Evaluation of a novel suture material for closure of intestinal anastomoses in canine cadavers

Lane A. Hansen, DVM, MS, and Eric L. Monnet, DVM, PhD

Objective—To compare leakage and maximum intraluminal pressures for a novel suture material with pressures for comparable suture material when used in closure of intestinal anastomoses in canine cadavers.

Sample—Healthy intestines from cadavers of dogs euthanized for reasons unrelated to the study.

Procedures—18 anastomoses were performed on intestinal sections within 72 hours after dogs were euthanized and intestinal samples collected. Anastomoses were performed with a simple continuous suture pattern. Leakage and maximum intraluminal pressures were measured and recorded for 6 control segments and 18 anastomosed sections. A barbed glycomer 631 suture (size 4-0 United States Pharmacopeia [USP]) was compared with glycomer 631 sutures (sizes 3-0 and 4-0 USP). Results for leakage and maximum intraluminal pressures were compared via an ANOVA.

Results—The barbed glycomer 631 suture material leaked at a significantly higher pressure than did the comparable glycomer 631 suture materials. Maximum intraluminal pressures were not significantly different among the suture materials.

Conclusions and Clinical Relevance—Barbed glycomer 631 4-0 USP suture material was as effective as glycomer 631 suture materials and may be a safe alternative for use in closure of enterectomies in dogs. (*Am J Vet Res* 2012;73:1819–1823)

Gastrointestinal or abdominal disease is encountered in small animal patients, and it frequently requires surgical treatment (biopsy, foreign body removal, or resection and anastomosis) of the small intestine.[1–3] Foreign body obstruction of the small intestine can result in perforation or necrosis of a portion of bowel, which necessitates resection and anastomosis of the remaining healthy intestine. Intestinal leakage can have devastating consequences and may lead to peritonitis and death.[1–4] The reported incidence for intestinal leakage and dehiscence is between 3% and 28%.[3,5–7] Decreasing the risk of leakage after intestinal resection and anastomosis is important for improving the long-term outcome after gastrointestinal surgery in dogs and cats. The current method of choice for end-to-end anastomosis in small animals is a simple, interrupted or continuous, single-layer, approximating technique with monofilament absorbable suture material.[2,3]

Received October 7, 2011.
Accepted December 28, 2011.
From the United States Army 106th MD BN VET SVC, APO AP (Korea), 96351 (Hansen); and the Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523 (Monnet).
The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the US Government.
Address correspondence to Dr. Monnet (Eric.Monnet@ColoState.edu).

Abbreviation

USP	United States Pharmacopeia

Barbed absorbable suture material is available to surgeons. Barbed suture is manufactured by a process that creates unidirectional barbs that become lodged in the tissue, which creates multiple anchor points to distribute tension along the suture. Barbed suture exerts bidirectional tensile pull strengths that are equivalent to those of a barbless suture of the same material that is the same size or 1 USP size smaller.[8] Suture stock (3-0 synthetic absorbable glycomer 631 material) is processed to create a barbed suture (4-0 barbed glycomer 631) equivalent in diameter to a nonbarbed 4-0 suture.

Barbed suture materials do not require knots for suture security at the end of a continuous suture line. This can result in more rapid suture placement and decreased wound complications.[9] Barbed suture materials have been used for urinary surgery, gastrointestinal surgery, and reconstructive surgery in human patients.[9–13] It has also been used extensively during laparoscopy because its use eliminates the need for intracorporeal knot tying.[14]

The purpose of the study reported here was to evaluate a novel suture material in comparison with currently available, comparable absorbable suture material. We hypothesized that small intestine enterectomies in canine cadaveric specimens sutured with barbed glycomer 631(4-0 USP) suture material would perform

similarly to small intestine enterectomies in canine cadaveric specimens sutured with glycomer 631 (3-0 and 4-0 USP) suture materials.

Materials and Methods

Healthy small intestine was harvested from the cadavers of 4 dogs euthanized for reasons unrelated to the study. Dogs were euthanized by IV infusion of pentobarbital-phenytoin sodium.[a] Intestines were harvested immediately after the dogs were euthanized. Intestines were cut into 40- to 60-cm segments, placed in sterile saline (0.9% NaCl) solution, and stored at 4°C for a period of < 72 hours. The segments were removed from the saline solution and cut into 6- to 8-cm sections for use in anastomoses. Each anastomosis was performed with 4-0 USP barbed glycomer 631 suture,[b] 3-0 USP glycomer 631 suture,[c] or 4-0 USP glycomer 631 suture[d] and a CV-23 one-half circle 17-mm taper needle.

Test constructs were created by anastomosis of 2 sections with the selected suture. In preparation for construction, luminal contents of a section were gently expressed. The cut edge was debrided to ensure that the 2 apposed sections were of similar size with regard to luminal diameter. Anastomoses were performed by initially placing 2 simple continuous sutures (1 at the mesenteric border and 1 at the antimesenteric border). All anastomoses were performed by the same investigator (LAH). The tension on the suture was not measured.

Anastomoses were performed in accordance with a standard surgical technique.[3] In anastomoses performed with 3-0 and 4-0 USP glycomer 631, each line was secured with 4 square knots. In anastomoses performed with 4-0 USP barbed glycomer, each line was secured by passing the needle and suture through the tissue of both intestinal sections and then passing it through the prefabricated suture loop (**Figure 1**). Tension was then placed on the suture to draw the loop tight to the tissue. A simple continuous suture was placed, with insertions 2 to 3 mm apart and 2 to 3 mm from the tissue edge. Tension was placed on the suture to draw it tight after each pass through the tissue to maintain constant noncrushing tension on the tissue. When the final antimesenteric loop was placed, the suture was tied with 4 square knots in a standard manner (3-0 and 4-0 USP glycomer 631 group) or 3 additional suture insertions were made before the suture was cut without tying a knot (4-0 USP barbed glycomer 631 group).[9]

Anastomosis of the remaining circumference of the intestinal sections was then completed in a similar manner. Once anastomosis of each section was completed, sections were replaced in the saline solution and stored at 4°C to prevent drying of the tissues. All anastomoses were performed during 2 construction sessions 24 hours apart, with half of the anastomoses completed during each session. Tissues were also stored in the saline solution at 4°C between the construction sessions.

Pressure testing—Testing was performed the day after the second construction session. The constructs were tested in random order. Sections in the control group were tested in the same manner as for the 3 treatment groups.

A 4-cm-long, 12F catheter was inserted 3.5 cm into the end of a section, which was then sealed with a Doyen clamp placed (from the mesenteric border) as close as possible to the catheter (approx 3 cm from the catheter tip). A right-angle Rochester-Carmalt forcep was placed closely parallel to the catheter and intersected with the Doyen clamp at a 90° angle to prevent leakage. A microtip pressure transducer[e] was introduced 3 to 4 cm into the lumen at the opposite end of the section. The transducer was connected to a data acquisition system[f]; the transducer was calibrated before each experiment. It was secured with a Doyen clamp placed across the intestine and transducer (**Figure 2**). The instrumented section of intestine was then submerged in a plastic tub filled with water. The infusion catheter system was primed with saline solution that contained methylene blue (1 part methylene blue[g]:500 parts saline solution). This dye-containing saline solution was delivered at a rate of 999 mL/h with an infusion pump.[h]

The system was purged of air, recording of pressure measurements was begun, and infusion of the saline solution was started. The leakage pressure was

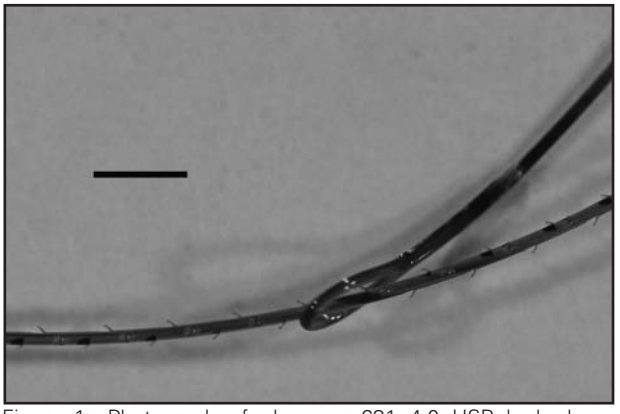

Figure 1—Photograph of glycomer 631 4-0 USP barbed suture material. Notice the prefabricated loop and the barbs. Bar = 5 mm.

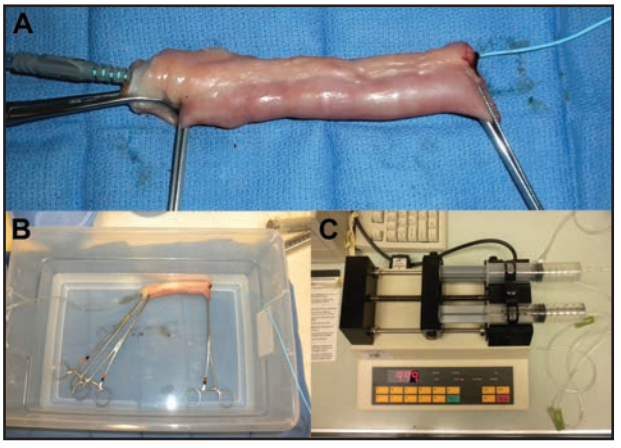

Figure 2—Photographs of the testing apparatus used to evaluate the efficacy of glycomer 631 4-0 USP barbed suture material for use in anastomoses of intestinal segments obtained from canine cadavers. An infusion catheter and pressure transducer are inserted in the left and right ends, respectively, of a control section of intestine (A), which is then submerged into a tub filled with water (B) for testing of leakage and maximum intraluminal pressures via an infusion system (C).

recorded. Leakage pressure was defined as the pressure at which the dye-containing saline solution was first observed to leak from the anastomosis. Once the initial leakage pressure was recorded, testing was allowed to continue until there was a catastrophic failure of the intestine, the intraluminal pressure reached a plateau, or the maximum pressure for the sensor system was achieved. The maximum intraluminal pressure reached and method of failure for each section were recorded.

Statistical analysis—Results for intestinal anastomoses were analyzed with commercially available software.[i] A Shapiro-Wilk test was used to evaluate whether the leakage pressure was normally distributed. The leakage pressure and maximum intraluminal pressure were compared between groups via a 1-way ANOVA. Data were reported as mean ± SD. Significance was set at values of $P \leq 0.05$.

Results

Mean ± SD leakage pressure was significantly ($P < 0.001$) higher for the 4-0 USP barbed glycomer 631 group (53.3 ± 5.7 mm Hg), compared with that for the 3-0 USP glycomer 631 group (34.0 ± 6.9 mm Hg) and 4-0 USP glycomer 631 group (28.0 ± 6.7 mm Hg; **Figure 3**). There was no significant difference in leakage pressure between the 3-0 USP glycomer 631 group and 4-0 USP glycomer 631 group. Maximum intraluminal pressure was not significantly ($P < 0.886$) different among the 4-0 USP barbed glycomer 631 group (185.2 ± 67.9 mm Hg), 3-0 USP glycomer 631 group (179.3 ± 47.6 mm Hg), and 4-0 USP glycomer 631 group (169.8 ± 44.6 mm Hg; **Figure 4**).

For the control group, the intraluminal pressure reached a plateau because there was leakage (around the infusion catheter or pressure transducer) or the maximum pressure for the sensor system was achieved. At values > 250 mm Hg, the sections had variable evidence of serosal tearing, but there was no leakage through the submucosa-muscularis layer. The mean ± SD maximum intraluminal pressure for the control group was 272.7 ± 22.7 mm Hg.

In the treatment groups, the first indication of failure was dye-containing saline solution that leaked through 1 or more suture holes. Mild tearing (on the side away from the anastomosed tissue edge) could be seen adjacent to the sutures and was the mode of failure for all the tested sections, regardless of suture type. With continued infusion, the intraluminal pressure reached a maximum pressure plateau. One of the sections in the 4-0 USP glycomer 631 group had serosal tearing at the maximal intraluminal pressure.

None of the tested sections ruptured or burst. All sections in the control group, except for 1, had some leakage (around the inflow catheter or pressure transducer) at the conclusion of testing, and 4 of the 6 sections had signs of serosal tearing.

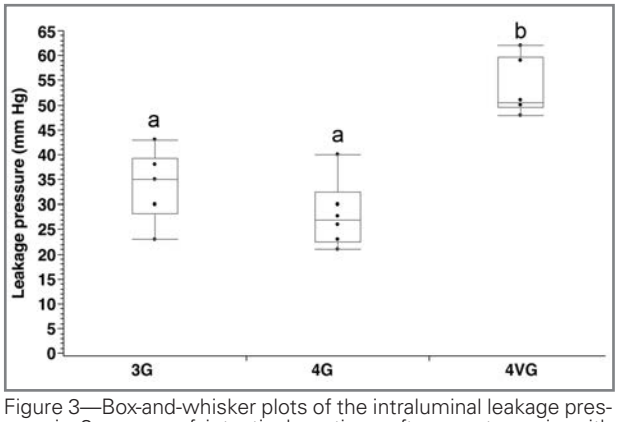

Figure 3—Box-and-whisker plots of the intraluminal leakage pressure in 3 groups of intestinal sections after anastomosis with various suture materials (3-0 USP glycomer 631 [3G], 4-0 USP glycomer 631 [4G], and 4-0 USP barbed glycomer 631 [4VG]). The bottom and top of the box are the 25th and 75th percentiles (the lower and upper quartiles, respectively), the horizontal line inside each box represents the median, and the whiskers represent the minimum and maximum of all the data; each black circle represents the pressure recorded for a specific section (values reported represent results for all 6 intestinal sections for each treatment, but some values overlap). [a,b]Values with different letters differ significantly ($P < 0.001$).

Discussion

Anastomoses closed with barbed glycomer 631 suture leaked at a higher intraluminal pressure than did anastomoses closed with conventional sutures. The maximum intraluminal pressure reached with each suture material did not differ significantly.

Within the first 24 hours after surgery, leakage of an anastomosis is the most common cause of septic peritonitis. Therefore, the leakage pressure is the most important variable for evaluation of the safety of a closure technique. In the present study, the barbed suture provided an anastomotic closure that was able to sustain a significantly higher leakage pressure (1.5 to 2 times as high) than the leakage pressure obtained with conventional sutures of similar diameter. Each suture material was able to sustain higher pressure than the typical jejunal pressure in a dog, even pressures obtained during peristaltic waves. Jejunal intraluminal pressures have been estimated at 15 to 25 mm Hg during peristalsis in healthy dogs.[15] In pigs, the leakage pressure of an enterotomy was 25 mm Hg at 3 days after surgery.[9]

Dogs with experimentally induced complete ileal obstruction had a maximum intraluminal pressure of

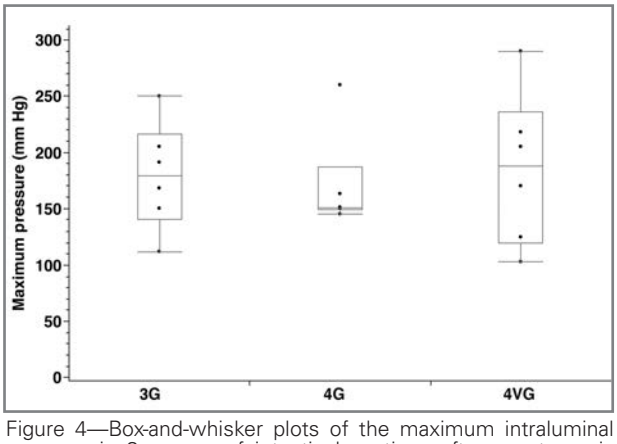

Figure 4—Box-and-whisker plots of the maximum intraluminal pressure in 3 groups of intestinal sections after anastomosis with various suture materials (3G, 4G, and 4VG). Values did not differ significantly ($P = 0.886$) among treatments. *See* Figure 3 for remainder of key.

44 mm Hg at 3 days after obstruction.[16] In a recent study[j] that involved the use of a wireless motility capsule, investigators detected a mean ± SD maximum pressure of 32 ± 6.2 mm Hg (maximum instantaneous pressure, 105 ± 75 mm Hg) in the small intestine of conscious dogs. The mean pressure decreased to 6.1 ± 5.8 mm Hg (maximal instantaneous pressure, 21 ± 23 mm Hg) during anesthesia maintained by administration of sevoflurane.[j] These maximal pressures were below the leakage pressure recorded for the 4-0 USP barbed glycomer 631 group in the present study. The importance of the maximum instantaneous pressure is unknown.

Maximum pressure recorded with a fluid infusion technique in the study reported here was similar to or greater than the pressures reported in other studies.[1,2,4,17–19] Testing of the control group sections revealed that the intestine retained strength. Postoperative maximum pressure after enterectomy repaired with various techniques is between 15 and 185 mm Hg.[1,2,4,17–19] The variability in the results can be attributed to the technique used to evaluate maximum pressure and the technique used to perform the enterectomy. The maximum intraluminal pressure (termed bursting pressure in some studies) recorded in the present study exceeded expected intraluminal pressures of healthy intestine (even in the presence of a complete intestinal obstruction).

Because the barbs are cut into the suture, the hole made by barbed suture should be larger than the shaft of the suture, which could be predicted to leak at a lower pressure than for the comparable nonbarbed sutures. Additionally, the barbs have the potential to cause more trauma to the tissue. The amount of tissue trauma was not directly evaluated in the cadaveric tissues of the present study. If the barbs caused more trauma, the degree was not substantial enough to induce leakage at the suture holes at a lower pressure than for the comparable conventional sutures. Leakage from the suture holes was detected in each sample in the study. This finding suggested that the barbs were not more traumatic than a conventional suture or the barbs contributed to a better seal. The barbs may pass through tissues without causing additional trauma, which allows the tissue to recoil onto the suture core and not allow leakage.

Another explanation is that the barbed design allows the suture to be tightened without a loss of tension as the anastomosis is performed, which may be the reason that the sections with the barbed suture yielded the best results. The amount of tension placed on the suture was not measured during anastomosis; however, all sections were sutured in accordance with clinical standards by the same investigator to minimize the effect of variation in tension. These results suggested that the barbed suture is a safe material for use in intestinal anastomosis in dogs.

Limitations of the present study include the nonphysiologic method of testing and the use of cadaveric tissues that may hold sutures or behave differently than intestinal tissues in living dogs. Testing of the fresh cadaver control tissues was performed to ensure that there had not been tissue breakdown and to enable us to evaluate the tissue strength relative to results in other studies.[1,2,4,17,19] The tissue performed extremely well (as indicated by the supraphysiologic leakage and maximum intraluminal pressures obtained), which we interpreted to indicate that the intrinsic tissue properties remained. In the present study, we did not assess the effect of early healing that may occur in vivo and that may influence protection against leakage during the postoperative period. The barbed suture would be expected to lose 50% of its tensile strength within 3 weeks after surgery, which is characteristic of the breakdown of glycomer 631 suture material. Glycomer 631 suture material is routinely used in intestinal surgery of dogs, and its use in intestinal surgeries in humans has been reported.[20]

In the study reported here, we determined that a barbed suture made of glycomer 631 can be used in anastomoses of dogs. The barbed glycomer 631 (4-0 USP) suture material was an effective material for use in performing an in vitro intestinal anastomosis in dogs and should be expected to perform as effectively as the glycomer 631 (3-0 and 4-0 USP) suture materials.

a. Beuthanasia-D Special, Intervet Inc, Merck Animal Health, Summit, NJ.
b. V-Loc 90, 4-0 USP, provided by Covidien Animal Health, Mansfield, Mass.
c. Biosyn, 3-0 USP, provided by Covidien Animal Health, Mansfield, Mass.
d. Biosyn, 4-0 USP, provided by Covidien Animal Health, Mansfield, Mass.
e. Mikro-Tip catheter transducer, Millar Instruments Inc, Houston, Tex.
f. SonoLab, Sonometrics Corp, London, Ontario, Canada.
g. Fisher Scientific, Pittsburgh, Pa.
h. Harvard Apparatus, Holliston, Mass.
i. JMP, SAS Institute Inc, Cary, NC.
j. Cochran S, Twedt DC, Boscan P. Evaluation of gastric transit time, motility, and pH during sevoflurane anesthesia in dogs (abstr). *Vet Anaesth Analg* 2011;38:3.

References

1. Saile K, Boothe HW, Boothe DM. Saline volume necessary to achieve predetermined intraluminal pressures during leak testing of small intestinal biopsy sites in the dog. *Vet Surg* 2010;39:900–903.
2. Coolman BR, Ehrhart N, Pijanowski G, et al. Comparison of skin staples with sutures for anastomosis of the small intestine in dogs. *Vet Surg* 2000;29:293–302.
3. Weisman DL, Smeak DD, Birchard SJ, et al. Comparison of a continuous suture pattern with a simple interrupted pattern for enteric closure in dogs and cats: 83 cases (1991–1997). *J Am Vet Med Assoc* 1999;214:1507–1510.
4. Bone DL, Duckett KE, Patton CS, et al. Evaluation of anastomoses of small intestine in dogs: crushing versus noncrushing suturing techniques. *Am J Vet Res* 1983;44:2043–2048.
5. Boag AK, Coe RJ, Martinez TA, et al. Acid-base and electrolyte abnormalities in dogs with gastrointestinal foreign bodies. *J Vet Intern Med* 2005;19:816–821.
6. Ralphs SC, Jessen CR, Lipowitz AJ. Risk factors for leakage following intestinal anastomosis in dogs and cats: 115 cases (1991–2000). *J Am Vet Med Assoc* 2003;223:73–77.
7. Allen DA, Smeak DD, Schertel ER. Prevalence of small intestinal dehiscence and associated clinical factors: a retrospective study of 121 dogs. *J Am Anim Hosp Assoc* 1992;28:70–76.
8. Rashid R, Sartori M, White LE, et al. Breaking strength of barbed polypropylene sutures: rater-blinded, controlled comparison with nonbarbed sutures of various calibers. *Arch Dermatol* 2007;143:869–872.
9. Demyttenaere SV, Nau P, Henn M, et al. Barbed suture for gas-

trointestinal closure: a randomized control trial. *Surg Innov* 2009;16:237–242.
10. Tewari AK, Srivastava A, Sooriakumaran P, et al. Use of a novel absorbable barbed plastic surgical suture enables a "self-cinching" technique of vesicourethral anastomosis during robot-assisted prostatectomy and improves anastomotic times. *J Endourol* 2010;24:1645–1650.
11. Paul MD. Barbed sutures for aesthetic facial plastic surgery: indications and techniques. *Clin Plast Surg* 2008;35:451–461.
12. Rosen AD. Use of absorbable running barbed suture and progressive tension technique in abdominoplasty: a novel approach. *Plast Reconstr Surg* 2010;125:1024–1027.
13. Zeplin PH, Zahn RK, Meffert RH, et al. Biomechanical evaluation of flexor tendon repair using barbed suture material: a comparative ex vivo study. *J Hand Surg* 2011;36:446–449.
14. Kaul S, Sammon J, Bhandari A, et al. A novel method of urethrovesical anastomosis during robot-assisted radical prostatectomy using a unidirectional barbed wound closure device: feasibility study and early outcomes in 51 patients. *J Endourol* 2010;24:1789–1793.
15. Tasaka K, Farrar JT. Intraluminal pressure of the small intestine of the unanesthetized dog. *Pflügers Arch* 1976;364:35–44.
16. Shikata J, Shida T, Amino K, et al. Experimental studies on the hemodynamics of the small intestine following increased intraluminal pressure. *Surg Gynecol Obstet* 1983;156:155–160.
17. Curran KM, Fransson BA, Gay JM. A comparison of in situ and in vitro techniques for bursting pressure testing of canine jejunum. *Am J Vet Res* 2010;71:370–373.
18. Ellison GW. End-to-end anastomosis in the dog: a comparison of techniques. *Compend Contin Educ Pract Vet* 1981;3:486–494.
19. Semevolos SA, Reed SK, Gamble K. In vitro bursting pressures of jejunal enterotomy closures in llamas. *Vet Surg* 2007;36:64–67.
20. Olah A, Belagyi T, Neuberger G, et al. Use of different absorbable sutures for continuous single-layer anastomosis in the gastrointestinal tract. A prospective, randomized study. *Dig Surg* 2000;17:483–486.