Colonic seromuscular augmentation cystoplasty following subtotal cystectomy for treatment of bladder necrosis caused by bladder torsion in a dog

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A 5-year-old 35-kg (77-lb) spayed female Labrador Retriever was evaluated at The Ohio State University Veterinary Teaching Hospital because of a 3-day history of lethargy, anorexia, vomiting, stranguria, and anuria after routine ovariohysterectomy. During abdominal palpation, signs of severe abdominal pain and a large urinary bladder were detected. Laboratory analyses of blood samples revealed leukocytosis (22.8 × 10^9 WBCs/L; reference range, 4.1 to 15.2 × 10^9 WBCs/L), mature neutrophilia (21.7 × 10^6 neutrophils/L; reference range, 3.0 to 10.4 × 10^6 neutrophils/L), and high serum concentrations of BUN (168 mg/dL; reference range, 5 to 20 mg/dL) and creatinine (9.8 mg/dL; reference range, 0.6 to 1.6 mg/dL); electrolyte abnormalities included high serum concentrations of potassium (6.9 mEq/L; reference range, 4.2 to 5.4 mEq/L) and phosphorus (16.2 mg/dL; reference range, 4.3 to 5.2 mg/dL) and low serum concentrations of sodium (131 mEq/L; reference range, 143 to 153 mEq/L) and chloride (88 mEq/L; reference range, 109 to 120 mEq/L). Abdominal radiography revealed a large, normally positioned urinary bladder. Urethral catheterization was unsuccessful, whereupon cystoscopy revealed a large, normally positioned urinary bladder; the urinary catheter was apparently free. Uroabdomen was tentatively diagnosed, and the dog was placed in the intensive care unit for IV administration of physiologic saline (0.9% NaCl) solution and monitoring of blood gases and urinary output. Despite bladder evacuation, serum concentrations of BUN, phosphorus, and potassium values remained high at 12 hours after the initial examination. At this point, abdominal ultrasonography revealed bilateral hydronephrosis and lack of an identifiable urinary bladder. The free abdominal fluid creatinine concentration was 10.8 mg/dL (serum creatinine concentration, 9.8 mg/dL). Because of the confirmed uroabdomen, suspected ureteral obstruction, and an inadequate response to fluid therapy, emergency exploratory laparotomy was elected.

Through a ventral midline approach, hemorrhagic abdominal fluid was evacuated and adhesions between the urinary bladder, omentum, and uterine body remnant were broken down. By use of the distal ureterovesicular junctions as landmarks, it was apparent that there was bladder torsion of approximately 130° in a counterclockwise direction at the level of the trigone (as observed from cranial to caudal). The median and lateral ligaments of the urinary bladder were torn. There was no ligature associated with the strangulation. Both ureters were dilated and obstructed because of their involvement in the bladder torsion. The bladder wall to the level of the ureters was dark purple, flaccid, and thin; these changes were thought to be a result of severe vascular compromise. The trigone was also dark in color but thickened. Urine leakage was...
detectable at the thin bladder apex. Because of the global nature of the urinary bladder injury and the dog’s critical condition, the decision was made to return the bladder to a normal position without performing a resection. It was hoped that additional time would allow for patient stabilization and also demarcation of irreversibly devitalized bladder tissue such that definitive repair could be better performed during a second laparotomy. A peritoneal sump-Penrose drain and a red rubber urethral catheter were placed, abdominal fluid was collected for bacteriologic culture, and the abdomen was closed.

Twenty-four hours after surgery, serum biochemical variables were markedly improved; the dog appeared comfortable and was ambulatory and eating. A second abdominal exploratory was performed 2 days after the first surgery, and there was persistent discoloration of the urinary bladder near the level of the ureters. Tissue viability was assessed by incising through the bladder wall, and 90% of the organ was estimated to be necrotic. The necrotic wall was circumferentially excised approximately 0.5 cm cranial to the ureteral orifices. Mucosa within the remaining bladder remnant (stump) was black, but the seromuscular layer was bleeding at the cut edge and was therefore considered viable. The urinary bladder was closed with a colonic seromuscular patch to protect against dehiscence and augment early bladder storage capacity (Figure 1). A 3.5-F red rubber catheter was inserted into the ureteral orifices to ensure patency of both ureters during the repair. Simple interrupted sutures of 4-0 polydioxanone were preplaced between edges of the remaining bladder remnant and the antimesenteric serosal surface of the adjacent colon (which was left intact). Sutures were then placed dorsally and the ligature knots were exposed to the bladder lumen to facilitate closure. The omentum was placed over and around the urinary bladder. As a result, the external wall of the colon became the cranial wall of the bladder. The original peritoneal drain and the urinary catheter were left in place, and the abdomen was closed routinely. After recovery from anesthesia, the dog’s condition continued to improve during the following week in the intensive care unit.

Histologic examination of sections of the resected bladder revealed diffuse acute hemorrhage with multifocal thrombosis and widespread necrosis, which were consistent with torsion-induced infarction. Few Enterococcus and coagulase-negative Staphylococcus bacteria were cultured from the abdominal fluid, and amoxicillin trihydrate-clavulanate potassium was prescribed (13 mg/kg [5.9 mg/lb], PO, q 12 h for 4 weeks). Six days following bladder resection, IV pyelography and contrast cystography revealed hydroureters, hydronephrosis, and poor filling of the remaining urinary bladder, but there was no evidence of leakage from the augmented bladder (Figure 2). The urinary bladder measured 5 cm in length and 2.7 to 3.4 mm in thickness on ultrasonographic images obtained the same day. Following catheter removal, stranguria and pollakiuria (3 to 4 urinations/h) were evident. Incontinence occurred during periods of recumbency. Nine days after the initial evaluation, the dog was discharged and weekly progress was assessed via telephone conversation with the owners. Stranguria resolved approximately 1 month after bladder resection, and the interval between urinations increased to 3 hours after approximately 2 months. When bacteriologic culture of urine obtained via cystocentesis yielded no growth (after approx 1 month of treatment), antimicrobial administration was discontinued.

Figure 1—Illustrations of colonic seromuscular augmentation cystoplasty in a dog. A—Ventral view of the suture line between the urinary bladder and colon. Cut edges of the bladder remnant are sutured to the antimesenteric serosal surface of an intact portion of the adjacent colon (upper portion of illustration). Dotted lines represent the ureters, and the black oval dots show the location of the ureteral opening. B—Transverse view of the lumen of the colon and the site of suture apposition between the bladder edges and the serosal surface of the colon. The sutures are placed full thickness through the bladder and partial thickness through the colonic wall (serosal and muscularis layers). The bladder edges are sutured to the colon adjacent to the colonic vasa recta (shown as a black line adjacent to the upper aspect of the colon). Prepared by Tim Vojt, Senior Medical Illustrator, College of Veterinary Medicine, The Ohio State University. (Reproduced with permission.)
and ureter; the lumen of the ureter was 2.1 cm in diameter, within normal limits (Figure 2). Abdominal ultrasound revealed adequate filling of the bladder, and its shape and position were normal. Cystoscopy revealed no urine exiting the right ureter (arrowheads) persisted at this time. Stainless steel hemostatic clips are visible cranial and ventral to the bladder. The contrast-filled vagina is dorsal to the urethra. Hydronephrosis was also detected but is not evident in this image. A peritoneal sump-Penrose drain and a red rubber urethral catheter are visible in the image. B—Results of contrast cystography performed 3 months after surgery. After infusion of 120 mL of contrast medium into the urinary bladder, the shape and extent of filling of the bladder appear normal. C—Results of contrast cystography performed 36 months after surgery. The site of the colonic seromuscular patch (black arrow) and the colonic loop sutured to the bladder (white arrows) are clearly identified; dilatation of the right ureter (arrowheads) persisted at this time. Stainless steel hemostatic clips are visible cranial and ventral to the bladder. The contrast-filled vagina is dorsal to the urethra.

The dog was returned for reevaluation in the 11th week after bladder resection, and a CBC, serum biochemical analyses, and urinalysis were performed. Cystoscopy, assessment of the urethral pressure profile, contrast cystography, and ultrasonography were also performed. Serum biochemical analyses revealed that concentrations of BUN (39 mg/dL), creatinine (2.1 mg/dL) were mildly high. Urine specific gravity was 1.020. Cystoscopy revealed no urine exiting the right ureteral opening and increased bladder wall vascularization, especially where the colonic serosa was sutured to the bladder. Contrast cystography revealed adequate filling of the bladder, and its shape and position were within normal limits (Figure 2). Abdominal ultrasonography revealed dilatation of the right renal pelvis and ureter; the lumen of the ureter was 2.1 cm in diameter, and it ended abruptly 2 cm from the bladder. Exploratory surgery was performed to investigate suspected right ureteral obstruction. The distal 2-cm portion of the ureter was narrow, firm, and devoid of peristalsis. Catheterization of the ureter was attempted via cystotomy, but only the most distal 1-cm portion was patent. Ureterotomy (centered over the narrowed area) revealed an intramural stricture, and the affected segment was resected. The remainder of the ureter was separated from retroperitoneal tissues to alleviate tension, and a mucosal apposition neoureterocystostomy without spataluation was performed. Simple interrupted 5-0 polydioxanone sutures were placed through the mucosa and submucosa of a healthy area of the bladder and full thickness through the distal ureter. Histologic examination of sections of the resected ureter revealed granulation tissue and infiltration of the ureteral wall with scattered lymphocytes and plasma cells, suggestive of previous trauma and inflammation. While hospitalized, the dog urinated normally, although small amounts of urine were present in the cage after periods of recumbency. Three days after ureteral resection and neoureterocystostomy, renal-associated serum biochemical variables were within reference limits and results of bacteriologic culture of abdominal fluid and urine samples were negative. The dog was discharged, and the owners were instructed to administer amoxicillin (routinely used after cystoscopy; 20 mg/kg [9.1 mg/lb], PO, q 12 h) for 10 days and phenylpropanolamine (1 mg/kg [0.45 mg/lb], PO, q 12 h). Ten days later, the owners reported that the dog could hold urine for 3 hours and was continent between voidings. Six weeks after neoureterocystostomy, the dog was urinating 5 to 6 times daily with occasional episodes of incontinence despite continued phenylpropanolamine treatment. Serum BUN concentration was slightly high (29 mg/dL), although other clinicopathologic values were within reference limits and results of bacteriologic culture of urine were negative. Abdominal ultrasonography revealed persistent dilatation of the right renal pelvis and right ureter (luminal diameter, 0.7 cm).

Ten months after neoureterocystostomy, the dog was still receiving phenylpropanolamine and urinating 4 to 5 times/d. Results of serum biochemical analyses indicated that concentrations of BUN (38 mg/dL), creatinine (3.1 mg/dL), and calcium (11.8 mEq/L; reference range, 9.3 to 11.6 mg/dL) were high and that bacteria (Enterococcus spp) were present in the urine. Ultrasonography revealed continued dilatation of the right renal pelvis and lumen of the right ureter (2.3 cm in diameter). After 24 hours of IV fluid administration, IV pyelography was performed and revealed right-sided hydronephrosis and a tortuous, dilated right ureter in which there was no evidence of obstruction. Contrast cystography revealed that the size and shape of the urinary bladder were normal. Bacteriologic cultures of urine samples obtained from the right kidney and the urinary bladder yielded positive results, which suggested a diagnosis of ascending pyelonephritis. Treatment with amoxicillin trihydrate–clavulanate potassium was immediately started, and the dog was reevaluated after 6 weeks of treatment. At that time, renal serum biochemical variables were within reference limits and bacteriologic culture of urine yielded...
no growth. However, the urine was isostenuric (urine specific gravity, 1.012 [range for isostenuric urine, 1.008 to 1.012]), and hydroureter of the right kidney was still evident ultrasonographically. Cystoscopy, cystometrography, assessment of the urethral pressure profile, and residual urine measurements were performed to investigate the mild urinary incontinence. Cystoscopy revealed a dilated right ureter, a vaginal septal diverticulum, a short urethra, and a well-healed colonic seromuscular bladder patch. No detrusor muscle activity was detected on the cystogram. Intraluminal pressure of the urethral sphincter was still low, indicative of mild urethral sphincter mechanism incompetence.

Additional follow-up evaluations, including physical examination, serum biochemical analyses, urinalysis, and bacteriologic culture of urine, were performed at 26 and 36 months. The dog continued to receive phenylpropanolamine (1 mg/kg, PO, q 12 h). The owners reported that the dog’s ability to retain urine was adequate, with only intermittent episodes of urine pooling after sleeping. Results of contrast cystography performed at the 36-month follow-up appointment indicated that there was substantial filling of the bladder and a persistently dilated right ureter (Figure 2).

**Discussion**

Urinary bladder torsion (rotation around the long axis) is a surgical emergency that, to our knowledge, has not been previously reported in dogs. In the dog of this report, torsion occurred at the neck of the urinary bladder, the more mobile bladder body rotated freely as a result of loss of ligamentous support. The specific cause of the torsion was not identified, but it was likely associated with ovariohysterectomy because clinical signs began to develop immediately after that surgery. Torsion resulted in strangulation of the cranial and caudal vesical arteries and veins at the trigone, which compromised the entire bladder wall and probably also the right ureter. Prolonged urethral obstruction and bladder overdistension may have also contributed to ischemia. Partial-thickness necrosis extended to the area of the trigone, and complete dehiscence was not attempted because of the need to maintain the dog as a functional pet. We opted to preserve areas of bladder wall where cut edges of the muscularis were bleeding and tried to augment blood supply with colon serosa and omentum. The extensive vascularity of the omentum can provide blood supply through its angiogenic, immunogenic, and adhesive properties, but it lacks the holding strength of seromuscular tissue. A seromuscular patch was used in the dog of this report because such patches readily form adhesions, have a good blood supply, and provide tensile strength. We did not pursue primary closure of the urinary bladder because of partial-thickness necrosis of the bladder wall and associated risk of dehiscence.

Various salvage procedures that replace affected portions of the urinary system with segments of the gastrointestinal tract have been used in experimental trials and clinical cases in humans and other animals. In humans, augmentation cystoplasty is used routinely for treatment of reduced bladder compliance and capacity or following ablative surgery. The use of intestinal segments to augment the urinary tract is widely accepted, but the associated high morbidity rate has renewed interest in alternative techniques involving urinary tract tissue. Other techniques, such as vesicomyectomy (excision of the detrusor muscle), ureterocystoplasty (use of a ureteral flap), and seromuscular cystoplasty (use of reversed intestinal segments), reportedly overcome the consequences of exposure of the intestinal mucosa to urine in humans. Of these procedures in humans, seromuscular cystoplasty is most similar to the technique used in the dog of this report. Following subtotal cystectomy, seromuscular cystoplasty is performed by suturing an isolated segment of intestine onto the urinary bladder with the intestinal serosa facing the lumen. The use of isolated and nonisolated segments of intestine in seromuscular cystoplasty has been compared experimentally in dogs. The authors of that study found no increase in serum BUN concentration and no evidence of calculus development or mucus formation in urinary bladders of treated dogs. Furthermore, none of the experimental dogs developed fibrosis or contraction of the augmentation flap, which suggests that scarring is not related to urine contact. Following seromuscular cystoplasty, the surface area and capacity of the dogs’ bladders either remained unchanged or were increased. Microscopically, the serosal surface was completely covered with transitional cells with little or no fibrosis in the subserosal tissue of the portion of ileum that faced the bladder lumen. In the dog of this report, the high serum BUN concentration was attributable initially to postrenal obstruction and later to pyelonephritis because in both instances, azotemia resolved after treatment. Ultrasonographic and radiographic examinations (positive contrast cystography) did not reveal evidence of flap contraction.

Complications encountered in the dog after surgery were similar to those that occur in humans who have undergone augmentation cystoplasty. In people, ureteral stricture may develop as an early or late complication following creation of a continent ileocolonic urinary reservoir. In the dog of this report, ureteral stricture was detected 2.5 months after surgery, although it may have developed earlier. During surgery, ureteral entrapment or extramural or intraluminal obstruction was not detected, supporting an inflammatory cause of the stricture secondary to infection or ureteral compromise associated with bladder torsion. Histopathologic findings suggested a traumatic-ischemic etiology for stricture formation, but infective ureteritis as a result of cystitis or pyelonephritis may have been a contributory factor. Pyelonephritis was identified along with the ureteral stricture. Different factors may have contributed to pyelonephritis. Ascending infection may have been caused by urinary stasis resulting from partial outflow obstruction, incomplete voiding, or ureteral reflux. We believe that complications in the dog of this report were unrelated to the surgery and more likely attributable to the initial trauma associated with bladder torsion. Presumably, the traumatic and ischemic effects of bladder torsion were greater for the right ureter than the left ureter, and the subsequent stricture of the right ureter and concurrent bacterial cystitis may have resulted in pyelonephritis.
The seromuscular augmentation cystoplasty technique described in this report can perhaps be applied in other dogs undergoing subtotal cystectomy. Indications for subtotal cystectomy are bladder neoplasia or necrosis.17 Bladder neoplasia is less commonly treated by surgical means because clean resection with preservation of the trigone is often impossible.17 Benign tumors such as leiomyoma, fibroma, or papilloma may be removed via conservative full-thickness resection. Bladder necrosis may be a more common indication for subtotal cystectomy. Blunt or penetrating trauma, prolonged urethral obstruction, or urinary bladder displacement or retroflexion into a perineal hernia may cause bladder necrosis as a result of vascular trauma, chronic distension, or strangulation at the bladder neck.2,18,19 In most cases, the urinary bladder can be primarily closed and, if necessary, covered with a serosal patch after debridement of the necrotic tissue or excision of neoplasm.20,21 Because of the severity and extent of bladder necrosis in the dog of this report, we used an alternative technique for primary closure in which the bladder remnant was attached to a healthy serosal surface of the colon rather than attempting apposition of the damaged edges of the bladder wall. We believed this would help decrease the risk of dehiscence and result in improved short-term urine storage. The cranial wall of the bladder reconstructed with colonic seromuscular tissue increases the capacity of the organ by augmenting the bladder wall. The surgical site healed successfully without any perioperative complication. The bladder size was partially restored after 2 months and was essentially normal after 6 months.

Previously, it has been reported22,23 that the urinary bladder in dogs regains normal size and function in 4 to 6 months after resection of 70% to 90% of the bladder wall. Radiographic evaluation of bladder size has some limitations associated with image magnification, bladder compliance, and variable volumes of urine. With these limitations in mind, the cystographic appearance of the urinary bladder in the dog of this report was nearly within normal limits at 3 months after subtotal cystectomy. The urinary bladder regenerates with a combination of epithelial proliferation, synthesis and remodeling of scar tissue, hypertrophy and proliferation of smooth muscle, and stretching of the bladder remnant.24 Urinary continence of an intact bladder depends on a balanced action of sympathetic, parasympathetic, and somatic innervation. During the storage phase of micturition, α-adrenergic receptors in the body of the bladder wall facilitate filling, while α-adrenergic receptors in the trigone region and somatic innervation of the external urethral sphincter prevent urine leakage. During the emptying phase, parasympathetic innervation of the body of the bladder wall causes detrusor muscle contraction, while inhibition of the α-adrenergic receptors and somatic innervation relaxes the urethral sphincters.25 Urinary continence is conserved even after total resection of the bladder body, but the regenerated bladder may be primarily governed by α-adrenergic receptors because of an alteration in the ratio of autonomic receptors.25 In the dog of this report, the absence of detrusor motor activity (as determined via cystometry) confirmed that function of the urinary bladder did not depend on the detrusor reflex for emptying. The preserved trigone and its predominant α-adrenergic innervation may have become responsible for the filling and emptying phases of urination.

Although it is difficult to prove that this technique contributed substantially to the ultimate success of treatment in the dog of this report, on the basis of our experience, we believe that it has merit as a treatment option for dogs undergoing radical subtotal cystectomy. Our clinical results certainly underscore the regenerative ability of the bladder wall as reported in the literature.26,27 Despite nearly complete loss of the urinary bladder wall, bladder function and storage capacity in the dog of this report returned to near normal levels after 4 to 6 months.

References