Cystotomy is one of the most common procedures in veterinary surgery. Because of the role of the urinary bladder as a urine reservoir, cystotomy closure must ensure a hydrostatic seal that prevents leakage and exceeds physiologic forces. The ultimate goals are realignment of tissue planes and maintenance of lumen diameter while avoiding mucosal penetration and resultant functional impairment. Failure of cystotomy closure results in uroperitoneum and peritonitis with resultant adhesions, fibrosis, discomfort, prolonged hospitalization, and, potentially, death.

Healing of the bladder is similar to that of other viscera, with initial strength attributed to suture. Because all layers contribute to the initial gain in wound strength and healing, proper realignment of tissue planes would be ideal. Compared with healing of the intestines, the bladder has a more rapid healing rate and tensile strength gain with a similar rate of collagen synthesis and no increase in synthesis of noncollagenous protein or smooth muscle regeneration.

Postoperative wound strength approximates preoperative values at the end of the fibroblastic stage (14 days). Compared with healing of the intestines, the bladder has a more rapid healing rate and tensile strength gain with a similar rate of collagen synthesis and no increase in synthesis of noncollagenous protein or smooth muscle regeneration.

Conclusions and Clinical Relevance—Simple continuous appositional closure was equal biomechanically and histologically to continuous Cushing for all comparison variables. Poliglecaprone 25 was acceptable for cystotomy closure.

Biomechanical and histologic comparison of single-layer continuous Cushing and simple continuous appositional cystotomy closure by use of poliglecaprone 25 in rats with experimentally induced inflammation of the urinary bladder

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Objective—To biomechanically and histologically compare single-layer continuous Cushing and simple continuous appositional cystotomy closure in rats with xylene-induced cystitis.

Animals—40 female Sprague-Dawley rats.

Procedure—Rats were anesthetized, their urinary bladders catheterized and evacuated, and xylene instilled in each bladder for 5 minutes and then aspirated. Forty-eight hours later, ventral midline celiotomy and cystotomy (8 mm) were performed. Cystotomies were closed with 6-0 poliglecaprone 25 by use of a single-layer continuous Cushing or simple continuous appositional pattern (20 rats/group), and cystotomy times were recorded. Rats were allocated to healing durations (5 rats/group) of 0, 3, 7, and 14 days. Celiotomies were closed in a routine manner. After the allotted healing interval, another celiotomy was performed, the urethra cannulated, and ureters ligated. The cannula was secured to the urethra, and the bladder infused at 0.1 mL/min. Leak pressure volume, leak pressure, peak pressure volume, and peak pressure were recorded via a pressure transducer. Bladders were harvested and histologically assessed.

Results—Cystotomy time, biomechanical testing values, and overall inflammation scores did not differ between closure methods for any healing duration. Both methods had significantly greater leak pressures, with the appositional method also having significantly greater peak pressures on day 7, compared to day 0. Biomechanical testing values decreased from day 7 to 14 as a result of juxta-incisional weakening of the bladder and xylene-induced changes in collagen.

Conclusions and Clinical Relevance—Simple continuous appositional closure was equal biomechanically and histologically to continuous Cushing for all comparison variables. Poliglecaprone 25 was acceptable for cystotomy closure.
are associated with a greater degree of inflammation and complications. With nonabsorbable suture, lumen exposure is acceptable when epithelialization precedes lithogenesis. Monofilament absorbable suture appears to be ideal because it induces minimal inflammation and is associated with reduced lithogenesis; however, not all are absorbed rapidly. The monofilament absorbable, poliglecaprone 25, is acceptable for closure of laparotomy, hysterotomy, gastrotomy, enterotomy, and capsulotomy incisions. Poliglecaprone 25 possesses excellent early tensile strength with complete early absorption and minimal reaction, which make it a logical choice for cystotomy closure. Although it has been used experimentally for cystotomy closure, scant information is available regarding its clinical use.

Inverting patterns are believed to offer leak-proof serosal seals, adequate strength gain, and superior healing, compared with other methods, with these properties further enhanced by the placement of a second inverting layer. Consequently, textbooks routinely recommend single- or double-layer Cushing patterns for cystotomy closure. However, inverting patterns are technically challenging in thickened bladders and contradict basic goals of realignment of tissue planes and maintenance of lumen diameter for optimal healing of vesical wounds. Appositional patterns are technically simpler in thickened bladders and, in theory, preserve lumen diameter. Studies on intestinal anastomosis and cystotomy closure in dogs reveal that bursting pressures for appositional methods equal or exceed bursting pressures for inverting techniques early in wound healing.

Studies on cystotomy closure have used naïve bladders, which do not mimic the in vivo clinical situation with cystitis or cystolithiasis because of the lack of inflammation and secondary bladder thickening. Rats are acceptable for use in evaluating experimentally induced cystitis because of their alkaline urine and propensity for lithogenesis when there is a foreign body. Various methods have been described, with reduction of vesicular volume by as much as one fifth. In rats, the aromatic hydrocarbon, xylene, induces a reproducible complex inflammatory response through stimulation of sensory nerves and direct damage to tissues.

The purpose of the study reported here was to biomechanically and histologically compare single-layer continuous Cushing (inverting) and simple continuous appositional (appositional) cystotomy closure in rats with xylene-induced cystitis. We hypothesized that the appositional method would be more rapid, cause a lower magnitude of overall inflammation, have similar leakage and failure pressures, and result in greater vesicular volumes, compared with results for the inverting method. Furthermore, we hypothesized that poliglecaprone 25 would prove acceptable for cystotomy closure in rats with experimentally induced inflammation of the urinary bladder.

Materials and Methods

Animals—Forty female Sprague-Dawley rats were used in the study. Rats weighed approximately 230 g. Rats were housed in pairs and provided ad libitum access to commercial chow and water throughout the study. The study was approved by the University of Florida Institutional Animal Care and Use Committee (No. D788).

Experimental design—Rats were randomly assigned to 2 groups (20 rats/group). Cystotomy closure for rats in 1 group would be accomplished by use of poliglecaprone 25 in an inverting method (single-layer continuous Cushing pattern), whereas cystotomy closure for rats in the other group would be by use of poliglecaprone 25 in an appositional method (single-layer simple continuous pattern). Body weights were recorded for all rats in each group. Within each method, rats were allocated (5 rats/group) to 4 healing durations (0, 3, 7, and 14 days, respectively; day 0 was designated as the day of cystotomy).

Anesthesia—Rats were anesthetized for 3 separate events (instillation of xylene into the bladder, cystotomy, and biomechanical testing). Rats were allowed access to food and water prior to each anesthetic episode. Rats were weighed and placed in an induction chamber. Anesthesia was induced by administration of 5% isofluorane in oxygen (1 L/min) until rats became laterally recumbent. Rats were then placed on a circulating warm-water blanket, and anesthesia was maintained via face mask by administration of 2% to 2.5% isofluorane and oxygen (1 L/min) through a semiclosed nonrebreathing system. Anesthetic depth was assessed by use of the blink reflex, toe pinch, and respiratory rate.

Induction of cystitis—A 20-gauge, 1.88-inch catheter was inserted into the bladder lumen via the urethra. Urine was evacuated by use of digital transabdominal expression and aspiration with a tuberculin syringe. A 0.3-mL aliquot of xylene was instilled by use of a tuberculin syringe with a 25-mm nylon, 0.2-µm sterile syringe filter. After a 5-minute period, the xylene was aspirated; the bladder lumen was then lavaged with 1 mL of sterile physiologic saline (0.9% NaCl) solution.

Surgery—Forty-eight hours after xylene instillation, the ventral portion of the abdomen and vulva were clipped with a No. 40 blade and aseptically prepared. Ventral midline celiotomy was performed with the incision beginning at the umbilicus and extending 2 cm in the caudal direction. The ventral ligament of the bladder was transected. Jeweller’s forceps were used to grasp the apex of the bladder at the cranial remnant of the ventral ligament, and the bladder was exteriorized in a cranial direction. An 8-mm ventral midline caudocranial cystotomy was performed by use of a No. 11 blade. We were careful to avoid the ventral ligament and vesiculocutaneous closure when making the incision in the bladder.

Cystotomies were closed by use of a single-layer closure in a continuous Cushing or simple continuous appositional pattern. Sutures (6-0 poliglecaprone 25 swaged on a TF taper needle) were inserted in a manner that engaged the submucosa without penetrating the mucosa. All sutures were inserted by 1 author (GWE), who used 3X magnifying loops to assist suture placement. Tissue bites were made such that suture holes were 1 mm apart and 1 mm from the incision. Knots were tied with sufficient tension to invert tissue to ensure serosal contact (inverting [ie, Cushing pattern]) or appose tissue edges without inverting or everting (appositional [ie, simple continuous pattern]). Cystotomy time was recorded from the time of incision until the last knot was tied; results were pooled on the basis of method. The linea alba was closed by use of 5-0 polydioxanone swaged on an RB-1 taper needle in a simple continuous pattern. Skin edges were apposed similarly by a combined subcuticular and subcutaneous closure.

Rats were allowed to recover from anesthesia by discontinuing isofluorane and breathing room air. Buprenorphine
(0.04 mg/kg, SC, q 8 h) was administered from the time of xylene instillation until 7 days after surgery (when applicable).

Biomechanical testing—After the respective healing duration, rats were again anesthetized and celiotomies performed. The peritoneal cavity was examined for evidence of uroabdomen and secondary peritonitis. The urethra was cannulated with a 46-mm, 20-gauge McIntyre straight lacrimal canulla with a 0.7-mm side port, and the bladder was evacuated as described previously. Ureters were ligated at the ureterovesical junction with stainless-steel ligating clips, and the urethra distal to the trigone area was secured to the canulla with 2 transfixation knots of 4-0 polydioxanone anchored in the uterine body. The canulla was attached to a syringe pump, and 1% povidone iodine in sterile physiologic saline solution was infused at a rate of 0.1 mL/min, with volume and pressure of the bladder recorded by use of a pressure transducer and data acquisition software. The LP and LPV were defined as the pressure and volume, respectively, recorded at the moment there was direct visual evidence of initial subserosal dissection attributable to the infusion. The PP and PPV were defined as the pressure and volume, respectively, on a pressure tracing at the moment there was deformation of the intravesical pressure curve in addition to visual evidence of infusion out of the serosa. Leakage and ultimate failure sites were recorded as to their location and whether they were incisional or nonincisional.

After biomechanical testing, rats were euthanized (while still anesthetized) by intracardiac administration of 0.2 mL of a solution of pentobarbital-phenytoin sodium. The infusion line was detached and the bladder evacuated, and 0.3 mL of neutral-buffered 10% formalin phosphate solution was then instilled into each bladder. Portions of the urogenital tracts extending from the canulla ligatures to the ureter ligating clips, and the urethra distal to the trigone area were secured with clips, and the urethra distal to the trigone area was secured to the canulla with 2 transfixation knots of 4-0 polydioxanone. Bladders from control rats that were instilled with xylene or subjected to cystotomy or biomechanical testing and bladders from control rats that were instilled with xylene, not subjected to cystotomy, but subjected to biomechanical testing 48 hours after xylene instillation were sectioned and stained in an identical manner for use in baseline histologic evaluation and comparison.

Statistical analysis—Pooled body weight and cystotomy time were compared between closure methods by use of a Student t test. Within each healing duration, data for biomechanical testing and overall inflammation score that were normally distributed and of equal variance were compared between closure methods by use of a Student t test, whereas data that were not normally distributed or had unequal variance were compared between closure methods by use of a Mann-Whitney rank sum test. Within each closure method, data for biomechanical testing and overall inflammation score that were normally distributed and of equal variance were compared among healing durations by use of a 1-way ANOVA, whereas data that were not normally distributed or had unequal variance were compared among healing durations by use of a Kruskal-Wallis 1-way ANOVA on ranks. Healing durations that appeared to differ significantly were compared by use of a Student t test (normally distributed and of equal variance) or by use of a Mann-Whitney rank sum test (not normally distributed or had unequal variance) to attain a precise significance value. Analyses were performed with commercial software. Significance was set at values of P < 0.05.

Results

Body weight and cystotomy time—Inverting and appositional closure methods did not differ significantly (P = 0.501) with regard to pooled initial body weight (mean ± SD, 233 ± 12 g and 236 ± 14 g for inverting and appositional methods, respectively). Similarly, they did not differ significantly (P = 0.142) with regard to pooled cystotomy time (396 ± 90 seconds and 353 ± 90 seconds for inverting and appositional methods, respectively).

Biomechanical testing—Biomechanical testing values were calculated for both closure methods and all healing durations (Table 1). Inverting and appositional LV and PPV did not differ significantly between closure methods at any healing duration. Similarly, LP and PPV did not differ significantly between closure methods and all healing durations at any healing duration.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Method</th>
<th>Day 0</th>
<th>Day 3</th>
<th>Day 7</th>
<th>Day 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV (mL)</td>
<td>Inverting</td>
<td>0.38 ± 0.25</td>
<td>1.54 ± 0.70*</td>
<td>3.98 ± 1.15*,†</td>
<td>2.11 ± 0.42*,†</td>
</tr>
<tr>
<td>Appositional</td>
<td>0.60 ± 0.18</td>
<td>1.88 ± 0.63*</td>
<td>5.37 ± 1.12*,†</td>
<td>2.21 ± 1.30*,†</td>
<td></td>
</tr>
<tr>
<td>LP (mm Hg)</td>
<td>Inverting</td>
<td>19.17 ± 3.72</td>
<td>46.34 ± 20.07</td>
<td>172.98 ± 57.02*</td>
<td>70.57 ± 32.33</td>
</tr>
<tr>
<td>Appositional</td>
<td>0.71 ± 0.17</td>
<td>1.96 ± 0.62</td>
<td>5.56 ± 1.09*,†</td>
<td>2.80 ± 2.07*,†</td>
<td></td>
</tr>
<tr>
<td>PPV (mL)</td>
<td>Inverting</td>
<td>4.22 ± 0.26</td>
<td>1.88 ± 0.68*</td>
<td>4.56 ± 1.38*,†</td>
<td>2.11 ± 0.42*,†</td>
</tr>
<tr>
<td>Appositional</td>
<td>29.26 ± 19.49</td>
<td>93.29 ± 50.22</td>
<td>119.29 ± 19.61*</td>
<td>70.37 ± 32.33</td>
<td></td>
</tr>
</tbody>
</table>

Day 0 was designated as the day of cystotomy. For each closure method at each healing duration, data were obtained from 5 rats. Values did not differ significantly (P > 0.05) between closure methods within the same healing duration for any biomechanical testing variable.

*Within a row, value differs significantly (P < 0.05) from the value for day 0. †Within a row, value differs significantly (P < 0.05) from the value for day 3. ‡Within a row, value differs significantly (P < 0.05) from the value for day 14.
and PP did not differ significantly between closure methods at any healing duration.

For both inverting and appositional closure methods, the LPV differed significantly among all healing durations, except for between days 3 and 14 for the inverting \((P = 0.312)\) and appositional \((P = 0.535)\) methods. There were no significant differences in LP scores between closure methods at any healing duration, except for between days 3 and 14 for the inverting \((P = 0.734)\) and appositional \((P = 0.355)\) methods. The increase in PPV for the appositional method from day 0 to 3 was not significant \((P = 0.073)\). There were no significant differences in PP, except that PP on day 7 was significantly \((P = 0.016)\) greater, compared with the PP on day 0, for the appositional closure method.

**Leakage and incisional failure sites**—We did not detect any in vivo incisional failures or suture failures during biomechanical testing. All leakage sites (which progressed to ultimate failure) were incisional at days 0 and 3, 6 were incisional and 4 were nonincisional (equally distributed between closure methods) at day 7, and all 10 were nonincisional at day 14. The trigone area was the site of all 4 nonincisional failures on day 7 and 6 nonincisional failures on day 14; the remainder of the nonincisional failures on day 14 were in the lateral bladder wall.

**Histologic assessment**—Overall inflammation scores were calculated (Table 2). In the epithelium, a primarily neutrophilic inflammatory infiltrate was detected at day 0 for both closure methods. This peaked at day 3, with a moderate to severe transmural infiltrate of primarily neutrophils, with fewer eosinophils and lymphocytes and luminal aggregates of neutrophils in cellular debris. At day 7, the infiltrate contained a mild to moderate population of neutrophils, with equal numbers of lymphocytes and macrophages. By day 14, there was minimal infiltration in the lamina propria, with the infiltrate consisting primarily of lymphocytes. The inflammatory infiltrate peak was detected at day 3, with scores being significantly lower on day 7 for the appositional closure method \((P = 0.016)\) and day 14 for the inverting \((P = 0.012)\) and appositional \((P = 0.016)\) closure methods. Despite a greater absolute difference in inflammation scores between days 3 and 7 for the inverting closure method, compared with inflammation scores for the appositional closure method, this difference was not statistically significant. This can be explained by the fact the inflammation scores for day 7 for the inverting closure method were not normally distributed; thus, a nonparametric comparison by use of median values was selected, which revealed a significant difference only with the appositional closure method. Additionally, inflammation scores on day 14 were significantly lower, compared with inflammation scores on day 0, for the inverting \((P = 0.016)\) and appositional \((P = 0.016)\) closure methods. There was no difference in inflammation scores between closure methods at any healing duration.

Changes in the epithelium at day 0 consisted of cytoplasmic vacuoles with minimal multifocal erosion. There was noticeable epithelialization at day 3, with the epithelium up to 10 cell layers thick, which was most pronounced in the peri-incisional area, with transincisional epithelial continuity evident for both closure methods. Peri-incisional epithelium on day 7 ranged from 4 to 7 cell layers thick, whereas epithelium was 2 to 4 cell layers thick in the portion of the bladder opposite the incision. On day 14, peri-incisional epithelium was 1 to 3 cell layers thick with mild to moderate cytoplasmic vacuoles with minimal multifocal erosion, with inflammation scores for the appositional \((P = 0.016)\) closure methods. There was no significant difference only with the appositional closure method. Additionally, inflammation scores on day 14 were significantly lower, compared with inflammation scores on day 0, for the inverting \((P = 0.016)\) and appositional \((P = 0.016)\) closure methods. There was no difference in inflammation scores between closure methods at any healing duration.

Table 2—Mean ± SD overall inflammation score obtained for inverting (continuous Cushing pattern) and appositional (simple continuous pattern) cystotomy closure methods in 40 rats after various healing durations.

<table>
<thead>
<tr>
<th>Method</th>
<th>Day 0</th>
<th>Day 3</th>
<th>Day 7</th>
<th>Day 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverting</td>
<td>5.0 ± 1.6</td>
<td>6.6 ± 2.8</td>
<td>2.4 ± 0.5</td>
<td>1.8 ± 0.5*</td>
</tr>
<tr>
<td>Appositional</td>
<td>3.6 ± 1.1</td>
<td>6.6 ± 2.5</td>
<td>2.6 ± 1.1</td>
<td>1.3 ± 0.5*</td>
</tr>
</tbody>
</table>

For each closure method at each healing duration, data were obtained from 5 rats. Values did not differ significantly \((P < 0.05)\) between closure methods within the same healing duration. See Table 1 for key.

Figure 1—Photomicrographs of tissue sections obtained from a representative rat urinary bladder that was not instilled with xylene nor subjected to cystotomy or biomechanical testing (A); instilled with xylene, not subjected to cystotomy, but subjected to biomechanical testing 48 hours after xylene instillation (B); instilled with xylene, subjected to cystotomy that included closure by use of an inverting (continuous Cushing) suture pattern, and allowed to heal for 7 days (C); and instilled with xylene, subjected to cystotomy that included closure by use of an appositional (simple continuous) suture pattern, and allowed to heal for 14 days (D). The epithelium (light red), collagen (green), and smooth muscle (dark red) are clearly evident. In panel C, notice that there are 2 or 3 transitional cell layers in the epithelium and dense collagen in the lamina propria. In panel D, notice the single layer of shrunken and separated transitional epithelial cells and that there is decreased collagen density in the lamina propria. H&E and Masson trichrome stains; bar = 200 \(\mu\)m.
spans of epithelium that were a single cell layer thick in some bladders. Additionally, there was separation and shrinking of transitional epithelial cells with adjacent spans of subepithelial clefts and a decrease in cytoplasm with frequent basilar vacuoles.

The lamina propria was approximately 20% of the transmural thickness on day 7, which increased to 40% of the transmural thickness by day 14. On day 14, evaluation of sections stained by use of Masson’s trichrome revealed decreased density of collagen in the lamina propria manifested by dissociation of collagen fibers and wide fiber spacing because of edema (Figure 1). No appreciable differences in elastin staining were observed in the lamina propria or muscular coat between closure methods or among healing durations.

Reaction around the suture material was similar between closure methods. On day 0, edema and hemorrhage were evident secondary to implantation trauma. Edema and a predominantly neutrophilic inflammatory infiltrate were evident on day 3. The infiltrate consisted primarily of eosinophils, lymphocytes, and macrophages on day 7. Additionally, there was active fibroplasia with numerous fibroblasts and abundant collagen. On day 14, the inflammatory reaction was of a lesser magnitude and consisted primarily of macrophages and fibroblasts with mature collagen. Additionally, there was evidence of suture resorption in many bladder sections on day 14.

**Discussion**

Appositional cystotomy closure compared favorably with inverting closure for all comparison variables. Both inverting and appositional cystotomy closure exceeded in vivo physiologic forces with no resultant incisional failures. Biomechanical testing measured intravesicular pressures, a reflection of physiologic stresses and distentional forces. It is believed that supraphysiologic intravesicular pressures result in incisional leakage and failure. Bursting strength is the measure of resistance to increased intravesicular pressure, and it approximates the in vivo clinical situation better than tensile strength does. Tensile strength testing negates precise histologic assessment because of focal disruption of the incision. For the study reported here, we chose an infusion rate of 0.1 mL/min, which was extrapolated from reports in which investigators assessed micturition thresholds by use of cystometry. Despite the fact that assessment of micturition threshold was not within the scope of our study, those reports revealed that infusion systems and not rate of infusion affect assessment, providing the rate does not exceed 0.2 mL/min. Data were collected at the moment there was direct visual evidence of initial subserosal dissection attributable to the infusate (LP) and ultimate failure (bursting strength [ie, PP]). We believe LP is more clinically relevant than PP because bladder leakage leads to uropertitoneum and associated complications.

To the authors’ knowledge, this is the first time cystotomy closure methods have been biomechanically and histologically compared in animals with experimentally induced cystitis and poliglecaprone 25 used successfully for cystotomy closure during in vivo chemical cystitis. A multitude of methods for inducing cystitis, including instillation of acidic and more neutral compounds, have been reported for use in studying physiologic and pharmacologic mechanisms. Microbial-induced methods include inoculation of *Streptococcus* spp, *Klebsiella* spp, and *Proteus* spp. Chemical or microbial methods may be mechanically modulated by mucosal irritation, temporary urethral obstruction, or foreign body inoculation. All methods induce inflammatory mediators and neuropeptides, which results in persistent and even an amplified magnitude of cystitis after removal of the inciting cause.

The authors believe experimentally induced cystitis is valid for use in evaluating cystotomy closure methods because it mimics the in vivo clinical situation. Xylene-induced cystitis was selected because of reports validating its mechanism and duration of inflammation; ease of availability and potency; practicality of avoiding the need to establish and propagate microbial cultures; and greater uniformity compared with results for mechanical irritation. Xylene induces a biphasic inflammatory response through stimulation of sensory and unmyelinated afferent neurons of the pelvic nerve. This leads to hyperreflexia and release of tachykinin, bradykinin, and histamine, which is characterized by early (15 minutes) and late (6 hours) extravasation of plasma proteins. Also, epithelium is damaged in a histamine-independent manner within 4 hours, which is not evident with other methods. In the study reported here, inflammation was induced by mechanical (minimal by catheterization and subsequently by cystotomy) and chemical (xylene) mechanisms. In another study, xylene caused larger, more frequent folding of mucosal and lamina propria layers with foci of denuded epithelium and lymphocyte infiltration of the lamina propria. Neutrophilic infiltration and vasculature congestion are most apparent 24 hours after xylene instillation, with negligible infiltrate at day 7; however, congestion and edema persist. These findings were similar to findings in our histologic assessment.

For the study reported here, healing durations of 0, 3, 7, and 14 days were selected. Poliglecaprone 25 maintains tensile strength for up to 14 days. Because bladder wounds are at approximately preoperative strength at the end of the fibroblastic stage, 14 days was chosen as the longest healing duration. The small size of the bladder in rats makes it a technical challenge to separate tissue planes and provide adequate closure; thus, failure to incorporate submucosa or to use tissue bites that are not uniform may result in falsely low values during biomechanical testing. For this reason, 5 rats were selected for each closure method and each healing duration. All leakage sites progressed to ultimate failure. The LPVs and PPVs for inverting and appositional closure methods did not differ significantly at any healing duration. In theory, appositional closure should maintain lumen diameter better than inverting closure because of realignment of tissue planes. It would also be expected that the inverting method would have...
resulted in a disproportionate increase in PP, relative to the increase in PPV, compared with the increase for the appositional method. This may be attributable to tissue inversion leaving a discrete section of bladder wall incapable of uniform expansion and the fact that typical bladder compliance is more appropriately addressed clinically with appositional closure via realignment of tissue planes. Despite these expectations, there was no significant difference in PP or PPV between closure methods for any healing duration. There was a significant increase in LP from days 0 to 7 for both the inverting and appositional methods. However, only appositional closure had a significant increase in PP from days 0 to 7. This may have been attributed to a greater pressure-shaping effect between suture material, the fibrin seal formed between realigned epithelium during the lag phase (days 3 to 5), and realigned collagen via realignment of tissue planes with the appositional method.

All biomechanical testing values were lower for day 14 than for day 7, which can be explained by 2 contributing mechanisms (juxtaincisional weakening of the bladder and xylene-induced changes in collagen). It has been believed that when there is leakage of cystotomy closures, it would be incisional in origin. All leakage (and ultimately failure) sites on day 14 were nonincisional. This is in accordance with reports that indicate incisional strength exceeds and wound healing weakens juxtaincisional bladder wall with progressive wound healing by day 10. In humans, the lamina propria proteins collagen I, collagen III, and elastin are considered the major capacitance layer. In the study reported here, elastin and Masson’s trichrome stains were used to assess the potential that xylene-induced collagen caused a decrease in biomechanical testing values from days 7 to 14. Masson’s trichrome staining on samples obtained on days 7 and 14 revealed a marked decrease in collagen density in the lamina propria (Figure 1). Additionally, there was increased epithelial compromise with multifocal spans of shrunken and separated transitional epithelial cells on day 14. These changes may indicate breakdown of the membrane apical plaque.

In naïve viscera, epithelial substructures are impermeable to urine. Urine leakage through compromised epithelium may damage collagen and capillaries through deposition of calcium salts. Compromised epithelium was apparent on the basis of subserosal dissection by infusate with increasing amounts of infused solution. Damage to capillaries in the lamina propria may have contributed to increased amounts of edema on day 14. All bladders on day 14 had loss of collagen density in the lamina propria and separation and clefts between epithelium and adjacent collagen, compared with results for day 7, which further validated discrepancies for variables on day 14. Differences in urodynamic variables in naïve rats can be extreme, with micturition thresholds between 29 and 66 mm Hg. Interestingly, LP and PP values for all healing durations, except for LP and PP for appositional closure on day 0 and LP for inverting closure on day 0, exceeded values for other reports. This may be clinically relevant, despite the fact that it was determined in rats, because it parallels the belief that cystotomy closures are biomechanically acceptable when intravesicular pressures can exceed the micturition threshold before leakage. Additionally, nonoperated naïve control bladders have revealed ultimate failure pressures at a mean ± SD value of 154 ± 43 mm Hg and ultimate failure volumes of 2.5 ± 2.0 mL. In our study, appositional closure exceeded those reported ultimate failure pressures and volumes in regard to LP, PP, LPV, and PPV on day 7 and PPV on day 14. Inverting closure exceeded those reported ultimate failure volumes in regard to LPV and PPV on day 7. Overall, our pressure SD values were of similar magnitude and our volume SD values were similar or smaller than those reported elsewhere.

Poliglecaprone 25 has been characterized as possessing the highest initial tensile strength, excellent pliability, and best handling of all monofilament absorbable sutures. Despite these attributes, it rapidly loses tensile strength (loss of 75% after 14 days and 100% after 21 days) and is completely absorbed by 120 days. After 14 days, which corresponds to the end of the fibroblastic stage and is considered the critical period of wound healing, in vivo breaking strength of poliglecaprone 25 is approximately 20% to 30% of initial values. In general, monofilaments are stiffer than multifilaments of similar composition, with stiffness increasing with progressive breakdown. In 1 study, poliglecaprone 25 was substantially stiffer than polyglyconate and polydioxanone but had a more progressive decrease in tensile strength and retained less than one third of initial strength from day 10 to 14 after immersion in bacteria-laden and various pH urine in vitro. In vivo, suture material is incorporated into the bladder wall, and in the event of inadvertent lumen penetration, we would not expect prolonged urine exposure because of rapid epithelialization, which can be complete within 3 days. Thus, the clinical importance of these findings has not been determined. Our clinical experience and results of the study reported here, which was conducted by use of rats with chemically induced cystitis, would suggest that poliglecaprone 25 is acceptable for use in cystotomy closure.

In the study reported here, few significant differences were found during biomechanical and histologic comparison of single-layer continuous Cushing and simple continuous appositional cystotomy closure in rats with xylene-induced cystitis. On the basis of these findings, a simple continuous appositional pattern is an acceptable alternative to a continuous inverting pattern in rats for cystotomy closure. In addition, poliglecaprone 25 is acceptable in rats for use in cystotomy closure.

a. Monocryl, Ethicon Inc, Somerville, NJ.
b. IsoFlo, Abbott Laboratories, North Chicago, Ill.
c. Angiocath, Becton Dickinson Infusion Therapy Systems Inc, Sandy, Utah.
d. Monoject, Sherwood Medical Co, St Louis, Mo.
e. Histologic grade xylene, Fisher Scientific International Inc, Hampton, NH.
f. Fisherbrand 25-mm nylon, 0.2-µm sterile syringe filter, Fisher Scientific International Inc, Hampton, NH.
g. 0.9% Sodium Chloride Irrigation, USP; Baxter Healthcare Corp, Deerfield, Ill.
h. Jeweller’s forceps, ASSI Corp, Westbury, NY.
References