THE EFFECTS OF INDWELLING TRANSURETHRAL CATHETERIZATION AND TUBE CYSTOSTOMY ON URETHRAL ANASTOMOSES IN DOGS

by

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This study compared the effects of urinary diversion by tube cystostomy catheterization, urethral catheterization and tube cystostomy and urethral catheterization on healing urethral anastomoses in the canine urethra. Fifteen intact, mature males were divided into three groups of five dogs. Urodynamic studies were performed under halothane anesthesia preoperatively and at ten weeks postoperatively. Urethral anastomosis was performed in all dogs over a urethral catheter with 4-0 polyglyconate. Group U dogs (n=5) received transurethral catheters. Group C dogs (n=5) received tube cystostomy catheters, and Group B dogs (n=5) had both a transurethral catheter and a cystostomy tube placed. All dogs had catheters maintained with a closed urine collection system for seven days. Dogs were observed for ten weeks following surgery, and urinalysis and urine cultures were performed on weeks 1, 4, and 8. Preoperative evaluations were repeated ten weeks postoperatively just prior to termination of the study. Radiographic and histopathologic evaluation of the urethral specimen was performed. No significant differences among the groups were noted after the second postoperative week when comparing observation scores for urination and posturing. Measurements made on in-vivo and in-vitro urethrographic studies revealed less luminal reduction at the anastomotic site in Group C when compared to Groups B and U. Results of this study indicated that urinary diversion by tube cystostomy will minimize the percent luminal diameter reduction (PLDR) when compared to transurethral catheterization alone and tube cystostomy combined with transurethral catheterization.

The author recommends tube cystostomy be considered for urinary diversion following primary closure of urethral defects due to the ease of maintenance and increased patient tolerance of the technique.

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INTRODUCTION:

Urethral stricture formation is a recognized sequela to urethral anastomosis in dogs and in people. Factors incriminated in urethral stricture formation include failure to include the mucosal layer during anastomosis, tension on the anastomotic site, inappropriately large urethral catheter size causing distention at the anastomotic site, suture composition and pattern, and incomplete urinary diversion techniques.[1]

Urinary diversion by urethral or urinary bladder catheterization is important in management of urethral injuries. Periurethral urine accumulation can delay wound healing and result in production of periurethral scar tissue. [2,3] A previous study which utilized urethral transection and apposition of the urethral ends over a catheter without primary anastomosis found increased fibrosis, uroepithelial flattening with areas of metaplasia, microabscesses in the epithelium, and large numbers of mononuclear cells infiltrating the mucosa and submucosa at 20 weeks postoperatively.[1] Changes were more severe in this group than in a group of dogs treated in a similar manner but with concurrent urethral anastomosis.

Prepubic and transurethral urinary diversion techniques have been used separately and in conjunction with each other. Investigators postulate that prepubic (antepubic) urinary diversion may provide more complete urinary diversion than transurethral catheters thus allowing urethral healing with less urine present at the anastomotic site.[1,4] However, there is no published data relative to the effect of prepubic (tube cystostomy) urinary diversion on healing of nontraumatized urethral anastomoses in dogs.

The purpose of this study was to evaluate urethral healing and determine whether tube cystostomy would result in decreased urethral stricture formation when compared to transurethral urinary diversion techniques. Clinical, radiographic, gross pathologic and histopathologic urethral changes and urodynamic alterations resulting from tube cystostomy and transurethral catheterization were examined and compared in this study. The following literature review will provide the background for the design of this study.

LITERATURE REVIEW:

Historical Perspective of Urethral Stricture Formation

A urethral stricture is a scar that forms from tissue injury or destruction. Contraction of a urethral scar in its lengthwise axis shortens the circumference of the circle and decreases luminal cross sectional area.[5,6] Strictures of the urethra have been recognized as a major medical problem for centuries. Mention of a specific treatment for this condition appears in the early Greek literature.[7] During the sixteenth through the eighteenth centuries, urethral strictures in people were thought to be "growths" within the urethra. During the 1800's, R. H. Thompson developed the first understanding of urethral stricture formation. He recognized that urethral stricture is a possible complication of normal wound healing of the urethra. Benefits heralded from urinary diversion techniques were well accepted by the early 1900's, and techniques for urethral reconstruction were being described. In 1915, Hamilton Russell described a urethral reconstruction procedure whereby the stricture was excised and one wall of the urethra was reapproximated. The other wall of the urethra was left to heal by second intention. This technique represented the first description of urethral reconstruction for urethral stricture.[6]

The regenerative capacity of the canine urethra was described in a study performed by Weaver in 1962. Dogs with 1/2 to 2/3 of the diameter of the urethra removed for 4 -5 centimeters and catheters used to divert urine had evidence of urethral mucosal regeneration in as few as seven days. The corpus spongiosum healed and appeared normal histologically in four to five weeks. Urethral stricture developed in dogs that had complete urethral transection managed only with urinary catheters. This information was applied to the treatment of urethral strictures in men by performing meatotomies and allowing the

meatotomies to heal with concurrent urinary diversion by urethral catheterization. This technique led to good results for six months to five years after treatment.[7]

Canine anatomy:

The canine urethra is composed of three distinct portions that include the prostatic, membranous, and penile or cavernous urethra. The prostatic portion extends from the neck of the urinary bladder to the caudal aspect of the prostate gland. It has a mucosal layer of transitional epithelium and a submucosal layer of connective tissue, glands and erectile tissue. Near the urinary bladder, the muscularis layer is composed of irregular layers of circular or obliquely oriented smooth muscle. More caudally, the muscularis layer of the prostatic urethra is composed of skeletal muscle. The membranous urethra extends from the prostate gland to the bulb of the penis. The cavernous urethra extends from the bulb to the tip of the penis. The mucosal layer of all portions of the urethra is composed of transitional epithelium, and the muscularis layer is composed of skeletal muscle. Transitional epithelium is present proximally in all portions of the urethra and becomes stratified squamous epithelium at the distal end of the cavernous urethra. Cavernous tissue is present beneath the epithelium, and the muscularis layer is composed of smooth muscle. Ligamentous attachments are present between the caudal aspect of the membranous urethra and the bulb of the penis.[4, 8-11]

Urethral disruptions in people often occur in the membranous urethra because the ligamentous attachments present between the caudal aspect of the membranous urethra and the bulb of the penis make this portion of the urethra susceptible to traction injuries. Because of similar anatomic features between the male dog's lower urinary tract and human male anatomy, this theory may be applicable to urethral injury in the dog.

Urethral Trauma:

The most common causes of urethral injury leading to urethral stricture formation in people are urethral disruption by primary traumatic urethral avulsion, surgical prostatectomy and urethral severance by fractured pelvic bones, although one investigator believes that urethral laceration by bone fragments is thought to rarely occur.[11, 12] Since the late 1980's, men with urethral trauma have been treated in one of three ways: 1) primary realignment of the injury site over a catheter, 2) primary urethroplasty, or 3) suprapubic cystostomy. Primary urethral anastomosis is fraught with complications such as high rates of stricture formation, impotence and incontinence. Most men with urethral trauma are treated with suprapubic cystostomy catheters and subsequent correction of urethral strictures four to six months later.[11]

Leading causes of urethral trauma in dogs include automobile accidents, bite wounds to the perineum, projectiles, calculi lodged in the urethra and iatrogenic injuries.[2, 13] Iatrogenic injuries occur secondary to urethral catheterization for diagnostic studies of the urinary bladder or urethra. Urethral obstruction treated with vigorous attempts to pass a catheter can cause urethral contusion or laceration and may lead to full thickness necrotic defects that result in cutaneous fistula formation.[13] The incidence of urethral injury associated with pelvic fractures in people ranges from 1.4 - 11%. Selcer reported a 5% incidence of this type of urethral injury in dogs in a prospective study.[11, 14] In that study, 39 of 100 dogs with pelvic fractures had urinary tract injury documented by positive contrast urethrography and cystography.[14]

Partial urethral tears in dogs are typically managed with transurethral catheterization for a period of two to three weeks. Complete urethral lacerations are optimally treated with debridement and primary anastomosis. Stricture formation may occur as a result of either partial or complete urethral injury. In people, stricture formation following complete urethral disruption is reported to be 69 % when treated with urethral alignment over a catheter without surgical anastomosis and 100 % when treated with only suprapubic cystostomy.[11] The incidence of urethral stricture formation after trauma or surgery in the dog is not known. Ideal treatment for urethral stricture in dogs is thought to be resection of the stricture and reanastomosis with appropriate urinary diversion.[13] If the urethral stricture is too long to permit resection and anastomosis, the urethra can be incised through the stricture longitudinally and allowed to heal over a urethral catheter. Surgical techniques such as scrotal urethrostomies or extrapelvic cystourethrotomies may also be employed to divert urine if the stricture is extensive.[13-15] Techniques that are less commonly used in treatment of urethral stricture in dogs include balloon catheter dilatation and bougienage of the affected area.

Evaluation of the Injured Urethra:

Urethral injuries are not always readily identifiable. Evaluation of fluid obtained through abdominocentesis or diagnostic peritoneal lavage can reveal urine in the abdomen and thus aid in the diagnosis but not localization of lower urinary tract disruption. Passage of a urinary catheter may lead to false negative information about the degree of urethral injury since a catheter can be passed retrograde into the urinary bladder in the presence of partial urethral tears.[16] However, it is unlikely that a urethral catheter can be successfully passed to the urinary bladder in a completely transected urethra. Urethral catheterization may also yield information regarding partial urethral obstructions. Partial urethral

obstructions of soft tissue origin may act as a one way valve preventing normal urine passage but allowing passage of a urinary catheter. If urethral trauma or partial obstruction is suspected, the urethra and urinary bladder should be examined by contrast radiographic studies.[17]

The urethra is not visible on survey radiographs, and contrast studies are necessary to allow visualization. Urethral abnormalities such as tears, mucosal irregularity, strictures and luminal filling defects can be diagnosed.[18] Three techniques used to evaluate the urethra include retrograde urethrography, antegrade urethrography and voiding urethrography. Survey radiographs should precede contrast radiography to confirm that fecal material in the intestinal tract will not interfere with the study, to evaluate structures visible on the survey radiographs, to provide a basis for comparison after contrast medium is injected, and to determine appropriate radiographic technique. Complete evaluation of the urethra requires at least two different radiographic projections, and in many instances three views are optimal. Projections commonly used include lateral, ventrodorsal and ventrodorsal oblique views. Ventrodorsal oblique projections are used to evaluate the male canine urethra since the prostatic and membranous urethra are frequently superimposed on the penile urethra on the ventrodorsal radiograph.[18, 19]

Positive contrast retrograde urethrography is the preferred diagnostic test for evaluating urethral luminal compromise. Catheters with distensible cuffs such as Foley or Swan-Ganz balloon catheters are preferred for catheter retention and to prevent retrograde flow of contrast medium. The catheter tip is advanced to the level of the os penis and the retention cuff is inflated. Aqueous, tri-iodinated organic contrast media with 100 to 150 mg I/ml are used for urethrography. Relatively dilute contrast medium is used to decrease the risk of obscuring filling defects within the lumen.[19] The catheter should be primed with

contrast medium prior to placement to minimize artifacts created by air bubbles. An estimated amount of contrast medium (10-25 ml) needed to fill and distend the urethra is injected, and the radiograph is exposed just prior to completion of the injection. Additional views should be preceded by injection of additional contrast medium.

Maximal distention retrograde urethrography (MDRU) was thought to be a relatively reproducible technique developed to more consistently evaluate the diameter of the prostatic and membranous urethra. Animals are typically placed under general anesthesia in lateral recumbency. The penile urethra is catheterized with an end hole balloon catheter and the retention cuff is inflated. Infusion of contrast medium is performed until the vesicourethral junction is distended as determined by fluoroscopic observation or palpation of the turgid urinary bladder. Lateral and ventrodorsal radiographs are made while an additional five to ten milliliters of contrast medium is injected. In a study performed in normal dogs, MDRU was shown to have reproducible results. However, potential complications of MDRU include hemorrhagic cystitis secondary to over distention of the urinary bladder and rupture of the urinary bladder.[20-23]

Antegrade urethrography is used infrequently, principally after initial radiographic studies of the urinary bladder. A catheter is placed in retrograde fashion into the urinary bladder, and contrast medium is injected through the catheter as the catheter is withdrawn. Repeat catheterizations are required for additional radiographic views. Artifacts are frequently encountered with this technique because of an inability to produce uniform urethral filling and distention and a constant urethral pressure.[24]

Voiding urethrography can be performed in animals, but because of the difficulty in inducing and sustaining urination during radiographic exposure this procedure is not

frequently performed. The procedure requires heavy sedation or light anesthesia. The urinary bladder is filled with contrast medium by retrograde catheterization, intravenous urography or direct antepubic infusion. Urination is induced by compression of the bladder with a radiolucent device placed on the abdomen. This technique is best used to evaluate the distal urethra because the urethra can be distended uniformly without interference of a catheter. Difficulty in obtaining multiple views further compromises the technique.[18, 24]

Trauma of the lower urinary tract is typically evaluated by positive contrast retrograde urethrography. Urethral contusions may be associated with radiographic evidence of narrowing of the urethral lumen. [4] Small lacerations and partial urethral tears may allow extravasation of contrast medium from the site of urethral damage. Contrast medium often reaches the urinary bladder in cases of partial urethral tears. However, with complete urethral disruption most of the contrast medium extravasates through the urethral defect into surrounding tissues. Urethral strictures produce narrowing of the lumen. Urethral spasm may mimic stricture but can, in many cases, be differentiated from stricture because spasms tend to result in gradual urethral narrowing as opposed to the abrupt urethral narrowing of most strictures.[18]

Urodynamics:

Urodynamic assessment of the lower urinary tract involves the measurement of pressure changes and flow rates induced by infusion of an appropriate medium. Sterile saline or CO_2 are the most commonly used media. The urethral pressure profile (UPP) measures change in urethral pressure as a recording catheter is moved distally from the bladder through the length of the urethra.[25] This procedure is useful in evaluating increased

resistance or pressure associated with urethral stricture. Urethral strictures increase urethral pressure which translates physiologically into increased resistance to urine flow.

Several parameters are measured on UPP studies that aid in assessment of micturition function. Maximum urethral pressure (MUP) is defined as the highest pressure value recorded and occurs in the middle or distal penile urethra in male dogs. Maximum urethral closing pressure (MUCP) is calculated as MUP minus resting intravesicular pressure (IVP). Functional profile length (FPL) is the distance over which the urethral pressure is greater than the intravesicular pressure as determined from urethral pressure profile (UPP) tracings. Electromyography (EMG) can also be performed in conjunction with urodynamic procedures. EMG records activity of the external urethral sphincter which is innervated by the pudendal nerve, and is useful in determining abnormal neuromuscular activity or coordination with detrusor activity.[17] Normal values reported for UPP measurements in male dogs are as follows: MUP = 44-110 cm H_2O, MUCP = 38-100 cm H_2O, IVP= 10-11 cm H_2O, and FPL =19-28 cm. [46, 57]

The cystometrogram (CMG) is a pressure-volume recording that provides measurements of urinary bladder capacity and compliance, detrusor activity, and threshold volumes and pressures. An infusion pump is attached to the pressure transducer to infuse the selected medium. Saline is a simple, reliable medium and is safe for cystometry and urethral pressure profilometry. Saline infusion does not require special equipment. The urinary bladder is filled with saline and vesicular pressures are recorded.

Cystometric values recorded include T-I, T-II, T-III, T -Threshold, T-Max and T-V. T-I is baseline intravesicular pressure. T - II is change in pressure from T- I to threshold pressure in relation to the volume infused (compliance). Compliance is calculated

as the change in pressure per change in volume ($\Delta P/\Delta V$). Compliance is a measure of the bladder's ability to accommodate infusion and is highly dependent upon filling rates. Normal compliance values are less than 10 cm H_2O/100 ml. T - III pressure is recorded just prior to a detrusor reflex and is rarely observed in dogs and cats.[17] T -Threshold is the intravesicular pressure at the onset of bladder contraction. T - Max is the maximum intravesicular pressure that is recorded during the detrusor contraction. T-V is the volume of fluid or gas infused that stimulated a detrusor reflex.[17] Although of comparative clinical value, it has not been determined how accurate urodynamic studies reflect true physiologic status and coordinated activity of the urinary bladder and urethra.[26] The voiding phase of micturition is better evaluated with uroflowmetry, which is performed by measuring flow of urine through the urethra during micturition. Cystometry is performed in conjunction with uroflowmetry for a complete study.

Factors Affecting Urethral Healing:

Factors that influence resolution of a urethral injury include urine extravasation, tension at the site of urethral anastomosis, and urethral continuity.[3] The potential for urethral stricture is enhanced when urine comes in contact with periurethral tissue.[5, 27] Urine is caustic to subepithelial tissues and results in periurethral inflammation, fibrosis, and delayed wound healing. Extravasation of urine for a 12-24 hour period is thought by some investigators to be insignificant.[28] However, extravasation of urine over a longer time results in cellulitis, edema and wound infection. In experimental studies of urethral injury in a rat model, failure to divert urine resulted in severe urethral inflammation resulting in fibrosis. When suprapubic drainage was employed in these rats, virtually no inflammatory reaction occurred. Even severe urethral injuries in rats were not followed by

stricture formation when urine was diverted.[5]

Lacerations of the urethra and urethrotomies that leave the mucosa partially intact have been shown to heal without stricture formation.[7, 27] Regeneration of the urethra was demonstrated by Raney in a study after partial prostatectomy and urinary diversion in dogs. Two additional studies also compared the effects of primary closure with second intention healing of prescrotal urethrostomies.[29, 58] In both studies, less hemorrhage resulted when the urethrotomy sites were sutured compared to when they were left to heal by second intention. Increased fibrosis and decreased inflammation were observed in urethras that healed by second intention, but radiographic or clinical evidence of stricture formation was not observed in either group of dogs.

If the urethra is completely transected, the mucosa retracts into cuffs of periurethral tissue due to contraction of the muscular layers within the walls of the urethra. If urethral ends are apposed with suture, but excessive tension is present at the anastomotic site, a gap is created between urethral ends. Proliferation of fibrous tissue occurs within the gap because of the discontinuity of the urethra and results in the formation of an obstructive scar.[30] Histologically, remodeling of fibrous tissue in the corpus spongiosum is responsible for stricture formation as opposed to fibrous tissue formation in the submucosal layer.[3]

Various suture patterns for closing urethral incisions and anastomoses have been evaluated experimentally. The continuous extraluminal pattern causes the least distortion of the urethra and minimal periurethral reaction.[31, 32] A two layer closure of the urethra has been suggested to cause less stricture formation in urethrotomies compared to a one layer closure.[3] With a two layer closure, the mucosal layer is closed as one layer and the tunica

albuginea is closed as the second layer. After complete disruption, apposition of the urethral mucosa by fine, absorbable sutures results in reestablishment of urethral continuity. Anastomosis of the urethra after a complete transection is expected to result in some decrease in lumen size because of the tendency for scars to contract in a length-wise axis.[33]

Suture materials recommended for use in urethral surgery in small animals include polyglycolic acid, polyglactin 910, polydioxanone and polypropylene. Polyglycolic acid suture was found to cause less inflammation and foreign body reaction than chromic catgut in one study.[34] When polydioxanone and polyglactin 910 were compared for closure of urethrotomies in dogs to nonsutured incisions, sutured urethrotomies had more inflammation present than those urethrotomies that were allowed to heal by second intention, however suture type did not influence the extent of inflammation.[29, 58] Polypropylene results in minimal tissue reaction consisting of a thin fibrous capsule when used for urethral anastomosis.[35] Polyglycolic acid, polyglactin 910, polyglyconate and polydioxanone have all been used clinically without complications attributed to suture material.[8]

The use of urethral catheterization for temporary urinary diversion to protect partial urethral defects or anastomotic sites has been referred to as urethral stenting. Use of urethral stents is controversial. Some investigators have suggested that urethral stents have a deleterious affect upon urethral healing. Catheters that over distend the urethra may delay wound healing by interfering with reepithelialization. [7, 36, 37] Urethral stents also increase the risk of ascending urinary tract infection and fibrosis which can exacerbate stricture formation.[4, 38-41] Investigators that advocate urethral stents cite urine diversion and channeling of reepithelialization as positive attributes of this technique.[3] Catheterization for

three to five days is thought to allow uroepithelium to bridge the wound and prevent urine extravasation.[42] Catheter composition could also conceivably affect the amount of inflammation in dogs. It has been surmised in some studies that cytologic reactions could cause submucosal thrombosis which may lead to ischemic necrosis and scar formation. [37, 43] This has not been confirmed in other studies. Catheters of latex, teflon covered latex and polyvinyl chloride were compared in one study, and silicone, latex rubber, teflon covered latex and polyvinyl chloride catheters were compared in another study. Size and type of catheter and duration of urethral catheterization varied in each study. No significant differences were found in one study, while only mild histopathologic changes were found in the other study. No one material uniformly produced the same tissue reaction in all animals in which it was implanted. [38, 44] Tissue reactions were thought to be the result of individual response to the catheter. A similar study performed in men using latex, plastic and silastic catheters concluded that no significant difference in the amount of inflammation was associated with the various types of catheters or with the duration of catheter use. In most cases the urethral epithelium was histologically normal after six weeks.[37] In summary, the use of urethral stents should be based on the potential complications that might be exacerbated by urine extravasation and the extent of urethral trauma.[2]

MATERIALS AND METHODS:

Fifteen, adult, intact male dogs with body weights ranging from 13.6 to 26.0 kg were studied. All dogs were vaccinated for distemper, hepatitis, leptospirosis, parvovirus[1†] and rabies[2†] and were dewormed with fenbendazole[3†] at least two weeks prior to the study period. Animals were housed in climate controlled runs and fed a commercial diet[4†] twice daily. All dogs were healthy based on results of physical examination and laboratory evaluation. Laboratory evaluations consisted of a complete blood count (CBC), blood chemistries, urinalysis (UA) and urine culture. Dogs were randomly assigned to one of three treatment groups. Treatment groups assigned were transurethral catheters (Group U), cystostomy catheters (Group C), and transurethral and cystostomy catheters (Group B).

Urodynamic Studies:

Dogs were fasted for 12 hours and were walked prior to each anesthetic episode and testing procedure. Anesthesia was induced with thiamylal[5†] (8 mg/kg) administered intravenously through a cephalic catheter. Dogs were intubated, and anesthesia was maintained with a mixture of halothane[6†] and oxygen (1-2 %) delivered via a cuffed endotracheal tube connected to a semiclosed circle system. Animals were placed in right

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[1†] Pfizer, Animal Health Division , New York, NY
[2†] Solvay, Animal Health Inc., Mendota Heights, MN
[3†] Hoescht-Roussel Agri-Vet Co., Somerville, NJ.
[4†] Canine Maintenance Diet, Hill's Company Inc., Topeka, KS.
[5†] Bioceutic Division, St. Joseph, MO.
[6†] Fort Dodge Laboratories, Fort Dodge, IA.

lateral recumbency, the prepuce was retracted, and the penis was cleaned with chlorhexidine scrub solution[7†] and sterile water.

A cystometrogram (CMG) was performed on each dog as follows. A 9 French (F), dual lumen, urethral catheter[8†] was passed into the urinary bladder. All urine was removed by gentle suction with a 35 ml syringe, and the volume was recorded as residual volume (RV). The dual lumen catheter was then attached to a pressure transducer[9†] with silastic tubing filled with sterile saline solution. The silastic tubing was connected through appropriate amplifiers to a physiograph[10†] equipped with a chart recorder. The second port of the catheter was attached by silastic tubing to a one liter bag of 0.9 % sodium chloride solution. Three trial runs of a medium fill (10-100 ml/min) CMG were performed, and pressures were recorded. Paper speed of the chart recorder was 2.5 mm/sec with a sensitivity of 10 cm of water. The CMG was terminated when urine or fluid dripped from the distal penis. The infused volume of saline was recorded. Resting vesicular pressure (P_{ves}), total infused volume (V_{max}), vesicular compliance (C_{ves}), and maximum bladder capacity ($V_{ves,\ max}$) were calculated for each of the three runs. This procedure was repeated 10 weeks postoperatively, just prior to termination of the study. Mean values were calculated for each of these variables.

Urethral pressure profiles were performed immediately following the CMG. An 8F urethral pressure profile catheter[11†] was introduced into the urinary bladder. Silastic tubing

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[7] †Nolvasan® Fort Dodge, Fort Dodge, IA.
[8] †Life Tech Inc., Houston, Texas
[9] †Gould Inc, Oxnard, California
[10] †Grass Physiograph Model 7D polygraph, Quincy, MA.
[11] †Life Tech Inc., Houston, TX.

filled with sterile saline was attached by a three way stopcock[12†] to the pressure transducer, and resting vesicular pressure was recorded. Sterile saline was infused at a rate of 2 ml/min for the urethral pressure profile (UPP). The urethral catheter was manually withdrawn at 1 cm/sec while pressures were recorded with a chart speed of 5 mm/sec and a sensitivity of 5 cm of saline. Three trial runs of the UPP were performed for each dog. Resting intravesicular pressure (IVP), maximum urethral pressure (MUP) and maximum urethral closure pressure (MUCP) were recorded or calculated for each run. This procedure was repeated 10 weeks postoperatively just prior to termination of the study. Mean values were calculated for each of these variables.

Radiographic Studies:

Lateral and ventrodorsal survey radiographs were made of the caudal abdomen and pelvis of each dog following the UPP procedure with the animals maintained under halothane anesthesia. The prepuce was retracted and the tip of the penis was cleaned with chlorhexidine solution. An 8-12F Foley catheter[13†] was inserted into the penis to the level of the distal end of the os penis. The cuff of the Foley catheter was inflated to secure the catheter and to prevent back flow of contrast medium. The contrast medium used for all studies was a sodium iothalamate solution[14†] diluted with sterile water to produce an iodine concentration of approximately 133 mg I/cc. This solution was injected during each of the four radiographic views. Lateral, lateral oblique, ventrodorsal oblique and repeat lateral radiographs were made for each study. For each radiograph, the exposure was made toward the end of the injection of contrast medium while still injecting. Radiographic studies were performed on each dog preoperatively and ten weeks postoperatively.

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[12] † Baxter Healthcare Corp., Bridgeport, NJ.
[13] † Bard Urologic Division, Covington, GA.

Contrast radiographs were also made of the gross urethral specimen obtained at necropsy as described below.

Surgical Procedure:

Surgery was performed following urodynamic studies and urethrography. The ventral abdomen was clipped from just cranial to the xiphoid process to the caudal aspect of the scrotum, and the prepuce was flushed. A standard preparation scrub was performed on the ventral abdomen with betadine and alcohol. An 8F, rubber, urethral catheter[15†] was aseptically placed into the urethra. The surgical site was isolated using disposable, quarter drapes and a laparotomy drape. A standard, peripreputial, ventral midline abdominal approach was performed. The membranous urethra was exposed by cranial traction of the urinary bladder and prostate gland. The prepubic tendon was partially incised at its origin on the prepubic eminence as required. A duck-billed rongeur was used to perform a partial pubic symphysectomy to provide access to the membranous urethra in some animals. The preplaced urethral catheter facilitated identification of the urethra for suture placement and urethral anastomosis. The surgical field was isolated with sterile saline moistened laparotomy sponges to decrease abdominal contamination and to prevent tissue desiccation. Two stay sutures were placed in the membranous urethra, 1 cm and 1.5 cm caudal to the caudal aspect of the prostate gland. The urethral catheter was withdrawn from the urinary bladder to a position caudal to the stay sutures. A 3-5 mm segment of the urethra was resected between the preplaced stay sutures and was submitted for histologic evaluation. The urethral catheter was advanced through the proximal urethral orifice into the urinary

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[14] † Conray 400, Mallincrodt Medical, St. Louis MO.
[15] † Sovereign Sherwood Medical Co., St. Louis, MO.

bladder. Eight, preplaced, simple interrupted sutures of 4-0 polyglyconate [16†] were tied reapposing the transected urethral ends to include mucosa, submucosa, muscularis and serosal layers.

Stay sutures were placed in the urinary bladder of dogs in Groups B and C. A 3-0, polyglyconate, purse string suture was placed into the ventral aspect of the body of the urinary bladder. A paramedian stab incision was made through the skin and abdominal wall, craniolateral to the abdominal incision. An 8 F, Foley catheter was placed through the abdominal stab incision and a stab incision was made into the bladder within the previously placed purse string suture. The purse string suture was tightened, and 3 ml of sterile saline was used to inflate the bulb of the Foley catheter. The urinary bladder was secured to the ventral abdominal wall with two, 3-0, polyglyconate sutures, placed cranial and caudal to the entrance of the Foley catheter into the urinary bladder. The prepubic tendon was secured to its origin on the prepubic eminence with 2-0 polypropylene suture.[17†] A warm sterile saline solution was used to flush the abdominal cavity prior to routine closure. Dogs in Group C had the urethral catheter removed prior to recovery. Cystostomy catheters were secured to the skin of the ventral abdomen with a chinese finger trap suture. Catheters were then connected to a one liter sterile urine collection bag by sterile silastic tubing.

Dogs in Group U were maintained with an 8F, transurethral catheter. A single purse string suture and chinese finger trap suture were placed at the tip of the penis and prepuce. Transurethral catheters were connected to a 1 liter sterile collection bag with silastic tubing. Dogs in Group B had the transurethral and cystostomy catheters connected

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[16 †] Davis and Geck Monofil Inc., Wayne, NJ.
[17 †] Prolene® Ethicon Inc. Johnson and Johnson Co., New Brunswick, NJ.

by a "Y" connector[18†] that was attached to a one liter sterile collection bag. Urine collection bags were attached to each dog's back by a sweater fashioned from stockingette[19†] and elastic tape bandage material. [20†] Dogs were fitted with Elizabethan collars for the first seven post-operative days to discourage catheter removal. Butorphanol tartrate[21†] (0.4 mg/kg SQ) was administered at the conclusion of the surgical procedure and prior to recovery from general anesthesia to control postoperative pain.

Postoperative Care and Evaluation:

All dogs recovered from general anesthesia and were monitored in individual cages for seven days. Butorphanol tartrate and acetylpromazine[22†] (0.2 mg/kg) were administered subcutaneously for pain control and to prevent removal of transurethral and cystostomy catheters. Temperature, pulse, respiratory rates and surgical sites were evaluated twice daily. Dogs were walked 3 times daily, and urine bags were emptied at the conclusion of each walk. Urine color was recorded at each collection period. Transurethral and cystostomy catheters were removed on the seventh post-operative day. Urinalysis and urine cultures were performed via cystocentesis when catheters were removed. Dogs were then returned to individual runs and walked twice daily for the remainder of the study.

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[18] † Small Parts Inc., Miami Lakes, FL.
[19] † Bioseal, Placentia, CA.
[20] † Elastikon® Johnson and Johnson, New Brunswick, NJ.
[21] † Torbutrol® Fort Dodge Lab Inc., Fort Dodge, IA.
[22] † Acepromazine® Fort Dodge Lab Inc., Fort Dodge, IA.

Beginning on the 7th post-operative day dogs were assessed twice daily for urinary posturing, stream quality and abdominal effort. Assessment scoring systems for each variable are listed in Table 1.

Urinalysis and culture of urine obtained by cystocentesis was performed at 1, 4, 8 and 10 weeks post-operatively. CMG, UPP and urethrograms were repeated under general anesthesia at the tenth week as previously described.

Necropsy:

Dogs were humanely killed ten weeks postoperatively by an overdose of pentobarbital phenytoin.[23 †] Animals were necropsied, and the entire lower urinary tract was harvested to include the urinary bladder to the distal end of the penis.

In-vitro radiographic studies were made of the removed urinary tract by inserting an 8F, Foley catheter into the trigone of the urinary bladder through a ventral incision in the body of the urinary bladder. Foley catheters were secured in place with a ligature proximal to the inflated bulb of the catheter. A second 8F, Foley catheter was placed in the distal urethra with the tip at the distal end of the os penis. The bulb of the catheter was inflated to secure the catheter in place and to prevent extravasation of fluid from the urinary tract. Foley catheters in the urinary bladder were attached to a water manometer, and positive contrast urethrography was performed on the specimen with radiographic exposures made at urethral pressures of 60 cm and 90 cm of water (Fig 1). The specimen was then fixed in

[23 †] Beuthanasia-D Special® Shering-Plough Animal Health Corp., Kenilworth, NJ.

10% buffered formalin and mounted in paraffin. Sections were made and stained with hematoxylin and eosin.

Histology:

Sections were examined under light microscopy by two pathologists blinded to the treatment groups. The pathologists assigned scores for inflammation and fibrosis. Inflammation scores were defined as follows: 0 = none; 1 = mild inflammation with focal areas of a small number of lymphocytes and plasma cells ; 2 = moderate inflammation with diffuse infiltrates of lymphoid cells in moderate numbers with infiltration of the cells into the epithelium and neutrophils present ; and 3 = severe inflammation with diffuse infiltrates of lymphoid cells extending into the muscularis forming lymphoid aggregates, neutrophils commonly extending into the epithelium, epithelial ulceration and erosion. Grades of fibrosis were assigned to histologic sections of each animal as follows: 0 = none; 1 = mild fibrosis with fibrous tissue through the muscularis layer forming a gap less than one half of the width of muscularis layer; 2 = moderate fibrosis forming a gap one half to full thickness of the width of the muscularis layer; and 3 = severe fibrosis with the fibrous gap being greater than the width of the muscularis layer.

Urethrographic Evaluations

Measurements of the urethral diameter were made from all in-vivo radiographs by three individuals blinded to the treatment groups using metric calipers. Radiographs included preoperative, ten week postoperative and in-vitro specimen series. Each in-vivo series included lateral, lateral oblique, ventrodorsal oblique and second lateral views, and each in-vitro series included lateral and ventrodorsal views, each made at both 60 cm and

90 cm of water pressure. Individual measurements obtained by three individuals were averaged for calculations and statistical analysis. Urethral diameter measurements were made at the following sites: 1 cm cranial to the surgical site, at the surgical site, 1 cm caudal to the surgical site, 2 cm caudal to the surgical site and at a site thought to represent the maximum urethral diameter in the pelvic canal and caudal to the surgical site (measurements made by two individuals) (Fig 2). Measurements made 1 cm cranial and 1 cm caudal to the surgical site were averaged for a single value for 1 cm site calculations. For preoperative radiographic measurements, the surgical site was identified on postoperative radiographs, and the location of this site was then transposed to the corresponding preoperative radiographs. The percent lumen diameter reduction (PLDR) was calculated by comparing the lumen diameter at the surgical site to each of the measurements of the 1 cm averaged site, the 2 cm site and the caudal maximum site using the following formula:

$$PLDR = 100 - (\text{Urethral Diameter}_{\text{Surgical Site}} \times 100 / \text{Urethral Diameter}_{\text{Comparative Site}})$$

Differences in the PLDR were then calculated from preoperative and postoperative radiographs for each in-vivo view and were compared between groups. The PLDR for specimen radiographs was compared between groups in absolute values, rather than differences, since there were no preoperative values. The PLDR of the specimen radiographs were found to be consistent in both views and at all measured areas of the urethrogram performed at 90 cm H_2O. For that reason, the PLDR for specimen radiographs were also compared to PLDR for postoperative in-vivo radiographs to evaluate correlation between in-vitro and in-vivo measurements.

Statistical Analysis:

Statistical analysis of residual urine volume, cystometry values (resting vesicular pressures, compliance, infused volumes and maximum bladder capacity), urethral pressure profilometry values (resting vesicular pressure, maximum urethral pressure and maximum urethral closure pressures) and clinical assessment observation scores were performed using a repeated measures analysis of variance with $p < 0.05$ being significant. Analysis of variance was used to analyze the differences in PLDR of the in-vivo preoperative and postoperative measurements as well as in-vitro measurements at all sites, with $p < 0.05$ being significant. Culture results were analyzed using Fischer's exact test, with $p < 0.05$ being significant. Inflammation and fibrosis scores were analyzed using the Kruskal-Wallis test, with $p < 0.05$ being significant. The relationship between the changes in the PLDR (in vivo views and specimen views) based on different radiographic views, were evaluated by calculating Pearson correlation coefficients. This analysis compared all possible pairs of radiographic views at each measurement site and determined whether there was significant correlation of values between each measurement site of all radiographic views. Treatment group effects on PLDR measurements were tested using ANOVA. Sheffe's multiple comparison procedure was used to compare PLDR at each measurement site between groups in a pairwise fashion until each group was compared to the other, with $p < 0.05$ considered significant.

RESULTS:

Preoperative Data Base:

The CBC and biochemical profiles were within normal limits for all dogs pre and postoperatively. Normal values for complete blood counts and blood chemistries are listed in Table 2. Urinalyses were normal preoperatively with the exception of Dog #628, which had a positive urine culture. Postoperative urine culture results are listed on table 8.

Differences in residual volumes (V_{res}) were present when Group U was compared to Groups B and Group C. Group U V_{res} was decreased when preoperative values were compared to postoperative values, however significant differences were not found postoperatively between any of the treatment groups (Table 3).

Cystometrogram (CMG) trial runs were performed, and the average of these trials were used in data analysis. Differences in averaged total volumes infused (Vi) were significant between preoperative and postoperative values ($p = 0.0049$) for all groups, but differences were not present between the three treatment groups (Table 3). Urethral opening pressures (Puo) revealed no significant differences when preoperative measurements were compared among and between treatment groups. One value was identified as an outlier and was excluded from analysis (Table 3). Vesicular compliance was calculated, and no significant differences were present when preoperative to postoperative measurements were compared among and between treatment groups (Table 3).

Urethral Pressure Profilometry (UPP):

Three consecutive trials of UPP tracings were performed immediately preoperatively and at ten weeks postoperatively with animals under anesthesia. Values for IVP, MUP and MUCP were averaged and used in statistical analysis. No significant differences were found when the preoperative values were compared to the postoperative values or when values were compared between groups (Table 3).

Clinical Assessment:

All clinical assessment scores changed significantly during the first several days of the observation period ($p < 0.05$), but the change over time was not affected by treatment. All dogs urinated in the squatting position for 2-3 days postoperatively (Table 4) and dogs in Group U and Group B exhibited mild to moderate abdominal effort (Table 5). Thereafter all dogs urinated by "leg hike" during urination with no abdominal effort. Gross urine color was abnormal in all groups for several postoperative days and then became normal for all groups (Table 6). Stream quality observation scores were not recorded for groups U and B because of the presence of urethral catheters for the first postoperative week. Significant differences in stream quality scores (Table 7) or abdominal effort observation scores were not present between groups after the second postoperative week.

Urinalyses, urine cultures and culture sensitivities were performed on postoperative weeks 1, 4, 8 and 10. Urine for the first postoperative urinalysis was obtained through indwelling transurethral catheters after the collection port was swabbed with alcohol. Urine for the remaining urinalyses was obtained by cystocentesis. During weeks four, eight and ten, ten, six and seven of the fifteen dogs respectively had positive urine cultures. There

were no significant differences between groups when analyzing for the frequency of bacterial urinary tract infection. Data are listed in Table 8.

Urethrography:

All in-vitro urethrographic values for PLDR were found to be consistent with each other within each measurement area in all views ($p < 0.05$). Statistical evaluations were not performed to evaluate values between measurement areas. The 1 cm PLDR values were compared between groups from all views of the in-vitro urethrograms. A 16% difference in PLDR values was present between Groups B and C. Group B had the greater PLDR (p ranged from 0.03 - 0.06 from the 60 and 90 cm H_2O ventrodorsal and lateral urethrograms). The in-vivo PLDR values were not as consistant with each other or with in-vitro values within the same measurement area with the exception of the 1 cm measurement site of the second lateral in-vivo urethrograms based on the corresponding measurement site of the in-vitro urethrograms ($p < .05$). A positive trend was identified for the second lateral radiographic 2 cm measurements and the specimen radiographic 2 cm measurements, however these findings were not statistically significant. No correlation was found between the caudal maximum radiographic values and the caudal maximum specimen radiographic values. The order of groups from the least to the greatest differences in in-vitro and in-vivo PLDR was Group C, Group U and Group B respectively. These findings were consistent, however not always statistically significant, for all areas measured in the radiographic studies ten weeks postoperatively (Tables 9a, 9b, 9c and 9d).

Histopathology:

Dogs were necropsied immediately after being humanely killed. No abnormalities were found in the kidneys or ureters in any dog. Lower urinary tracts were harvested from the bladder to the os penis in 14 of 15 dogs. The urethra of the fifteenth dog was severed through the surgical site during harvesting. After in-vitro radiographic studies were performed on the lower urinary tract specimen, the urinary bladder and urethra were examined. Two dogs (# 628, Group C and # 625, Group B) had urethral calculi present in the prostatic urethra. Dog # 627 of Group U, had a small prostatic abscess. No gross evidence of stricture formation or pre or post stenotic urethral dilation was noted in any dog. Histologic inflammation and fibrosis scores assigned to each urethra were compared between individuals and groups (Table 10), and no significant difference in inflammation or fibrosis scores were noted.

DISCUSSION:

Urodynamic Studies:

Cystometry was used in this study to evaluate changes in bladder contractility, storage capacity and compliance that could occur in response to partial or complete urethral obstructions. Alteration in detrusor activity was not clinically significant even though many dogs had urinary tract inflammation present caused by infection. There was a decrease in V_{res} found when the preoperative values were compared to the postoperative values, but no differences were found between groups. Decreased postoperative V_i values were found in all dogs. This could have indicated a decreased capacity, or urinary bladder inflammation could have contributed to detrusor spasticity resulting in decreased V_i in all dogs postoperatively. Inflammatory changes in the bladder could be expected to result in increased or inappropriate bladder contractions in response to urodynamic testing. It is possible that the sensitivity level of the physiograph did not allow recognition of small differences in detrusor activity. In addition, certain bacteria are also known to produce substances that result in decreased smooth muscle activity as well.[17] Finally, cystometric studies could have been affected by general anesthesia that was maintained by halothane. Drugs that depress detrusor activity include acepromazine maleate, fentanyl-droperidol, ketamine, diazepam with ketamine, pentobarbital, methoxyflurane and halothane. Because of the use of halothane during urodyanamic studies, increased detrusor activity caused by inflammation could have been depressed.[37, 45-47] However, use of drugs was limited to minimize effects upon urodynamic testing procedures. [17] In addition, each dog acted as its own control since tests were performed under the same conditions without potential artifacts associated with struggling.

Bladder capacities in dogs in this study decreased over the course of the study, but differences were not noted between treatment groups. Decreases in bladder capacity could have been the result of reduced compliance or from increased detrusor activity associated with inflammation. It appears that, overall, the dogs studied had reductions in V_{res}, V_i and compliance, which is most compatible with urinary tract inflammation rather than obstruction and overdistention.

Urethral pressure profilometry was used to evaluate resistance to urine flow by measuring pressures throughout the urethra. The UPP measures the response of the urethral smooth muscle, striated muscle and surrounding fibroelastic tissue and is used to determine whether the intraurethral pressure is reduced, normal or increased. The profile is affected by urethral lumen diameter. Increased urethral pressures can be associated with partial urethral obstruction.[17] Since stricture formation severe enough to cause partial obstruction and over-distention did not occur, significant CMG or UPP abnormalities were not seen in any of the dogs postoperatively.

Clinical Assessments:

Positions assumed during urination were observed to aid in assessing urethral function. It was thought that dogs experiencing difficulty in urination would "squat" during urination rather than "hike". During the first three postoperative days, all dogs urinated by squatting, which was attributed to postoperative discomfort. Dogs # 625 and # 627 (Group C and B respectively) also squatted for several days during postoperative weeks six and seven. Stranguria, hematuria, and dysuria were observed in these dogs during that time period. Gross hematuria was noted in two dogs intermittently until

termination of the study. All other dogs "hiked" during urination throughout the study after the third postoperative day.

In one study, increased abdominal straining was observed in eight dogs with moderate to severe urethral strictures two to six weeks after urethral severance and anastomosis.[1] Abdominal effort was therefore thought to be useful as a means of assessing clinical response to the surgical procedure. Dogs were monitored and scored during the daily observation periods. Increased abdominal effort was observed during times of dysuria at weeks six and seven in two dogs (Dog # 625 and Dog # 627). No other dogs exhibited increased abdominal effort during urination after the first postoperative week.

Stream quality was observed to determine whether any of the dogs exhibited pollakiuria and/or a diminished stream. With the exception of Dogs # 627 and # 625 during the sixth and seventh postoperative weeks, none of the dogs exhibited diminished urine stream or dribbling.

Urinalysis and Urine Cultures:

Urinary tract infection (UTI) was identified in thirteen dogs during the course of the study. Urinary tract infection indicates a disruption of host defense mechanisms. Complete and unimpeded voiding, uroepithelial surface characteristics and substances, normal epithelial cell turnover, and specific components in urine may all contribute to resistance to infection of the normal urinary tract.[48-50]

In this study, UTI was present based on isolation of bacterial agents from urine collected by cystocentesis. Cystocentesis is considered the "gold standard" by which urine should be collected to decrease the incidence of false positive test results associated with sampling of resident flora in catheterized or voided urine specimens.[51-53] One dog had a preoperative Staphylococcus spp. isolate identified on urine culture. This was most likely the result of a contaminated sample, because this specimen was collected by urethral catheterization.

Catheterization of animals is associated with an increased risk of ascending infection of the urinary tract. Bacteria may enter the urinary bladder via catheterization by three routes. Introduction of bacteria may occur by mechanical means during catheterization when resident population of bacteria present in the distal urethra are carried to the bladder. Microbes may also enter the urinary bladder lumen by ascending the catheter lumen. Lastly, motile species of bacteria can ascend into the urinary bladder by transport on the surface film layer surrounding the transurethral indwelling urinary catheters. Within 12-24 hours, the space between the catheter and urethral mucosa is filled with fluid composed of urine and exudate. [51-54]

Several studies show that the incidence of urinary tract infection increases in relation to the duration and type of urinary catheterization.[40] Continous indwelling catheterization has greater risk than intermittent catheterization. Promotion of polyuria and use of antibacterial agents also increase the resistance of bacterial agents isolated from urine samples in catheterized patients.[54]

Closed urinary drainage systems lessen the risk of infection as compared to other types of procedures. Use of stockingettes to immobilize the urine collection bags on backs

of the treatment animals was fraught with complications. Reflux of urine from the collection system into the urinary tract occurred when animals were walked. Application of side bar appliances, with the collection system attached to the rear leg, may have prevented reflux and possibly decreased the incidence of urinary tract infection.[55]

The effect of urinary catheter composition on histologic scores of inflammation and fibrosis in this study is not known. Differences in catheter composition have been implicated to influence urethral reactions. Teflon and silastic coated catheters have been found to result in less severe urethral reactions than plastic or latex catheters, however a study of urinary catheter composition and their effect on the proximal urethra of female dogs revealed that urethral reactions were similar and that infection may play a more important role on tissue reaction to foreign material. [38, 43]

Antibiotics were not administered in this study with the exception of three dogs that had severe diarrhea during the catheterization period. The use of antibiotics during urethral catheterization has been controversial. Prophylactic antibiotic therapy may decrease the incidence of infection and decrease bacteria present during the introduction of the urinary catheter. However, resistant bacterial infections can be created from antibiotic use during the catheterization period. Urinalysis and urine cultures were evaluated for bacteruria and changes in the urine sediment that could indicate pyelonephritis secondary to ascending infection.

The most common organism cultured from urine during this study was Staphylococcus spp. Agents isolated from dogs with urinary tract infections were organisms associated with skin and urogenital or gastrointestinal tracts. Dog # 628 had a

positive preoperative urine culture which was obtained via catheterization prior to CMG studies, and this could explain a positive preoperative culture.

All dogs developed mild scrotal edema immediately postoperatively. The edema appeared to be related to surgical manipulation and retraction associated with gaining exposure to the membranous urethra. Dog # 504 of Group U developed diarrhea and severe scrotal edema three days postoperatively and died while undergoing emergency castration. Necropsy findings indicated a generalized septicemia, spermatic cord thrombosis, and a localized peritonitis around the surgical site. However, the urethral anastomosis appeared to be intact. This dog was replaced with Dog #454 which had been appropriately conditioned. Five other dogs developed diarrhea during the first postoperative week. Dog # 625 of Group C had a cystostomy catheter replaced three days postoperatively and developed diarrhea six days postoperatively. Dog #622 of Group B developed diarrhea on the second postoperative day. Dog #597 of Group U developed scrotal and inner thigh edema on the fifth postoperative day, and trimethoprim sulfonamide was instituted. A scrotal ablation was performed on the seventh postoperative day, and recovery from the second surgery was uneventful. Dog #614 of Group U developed diarrhea on the third postoperative day, and Dog # 611 of Group B developed diarrhea on the second postoperative day. Trimethoprim sulfonamide (15 mg/kg) was administered twice daily for three days. Dog #627 of Group U had to have the urethral catheter replaced 5 days postoperatively. Direct fecal smears and fecal flotations were performed on all dogs that developed diarrhea, but results were negative for all parasites. All dogs that developed diarrhea had overlapping periods of time in holding facilities for the seven postoperative days. An infectious agent was thought to be responsible but could not be identified.

Three dogs that received antibiotics were placed on 15mg/kg of trimethoprim sulfonamide twice daily because of the broad antimicrobial spectrum of this antibiotic. This course of antibiotic therapy may have affected urine culture results of Dog # 611.

Urethrography:

Five areas were measured from the urethrograms. Measurements made 1 cm cranial and caudal to the surgical site were made in a similar manner to the technique described by Layton.[1] Variability in the diameter of the prostatic urethra has been well documented.[20, 56] Because the surgical site involved the prostatic urethra, more caudal measurements were made in an attempt to find a more constant measurement by which to calculate the percent lumen diameter reduction. The differences in PLDR values of the in-vivo 2 cm measurement site and the most caudal site were compared to the absolute PLDR values of corresponding specimen contrast radiographic measurements.

The second lateral in-vivo urethrographic measurements made at 1 cm cranial and caudal to the surgical site and at 2 cm caudal to the surgical site had a high correlation factor of PLDR values to the 1 cm and 2 cm measurements on the radiographs of the specimens taken at 90 cm of water pressure. The second lateral in-vivo radiograph was made after all of the in-vivo views had been made. Thus the urinary bladder was more distended on this radiograph than on previous radiographs due to the cumulative effects of multiple injections, and is closer in effect to maximum distension urethrography. This finding suggests that one can extrapolate, with relative confidence, that radiographic measurements averaged at one centimeter cranial and caudal, and at two centimeters caudal to the surgical site would correlate closely to in-vivo urethral measurements. Dogs in Group C had the least PLDR followed by dogs in Group U. Dogs in Group B consistently had the greatest

PLDR in all measurements. Differences between treatment groups resulted in the least urethral luminal diameter reduction in Group C as compared to Groups B and U.

Prostatic enlargement and radiographic evidence of cystitis was found in two out of five and four out of five dogs respectively in Group U on the postoperative urethrograms. In Group B, one out of five and two out of five dogs had postoperative radiographic evidence of cystitis and prostatic enlargement. Prostatic enlargement and radiographic evidence of cystitis was found in one out of five and two out of five dogs respectively in Group C. Prostatic enlargement was considered mild when present. Cystitis, typically characterized by gradual, diffuse thickening and mucosal irregularity of the urinary bladder wall, was most likely the result of urinary infection.

In Group U, one out of five dogs had urethroprostatic reflux in the postoperative in-vitro urethrograms and all of the dogs in Groups B and C had urethroprostatic reflux in the in-vitro urethrograms. Very small fistulous tracts or diverticula were seen on the in-vitro urethrograms in four of the five dogs in Group C, three out of five dogs in Group B and three out of four dogs in Group U. Urethroprostatic reflux during urethrography has been reported in dogs with prostatitis, prostatic hyperplasia and neoplasia. Mild urethroprostatic reflux, as seen in these dogs, does not differentiate normal from abnormal urethrograms since small amounts of contrast medium reflux can be seen in normal dogs during urethrography.[20] Urethroprostatic reflux in the in-vitro urethrograms may have indicated prostatitis to varying degrees, however the findings were not seen in the in-vivo postoperative urethrograms.

Histopathology:

Prostatic urethras were slightly U- shaped as compared to the remaining membranous urethra in all dogs after the urethral specimens were fixed in 10 % buffered formalin. Similar findings were noted in the study performed by Layton. Although surgical sites could be easily identified, stenosis was not observed, nor was there dilatation of the urethra present in any dog cranial or caudal to the surgical sites. Mild histologic changes were observed at the anastomotic site in each dog. As urethral anastomoses heal there will be some amount of lumen diameter reduction because the wound contracts. A small prostatic abscess was found in Dog # 627 but did not result in clinical signs of disease. Significant differences in inflammation and fibrosis scores were not found between groups when analyzed. This may represent the fact that groups were similar in these scores but may also represent statistical limitations, the small numbers of experimental animals or insensitivity of histologic evaluation of urethral stenoses.

Scientific guidelines for choosing appropriately sized urethral catheters as stents for urinary diversion have not been reported. Large urethral catheters could stretch the urethra and thereby contribute to fibrous tissue formation by delaying wound healing.[7, 36, 37] Small catheters may inadequately divert urine and could allow urine to irritate surgical sites. Treatment Groups U and B had urethral catheters present for seven days postoperatively. If presence of a urethral catheter contributes to fibrosis, one would expect a significant difference in PLDR between Groups U and B and Group C. This was not the case, and there were no significant differences in inflammation and fibrosis scores in this study. However, the small number of animals in this study may have prevented the detection of significance in the inflammation and fibrosis scores. Urine was diverted from the healing

urethral anastomosis by tube cystostomy without the presence of a urethral catheter at the anastomotic site in Group C. Catheterization of seven days appears adequate to allow urethral healing without excessive fibrosis resulting in significant stricture formation. A similar earlier study used transurethral catheters for two weeks, and one dog in the urethral anastomosis transurethral catheter group developed severe stricture formation. Prolonged use of urethral catheters could contribute to this outcome. All dogs in that study with urethral anastomosis and urethral catheters developed mild to severe clinical signs and pronounced histologic changes in the urethra.[1]

Dogs in this study did not develop urethral stricture severe enough to result in clinical signs. In one study, lumen diameter reductions of 60 % or greater were necessary to produce clinical signs of stranguria associated with urethral strictures. [1] The absence of severe stricture formation (> 60 % lumen diameter reduction) in this study may have been realized because most, if not all, of the reported factors that contribute to urethral stricture formation were minimized. All dogs in the present study had in-vivo percent lumen diameter reduction ranging from -5.76 to 41.48 % in the second lateral in-vivo urethrogram measurements. Careful tissue handling, proper hemostasis, nonirritating suture material, minimal tension at the anastomotic site and urine diversion for an appropriate time appeared to prevent clinical stricture formation in this study.[1, 2] Clinically, dogs in Group C appeared more comfortable and did not experience urethral spasms associated with irritation after urethral catheters were removed. Similar findings were reported in another study evaluating cystostomy catheterization in comparison to urethral catheterization. [55] Dogs in Group C had less PLDR than dogs in Groups B or U, which probably reflects more complete urine diversion from the surgical site. The absence of a urinary catheter at the surgical site may have also contributed to less PLDR in Group C. This finding may be useful in clinical cases where the urethra has undergone trauma prior to anastomosis.

Conclusion:

Urinary diversion by tube cystostomy and/or transurethral catheterization resulted in acceptable urethral lumen diameters in normal dogs following urethral anastomosis. Results of this study indicate that urinary diversion by tube cystostomy decreases the amount of PLDR as compared to transurethral catheterization techniques. Due to the ease of maintenance and increased patient tolerance of tube cystostomy, the author recommends diversion of urine via tube cystostomy following primary closure of urethral defects for optimal urethral healing.

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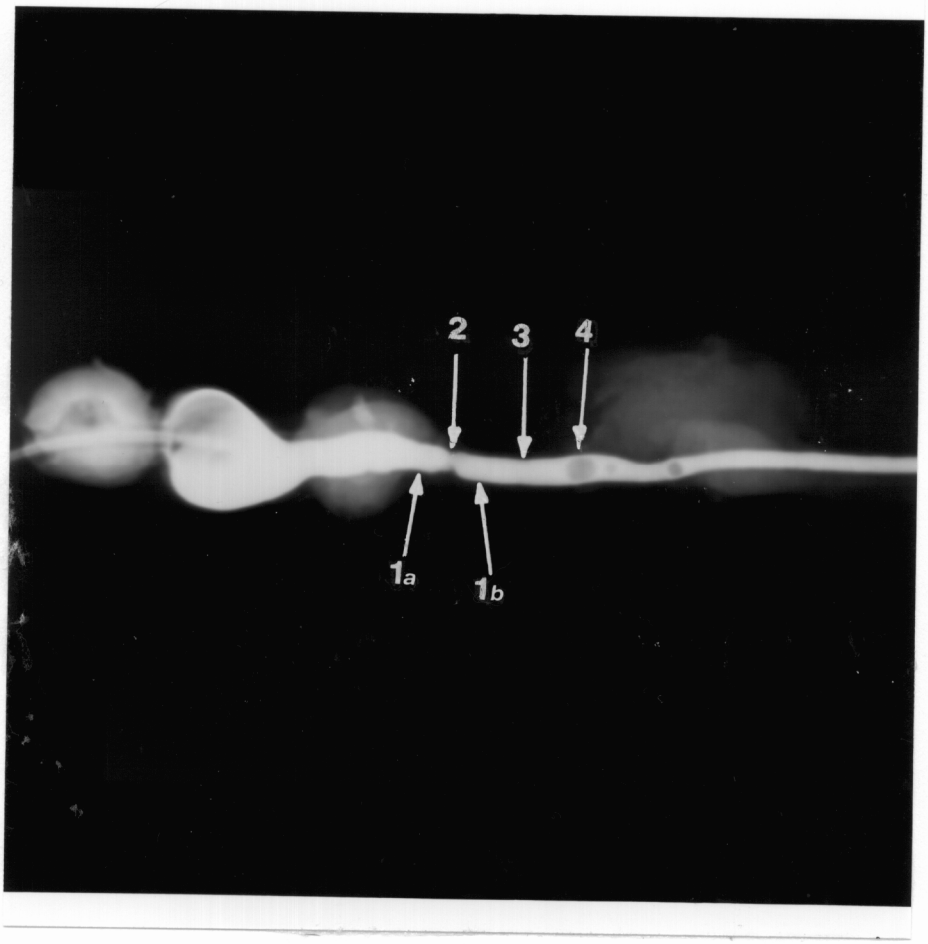

Figure 1: In-vitro urethrographic study at 90 cm H_2O.

Sites 1a and 1b = One cm cranial and caudal to the surgical site respectively.
Site 2 = The surgical site.
Site 3 = Two cm caudal to the surgical site.
Site 4 = Distant caudal site.

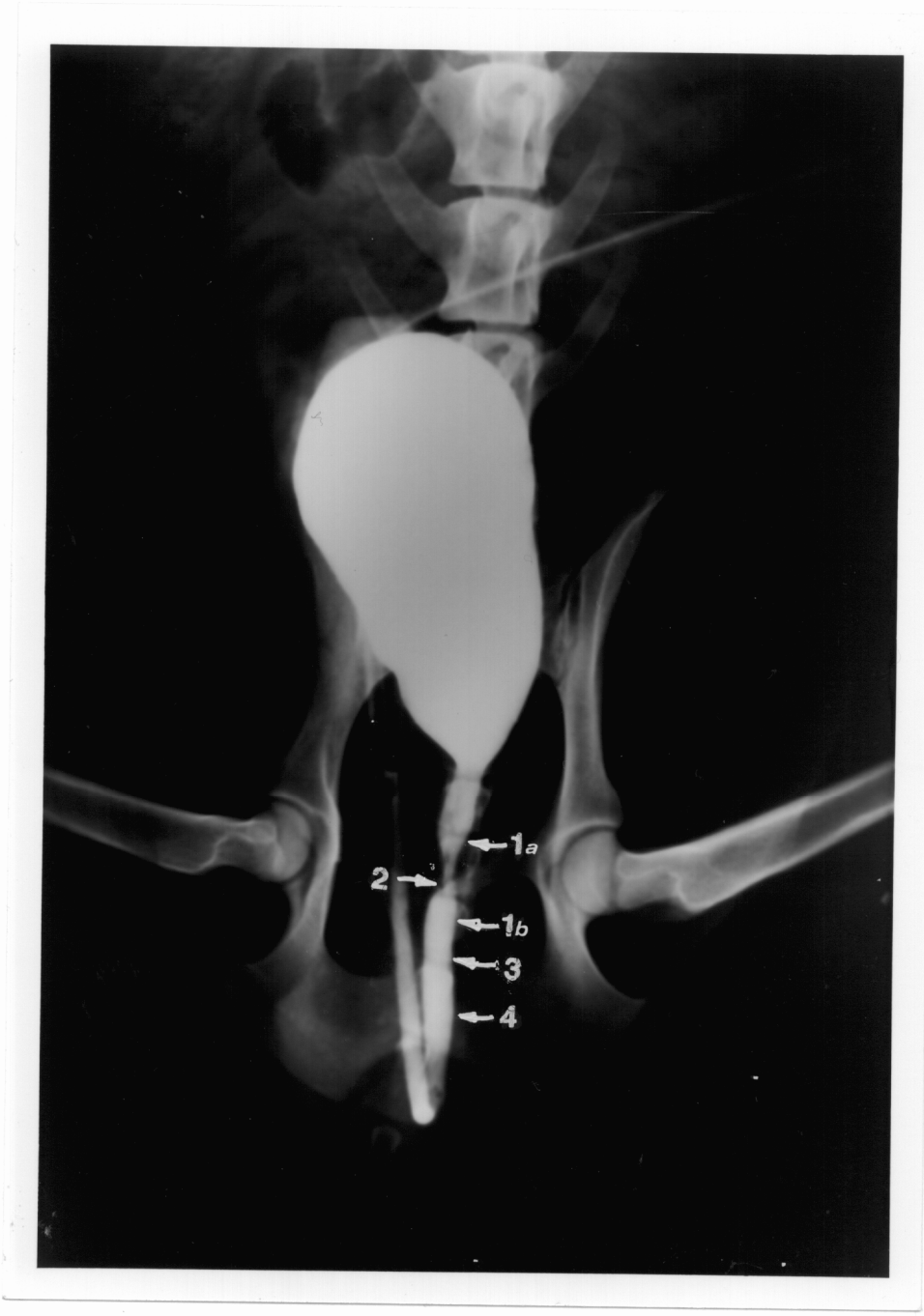

Figure 2a: Ventrodorsal oblique in-vivo postoperative urethrographic study.

Sites 1a and 1b = One cm cranial and caudal to the surgical site respectively.
Site 2 = The surgical site.
Site 3 = Two cm caudal to the surgical site.
Site 4 = Distant caudal site.

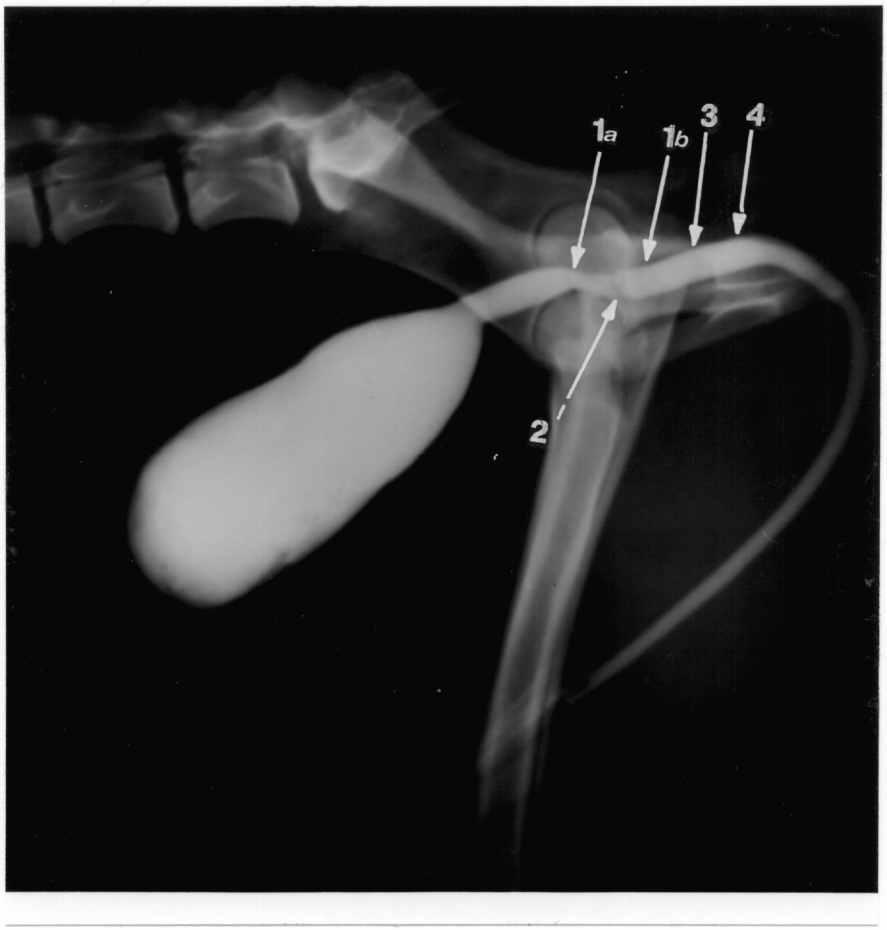

Figure 2b: Second lateral in-vivo postoperative urethrographic study.

Sites 1a and 1b = One cm cranial and caudal to the surgical site respectively.
Site 2 = The surgical site.
Site 3 = Two cm caudal to the surgical site.
Site 4 = Distant caudal site.

Table: 1

Clinical Assessment Scoring System:

Posturing	Number of leg hikes/week
Stream Quality	0 = None
	1= Dribble
	2= Pulse
	3= Stream
Abdominal Effort	0 = None
	1 = Mild
	2 = Moderate
	3 = Severe
Urine Quality	0 = Normal
	1= Abnormal

Table: 2

Normal Complete Blood Count Values:

RBC	5.50 - 8.63	x 10^6/ul
HGB	13.0 - 20.5	gm/dl
HCT	37.3 - 62.0	%
MCV	58 - 83	fl
MCH	22.2 - 26.2	pg
MCHC	31.6 - 36.5	%
RETIC		%
WBC	5.4 - 16.6	x 10^3/ul
SEG	3.2 - 10.7	x 10^3/ul
BAND	0.0 -0.2	x 10^3/ul
LYMPH	0.8 - 5.6	x 10^3/ul
MONO	0.0 - 1.1	x 10^3/ul
EOS	0.0 - 2.4	x 10^3/ul
BASO	x 10^3/ul	
META	x 10^3/ul	
MYELO	x 10^3/ul	
PLATELETS	179 - 473	x 10^3/ul

Blood Chemistries:

TOTAL PROTEIN	5.30 - 7.40	g/dl
ALBUMIN	2.80 - 3.60	g/dl
UREA NITROGEN	6.0 - 28.0	mg/dl
CREATININE	0.80 - 1.90	mg/dl
TOTAL BILIRUBIN	0.10 - 0.50	mg/dl
ALT	13 - 100	U/L
ALP	20 - 167	U/L
SODIUM	140.0 -152.0	mmol/L
POTASSIUM	3.30 - 4.60	mmol/L
CHLORIDE	109 - 120	mmol/L
CARBON DIOXIDE	17.4 - 27.9	mmol/L
ANION GAP	8 -15	mmol/L
CALCIUM	9.70 - 11.10	mg/dl
PHOSPHORUS	1.30 - 5.00	mg/dl
GLUCOSE	87 - 127	mg/dl
CHOLESTEROL	127- 336	mg/dl

TABLE 3a. Pre and Postoperative urodynamic test results in dogs with surgically created urethral anastomosis.

DOG ID	BW (kgs)	TRX GRP.	Pre Vres (mls) ml/kg	Post Vres (mls) ml/kg	Pre Vi & Vi/kg (mls) ml/kg	Post Vi & Vi/kg (mls) ml/kg	Pre Puo (cm H20)	Post Puo (cm H20)	Pre Cves (cm H20/ 100 mls)	Post Cves (cm H20 /100 mls)	Pre Pves (cm H20)	Post Pves (cm H20)	Pre MUCP (cm/H20)	Post MUCP (cm/H20)	Pre MUP (cm/H20)	Post MUP (cm H20)
626	26.0	U	148* 5.7	25 1.0	525 20.2	270 10.4	250*	50	2.1	5.4	-3.75	1.25	18.8	13.8	15	15
627	19.5	U	75* 3.8	4 0.2	555 28.5	185 9.5	30	45	18.5	4.1	0	0	32.5	23.8	32.5	23.8
597	22.7	U	13 0.6	2 0.1	528 23.2	150 6.6	65	60	8.1	2.5	-1.25	-2.5	51.3	37.5	50	35
454	21.0	U	9 0.4	0 0	510 24.2	240 11.4	50	45	10.2	5.3	-3.75	-2.5	23.8	28.8	20	26.3
614	13.6	U	1 0.1	0 0	132 9.7	157 11.6	70	40	1.9	3.9	-5	-5	21.3	36.3	16.3	31.3

U = Urethral Catheter Group

Vres= Residual Volume, Vi= Volume Infused, Puo= Urethral Opening Pressure, Cves= Vesicular Compliance,

Pves= Vesicular Pressure, MUCP= Maximum Urethral Closure Pressure, MUP= Maximum urethral pressure, NR= no results,

* = Outlier, value not used in statiscal anaylsis.

TABLE 3b. Pre and Postoperative urodynamic test results in dogs with surgically created urethral anastomosis.

DOG ID	BW (kgs)	TRX GRP.	Pre Vres (mls) ml/kg	Post Vres (mls) ml/kg	Pre Vi & Vi/kg (mls) ml/kg	Post Vi & Vi/kg (mls) ml/kg	Pre Puo (cm H20)	Post Puo (cm H20)	Pre Cves (cm H20/ 100 mls)	Post Cves (cm H20 /100 mls)	Pre Pves (cm H20)	Post Pves (cm H20)	Pre MUCP (cm/H20)	Post MUCP (cm/H20)	Pre MUP (cm/H20)	Post MUP (cm H20)
625	25.0	B	3 0.1	0 0	230 9.2	345 13.8	30	40	7.7	8.6	0	-1.25	21.3	31.3	21.3	30
630	18.6	B	4 0.2	2 0.1	60 7.0	185 9.9	25	25	2.4	7.4	-7.5	10	47.5	27.5	40	37.5
622	15.9	B	6 0.4	2 0.1	140 8.8	150 9.4	40	50	3.5	3	-3.75	-2.5	18.8	30	15	27.5
621	22.7	B	9 0.4	12 0.5	290 12.7	350 15.4	60	40	4.8	8.8	-1.25	-1.25	16.3	31.3	15	30
611	13.6	B	7 0.5	1 0.1	87 6.4	47 3.5	40	135*	2.2	NR	-2.5	11.25	18.8	28.8	16.3	31.3

B = Urethral and Cystostomy Group

Vres= Residual Volume, Vi= Volume Infused, Puo= Urethral Opening Pressure, Cves= Vesicular Compliance, Pves= Vesicular Pressure, MUP= Maximum urethral pressure, MUCP= Maximum Urethral Closure Pressure, NR= no results, * = Outlier, value not used in statiscal anaylsis.

TABLE 3c. Pre and Postoperative urodynamic test results in dogs with surgically created urethral anastomosis.

DOG ID	BW (kgs)	TRX GRP.	Pre Vres (mls) ml/kg	Post Vres (mls) ml/kg	Pre Vi & Vi/kg (mls) ml/kg	Post Vi & Vi/kg (mls) ml/kg	Pre Puo (cm H20)	Post Puo (cm H20)	Pre Cves (cm H20/ 100 mls)	Post Cves (cm H20 /100 mls)	Pre Pves (cm H20)	Post Pves (cm H20)	Pre MUCP (cm/H20)	Post MUCP (cm/H20)	Pre MUP (cm/H20)	Post MUP (cm H20)
628	23.0	C	20 0.9	0 0	210 9.1	115 5.0	62	75	3.4	1.5	-3.75	2.5	28.8	18.5	25	15
629	22.7	C	55* 2.4	0 0	230 10.1	200 8.8	32	80	7.2	2.5	2.5	-1.25	20	19.8	22.5	18.5
623	15.9	C	2 0.1	20 1.3	50 3.14	140 8.8	40	45	1.3	3.1	-2.5	1.25	15	30	12.5	31.3
598	13.8	C	2 0.1	1 0.1	20 1.4	140 10.1	100*	85	0.2	1.7	0	0	41.3	83.8	41.3	83.8
615	19.6	C	1 0.1	1 0.1	313 16.0	185 9.4	35	55	8.9	3.4	-3.75	-2.5	33.8	26.3	30	23.8

C = Cystostomy Group

Vres= Residual Volume, Vi= Volume Infused, Puo= Urethral Opening Pressure, Cves= Vesicular Compliance,

Pves= Vesicular Pressure, MUP= Maximum urethral pressure, MUCP= Maximum Urethral Closure Pressure, NR= no results,

* = Outlier, value not used in statiscal anaylsis.

Table 4:

Urination Posture Scores

Dog ID	Group	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK10
626	**U**	0	.3448	.8605	.9737	.8684	.8936	.8723	.9803	.9762	.7778
627	**U**	.4375	.5946	.6750	.6957	.9194	.9180	.8333	1	1	.9063
597	**U**	0	.8947	1	.9738	.8235	.8286	.9655	.9355	.9444	1
454	**U**	0	1	1	1	1	.9762	.9459	1	1	.9714
614	**U**	0	.8529	1	.7930	.9063	.7857	.3929	.7097	.7692	.4615
625	**B**	0	.7826	.9792	1	1	.9523	1	1	1	1
630	**B**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
622	**B**	.2857	1	1	.9667	1	.9865	1	1	1	1.
621	**B**	.3571	.8750	.8485	.9762	.5435	3.571	.6600	.7059	1	.9730
611	**B**	.8636	1	1	1	1	1	.9714	.9474	1	.7500
628	**C**	.1528	.6122	.8529	.8182	.8077	.6216	.8846	.6829	.5294	.4667
629	**C**	1	.8571	1	1	1	1	.9730	.7500	.7500	.7647
623	**C**	.1951	.7797	.9474	.8518	.9444	.8471	.8649	.5833	.8140	.9063
598	**C**	.7142	.9730	.9454	.2308	.8409	1	.9487	.1136	.9474	1
615	**C**	.7142	.9804	.9057	.8493	.9434	.8837	.8200	1	.8378	1

U = Urethral Catheter Group, B = Urethral and Cystostomy Group, C = Cystostomy Group

Weekly scores obtained by averaging daily urination scores and dividing that number by the number of observations per week.

NO= No observation.

Table 5:

Abdominal Effort Scores

Dog ID	Group	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK10
626	**U**	0.5	.0556	0	.2143	.1428	.2857	.2857	.5	.2143	.1538
627	**U**	0	.1111	0	0	0	0	0	0	0	0
597	**U**	1.333	.0714	.2857	0	0	0	0	0	0	0
454	**U**	.9090	0	.0714	0	0	0	0	0	0	0
614	**U**	0	0	0	0	0	0	0	0	0	0
625	**B**	0.25	.1111	0	0	0	0	0	0	0	0
630	**B**	NO	NO	NO	NO	NO	NO	NO	0	NO	NO
622	**B**	.4615	.2857	.2857	.4286	0	.1111	.0714	0	.0769	0
621	**B**	1	.6428	0	.0714	.5714	1.857	1.857	1.857	0	.1538
611	**B**	1	.5714	.2143	.1429	0	0	.0833	0	0	0
628	**C**	.5714	.2778	.0667	.2857	.2142	.5	.5	1.143	1.5	1
629	**C**	0	0	0	0	0	0	0	0	0	0
623	**C**	0.5	.6429	.6429	.3571	.0714	.1429	.0714	0	0	0
598	**C**	.7143	.7143	.0714	.2143	0	0	0	0	.0769	0
615	**C**	1	.5385	1.5	.0714	.1429	.0714	.0714	0	0	0

U = Urethral Catheter Group, B = Urethral and Cystostomy Group, C = Cystostomy Group

Weekly scores obtained by averaging daily abdominal effort scores and dividing that number by the number of observations per week. NO = No observation.

Table 6:

Gross Urine Color Scores

Dog ID	Group	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK10
626	**U**	0.5	0	0	0	0	0	.0714	.2857	0	.1538
627	**U**	0.5	0	0	0	0	0	.1429	0	0	0
597	**U**	1	0	0	0	0	0	0	0	0	0
454	**U**	.1818	0	0	0	0	0	0	0	.7857	0
614	**U**	.7143	0	0	0	0	0	0	0	0	0
625	**B**	0.125	0	0	0	0	0	0	0	0	0
630	**B**	NO	NO	NO	NO	NO	NO	NO	NO	NO	0
622	**B**	.7692	0	0	0	0	0	0	0	0	0
621	**B**	1	0	0	0	.2857	1.857	.8571	0	.7857	.3077
611	**B**	1	0	0	0	0	0	.0833	0	0	0
628	**C**	.5714	0	0	0	0	.3333	0	0.500	0	.9286
629	**C**	.4286	.1875	0	0	0	0	0	0	0	0
623	**C**	.1667	0	0	0	0	.0714	0	0	0	0
598	**C**	.2143	0	0	0	0	0	0	0	0	0
615	**C**	0.500	0	0	0	0	0	0	0	0	0

U = Urethral Catheter Group, B = Urethral and Cystostomy Group, C = Cystostomy Group

Weekly scores obtained by averaging daily gross urine color scores and dividing that number by the number of observations per week. NO = No observation.

Table 7:

Stream Observation Scores

Dog ID	Group	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK10
626	**U**	3	2.167	2.063	2	1.929	2.071	2.071	0.143	2.214	2.077
627	**U**	1	2.625	2.714	2.500	2.143	2.571	2.214	2.5	2.571	2.231
597	**U**	3	2	1.643	2.286	2.428	2.071	2.429	2.5	2.286	2
454	**U**	1.909	1.786	1.786	2.500	2.214	2.286	2.214	2.357	2.571	2.769
614	**U**	1.429	1.643	2.357	2.231	2.5	2.357	2.071	2.385	2.461	2.5
625	**B**	1.750	2.111	1.857	2	1.857	2.071	2.786	2.286	2.357	2.308
630	**B**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
622	**B**	0	1.429	1.786	1.857	1.929	1.444	2.714	2.214	1.769	2
621	**B**	1.1	2.714	2.214	2.357	1.857	1.429	1.50	1.286	1.929	2.385
611	**B**	.8333	.6429	1.714	1.857	2	1.857	1.583	1.385	1.5	2.125
628	**C**	.2857	1.611	2	1.714	1.786	1.750	1.357	1.357	1.571	1.286
629	**C**	1.071	2.625	2.214	2	2	2.143	2.5	2.5	2.571	2.385
623	**C**	1.583	1.574	.1951	2	1.857	2.143	2	2.286	2.143	2.385
598	**C**	.6429	1.786	2.071	2.429	2.286	2.571	2.50	2.643	1.846	1.917
615	**C**	1.900	1.800	1.857	2.214	2.286	2.571	2.357	2.286	1.5	2.111

U = Urethral Catheter Group, B = Urethral and Cystostomy Group, C = Cystostomy Group

Weekly scores obtained by averaging daily stream observation scores and dividing that number by the number of observations per week. NO = No observation.

Table 8a.
Urine Culture Results

DOG NO.	GROUP	PREOP	WEEK 1	WEEK 4	WEEK 8	WEEK 10
626	**U**	NG	Staph. I $>10^5$ Enterobacter spp. $>2X10^3$	Staph. I $>10^5$ Staph. coag.- $>10^5$	Staph. I $>10^5$	Staph. I $>10^5$ Staph. aureus $>10^5$
627	**U**	NG	E. coli $3X10^3$ Staph. sp coag - $1.1X10^3$	NG	E. coli $3X10^2$	E. coli $4X10^2$ Pseudo. spp $2X10^2$
597	**U**	NG	Staph. spp. coag - $2.2X10^3$	NG	NG	Bacillus spp. $8X10^2$ Corynebacterium spp. $4.5X10^3$ Pasteurella spp. $3X10^3$
454	**U**	NG	Staph. spp. coag - $> 10^5$ Leminonella spp $>10^5$ Enterococcus spp. $> 10^5$	Staph. spp. coag - $> 10^5$ Staph. I $>10^5$	Staph aureus $>10^5$ Enterococcus spp $>10^5$	E. coli $> 10X^5$ Enterococcus spp $>10^5$ Staph. I $>10^5$
614	**U**	NG	Pseudo. A $>10^5$	Pseudo. A $>10^5$	Pseudo. A $>10^5$	NG

Log base 10 in CFU = Colony forming units
Staph I. = Staphylococcus intermedius
Pseudo spp. = Pseudomonas aeroginosa or alcaligenes
E. Coli = Escherichia coli

Table 8b.
Urine Culture Results

DOG NO.	GROUP	PREOP	WEEK 1	WEEK 4	WEEK 8	WEEK 10
625	**B**	NG	Enterobacter cloacae $>10^5$	NG	NG	NG
630	**B**	NG	Staph. I $>10^5$	NG	NG	NG
622	**B**	NG	Staph. I $>10^5$	NG	NG	NG
621	**B**	NG	Enterobacter amnigenus $1.8X10^3$ Staph I $>10^5$	Staph. I $>10^5$	Staph aureus $>10^5$	Staph. I$>10^5$ Staph. spp. coag(-) $> 10^5$
611	**B**	NG	NG	NG	NG	NG

Log base 10 in CFU = Colony forming units
Staph I = Staphylococcus intermedius
Pseudo spp = Pseudomonas aeroginosa or alcaligenes

Table 8c.
Urine Culture Results

DOG NO.	GROUP	PREOP	WEEK 1	WEEK 4	WEEK 8	WEEK 10
628	**C**	Staph. I 10^5	Acinitobacter calcoaceticus $>10^5$ Staph. spp. coag (-) $> 10^5$	Staph. I $>10^5$ Staph. spp. coag (-) $> 10^5$	Staph. I $>10^5$	Staph I $>10^5$ Staph. spp. coag(-) $> 10^5$
629	**C**	NG	ß Strep group B $>10^4$ Staph. spp. coag(+) $> 10^4$ Bacillus spp. $1X10^3$	NG	Staph I $1x10^2$	Staph I $2x10^2$ ß Strep group B $>10^3$ Strep group D $1.8X10^4$
623	**C**	NG	Pseudo spp $>10^5$	NG	NG	NG
598	**C**	NG	Citrobacter amalonaticus $>10^5$ Pseudo spp $>10^5$ Staph I $>10^5$	Enterobacter cloacae $>10^5$ Citrobacter spp. $>10^5$	NG	Strep. viridans $8.5X10^3$
615	**C**	NG	NG	NG	NG	NG

Log base 10 in CFU = Colony forming units
Staph I = Staphylococcus intermedius
Pseudo spp = Pseudomonas aeroginosa or alcaligenes
Strep. = Streptococcus

Table 9a- Differences between in-vivo percent lumen diameter reduction (PLDR) of postoperative from preoperative values obtained from urethrograms comparing measurements made at the surgical sites to those made one centimeter cranial and caudal (averaged) to the surgical site.

Dog #	Group	1 Lat PLDR	2 Lat PLDR	Lt O PLDR	VDO PLDR
597	U	39.95	35.07	34.22	37.29
614	U	-11.41	7.80	9.45	28.49
626	U	-19.96	X	8.22	17.43
627	U	21.55	15.27	13.45	26.45
656	U	27.60	X	38.99	20.97
598	C	-15.73	-38.12	10.53	-16.09
615	C	7.30	-3.16	6.95	28.87
623	C	X	3.42	22.97	15.48
628	C	46.04	X	-0.44	30.86
629	C	23.47	X	14.24	27.68
625	B	33.36	X	41.68	55.14
622	B	52.24	18.01	13.05	20.86
611	B	51.87	27.35	46.08	30.79
630	B	X	63.49	0.15	68.61
621	B	32.06	X	28.24	-8.42

1 Lat PLDR = patient first lateral urethrogram percent lumen diameter reduction

2 Lat PLDR = patient second lateral urethrogram percent lumen diameter reduction

Lt O PLDR = patient lateral oblique urethrogram percent lumen diameter reduction

VDO PLDR = patient ventrodorsal oblique urethrogram percent lumen diameter reduction

X = no radiographic measurements made.

Table 9b- Differences between in-vivo percent lumen diameter reduction (PLDR) of postoperative from preoperative values obtained from urethrograms comparing measurements made at the surgical sites to those made two centimeters caudal to the surgical site.

Dog #	Group	1 Lat PLDR	2 Lat PLDR	1 Lt O PLDR	1 VDO PLDR
597	U	25.54	41.48	33.56	28.26
614	U	2.93	13.55	14.49	15.55
626	U	-76.22	X	-31.19	3.68
627	U	3.90	5.80	-5.38	16.58
656	U	19.09	X	22.94	24.41
598	C	-25.82	-49.82	10.15	-8.87
615	C	6.37	9.80	19.23	32.96
623	C	X	-5.76	11.68	17.17
628	C	24.27	X	-1.10	15.77
629	C	-5.34	X	-7.77	23.51
625	B	9.65	X	25.48	51.70
622	B	32.74	11.65	1.99	23.77
611	B	49.31	27.92	44.47	43.51
630	B	X	27.16	-6.64	59.93
621	B	9.05	X	11.73	4.41

1 Lat PLDR = patient first lateral urethrogram percent lumen diameter reduction

2 Lat PLDR = patient second lateral urethrogram percent lumen diameter reduction

Lt O PLDR = patient lateral oblique urethrogram percent lumen diameter reduction

VDO PLDR = patient ventrodorsal oblique urethrogram percent lumen diameter reduction

X = no radiographic measurements made.

Table 9c- Differences between in-vivo percent lumen diameter reduction (PLDR) of postoperative from preoperative values obtained from urethrograms comparing measurements made at the widest dimension of the intrapelvic urethra caudal to the surgical site.

Dog #	Group	1 Lat PLDR	2 Lat PLDR	1 Lt O PLDR	1 VDO PLDR
597	U	19.18	39.23	33.55	22.51
614	U	5.81	15.53	15.65	19.56
626	U	-20.36	X	0.43	16.09
627	U	-2.13	3.63	-8.21	3.88
656	U	7.65	X	20.07	13.64
598	C	-12.10	-16.24	-8.38	-1.92
615	C	3.49	3.84	22.01	30.94
623	C	X	-4.72	16.48	18.12
628	C	20.35	X	6.30	22.98
629	C	-10.78	X	-17.98	11.75
625	B	5.20	X	18.72	38.75
622	B	24.79	10.06	1.13	18.95
611	B	34.80	27.61	42.74	30.47
630	B	X	24.16	-9.50	56.65
621	B	32.91	X	15.52	2.76

1 Lat PLDR = patient first lateral urethrogram percent lumen diameter reduction

2 Lat PLDR = patient second lateral urethrogram percent lumen diameter reduction

Lt O PLDR = patient lateral oblique urethrogram percent lumen diameter reduction

VDO PLDR = patient ventrodorsal oblique urethrogram percent lumen diameter reduction

X = no radiographic measurements made.

Table 9d -In-vitro, absolute percent lumen diameter reduction (PLDR) obtained from specimen urethrograms comparing measurements made at the surgical site to those made one centimeter cranial and caudal (averaged) to the surgical site, two centimeters caudal to the surgical site, and at the widest dimension of the intrapelvic urethra caudal to the surgical site.

Dog #	Group	**1 cm** 1 SL PLDR	**1 cm** 2 SL PLDR	**1 cm** 1 SVD PLDR	**1 cm** 2 SVD PLDR	**2 cm** 1 SL PLDR	**2 cm** 2 SL PLDR	**2 cm** 1 SVD PLDR	**2 cm** 2 SVD PLDR	**Distal** 1 SL PLDR	**Distal** 2 SL PLDR	**Distal** 1 SVD PLDR	**Distal** 2 SVD PLDR
597	U	50.73	48.53	45.20	47.55	47.93	44.33	44.22	42.71	57.73	54.14	54.33	55.87
614	U	53.36	49.04	52.72	40.75	41.82	39.96	44.42	31.64	45.40	43.26	42.80	36.22
626	U	58.59	57.58	55.71	56.18	57.32	55.58	54.08	55.02	57.12	54.78	55.29	55.06
627	U	X	X	X	X	X	X	X	X	X	X	X	X
656	U	27.28	31.13	34.92	33.67	30.94	32.50	37.47	35.80	32.64	36.41	38.75	38.22
598	C	38.19	35.12	37.92	38.06	30.18	28.07	29.57	26.44	43.45	42.59	41.08	41.46
615	C	43.99	45.63	34.86	38.32	43.85	43.48	27.26	28.43	47.23	46.78	32.71	36.43
623	C	42.43	39.78	41.53	39.69	40.58	40.67	40.33	41.52	47.36	46.20	48.59	47.33
628	C	38.32	38.31	39.57	34.67	35.54	35.17	35.39	31.27	45.27	48.08	45.10	40.74
629	C	46.63	47.39	51.19	51.21	45.15	47.04	46.21	47.86	50.94	51.33	54.22	52.32
625	B	57.82	55.25	56.26	58.52	58.01	56.30	55.29	57.92	62.51	62.23	61.91	64.79
622	B	60.16	59.75	62.39	61.55	61.98	62.57	64.79	63.92	62.67	63.49	65.86	65.52
611	B	47.24	48.46	48.26	48.26	35.43	37.04	37.45	37.09	42.73	42.36	44.21	43.30
630	B	70.23	69.73	72.14	72.61	61.24	62.16	67.10	65.33	63.23	65.95	66.92	67.58
621	B	52.60	52.04	44.93	46.66	48.23	48.25	40.16	44.33	62.87	62.55	58.74	59.59

1 SL PLDR = specimen lateral urethrogram percent lumen diameter reduction at 60 cm H2O

2 SL PLDR = specimen lateral urethrogram percent lumen diameter reduction at 90 cm H2O

1 SVD PLDR = specimen ventrodorsal urethrogram percent lumen diameter reduction at 60 cm H2O

2 SVD PLDR = specimen ventrodorsal contrast urethrogram percent lumen diameter reduction at 90 cm H2O

X = no radiographic measurements made.

Table 10: Inflammation and Fibrosis Scores

Dog ID	Group	Inflammation scores	Fibrosis scores
626	**U**	3	3
627	**U**	2	2
597	**U**	2	1
454	**U**	3	3
614	**U**	1	1
625	**B**	1	2
630	**B**	1	2
622	**B**	1	1
621	**B**	2	2
611	**B**	1	1
628	**C**	3	3
629	**C**	2	1
623	**C**	1	2
598	**C**	1	2
615	**C**	1	2

None = 0 Mild = 1 Moderate = 2 Severe = 3

VITA

Anjilla J. Cooley was born on June 11, 1966 in Cleveland Ohio and is the daughter of Drs. W. Braxton and Iris H Cooley. Two years later, her family moved to Madison, New Jersey where she spent five years of her life. It was during this time that the family realized that there was an "animal doctor" in the house. At the age of seven, her family moved to Harrisburg, Pennsylvania where she spent the remainder of her childhood. After graduating from high school in 1984, Anjilla attended North Carolina Agricultural and Technical State University, majoring in laboratory animal science in preparation for Veterinary School. In 1988 she began the veterinary curriculum at the University of Tennessee. After receiving her DVM in 1992, Anjilla completed a small animal internship at The University of Missouri. A strong interest in small animal surgery led her to the Virginia-Maryland Regional College of Veterinary Medicine where she is currently finishing a small animal surgical residency.