA).

In our study, tissue glue (*n*-butyl-cyanoacrylate) was used as the sole method to close the skin after the subcutaneous tissue was apposed, resulting in a mild to moderate inflammatory response especially in the deepest tissues. To our knowledge there are no studies evaluating the effect of the *n*-butyl-cyanoacrylate on equine skin. Studies in rats[26] and dogs[27,28] using cyanoacrylate in the skin have shown similar tensile strength compared with suture closures providing evidence that cyanoacrylate glues are an alternative to skin sutures in those species. It is possible the catgut suture used to appose the subcutaneous tissue in our study contributed to the inflammatory response observed in our horses; therefore, further studies are needed to determine the potential use of cyanoacrylates for skin closure in horses.

We observed a severe inflammatory response on places were *n*-butyl-cyanoacrylate was used to attach the flap to the intestine. Similarly, use of *n*-butyl 2 cyanoacrylate to close equine descending colon enterotomies resulted in moderate inflammatory reaction 35 days after surgery and the *n*-butyl cyanoacrylate was still present on day 70.[29]

Postoperative fluid therapy is used to maintain hydration after intestinal surgery. Fluids administration by nasogastric tube has been described as an effective and relatively inexpensive hydration method in equine clinical cases[21]; however, use of enteral fluid therapy immediately after intestinal surgery has not been reported in horses. We observed no adverse effects of enteral fluid therapy after recovery from general anesthesia potentially supporting this approach for immediate postoperative fluid therapy after some types of abdominal surgery in horses. It should also be noted that these were otherwise healthy horses, and horses that have surgery to correct gastrointestinal disease may respond differently.

Some postoperative procedures we used are not commonly performed or recommended in clinical cases. Pain management was limited in an attempt to prevent deleterious effects of prostaglandin inhibition on tissue healing. However, a recent study reviewed the scientific information on the effect of non-steroidal anti-inflammatory drugs on tissue healing and concluded that short-term, low dose use of non-steroidal anti-inflammatory drugs do not appear to have a detrimental effect following soft tissue injury.[30] Our horses were administered analgesic agents only when they showed either occasional or apparent continuous pain behavior (pawing, sweating, looking at the flanks, flehmen, and lying down/standing up repeatedly).[22] Horses are prey animals and commonly do not display obvious pain in an effort to mask an injury. For this reason, it has been suggested to use additional physiologic and behavioral variables (posture and socialization scores) to evaluate pain after exploratory celiotomy. In a study by Pritchett, horses after abdominal surgery demonstrated pain only occasionally and spent most of the time without moving.[22] Similarly, dogs severely debilitated by major surgery may be less able to show painful behavior.[31] Therefore, it is possible that pain may have been underestimated in our horses. Further, if non-steroidal anti-inflammatory drugs are not used, the use of alternative analgesic drugs needs to be considered.

Our study had some limitations. The long surgery and anesthesia time and the pattern used to perform the anastomosis could have contributed to the high rate of adhesions and incisional complications observed. The use of cyanoacrylate glue to attach the MFs could have induced additional inflammatory response in the experimental group. Also, the lack of a significant difference in the number of adhesions between groups needs to be interpreted with caution because the low statistical power for this variable may have produced a type II error (failure to detect a significant difference).

We concluded that covering a jejunal anastomosis with 2 onlay MFs, using the technique we described significantly increased surgical time, serosal fibrosis and length of reduced luminal diameter and fail to prevent adhesions formation.

REFERENCES

1. Dean PW, Robertson JT: Comparison of three suture techniques for anastomosis of the small intestine in the horse. *Am J Vet Res* 1985;46:1282–1286
2. Mueller PO, Allen AD: Instrumentation and techniques in equine gastrointestinal surgery. *Vet Clin North Am Equine Pract* 1996;12:207–233
3. Nieto JE, Dechant JE, Snyder JR: Comparison of one-layer (continuous Lembert) versus two-layer (simple continuous/Cushing) hand-sewn end-to-end anastomosis in equine jejunum. *Vet Surg* 2006;35:669–673
4. Eggleston RB, Mueller E, Quandt JE, et al: Use of a hyaluronate membrane for jejunal anastomosis in horses. *Am J Vet Res* 2001;62:1314–1319
5. Avital S, Bollinger TJ, Wilkinson JD, et al: Preventing intra-abdominal adhesions with polylactic acid film: an animal study. *Dis Colon Rectum* 2005;48:153–157
6. Mair TS, Smith LJ: Survival and complication rates in 300 horses undergoing surgical treatment of colic. Part 1: short-term survival following a single laparotomy. *Equine Vet J* 2005;37:296–302
7. Baxter GM, Broome TE, Moore JN: Abdominal adhesions after small intestinal surgery in the horse. *Vet Surg* 1989;18:409–414
8. Parker JE, Fubini SL, Todhunter RJ: Retrospective evaluation of repeat celiotomy in 53 horses with acute gastrointestinal disease. *Vet Surg* 1989;18:424–431
9. Mair TS, Smith LJ: Survival and complication rates in 300 horses undergoing surgical treatment of colic. Part 3: long-term complications and survival. *Equine Vet J* 2005;37:310–314
10. Gorvy DA, Barrie Edwards G, Proudman CJ: Intra-abdominal adhesions in horses: a retrospective evaluation of repeat laparotomy in 99 horses with acute gastrointestinal disease. *Vet J* 2008;175:194–201
11. Eggleston RB, Mueller PO: Prevention and treatment of gastrointestinal adhesions. *Vet Clin North Am Equine Pract* 2003;19:741–763
12. Parker JE, Fibini SL, Car BD, et al: Prevention of intraabdominal adhesions in ponies by low-dose heparin therapy. *Vet Surg* 1987;16:459–462

13. Hague BA, Honnas CM, Berridge BR, et al: Evaluation of postoperative peritoneal lavage in standing horses for prevention of experimentally induced abdominal adhesions. *Vet Surg* 1998;27:122–126
14. Kuebelbeck KL, Slone DE, May KA: Effect of omentectomy on adhesion formation in horses. *Vet Surg* 1998;27:132–137
15. Hay WP, Mueller PO, Harmon B, et al: One percent sodium carboxymethylcellulose prevents experimentally induced abdominal adhesions in horses. *Vet Surg* 2001;30:223–227
16. Hashimoto D, Hirota M, Yagi Y, et al: Hyaluronate carboxymethylcellulose-based bioresorbable membrane (Seprafilm) reduces adhesion under the incision to make unplanned re-laparotomy safer. *Surg Today* 2012;42:863–867
17. Hellebrekers BW, Trimbos-Kemper GC, van Blitterswijk CA, et al: Effects of five different barrier materials on postsurgical adhesion formation in the rat. *Hum Reprod* 2000;15:1358–1363
18. Mueller PO, Hay WP, Harmon B, et al: Evaluation of a bioresorbable hyaluronate-carboxymethylcellulose membrane for prevention of experimentally induced abdominal adhesions in horses. *Vet Surg* 2000;29:48–53
19. Freeman DE, Schaeffer DJ: Clinical comparison between a continuous Lembert pattern wrapped in a carboxymethylcellulose and hyaluronate membrane with an interrupted Lembert pattern for one-layer jejunojejunostomy in horses. *Equine Vet J* 2011;43:708–713
20. Gandini MB, Bertuglia A: Mesenteric flap to prevent adhesions after small intestinal end to end anastomosis in the horse. *Proc 8th International Equine Colic Research Symposium*, Quebec City, Canada, August 2005, pp 94–96
21. Lopes MAF: Administration of enteral fluid therapy: methods, composition of fluids and complications. *Equine Vet Educ* 2003;15:107–112
22. Pritchett LC, Ulibarri C, Roberts MC, et al: Identification of potential physiological and behavioral indicators of postoperative pain in horses after exploratory celiotomy for colic. *Appl Anim Behav Sci* 2003;80:31–43
23. Baxter GM, Jackman BR, Eades SC, et al: Failure of calcium channel blockade to prevent intra-abdominal adhesions in ponies. *Vet Surg* 1993;22:496–500
24. Baxter GM, Hunt RJ, Tyler DE, et al: Sutured end-to-end and stapled side-to-side jejunal anastomoses in the horse. *Vet Surg* 1992;21:47–55
25. Rizzo A, Spedicato M, Mutinati M, et al: Peritoneal adhesions in human and veterinary medicine: from pathogenesis to therapy. A review. *Immunopharmacol Immunotoxicol* 2010;32:481–494
26. Sabol F, Vasilenko T, Novotny M, et al: Intradermal running suture versus 3M Vetbond tissue adhesive for wound closure in rodents: a biomechanical and histological study. *Eur Surg Res* 2010;45:321–326
27. De Carvalho Vasconcellos CH, Matera JM, Zaidan Dagli ML: Clinical evaluation of random skin flaps based on the subdermal plexus secured with sutures or sutures and cyanoacrylate adhesive for reconstructive surgery in dogs. *Vet Surg* 2005;34:59–63
28. Pope JF, Knowles T: The efficacy of *n*-butyl-cyanoacrylate tissue adhesive for closure of canine laparoscopic ovariectomy port site incisions. *J Small Anim Pract* 2013;54:190–194
29. Duarte CA, Cattelan JW, Alessi AC, et al: Conventional appositional pattern and cyanoacrylate tissue adhesive in descending colon enterorrhaphy in horses. *Ciência Rural* 2002;32:595–601
30. Chen MR, Dragoo JL: The effect of nonsteroidal anti-inflammatory drugs on tissue healing. *Knee Surg Sports Traumatol Arthrosc* 2013;21:540–549
31. Hansen B: Through a glass darkly: using behavior to assess pain. *Semin Vet Med Surg* 1997;12:61–74