# INTRAPELVIC URETHRAL ANASTOMOSIS:

## A Comparison of Three Techniques

by

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# INTRODUCTION

Urinary tract trauma is a rare surgical problem when compared to fractures of the appendicular skeleton and other soft tissue trauma.[15,25,26,48,49] Urethral trauma may be sustained due to penetrating wounds, falls, or improper catheterization techniques. Most urethral trauma in both man and dogs is associated with pelvic fractures.[10,11,13,22,51,65]

Regardless of the mechanism involved in the rupture of the intrapelvic or membranous urethra, it is accepted that the overall occurrence is low, with low mortality but high morbidity.[20] The best approach to the management of urethral transection has not been established. Techniques used include primary suturing of the torn urethral ends immediately post-trauma and establishing urinary diversion, with repair of the urethra four to eight weeks later. The long-term effects of complete urethral transection, regardless of the initial therapy, can be devastating. In man, a frequent sequela of complete urethral transection is stricture. Treatment may require periodic, painful "sounding" or bougienage therapy. It may lead also to chronic cystitis associated with urine retention and progressive upper urinary tract disease such as hydronephrosis or pyelonephritis.[13,37,43,44] Many such patients eventually undergo urinary diversion with transplantation of ureters to colon or ileum. Others suffer urethral reconstruction via grafts, tube prosthesis, or extrapelvic urethral anastomosis.[19,27,34,47,51]

The present study compares three techniques for repair of complete membranous or intrapelvic urethral rupture. Primary suturing of the

urethra using 4-0 Dexon* was performed on the Group I dogs. A transurethral catheter was inserted through a perineal urethrostomy and left in place for two weeks. Group II dogs had primary suturing of the urethra using 4-0 Dexon sutures but without a transurethral splinting catheter left in place. Group III dogs had urethral anastomosis performed using a traction catheter alone, without sutures.

The three techniques were evaluated using four criteria: 1) clinical observation, 2) clinical pathology, 3) positive contrast urethrography, and 4) histopathology. Clinical evaluation of the urethral repair includes observation of the post-management problems and urinary patterns. Urinary tract function was monitored by periodic blood urea nitrogen and serum creatinine analysis along with complete blood counts and total protein. Static and dynamic radiographic evaluations were performed. Static radiographic analysis involved pre- and post-operative retrograde, positive contrast urethrographs performed on the intact patient. Dynamic positive contrast urethrographs were made on the isolated lower urinary tract and taken under continuous, positive pressure. Histopathological evaluation was based on epithelial regeneration, fibrous reaction, and urinary tract epithelial alterations due to inflamation and chronic urine retention.

No attempt was made to evaluate the advantages of immediate repair versus delayed repair of the transected urethra.

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*Dexon "S," polyglycolic acid, Davis & Geck, Inc., Manati, P.R., 00701.

# LITERATURE REVIEW

## A. Incidence

The incidence of lower urinary tract trauma, particularly of the intrapelvic urethra, is difficult to determine in veterinary literature.[48] A study by Kolata provides some indication of the number of pelvic fractures incurred by dogs and cats.[25,26] This, in turn, may be correlated with the types of soft tissue trauma sustained. Approximately 34 percent of the injuries due to motor vehicles involved the pelvis (20.9%) and the abdomen (13%).[24] Out of 600 motor vehicle accident cases involving dogs, there were two cases of urethral avulsion from the bladder neck and two injuries to the prostate and urethra which were associated with fracture of the pubic symphysis.[26] Crane cites a preliminary study by the American Animal Hospital Association in which 31 of 82 patients with pelvic fracture sustained significant urinary tract trauma.[14] Rawlings reports more than four percent of pelvic fractures have associated urinary tract trauma.[51] Urinary tract injuries in decreasing order of incidence, as reported by Kleine, were ruptured bladder (62%), ruptured kidney (15%), ruptured urethra (11%), ruptured ureter (9%), and peri-renal hematoma (5%).[24] Urethral ruptures in man and the dog are most prevalent in males.[23,48,51,65]

In human literature, the incidence of lower urinary tract trauma and its association with pelvic fractures has been widely reported. Exact incidence of urethral trauma is made difficult by inclusion of more than one organ when determining percentages. McRoberts and Ragde reported 14 percent of patients with pelvic fractures would have associated rupture of bladder or prostato-membranous urethra.[38] Holdsworth reported a

five percent incidence but included only ruptures of the posterior urethra.[41] Most authorities cited an incidence of 10 to 17 percent for lower urinary tract trauma associated with pelvic fracture[11,12,13,29,35,38] with an incidence of two to four percent for urethral rupture.[63]

B. Anatomy

The canine urethra is divided into three segments: the prostatic urethra, the membranous (intrapelvic) urethra, and the cavernous (extrapelvic) urethra.[6,10,18,40] Similar terms are used for man, with the urethra divided into a prostatic portion and a supramembranous urethra surrounded by no glandular structures. These two segments are frequently referred to collectively in human literature as the posterior urethra, and correspond to the canine prostatic and intrapelvic uretha.[13] Human anatomists further divide the intrapelvic urethra into a supramembranous and membranous portion. The membranous portion traverses a structure known as the urogenital diaphram.[13] A urogenital diaphram is not recognized in the dog.[40] The extrapelvic urethra in man is divided into a bulbous urethra and a pendulous urethra.[13]

C. Mechanism of Injury

The anatomy of the urethra and its relationship to the pelvis helps to explain the mechanism of membranous urethral trauma frequently sustained by man and the canine. While the canine urethra can be injured with blunt abdominal trauma, gunshot wounds, and penetrating wounds such as dog bites, the majority of injuries are related to pelvic fractures resulting from motor vehicle accidents.[10,26,45,64,65] In man, urethral trauma is

usually associated with pelvic fractures which are the result of construction, mining, industrial, farming, sport, and automotive accidents.[11,13,17,22,23,29,35,37]

Fractures in both species involving the pubic rami or pelvic symphysis are most often associated with lower urinary tract trauma.[11,13,17,22,23,31,41,43,44,65] While the urethra may be lacerated with bony spicules, rupture is almost always due to shearing forces.[13,15,17,22] The bladder and prostate are mobile structures which can be displaced cranially. The distal portion of the urethra is relatively immobile in man as it crosses the urogenital diaphram, and in the canine as the urethra passes over the ischial arch.[10,13,40] When external forces are applied and the pelvic ring disrupted, the bladder and prostate are displaced into the abdominal cavity, shearing forces are concentrated on the membranous urethra as it emerges from the prostate, and partial or complete rupture of the urethra occurs.[13,17,22,43,44]

D. Pathophysiology

With partial or complete urethral rupture, extravasation of urine occurs. It is now recognized that the leakage of urine into the surrounding tissue is not a surgical emergency. Chemical irritation may result after 24 to 48 hours, but unless the urine is infected at the time of injury or subsequently innoculated during diagnostic catheterization, gross necrotizing cellulitis is not a problem.[41,42] Long-term (greater than 48 hours) urine drainage will result in tissue slough and fistulous tracts.[29,42,51,65]

The urethra may be contused, partially or completely transected. Partial ruptures are reported to be more common in human literature.[42]

After complete transection of the urethra, the mucosa tends to retract into the periurethral connective tissue.[38] In most cases, the internal sphincter of the bladder is intact, and the bladder becomes distended with urine. The patient may exhibit a desire to urinate, but is unable to void. The exact mechanism for urine retention is not known. It may be due to failure of the prostatic urethra to shorten, which is necessary to initiate micturation.[13]

E. Diagnosis

Since the clinical signs and the diagnosis of posterior urethral trauma have been described in detail by many authorities, they will not be discussed here.[5,6,13,24,51,56] The human diagnostician frequently relies on rectal palpation to determine the placement of the prostate. Displacement of the prostate dorsally and palpation of a "boggy" mass are an indication that the membranous urethra is ruptured and the bladder and prostate gland relatively free floating.[11,13,15,23,62] This diagnostic sign was not mentioned in the veterinary literature. This may be due to a difference in anatomy or in the fact that veterinary surgeons are not looking for that particular sign. A second sign of urethral trauma is the presence of blood at the external meatus or orifice of the urethra. The amount of blood is not necessarily proportional to the amount of urethral injury since a completely torn urethra may not result in significant hemorrhage at the external meatus.[13,41]

The diagnostic catheterization technique is condemned by several authorities. Reasons cited include the possible conversion of a partial tear into a complete rupture, innoculating the sterile hematoma, and the increased risk of a false diagnosis.[13,21,41,57] Positive contrast

retrograde or intravenous studies are recommended as a more accurate method of confirming the diagnosis.

F. Treatment

In man, partial urethral rupture is managed by many surgeons with suprapubic urinary diversion and a transurethral splinting catheter.[13,15,23,37,38,41,50] The success of the therapy is due to the excellent regenerative capabilities of the urethral mucosa. These capabilities were demonstrated by Weaver and Schulte in their study on urethral regeneration. They demonstrated that the urethra would reform itself, provided a strip of mucosa and corpus spongiosum remained intact.[62]

The main controversy concerning lower urinary tract trauma is with the management of complete posterior or membranous urethral transection. Surgeons are divided into two major groups: those who recommend immediate exploration and re-establishment of the urethral continuity and those who prefer urinary diversion and delayed repair of the resulting stricture with urethroplasty techniques.[56]

The major arguments presented for immediate surgery include only a single procedure necessary if stricture does not result, evacuation of the hematoma and establishment of ventral drainage, direct visualization of associated trauma such as ruptured colon, and the realignment of pelvic fractures. Delay in realignment of the urethra has also resulted in inclusion of prostate and ruptured intrapelvic urethra within excessive cicatrical tissue or osseous callus. Excessive scar tissue with associated cranial displacement of the prostate and bladder frequently frustrates attempts at urethroplasty.[11,13,21,31,43]

The main argument for delayed repair is the fact that urethral stricture commonly occurs following complete transection.[29,38,41,42] Therefore, it is better to establish urinary diversion and attempt urethroplasty when the tissues are less compromised by trauma and hemorrhage and the patient can withstand more prolonged surgery.

Within the first group, some disagreement exists as to the preferred method for re-establishing the urethral continuity. Several surgeons admit to preferences for the ideal situation where primary suturing of the urethra can be performed. They recognize less chance of stricture with primary suturing, but believe that the procedure is too time-consuming, that damaged tissues are often unrecognizable, and that the pelvic fractures are frequently worsened by surgical positioning.[15,22,29,38,43,44] Wiggishoff states that the sutures themselves act as a foreign material, contributing to fibrosis and stricture formation.[63]

Due to the fact that the torn urethral ends may not be identified, that there is decreased surgical time and complications for the patient, and that the procedure does not require a surgeon skilled in urethroplasy, many surgeons recommend suprapubic urinary diversion and a traction catheter, either Foley or Pilcher, to approximate the severed ends of the urethra.[11,15,21,22,31,37,44,52,57] A variety of techniques have been described for maintaining traction on the catheter. Kaiser taped the Foley catheter to the thigh under moderate tension.[23] Leadbetter described a technique using traction sutures of silk placed through the prostate and exiting via the perineum.[31] DeWeerd advocates pulley traction of the urethral catheter maintained at a 45-degree angle from the horizontal.[15] Orkin used both traction on the urinary catheter with traction sutures and elastic bands placed around the knee.[43]

Ragde and McInnes reported eight cases with successful urethral anastomosis using primary suturing and symphysiotomy. They found that satisfactory apposition of the ruptured urethra was not possible using traction catheters alone. During the eight procedures cited, apposition defects, ranging from 1.5 to 4 centimeters, were observed, even with maximum traction. After mobilization of the urinary bladder neck and prostate, the mucosal edges could more easily be brought into apposition.[49] McRoberts and Ragde compared direct suturing of the posterior urethra with anastomosis achieved by traction catheter with mobilization of prostate and bladder. None of the eleven dogs in the sutured group developed signs of stricture or upper urinary tract disease while six out of eleven dogs of the second group had gross urethral strictures, seven had microscopic urethral stricture, and four of the eleven dogs had some degree of hydronephrosis.[38]

Most veterinary surgeons prefer immediate repair using absorbable suture over an indwelling transurethral catheter.[6,10,27,64,65] A ventral midline approach is recommended with pelvic symphysiotomy or pubic plate reflection as required to expose the intrapelvic urethra. The techniques of pelvic symphysiotomy or pubic place reflection require a more experienced surgeon, specialized equipment, and at least one assistant. The increased time and effort involved in exposing the pelvic canal frequently results in increased morbidity for the patient. Most veterinary surgeons place their urethral catheter through the penile urethra or a pre-scrotal urethrotomy. No attempt to relate post-surgical stricture with method of repair has been documented in the veterinary literature.

Opinions concerning the pros and cons of splinting catheters, suprapubic drainage, closed or open urinary drainage systems, or selection of suture material are mentioned in veterinary literature, but few objective studies have been made.

## MATERIALS AND METHODS

Twelve mature male dogs averaging 20 kg. (44 lbs.) body weight were used for the study. Each dog had been vaccinated and dewormed prior to housing at Kansas State University. All dogs were housed together at the Veterinary Clinical Science building in 3' x 6' runs and fed a commercial dry dog chow once a day. Water was provided ad lib by automatic watering devices.

The dogs were randomly divided into three groups of four. Group I (numbers 1-4) underwent urethral anastomosis consisting of suturing of the membranous urethra using interrupted sutures of 4-0 Dexon* over a urethral Foley catheter** placed via a perineal urethrostomy. The catheter was not removed and remained in place following surgery. The urethrostomy site after catheter removal was not sutured, but left to heal as an open wound, in all groups.

Group II dogs (numbers 5-8) had urethral anastomosis consisting of primary suturing of the membranous urethra over a transurethral Foley catheter. Six to eight interrupted sutures of 4-0 Dexon were used as in Group I, but the Foley catheter acted primarily as a guide during suturing. All four dogs had their urinary catheters placed via a perineal urethrostomy, and all catheters were removed immediately following surgery.

Group III dogs (numbers 9-12) did not have any sutures placed to oppose the transected urethral ends. Instead, a Foley catheter was placed through the perineal urethrostomy site into the bladder. Traction on the

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*Dexon "S", polyglycolic acid, Davis & Geck, Inc., Manati, PR 00701.

**Bardex Foley Catheter, C.R. Bard, Inc., Murrary Hill, NJ 07974.

catheter pulled the prostate and bladder caudally, thereby maintaining the urethral ends in close apposition. Two dogs accidentally pulled their traction catheters too soon and obstructed. The two dogs were dropped from the study. Two additional dogs were obtained and anastomosis performed using traction catheter and traction sutures of 0-Prolene* secured to the Foley catheter and exiting from the perineal urethrostomy site (Table 1).

Routine complete blood counts, serum chemistry profile, and blood parasite exams were performed on each dog prior to surgery. Serum chemistry panel included analysis for BUN, SGPT, Creatinine, Total Protein, Albumin, Glucose, Sodium, Potassium, Chloride, Calcium, Phosphorus, and Serum Alkaline Phosphatase. Post-operative values for BUN, creatinine, total protein, and complete blood counts were monitored at two weeks, then monthly intervals.

A retrograde, positive contrast urethrograph was performed on each dog prior to surgery and again the day the dog was euthanized. The technique used in this study to obtain the retrograde contrast urethrographs is described by Ackerman in Modern Veterinary Practice[3,4] and by Ticer, Spencer, and Ackerman in Radiology.[59] Initially, a number 8 French Foley catheter with a 26-guage wire stylet was placed in the penile urethra to the level of the os penis and the balloon cuff inflated with air. A three-way stop-cock was attached to a 60-cc. syringe containing the contrast media. 15-20 cc. of diluted contrast media was injected and radiographs taken near the end of the injection period while positive pressure was maintained. A water soluble iodide, Renografin 60** was used

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*Prolene, polypropylene, Ethicon, Inc., Sommerville, NJ 08876.

**Renografin 60, E.R. Squibb and Sons, Inc., Princeton, NJ 08540.

TABLE 1

Summary of Group Organization:
Surgery and Euthanasia Dates

| Dog Number | Identification Number | Surgery Date | Euthanasia Date |
|---|---|---|---|
| | GROUP I: sutured over a catheter which was removed 14 days post-op | | |
| 1 | 1660 | 12/08/81 | 4/23/82 |
| 2 | 1642 | 12/16/81 | 5/10/82 |
| 3 | 1480 | 12/17/81 | 5/12/82 |
| 4 | 107 | 12/29/81 | 5/24/82 |
| | GROUP II: sutured over a catheter which was removed post-op | | |
| 5 | 1615 | 12/11/81 | 5/04/82 |
| 6 | 1658 | 12/22/81 | 5/21/82 |
| 7 | 1636 | 12/23/81 | 5/20/82 |
| 8 | 490 | 12/30/81 | 5/24/82 |
| | GROUP III: traction catheter alone without sutures | | |
| 9 | 1481 | 12/10/81 | 5/19/81 |
| 10 | 1641 | 12/15/81 | 5/04/82 |
| 11 | 14 | 2/22/82 | 5/24/82 |
| 12 | 15 | 3/05/82 | 5/24/82 |

as the contrast media, in a one-to-four ratio of Renografin 60 to bacteriostatic water. Dilution of the media is said to decrease urethral mucosal irritation and spasm, allowing for good visualization of small mucosal defects or luminal structures.[3,4,59] Oblique views of the posterior abdomen demonstrated clearly the entire lower urinary tract.

Surgical Technique

All dogs were given atropine* at the rate of 0.02 mg. per pound subcutaneously fifteen minutes prior to induction of anesthesia. Anesthetic induction was with thiamylal sodium** given at the rate of 8 mg. per pound of body weight. After induction, cuffed endotracheal tubes were inserted, and the patients were placed on an inhalation mixture of halothane*** and oxygen. Lactated Ringer's Solution**** at the rate of 10 ml. per pound per hour was given intravenously throughout each surgical procedure.

Ventral abdomen and perineal regions were clipped and surgically prepped. A sterile polypropylene catheter was placed into the bladder transurethrally and attached to a closed drainage system. The patients were placed in dorsal recumbency with the hind legs flexed and the perineal region elevated slightly. Field towels were placed to allow draping of the ventral abdomenal area plus the perineal region within one fenestration of the drape.

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*Atropine sulfate, Med-Tech, Inc., Elwood, KS 66024.

**Halothane, Halocarbon Laboratories, Inc., Hackensac, NJ 07601.

***Bio-tal, Bio-ceutic Laboratories, Inc., St. Joseph, MO 64502.

****Lactated Ringer's Injection, USP, Travenol Laboratories, Inc., Deerfield, IL 60015.

The approach used for all twelve dogs was similar. A ventral incision was made extending from the umbilicus caudally, lateral to the prepuce, to end at the level of the scrotum. Prepuce and penis were undermined and retracted laterally. Linea alba was identified and incised to the pubis. After entering the abdomen, Balfour retractors were utilized to improve visualization. The bladder was retracted cranially to expose the prostate and periprostatic fat was dissected free, staying close to the midline of the gland. Using blunt dissection, the membranous or posterior urethra was identified and isolated as it emerged from the prostate. The polypropylene catheter was backed out and the urethra transected by scapel approximately one centimeter caudal to the prostate. Significant hemorrhage occurred mimicking the hemorrhage occurring with traumatic urethral rupture. Laparotomy sponges were used to pack off the abdomen and the perineum approached for the urethrostomy.

The polypropylene catheter could be palpated within the perineal urethra. An incision was made on the midline and extended from just dorsal to the scrotum for a distance of four to five centimeters. The retractor penis muscle was identified and retracted laterally while the bulbocavernosus muscle was separated over the urethra. A one to two centimeter incision was then made through the cavernous tissue into the urethra and the mucosal edges grasped with Babcock forceps.

Up to this point, all three groups' surgical procedures were essentially identical. After insertion of the largest possible (14 to 20 French) Foley catheter through the perineal urethrostomy and into the abdomen, three different techniques were then used to anastomose the transected membranous urethra.

Group I. After directing the Foley catheter into the urethra, it was advanced into the site of simulated urethral rupture. The Foley catheter

was then inserted into the anterior free end of the urethra, through the prostate, and into the bladder. The balloon cuff was then inflated with 30 cc. of saline. The transected urethra was then re-opposed with interrupted, preplaced sutures of 4-0 Dexon, including mucosa in each bite. By pre-placing the sutures, the urethra could be manipulated to facilitate placement of sutures 360 degrees around the urethra. The Foley catheter was then left within the bladder to exit via the urethrostomy site and was sutured to the perineal region and along the prepuce opposite the surgical incision.

Group II. A Foley catheter was also instilled into the bladder as in Group I dogs. The simulated urethral tear was identified and interrupted sutures of 4-0 Dexon were pre-placed, care being taken to include urethral mucosa in each bite. After the urethra was sutured, the Foley catheter was removed and the perineal urethrostomy allowed to heal by granulation.

Group III. This group did not have any sutures placed to anastomose the urethra. Instead, the Foley catheter was placed within the bladder and firm traction applied to pull the prostate and bladder caudally, opposing the torn urethral ends. The catheter was secured under tension by sutures to the perineum and ventral abdomen. Two dogs removed their catheters too soon and were not included in the study. Two additional dogs were managed similarly but also had traction sutures of 0-Prolene. The suture was secured to the Foley catheter at the level just distal to the anastomotic site and brought out to exit through the perineal urethrostomy. These traction sutures were then tied under tension over button stents placed lateral to the urethrostomy site.

All abdomens were flushed with saline and closed routinely using 0-Dexon in an interrupted pattern in the rectus fascia. A continuous

suture of 2-0 Dexon was placed in the deeper aspect of the subcutaneous tissue and repeated again in the more superficial aspect of the subcutaneous tissue. Interrupted sutures of 3-0 Ethilon* were placed in the skin. All perineal catheters were left in place for two weeks as open, indwelling catheters. Sidebars of aluminum rods were constructed to prevent the dogs from removing their catheters or traumatizing the surgical site.

Post-operative Follow-up

All dogs were observed on a daily basis to monitor healing and catheter function. Two weeks following surgery, the urinary catheters were removed and the perineal urethrostomies allowed to granulate in. Periodic observation several times a week was continued to observe urinary function such as urine volume passed, straining, size of urine stream, frequency of attempts, and length of time spent trying to urinate. A few patients required catheterization at intervals to relieve the posterior urethral obstruction.

Four to five month post-operative follow-up studies included:

1) Regrograde, positive contrast urethrographs made the day the subject was euthanized. This study was compared to the pre-operative radiographs to determine clinically the amount of urethral stricture and or altered anatomical characteristics.

2) Dynamic, positive contrast urethrographs of the isolated lower urinary tract were taken as contrast media was injected until urethral pressure was equal to 90 centimeters of water pressure.

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*Ethilon, nylon, Ethicon, Inc., Sommerville, NJ 08876.

3) Histological studies of the urinary tract were made to include intrapelvic urethra distal to the site of simulated injury, the surgical site, prostatic urethra, bladder, ureters, and kidneys with emphasis placed on the recognition of mucosal changes, fibrosis associated with stricture, and upper urinary tract disease.

The post-op retrograde, positive contrast studies were performed in the same manner as previously described. Each dog was then euthanized with intravenous solution, T-61,* and the lower urinary tract dissected free. An incision over the previous surgical site was made and extended into the abdomen. Any abnormalities, including adhesions, were observed and dissection continued to free the bladder and prostate. Bone cutters were used to remove the ventral aspect of the pelvis. The penis was transected just cranial to the os penis and the penile body dissectd free to the root where the crura and the ischiocavernosus muscles were incised along their ischial attachments. The entire lower urinary tract from the bladder to the level of the os penis was then removed intact. Excessive fatty tissue and periurethral fascia were trimmed away and the bladder excised at its neck. A number 8 French Foley catheter was placed within the remnant of the bladder neck so that the catheter tip was just within the prostatic urethra. The balloon cuff was inflated with three milliliters of air and a purse-string suture of 3-0 Ethilon applied to effect a seal. A second Foley catheter was then placed within the other end of the urethra and secured with the balloon inflated and a purse-string suture. The second catheter was attached to a 60-cc. syringe filled with contrast media (1:4 Renografin 60 to bacteriostatic water). The out-flow catheter from the prostatic urethra was attached to a three-way stop-cock and then to a

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*T-61, euthanasia solution, Taylor Pharmacal Co., Decatur, IL 62525.

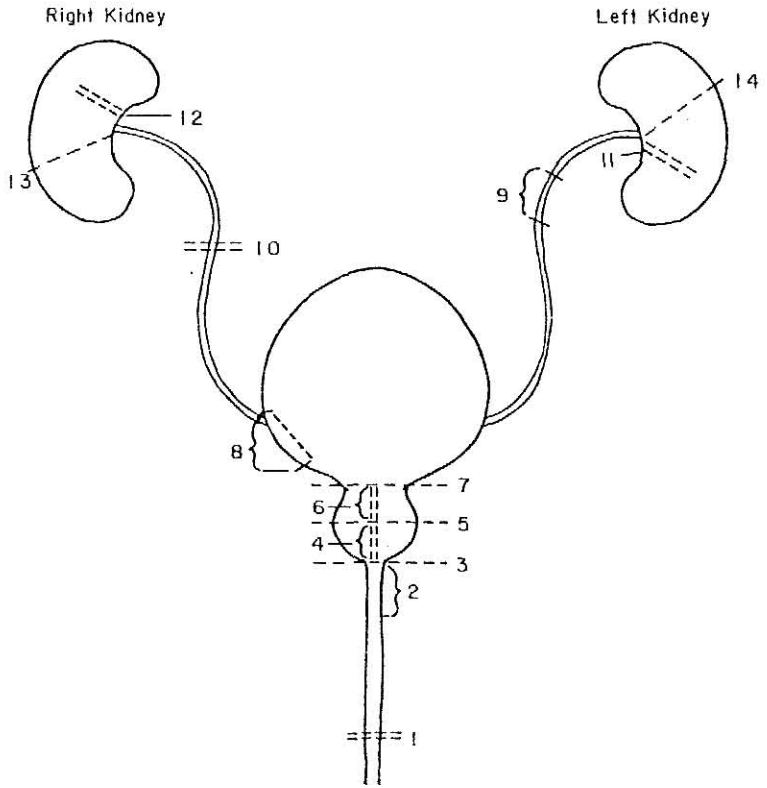
water manometer. After placement of the catheters, the entire tract was submerged in warm saline in a plastic pan and transported to radiology. All exposures were made through a plastic pan and saline solution. Time from euthanasia to exposure was between 40 and 55 minutes.

It was difficult to obtain radiographs of good contrast due to overall sameness of density of the tissue mass versus the stark density of the contrast media. A technique of 45 KVP, .008 seconds, and 300 Ma produced acceptable results whereby the involved structures could be identified. Radiographs were exposed when urethral pressures reached 90 cm. of water pressure. Direction of the flow of contrast media was the same as in vivo retrograde studies, from the penile urethra towards the bladder.

After the dynamic pressure studies were performed, all tracts were placed in a 10 percent buffered formalin solution. Both kidneys and ureters were also submitted for histopathological study. Longitudinal and cross sections were submitted from areas throughout the urinary tract. A standard protocol was devised so that the tissue samples came from relatively the same area for each dog (Figure 1). The specimens were routinely formalized, placed in parafin blocks, and processed with the Technicon processor using hematoxylin and eosin stain.

DIAGRAM DEPICTING HISTOPATHOLOGY PROTOCOL

Tissues submitted for exam were from similar regions for each dog




1. cross-section of urethra 2 cm distal to simulated rupture
2. longitudinal-section of simulated urethral rupture site
3. cross-section of caudal prostate
4. longitudinal-section of caudal prostatic urethra
5. cross-section of mid-prostatic urethra
6. longitudinal-section of cranial prostatic urethra
7. cross-section of cranial prostate
8. section of bladder wall
9. longitudinal-section of left ureter
10. cross-section of right ureter
11. left renal pelvis
12. right renal pelvis
13. right renal cortex
14. left renal cortex

# RESULTS

## A. Clinical Observation

Immediate post-operative complications for all dogs were minimal. Primary problems encountered involved occasional removal of aluminum sidebars and urinary catheters in Groups I and III. Eight days post-surgery, dog 3 removed his transurethral catheter. This was replaced without incident and remained in situ for the remainder of the two-week period. Two dogs in Group III removed their urethral catheters five and eight days post-operative, respectively. Both of these dogs strictured to the point of complete obstruction and were not included in the study. Ventral preputial edema occurred in several dogs but resolved in five to seven days.

All perineal urethrostomy sites healed by granulation within one week of catheter removal for the Group I and III dogs and within the first week following surgery of the Group II dogs. No evidence of fistulous tracts were seen in any of the dogs.

Group I. All four dogs exhibited minor changes in urinary patterns the first seven days following removal of their splinting catheters. Primary signs observed included squatting to urinate versus lifting a rear leg, increased time of micturation, and a diminished, intermittent urinary stream. Dog 2 had urine retention noted within the first week after his catheter was removed. A number 8 French catheter was passed on three occasions to remove the retained urine. He then continued to void throughout the remainder of the study without further need for catheterization. Dog 2 continued to have a moderate degree of dysuria exhibited as squatting to urinate, increased time of micturation, and a

diminished urinary stream, compared to the other three dogs. A number 8 French catheter could be passed with some resistance at the termination of the study, while a number 10 French catheter could be easily passed into the bladder of the other three dogs. Dogs 1, 3, and 4 demonstrated essentially normal patterns of urination at the end of the study. None of these dogs ever required catheterization following initial removal of their urethral catheters.

Group II. All dogs passed some urine through the perineal urethrostomy for a few days before the incisions healed by granulation. Dogs 5, 6, and 8 exhibited similar signs including increased time of urination, a slightly diminished urinary stream which was comparable to dog 2, and intermittent episodes of squatting during micturation. Three weeks post-operative, dog 8 was dysuric with a distended bladder. He was catheterized daily for four days to relieve the urine retention. After this time period, he continued to void but had a moderately diminished urinary stream, would consistently squat and strain when urinating, and maintained some residual urine and a slightly distended bladder. At euthanasia a number 8 French catheter could only be passed with resistance. Hematuria and multiple calculi were also noted. A number 10 French catheter could be passed with slight resistance in dogs 5 and 6.

Dog 7 became completely blocked two weeks following surgery. He was catheterized daily for four weeks, then began to intermittently void on his own. For two additional weeks he was catheterized every two to three days. After this time period, he continued to urinate without assistance to the termination of the study. At the time of euthanasia, dog 7 exhibited significantly increased time of urination with abdominal straining. The urinary stream was very diminished, and he made frequent attempts to

urinate while voiding only a few drops of urine. The bladder maintained a volume of 300-400 ml. of urine at all times, as determined by palpation and catheterization.

Dogs 5 and 6 had more normal patterns of urination at the closure of the study, which were similar to Group I dogs.

Group III. Dog 9 presented a more normal pattern of urination similar to Group I dogs. He exhibited a slight increase in time of micturation and a slightly diminished urinary stream. On occasion he was noted to squat during micturation, but the majority of the time he would lift his rear leg in normal fashion. The other three dogs (10, 11, and 12) encountered major problems with urination. Dog 10 required repeated, intermittent catheterization until he strictured to the point where it was difficult to pass a number 3.5 French catheter. He did continue to void but with severe abdominal straining and would crouch low to the floor while attempting to urinate. Attempts at urination were frequent, and the urinary stream was an intermittent dribble. Dog 10 also retained a significant volume of urine, estimated to be approximately 200-400 ml. by palpation and catheterization.

Dog 11 had no major problem until three weeks after surgery when he gradually became obstructed. He was catheterized daily for eight days after which he continued to void without assistance until termination of the study. His time of urination and urinary stream were similar to dog 10, but he did not exhibit as severe a degree of straining. Occasional hematuria and crystal formation were noted along with increased frequency of attempts. A residual volume of urine, approximately 200-300 cc., was maintained.

Dog 12 exhibited moderate problems when compared to dogs 10 and 11. His time of micturation and urine retention was increased. The urinary stream was also significantly diminished.

See Table 2 for a summary of urinary patterns for each dog at termination of the study.

B. Clinical Pathology

Pre-operative values for serum chemistries and complete blood counts were within normal limits for eleven dogs. Dog 10 had a decreased red cell count ($4.5 \times 10^6$), decreased Hgb. (9.0 g./dl), and a microcytic, normochromic anemia. Renal function tests for dog 10 were normal. Serum chemistries indicated a decrease in albumin to 1.6 gm. percent and moderate increases in SGPT (96.0 I.U.) and alkaline phosphatase (142.0 I.U.). These values continued to be abnormal until the end of the study when they began to return toward normal limits (Appendix).

Some dogs exhibited a moderate eosinophilia, which was assumed to be related to the presence of heartworms or intestinal parasites. Dogs 2, 3, and 9 were positive for heartworms with the Knotts test. Groups I and III tended to have an elevated white cell count, primarily a neutrophilia, two weeks following surgery. Values ranged from $15.5 \times 10^3$ (dog 4) to $23.0 \times 10^3$ (dog 2). Group II did not exhibit as significant increases in neutrophils or total white count at the two-week follow-up. A definite trend between neutrophilia or eosinophilia and the surgical technique could not be established (Appendix).

Total protein values for all three groups varied considerably. Increased values were recorded at the termination of the study for dogs 3, 9, and 10. Dog 10 had exhibited a consistent elevation of total protein over the last 12 weeks (Table 3).

TABLE 2

Urinary Patterns Observed for each Dog
at Termination of the Study

| Dog Number | Abdominal Straining | Micturation Time | Urinary Stream | Residual Volume |
|---|---|---|---|---|
| | | GROUP I: | | |
| 1 | none | normal | normal | normal |
| 2 | moderate | increased | decreased | occasional |
| 3 | none | normal | normal | normal |
| 4 | none | normal | normal | normal |
| | | GROUP II: | | |
| 5 | sl.-mod. | increased | decreased | occasional |
| 6 | sl.-mod. | increased | decreased | occasional |
| 7 | severe | increased | intermittent | 300-400 ml. |
| 8 | moderate | increased | decreased | occasional |
| | | GROUP III: | | |
| 9 | none | normal | normal | normal |
| 10 | severe | increased | intermittent | 200-400 ml. |
| 11 | severe | increased | intermittent | 200-300 ml. |
| 12 | moderate | increased | decreased | occasional |

TABLE 3

Total Protein in Gm. Percent

| Dog Number | Pre-op | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| | | | GROUP 1 | | | |
| 1 | 7.5 | 8.0 | 7.5 | 8.0 | 8.0 | 8.1 |
| 2 | 6.8 | 6.7 | 7.3 | 7.4 | 8.4 | 7.9 |
| 3 | 6.4 | 6.3 | 6.8 | 7.8 | 6.9 | 8.7 |
| 4 | 6.7 | 6.8 | 7.8 | 7.7 | 8.1 | 7.5 |
| | | | GROUP II | | | |
| 5 | 7.6 | 7.2 | 7.4 | 7.8 | 8.3 | 8.1 |
| 6 | 6.5 | 6.7 | 7.4 | 8.4 | 8.4 | 8.1 |
| 7 | 6.0 | 6.4 | 7.2 | 6.8 | 6.9 | 6.6 |
| 8 | 7.7 | 7.2 | 7.0 | 6.8 | 7.1 | 7.0 |
| | | | GROUP III | | | |
| 9 | 6.8 | 7.0 | 7.7 | 7.8 | 8.7 | 8.7 |
| 10 | 7.2 | 7.5 | 9.8 | 12.3 | 10.4 | 10.1 |
| 11 | 8.1 | 8.6 | 8.3 | 7.4 | | |
| 12 | 7.9 | 7.0 | 7.3 | 7.6 | | |

Urinalysis performed at termination of the study demonstrated a urine pH of 7.0 or higher for every dog. All dogs had triple phosphate crystals present in their urine with urinary calculi noted with dog 8. Many dogs also exhibited a bactinuria. No trends could be established concerning urinalysis and surgical procedure except for the number of white cells observed. Groups I and III had a relatively higher number of white cells per high power field when compared to Group II (Table 4).

Group I. Dogs 1, 2, and 4 demonstrated slight elevations in BUN and creatinine values two weeks following surgery, while dog 3 remained within normal limits. All dogs returned to normal values by the conclusion of the study (Tables 5 and 6).

Group II. BUN and creatinine values did not increase significantly at the two-week follow-up. Dogs 5 and 7 exhibited a slight increase in BUN six weeks post-operative. Values noted were 27.0 mg. percent and 36.3 mg. percent, respectively. At termination of the study, all four dogs had normal values for BUN, and three dogs had normal values for creatinine. Dog 7 had a slightly elevated creatinine, recorded to be 1.6 mg. percent (Tables 5 and 6).

Group III. Dogs 9, 11, and 12 had elevations of BUN two weeks post-operative. Recorded values were 25.5 mg. percent, 45.6 mg. percent, and 27.7 mg. percent, respectively. With the exception of dog 11, all values returned to normal. Dog 11 maintained an elevated BUN until termination of the project, but his creatinine values were not remarkable. Dog 10 initially maintained a normal BUN and creatinine. At 14 weeks following surgery, his BUN increased to 55.7 mg. percent and creatinine to 1.8 mg. percent. However, both of these values returned to normal limits by closure of the study (Tables 5 and 6).

TABLE 4: SUMMARY OF URINALYSES PERFORMED AT TERMINATION OF THE STUDY

| DOG NUMBER | COLOR/CHAR. | SP. GR. | pH | GLU | KET. | PROT. | OC. BL. | BIL | RBC | WBC | CASTS | EPITH. CELLS | SED. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | straw/sl. cloudy | >1.035 | 7.5 | - | - | trace | trace | - | 15-20/hpf | - | - | occ. renal<br>few squ. | 3+ triple phos. |
| 2 | yellow/cloudy | 1.025 | 8.0 | - | - | 1+ | trace | - | 3- 5/hpf | 20-25/hpf | - | few squ.<br>occ. renal | 3+ triple phos.<br>2+ bact. |
| 3 | straw/sl. cloudy | 1.021 | 8.0 | - | - | - | trace | - | 2- 3/hpf | 3- 5/hpf | - | rare squ. | 2+ triple phos. |
| 4 | straw/cloudy | 1.014 | 8.0 | - | - | 1+ | trace | - | 0- 1/hpf | 30-40/hpf | - | few renal | 1+ triple phos.<br>4+ bact. |
| 5 | yellow/cloudy | 1.033 | 8.0 | - | - | 1+ | trace | - | 2- 3/hpf | occ. | - | - | 2+ triple phos. |
| 6 | yellow/cloudy | 1.030 | 8.5 | - | - | 3+ | - | + | - | 1- 2/hpf | - | occ. squ. | 4+ bact.<br>2+ triple phos. & $Ca^{+}$ |
| 7 | straw/clear | 1.025 | 8.5 | - | - | - | - | - | - | 3- 5/hpf | - | rare squ. | 4+ triple phos.<br>3+ bact. |
| 8 | reddish/cloudy | 1.034 | 7.0 | - | - | 2+ | 2+ | - | 20-35/hpf | 10-15/hpf | - | - | 4+ triple phos.<br>1+ bact. |
| 9 | straw/cloudy | 1.033 | 8.0 | - | - | 1+ | trace | - | 50-60/hpf | 5-10/hpf | - | occ. sq.<br>rare renal | 1+ triple phos. |
| 10 | yellow/cloudy | 1.032 | 7.0 | - | - | 1+ | 3+ | + | TNTC | TNTC | - | mod. renal | 2+ bact. |
| 11 | yellow/clear | 1.030 | 8.0 | - | - | 1+ | trace | - | 5-10/hpf | 20-25/hpf | - | - | 3+ triple phos.<br>3+ bact. |
| 12 | yellow/cloudy | 1.035 | 8.0 | - | - | 1+ | - | - | occ. | 25-30/hpf | - | - | 1+ triple phos. |

TABLE 5

Blood Urea Nitrogen in Mg. Percent

| Dog Number | Pre-op | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| | | | GROUP 1 | | | |
| 1 | 18.0 | 27.6 | 15.9 | 16.0 | 17.8 | 10.1 |
| 2 | 14.0 | 31.1 | 13.0 | 16.0 | 13.7 | 10.9 |
| 3 | 21.0 | 20.7 | 15.2 | 16.8 | 16.4 | 11.9 |
| 4 | 19.0 | 31.1 | 16.7 | 16.8 | 16.4 | 13.4 |
| | | | GROUP II | | | |
| 5 | 19.0 | 16.3 | 27.0 | 13.3 | 15.2 | 14.0 |
| 6 | 11.0 | 7.9 | 14.4 | 12.7 | 10.6 | 8.9 |
| 7 | 14.0 | 13.1 | 36.3 | 15.1 | 21.4 | 21.0 |
| 8 | 16.0 | 18.1 | 11.0 | 17.9 | 17.8 | 12.0 |
| | | | GROUP III | | | |
| 9 | 13.0 | 25.5 | 17.6 | 12.7 | 12.9 | 12.9 |
| 10 | 15.0 | 21.8 | 18.9 | 29.8 | 55.7 | 18.0 |
| 11 | 19.0 | 45.6 | 27.4 | 40.0 | | |
| 12 | 18.0 | 27.7 | 20.0 | 23.0 | | |

TABLE 6

Creatinine in Mg. Percent

| Dog Number | Pre-op | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| | | | GROUP 1 | | | |
| 1 | 0.9 | 1.3 | 0.8 | 0.8 | 0.9 | 1.1 |
| 2 | 0.9 | 1.5 | 0.7 | 0.6 | 1.0 | 1.1 |
| 3 | 1.3 | 1.1 | 0.9 | 0.6 | 1.0 | 1.3 |
| 4 | 0.9 | 1.3 | 0.8 | 0.7 | 1.0 | 1.3 |
| | | | GROUP II | | | |
| 5 | 0.7 | 1.2 | 1.1 | 0.8 | 1.1 | 1.1 |
| 6 | 0.7 | 0.7 | 0.6 | 0.9 | 0.9 | 1.1 |
| 7 | 0.8 | 1.0 | 0.9 | 0.8 | 1.3 | 1.6 |
| 8 | 0.7 | 1.1 | 0.9 | 0.9 | 0.7 | 1.1 |
| | | | GROUP III | | | |
| 9 | 0.7 | 1.3 | 0.9 | 0.9 | 1.1 | 1.2 |
| 10 | 0.8 | 1.0 | 0.9 | 1.2 | 1.8 | 1.3 |
| 11 | 1.6 | 1.6 | 1.2 | 1.4 | | |
| 12 | 1.0 | 1.1 | 1.1 | 1.0 | | |

Values for BUN and creatinine were averaged for each group and plotted against time to demonstrate the general trends (Tables 7 and 8).

C. Radiography - static studies

Pre-operative, retrograde, positive contrast studies of all dogs demonstrated typical radiographic anatomy. Narrowing of the urethra as it passed over the ischial arch, and again before it entered the bladder, was routinely observed. Some dogs (1, 3, 7, and 9) had reflux of contrast media into the prostate. The anterior segment of the membranous urethra tended to gradually taper as it entered the area of the prostate. On some dogs, a dilation of the membranous urethra just caudal to the prostate gland was noted. An S-bend of the intrapelvic urethra was also seen occasionally on normal pre-operative films.

Nine of the twelve dogs had urethral dilation at the site of the perineal urethrostomy. There was no correlation between length of time the urethrostomy was kept patent and the amount of dilation.

Group I. Three of the dogs (1, 3, and 4) exhibited a slight dilation of the urethra caudal to the prostate gland when compared to their pre-operative studies. Dogs 3 and 4 in the area of the prostate had slightly blunted or rounded-off conformation of the anterior aspect of the membranous urethra when compared to their pre-operative films. Normal membranous urethra at this point tapers into the prostate gland. The post-operative films of dog 2 appeared essentially the same as his pre-operative studies, with no dilation of the urethra caudal to the prostate or blunting of the membranous urethra.

Grpup II. Dogs 5, 6, and 8 did not present evidence of urethral dilation caudal to the surgical site compared to pre-operative films or to

TABLE 7: BLOOD UREA NITROGEN IN mg.%.
VALUES AVERAGED FOR EACH GROUP AND PLOTTED AGAINST TIME

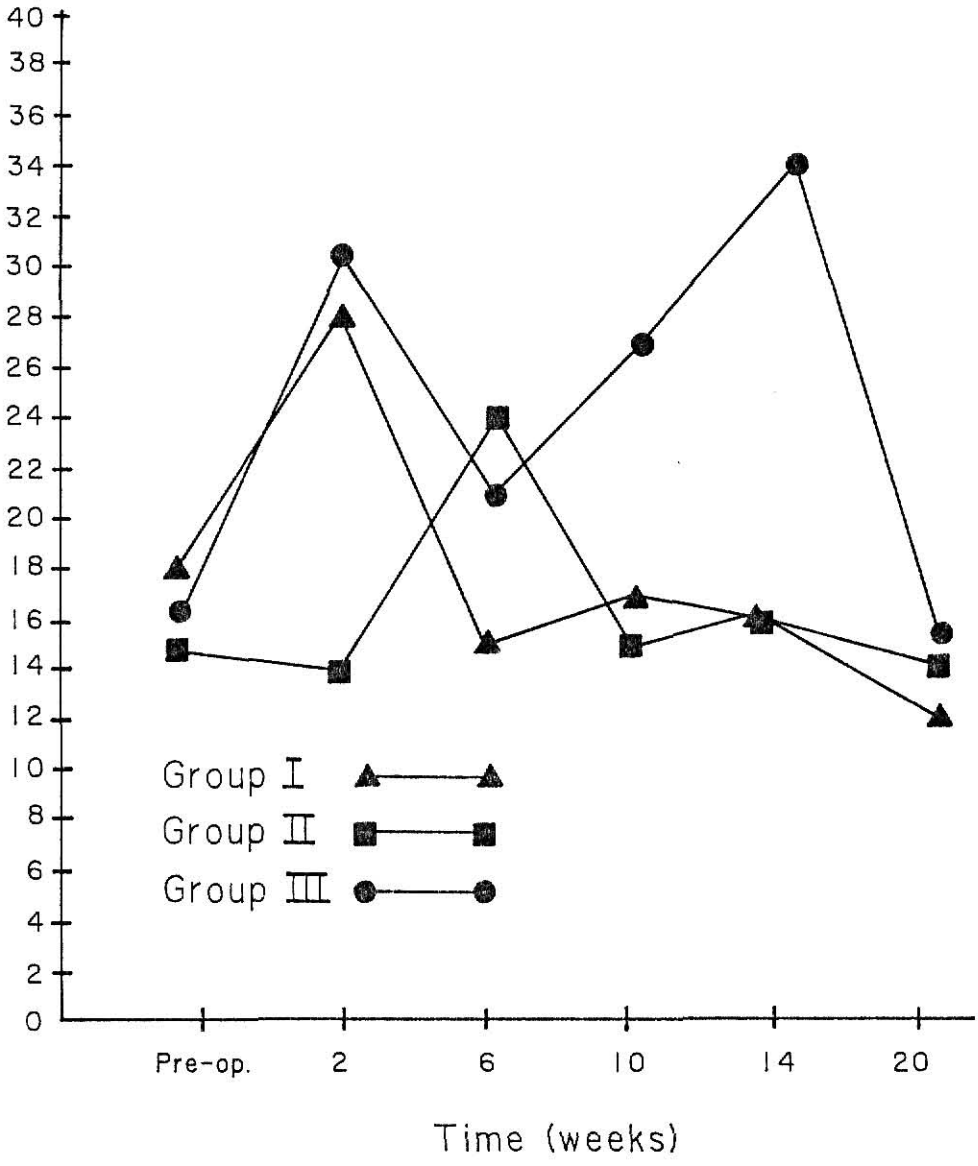
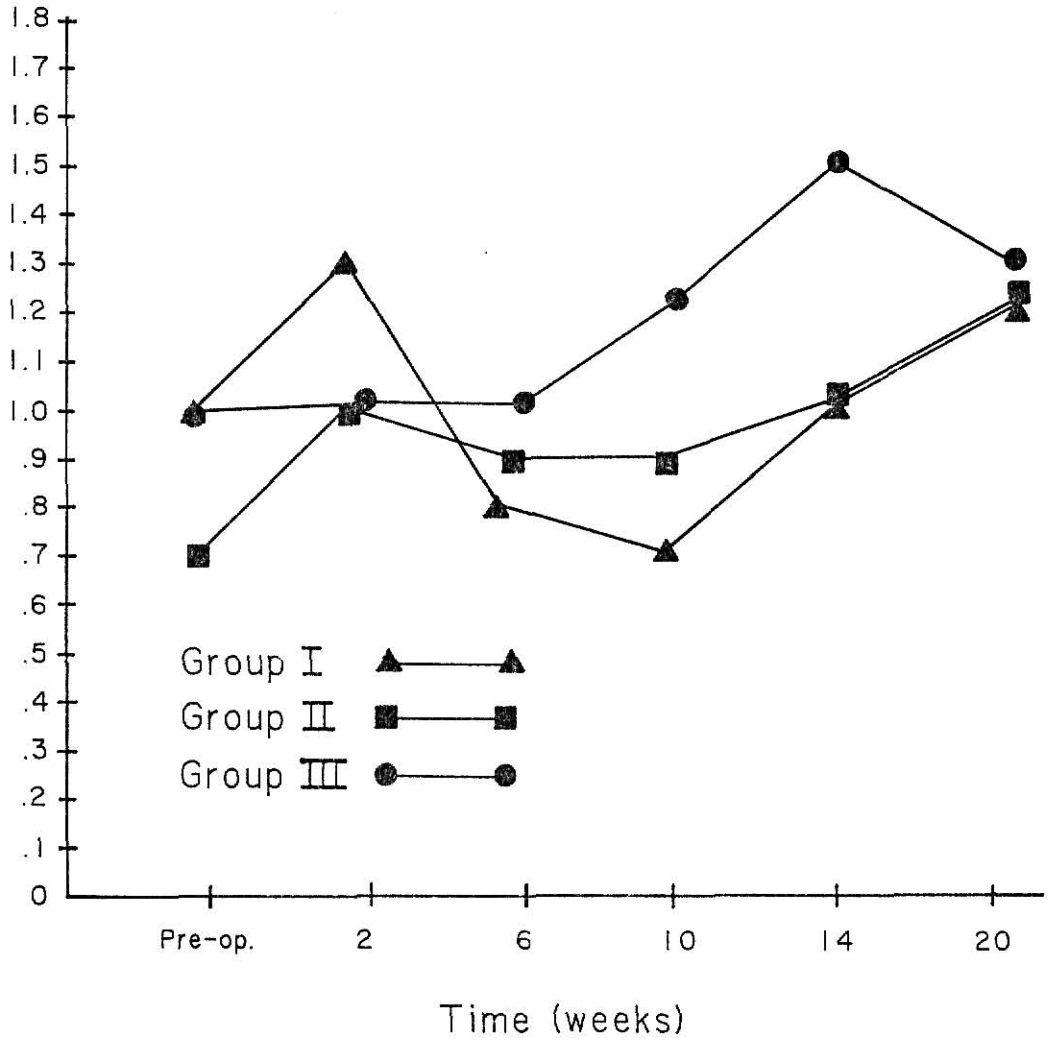


TABLE 8: CREATININE IN mg.%.
VALUES AVERAGED FOR EACH GROUP AND PLOTTED AGAINST TIME



the Group I dogs. Dogs 5 and 6 did exhibit some slight blunting or rounding-off of the anterior aspect of the membranous urethra only when compared to their normal films. Dog 7 demonstrated noticeable dilation of the membranous urethra, compared to the Group I dogs and to the other three dogs of Group II. His anterior segment of the membranous urethra was very blunted, and a tortuous tract of contrast material could be defined at the area of the surgical site.

Group III. Pre-operative and post-operative studies of dog 9 were essentially the same, with no dilation or blunting of the membranous urethra. Dog 12 also did not exhibit remarkable changes on the post-operative films, other than a very slight dilation of the membranous urethra when compared to his normal study. Dogs 10 and 11 demonstrated noteable dilation of the membranous urethra with pronounced blunting of its anterior segment. Distinct strictured areas could be identified in both dogs without comparison to their normal films. Dog 10 had an area of reflux or probable fistulous tracts identified in the area of the stricture.

C. Radiography - dynamic studies

All twelve dogs exhibited noticeable urethral stricture. Measurements were taken of the stricture and compared to the average diameter of the membranous urethra. The average membranous diameter was determined by measurements taken .5 cm. anterior and posterior to the stricture. The ratio of stricture to the average urethral diameter provided the basis for calculation of the percentage of lumen reduction. Results may be best demonstrated in Table 9. The least amount of stricture occurred in dogs 1, 3, and 4. Dogs 10 and 11 demonstrated the most lumen reduction with 84.0 and 79.0 percent, respectively.

TABLE 9: DYNAMIC RADIOGRAPHY - SUMMARY OF MEASUREMENTS AND CALCULATION OF % LUMEN REDUCTION

| DOG NO. | POST. STRICTURE MEASUREMENTS | STRICTURE DIAMETER | ANT. STRICTURE DIAMETER | AVERAGE OF POST. AND ANT. STRICTURE DIAMETER | RATIO | % REDUCTION |
|---|---|---|---|---|---|---|
| 1 | 8 mm | 6 mm | 8 mm | 8.0 mm | 6/ 8.0 = 75.0 | 25.0% |
| 2 | 9 | 3 | 10 | 9.5 | 3/ 9.5 = 31.6 | 68.4% |
| 3 | 8 | 5 | 8 | 8.0 | 5/ 8.0 = 62.5 | 37.5% |
| 4 | 8 | 5 | 8 | 8.0 | 5/ 8.0 = 62.5 | 37.5% |
| 5 | 7 | 2 | 10 | 8.5 | 2/ 8.5 = 23.5 | 76.5% |
| 6 | 8 | 3 | 8 | 8.0 | 3/ 8.0 = 37.5 | 62.5% |
| 7 | 10 | 2 | 13 | 11.5 | 2/11.5 = 17.4 | 82.6% |
| 8 | 7 | 3 | 8 | 7.5 | 3/ 7.5 = 40.0 | 60.0% |
| 9 | 7 | 5 | 7 | 7.0 | 5/ 7 = 71.4 | 28.6% |
| 10 | 10 | 2 | 15 | 12.5 | 2/12.5 = 16.0 | 84.0% |
| 11 | 9 | 2 | 10 | 9.5 | 2/ 9.5 = 21.0 | 79.0% |
| 12 | 7 | 3 | 8 | 7.5 | 3/ 7.5 = 40.0 | 60.0% |

D. Pathology: 1) gross specimens

The normal membranous urethra on gross examination was collapsed throughout its length. As the urethra entered the prostate gland, it tended to narrow even more. On cross-section, the normal prostatic urethra was U-shaped and relatively flattened. Some degree of dilation of the prostatic urethra may be normal.

Group I. The gross appearance of the membranous urethra of dogs 1 and 3 was essentially normal. Dog 4 also had a similar appearance, but the urethra was slightly dilated distal to the surgical site. Prostatic urethra anterior to the surgical site appeared within normal limits. The membranous urethra of dog 2 demonstrated an area of definite stricture with increased fibrosis and dilation of the urethra anterior and posterior to the stricture. A patent lumen could be identified.

Group II. All four dogs exhibited areas of stricture with dilation of the urethra distal to the surgical site. Dogs 5 and 6 appeared similar with moderate dilation of the urethra distal to the stricture. After the urethra entered the prostate, it began to dilate slightly more than expected. Dog 8 exhibited slightly less dilation of the urethra when compared to dogs 5 and 6. The prostatic urethra was normal in appearance. Dog 7 demonstrated the most pronounced changes of the Group II dogs. Dilation of the membranous urethra anterior and posterior to the surgical site was severe. An area of definite stricture with increased fibrosis and a greatly reduced lumen was observed. The prostatic urethra appeared dilated throughout its length.

Group III. Dog 9 demonstrated a normal appearing membranous urethra similar to dogs 1 and 3, and to the normal control. Severe dilation of the urethra anterior and posterior to the surgical site was seen in dogs

10 and 11. Dog 10 especially exhibited dramatic dilation with areas of gross mucosal hemorrhage. Increased fibrosis was present at the surgical site, and the lumen was barely patent. Dog 11 demonstrated a more tortuous, dilation of the membranous urethra with an area of probable fistulous tracts. Dilation of the prostatic urethra of dogs 10 and 11 was pronounced. The membranous urethra of dog 12 was not as dilated as dogs 7, 10, and 11. An area of increased fibrosis at the surgical site was observed along with moderate dilation of the urethra anterior and posterior. His prostatic urethra appeared within normal limits.

D. Pathology: 2) microscopic specimens

A standard protocol was prepared and followed in order to exam tissues from comparative areas. Longitudinal and cross-sectional cuts were taken of the entire tract, including ureters and kidneys.

The urethra distal to the surgical site exhibited some dilation, except in dogs 1, 3, and 9. Epithelial changes seemed to be correlated with amount of dilation, rather than surgical technique employed. Dogs 7, 10, and 11, with a severe amount of dilation distal to the stricture, demonstrated irregular dilation of venous plexuses, edema of the connective tissue, and an increased amount of fiberous tissue. The epithelium appeared to be exfoliating in some areas while in other locations the epithelial cells tended to be flattened and compressed. Metaplastic changes involving the epithelium were observed, along with large numbers of mononuclear cells, lymphocytes and plasma cells, infiltrating the submucosa and mucosa. Similar but not as severe changes were observed in the rest of the dogs with urethral dilation distal to the surgical site.

Changes in epithelium of the prostatic urethra and in the associated submucosal layers were difficult to interpret. Several dogs had microscopic lesions of chronic, active prostatitis with areas of mononuclear cells infiltrating through the epithelium. The prostatic and urethral tissue both appeared to be involved in a disease process, but it was not possible to determine which came first, the prostatitis or the urethritis.

All dogs exhibited some enlargement of the bladder and increase in bladder wall thickness when compared to normal. Mild inflammatory changes, such as micro-abscesses and large numbers of mononuclear, infiltrative cells were observed in the majority of the bladder walls. The epithelium appeared to be normal transitional epithelium. Dogs 7, 10, and 11 demonstrated pronounced hypertrophy of the submucosal layer, severe interstitial fibrosis, follicular aggregates of lymphocytes, and prominent blood vessels.

Severe hydroureters were observed in two dogs (10 and 11). The epithelial cells tended to be flattened and tightly packed together with the outer nucleui lined up in a row parallel to the lumen. Overall thickness of the submucosal layer was decreased when compared to normal, and linear stress patterns were seen in the supporting connective tissue. Dogs 2 and 7 exhibited slight dilation of the ureter with normal appearing transitional epithelium.

Chronic, ascending lymphocytic pyelonephritis was present in dogs 6, 7, 10, and 11. Dogs 10 and 11 demonstrated a moderate degree of hydronephrosis.

Group I - surgical site. All dogs exhibited moderate to severe chronic inflammation made up of mononuclear cells, primarily lymphocytes,

and a few plasma cells. A few intraepithelial micro-abscesses were noted in the mucosa. The submucosa was relatively thickened in dog 2 and included increased collaginous tissues.

Epithelial changes noted in dog 2 included areas of mucosal hypertrophy with rounding up or individualization of cells and areas where the mucosa was flattened with the epithelial cells tightly compressed. Dogs 1, 3, and 4 exhibited essentially normal appearing transitional epithelium except for the inflammatory changes noted previously. Dog 4 tended to have more areas distal to the surgical site where the epithelial cells were flattened.

Group II - surgical site. Compared to the Group I dogs, dogs 5 and 8 had relatively fewer numbers of mononuclear cells migrating through the submucosa and mucosa. Dog 6 demonstrated more inflammatory cells and intraepithelial micro-abscesses. Thickness of the epithelium varied from one to two cell layers to multiple cell layers. Distal to the surgical site, pronounced urethral dilation could be seen, especially in dog 7. The mucosa was flattened without its normal involutions, and the cells were tightly packed together. There was an increased amount of disorganized fibrous connective tissue involving the surgical site of dog 7.

Group III - surgical site. The epithelium of dog 9 was relatively normal with some infiltration of mononuclear cells within the mucosa and submucosa. Dogs 10, 11, and 12 demonstrated epithelial changes similar to dog 7. Large numbers of lymphocytes and a few plasma cells were noted migrating through the mucosa. There were areas where the mucosa was very flattened and the cells compressed, especially dogs 10 and 11. Other areas exhibited an irregular thickness to the mucosa with prominent cornification. Some of the epithelial cells demonstrated metaplastic changes with individualization of cells.

# DISCUSSION

Correlation of clinical assessment of urinary patterns with the degree of urethral stricture was good. Dogs 7, 10, 11, and 12, with severe strictures, demonstrated noticeable changes in urinary habits, primarily increased straining, increased frequency of attempts, and diminished urinary stream. Dogs 1, 3, 4, and 9, with lesser degree of stricture, and more normal patterns of urination.

Clinical evaluation of urination patterns is by necessity a subjective method. Although all the dogs exhibited some signs of abnormal micturation, all were adapting well, eating normally, active, and alert. Even the three most severely strictured dogs were alert, did not show signs of toxicity, and continued to void some urine. Despite the clinical findings, their degree of stricture was severe and signs of progressive upper urinary tract disease, due to back pressure and chronic infection, were present on both gross and histological specimens. The inconsistency between clinical signs and the actual degree of stricture may help to explain why the problem of post-traumatic urethral stricture is not reported frequently in the veterinary literature. Long-term follow-ups would be necessary to adequately evaluate the results of repair. This may be difficult to do in the veterinary field.

Although many of the dogs were observed to have normal male urinary habits prior to surgery, specific observation of each subject was not performed. It would have been helpful in making a more meaningful clinical assessment if normal pre-operative urinary patterns had been established for each dog.

Catheter maintenance was the primary management problem. The complete obstruction of two dogs with premature removal of their urethral

catheters points to the need for close monitoring under hospital conditions. Aluminum sidebars seem to provide a more effective method of preventing self-trauma and catheter removal than the conventional Elizabethian collar, which is frequently manipulated by the dog. The sidebars also allowed freer access to food and water.

The use of indwelling urinary catheters is an area of potential problem in determining the ideal method of repair. It is accepted that open indwelling catheters allow a much higher incidence of infection than intermittent or closed catheterization. But no well-controlled study has definitely shown this to be true.[61] The effects of the catheter due to size and composition provides another area for debate. A large size, snug-fitting catheter has been said to increase urethral mucosa trauma and ultimately cause stricture.[11] In cats, the presence of an indwelling catheter post-urethrostomy resulted in a higher incidence of urethral stricture.[59] A second study in cats using indwelling catheters of two types of materials revealed differing degrees of gross and microscopic lesions.[32,33] Similar findings have also been observed in man and dog.[32] The role of infection in modifying the mucosal reaction to the catheter is not known. It would appear that there is an influence of infection on the urethral mucosa in regards to foreign material.[16]

All of these issues point to the fact that short- or long-term effects of catheters on the urinary system are not understood. Due to the possibility of catheter-induced lesions and the catheter management problems, it would be preferable in veterinary medicine to avoid the use of catheters. It is apparent from the present study that the majority of dogs sutured over an indwelling splinting catheter did better than those sutured without a catheter. The advantages of less urethral stricture

would seem to outweigh the potential problems of an open, indwelling system.

Perineal urethrostomies were performed instead of a prescrotal urethrostomy to allow for use of a larger catheter. It has been reported in the human literature that the incidence of stricture post-urethrostomy (perineal) is from less than one to eight percent.[39] Yet both human and veterinary surgeons tend to avoid using perineal urethrostomies due to unfamilarity with the surgical approach and the fear of stricture. All urethrostomy sites healed within one to two weeks after catheter removal by granulation. No strictures or fistulous tracts occurred in any of the dogs, and the technique is relatively simple without need for specialized equipment.

Several techniques have been described for contrast urethrography including antegrade, retrograde, and voiding.[46,60] Voiding contrast studies are extremely difficult to obtain due to lack of patient cooperation. Antegrade studies may be diagnostic for lower urinary tract disorders, but a more complete examination of the urethra may be obtained with a retrograde technique.[2,3,60]

Two types of catheters have been used to perform retrograde urethrography. With the Foley or Schwann-Ganz catheter, a balloon cuff effectively occludes the urethral lumen, which allows for complete filling. Urinary catheters without balloon cuffs can be used but contrast media will reflux around the catheter. False negative films have been observed if the amount or pressure of contrast media is insufficent to cause extravasation at the rupture site.[1,66] Retrograde studies may be performed with negative or positive contrast media. The problems with negative contrast media, especially air, is the risk of air embolism and

the misinterpretation of the films due to insufficient air or subcutaneous emphysema.[1]

In this study it was important to perform both the pre-operative and post-operative studies under identical circumstances. The urethra, being a highly distendable organ, may exhibit differing lumen diameters with differing injection pressures. The Foley catheter enables a significant, repeatable positive pressure to be obtained.

Although the same basic technique was performed by the same person, it was apparent that the results of the urethrography varied more than expected. Urethral diameter was most easily altered, depending on the amount of contrast media injected and the pressures obtained. Positioning of the dog would also cause problems, primarily with the bony structures obscuring the lower urinary tract. Two views are recommended to definitely define a possible lesion. An oblique VD with hind legs extended caudally revealed the entire lower urinary tract adequately, and only one view was taken. Standard radiographic technique was increased to penetrate the dense pelvic structures. A technique of 80 KVP, .016 seconds, and 300 Ma produced the best radiographs in the majority of the dogs.

The most important observation revealed by the static in-vivo studies was the inconsistency and lack of correlation of radiographic signs with the actual degree of stricture. For example, dogs 2 and 7 had severe strictures identified both clinically and on gross exam. Yet their post-operative urethrographs were essentially normal in appearance.

A possible explanation for this lack of correlation involves the site of rupture. On normal films, the prostatic urethra was usually seen as a narrowed tract leading into the bladder. Since the stricture occurred immediately caudal to the prostate, one would tend to see only an extension

of the narrowed prostatic urethra. A more reliable sign of severe urethral stricture may be the blunting or rounding-off of the anterior segment of the membranous urethra. This was demonstrated well by dogs 10 and 11. This sign was not observed with dog 2 and is probably due to technique. If the contrast media is not injected under sufficient pressure, complete dilation of the urethra may not occur.

Other minor problems with the static urethrography involved the mechanics of the technique. Large-guage wire used in the stylet (20 g. or 22 g.) would kink, making removal difficult if not impossible. Smaller-guage wire (26 g. or 28 g.) worked more effectively. It was possible to pass the Foley catheter a short distance without the stylet, but seldom past the os penis. Over-inflation of the balloon cuff can cause collapse of the catheter lumen and subsequent difficulty in injecting the contrast media. Air bubbles were a frequent artifact unless great care was taken to remove all air from the system. Air bubbles were distinguished from calculi by their smoothness and the fact that the air bubble conforms to the shape of the urethra.[66]

The dynamic studies evolved from a need to objectively determine the degree of urethral stricture. Richardson demonstrated a technique using positive pressure and negative contrast (air) to determine the degree of colonic stricture secondary to anastomosis.[54] A section of colon was fitted with Foley catheters on either end. Air was injected through one Foley catheter until a pressure guage attached to the opposite Foley catheter recorded the predetermined pressure. This basic concept was utilized in our dynamic studies using positive contrast instead of air and a water manometer instead of a pressure transducer.

Urethral pressure profiles are presently under investigation.[8] At this time, the values differ due to factors like the material used in the

catheter and the number and position of holes.[21] One study by Rosin et al., determined the normal urethral pressure profiles for both male and female dogs. The average maximum urethral pressures recorded for males was 32.7± 4.1 mm Hg, which is equal to 44 cm water pressure (1 mm Hg = 1.36 cm $H_2O$).[55] A pressure of 90 cm $H_2O$ is approximately twice the maximum urethral pressure and should result in complete distention of the urethra.

The primary problem in performing the contrast studies was leakage which decreased the pressure build-up. It was not possible to reach a significant pressure (greater than 40 cm $H_2O$) with the bladder left intact due to the great distensibility of that organ. Therefore, the bladder was transected just distal to the neck, leaving a remnant which could be secured around the Foley catheter. Time elapsed between euthanasia and exposure of the dynamic study was kept between 40 and 55 minutes to eliminate changes in organ elasticity due to autolysis.

The dynamic studies were surprising in the dramatic amount of stricture they revealed for every dog, regardless of anastomotic technique used. While it was easily demonstrated that three out of four dogs in Group I had almost normal sized urethral lumens, a significant degree of stricture remained. The severe strictures in some of the more clinically compromised dogs were remarkable in that the dogs could void. An attempt was made to correlate the degree of prostatic urethral enlargement due to increased back pressure with the degree of stricture. This could not be done with any consistency since all of the prostatic urethras were dilated, as was the normal control study. This was assumed to be due to the high injection pressures. Dog 8 demonstrated more severe clinical signs than dogs 5 and 6, yet his percentage of lumen reduction was less according to

the dynamic studies. A possible explanation may be due to the multiple cystic claculi that occurred in dog 8.

Results of serial monitoring of kidney function tests and the hemograms were inconclusive. Elevation of white count with neutrophilia and eosinophilia were observed in many cases, but could not be correlated to a particular type of anastomosis performed. Even with a severe amount of stricture (60 percent or more), only two of the dogs presented slightly abnormal renal function tests. The reason for the normal values throughout the study lies in the fact that all dogs were still voiding. Transient increases in BUN and creatinine were associated with urethral obstruction which was relieved by catheterization. Unless the urethra becomes completely occluded or the kidneys incur damage to 75-80 percent of their functional parenchyema, increases in BUN and creatinine would not be seen.

Total protein and WBC values did not correlate with the degree of stricture or urinary dysfunction. Urinalysis did not provide any indication of the degree of stricture and/or the presence of upper urinary tract disease. Until sufficent damage to renal parenchyema had incurred, changes in the urinalysis, such as a fixed specific gravity or a proteinuria, would not be expected. Groups I and III tended to have higher numbers of white blood cells per high power field when compared to Group II dogs. This comparative increase may be due to the open indwelling catheters employed in these two groups. Large amounts of triple phosphate crystals were seen in all urinalysis specimens. Other causes of urinary infection could include contamination during intermittent catheterization and the retention of urine.

It has been stated that complete transection of the membranous urethra will invariably result in stricture.[40] The findings of the present

study would support that statement in that every dog had a 25 percent or more reduction of lumen diameter. An increase in resistance to urine flow or partial obstruction leads to increased volume and back pressure anterior to the point of obstruction. The higher volume and back pressure contributes to changes in urinary tract pathophysiology resulting in a syndrome known as post-renal uropathy. The severity and type of lesions demonstrated depends on the location of the obstruction and if it is acute, chronic, complete, partial, unilateral or bilateral.[44,72] An acute obstruction might show elevation of renal function tests, yet have basically normal urinary pathology. A more chronic lesion would provide time for cellular changes to occur while allowing the animal to compensate for the azotemia. Obstruction of the urethra causes bladder distention with an increase in residual volume and pressure. Because the bladder is such a distendable organ, it can effectively absorb increased pressure while protecting the ureters and kidneys. With continued obstruction or resistance to outflow, gradual fatique of bladder musculature occurs. Overdistention leads to a hypotonic or atonic bladder, and the pressure begins to increase in ureter and kidneys. An increase in pressure leads to decreased renal blood flow, decreased glomerular filtration rate, and alteration of normal tubular function. The mechanical effects of pressure contribute to altered cellular dynamics leading to epithelial changes such as sloughing or metaplasia.

An increase in residual urine volume invariably leads to infection. Under normal circumstances, urine is considered to be sterile. The mechanics necessary to maintain urine sterility include the antibacterial nature of urine, mechanical washout associated with voiding, structural and functional barriers to ascending organisms (as with the zone of high

pressure in the urethra), and the antibacterial activity of the urinary tract mucosa.[7,45] If these mechanisms are compromised, then urinary tract infection is the sequela. The problem is in determining which came first, infection due to technique and leading to stricture or infection resulting secondary to stricture and urine retention. This may be difficult to differentiate on a clinical basis.

Ultimately, the presence of partial obstruction or stricture leads to chronic, progressive upper urinary tract disease, such as hydronephrosis and pyelonephritis. This was exhibited by dogs 6, 7, 10, nd 11. If the study had been continued, it is likely that more dogs would have developed obstructive uropathy. At this time a correlation between degree of stricture and the occurrence of obstructive uropathy has not been established.

In addition to infection, other factors contributing to stricture formation may be: 1) the type of catheter and how it is used, 2) composition of the suture material, and 3) urine leakage at the anastomotic site. Surgical technique, including exposure, tissue handling, and identification of mucosa edges play an important role in the degree of stricture.

The exact role of infection has not been clarified in this study. Dogs with indwelling catheters could be expected to have a higher incidence of infection and related problems. Yet Group I had the best results, and those dogs without catheters in Group II had more degree of stricture. A factor here may be the leakage of urine at the anastomotic site. Some authorities claim that urine will leak along the transurethral catheter, and they recommend using suprapubic drainage in addition to the urinary catheter.

Suture material has also been incriminated with increasing the amount of stricture. Dexon suture was selected due to its decreased amount of inflammatory reaction. Dexon suture has been reported to lose its tensile strength in vitro when immersed in urine. This has not been confirmed by clinical and laboratory evaluation.[9,58] No histopathological lesions were noted in relation to the suture materials.

Identification and suturing of the simulated urethral tear could be managed without pelvic symphysiotomy or pubic plate reflection. The advantage of this simplified approach is less surgical time, ease of approach, and the lack of need for specialized orthopedic equipment.

When the urethra is transected, the ends tend to retract back into the periurethral tissue. If close apposition with the traction catheter cannot be achieved, then a gap is left that will eventually fill in with fiberous tissue. Care must be taken to include the urethral mucosa and not the periurethral tissue when placing sutures. An enlarged prostate may cause displacement of the anterior urethral segment, leaving a gap which may lead to increased fibrosis and stricture.

With stricture, dilation of the urethra, both proximal and distal to the site, occurred. Dilation proximally may be due to urine retention, increased volume, and pressure during micturation. The mechanism for the distal dilation is not known. It may be due to transection of a longitudinal nerve plexus when the urethral rupture occurs. With loss of the innervation, the urethra loses its tone and passively dilates. A second theory argues that the dilation is due to the turbulence and force generated as the urine passes through a small lumen. More work is necessary to define the mechanism of dilation distal to the stricture.

The gross and histopathological changes observed included chronic lymphocytic inflammation, flattening of the epithelial cell layer and

submucosa, and lesions associated with obstructive uropathy such as hydroureter or pyelonephritis. Correlation could not be made between inflammatory changes and type of surgical procedure employed. In many cases, previous disease processes, such as prostatitis, may have influenced the reaction of the urethra. Classically, the flattening of the epithelial cells and submucosa has been attributed to either pressure or infection. This seems to be a reasonable explanation when considering the urethral mucosa proximal to the surgical site. Epithelial changes distal to the surgical site, especially in areas of moderate to severe dilation, may not be as easily explained. Pressure distal to the stricture would not seem to be a factor. Infection may be the inciting cause, but a clear relationship between the degree of inflammation and the epithelial changes could not be determined from this study. It is clear that the majority of dogs demonstrated some epithelial changes, most likely due to the surgical techniques and resulting strictures. Severe stricture is likely to lead to significant upper urinary tract disease.

# SUMMARY AND CONCLUSIONS

Twelve dogs were randomly divided into three groups of four. A ventral midline approach was made and the membranous urethra transected with scalpel approximately one centimeter distal to the prostate. Perineal urethrostomies were performed on all dogs to allow placement of a Foley catheter into the bladder. At this point, three different techniques were employed for urethral anastomosis:

1) Group I dogs had interrupted, absorbable sutures placed in the membranous urethra. An indwelling urethral Foley catheter was left in place for two weeks.

2) Group II dogs had interrupted, absorbable sutures placed in the membranous urethra, but the Foley catheter was removed immediately following surgery.

3) Group III dogs had apposition of the membranous urethra maintained with traction Foley catheter for two weeks without sutures.

All dogs were evaluated by clinical observation of urinary patterns, serial renal function tests, static and dynamic positive contrast urethrography, and histopathology.

At termination of the study, all dogs were voiding some urine. Dogs 7, 10, and 11 exhibited signs of severe stricture with increased abdominal straining and an intermittent, diminished urinary stream. Three dogs of Group I (1, 3, and 4) demonstrated essentially normal urinary patterns.

BUN and creatinine values were within acceptable limits at the end of the project. Moderate increases in renal function tests were occasionally noted. These elevations seemed to be associated with episodes of urethral obstruction which was relieved by intermittent catheterization.

Static, retrograde, positive contrast urethrography revealed radiographic signs of definite stricture in only three dogs (7, 10, and 11). The majority of the post-operative urethrographs were nonconclusive as to the degree or location of the strictures. Dynamic, positive contrast urethrography demonstrated significant stricture in all twelve dogs. An average urethral diameter was obtained by measurements taken .5 centimeters anterior and posterior to the stricture. The ratio of average urethral diameter to the stricture diameter was the basis for calculation of percent reduction of lumen. Group I had the least amount of stricture, with dogs 1, 3, and 4 having 25.0 and 37.5 percent reduction, respectively. Nine of the twelve dogs demonstrated some degree of urethral dilation at the site of the perineal urethrostomy.

Epithelial changes of the urinary tract were difficult to correlate with the degree of stricture. The majority of the dogs demonstrated signs of chronic inflammation with infiltration of mononuclear cells into mucosa and submucosa. Flattening of the urethral mucosa was seen in areas of dilation and was especially prominent in the more severely strictured dogs (7, 10, and 11). Chronic, ascending lymphocytic, pyelonephritis was present in four dogs (6, 7, 10, and 11). Dogs 10 and 11 also had marked hydroureter and hydronephrosis.

Several conclusions may be made from the results of this study:

1) Complete transection of the membranous urethra resulted in 25 percent or more reduction of lumen diameter in all dogs. Long-term effects of increased resistence and urine retention lead to the syndrome of post-renal obstructive uropathy.

2) Of the three techniques used, suturing of the membranous urethra over an indwelling catheter appeared to have the least clinical problems with micturation and the least amount of stricture.

3) Correlation of static, retrograde, positive contrast urethrographs was not good with the presence or the degree of stricture. Clinical evaluation using this radiographic technique may be misleading.

4) Dynamic, positive contrast urethrography was an objective method of determining the percent reduction of urethral lumen, although the technique is not clinically applicable.

5) The technique of perineal urethrostomy is simple with minimum post-operative management problems. Healing by granulation did not result in stricture formation or fistulous tracts.

6) Serial renal function tests were within acceptable limits at termination of the study. No correlation between the degree or the duration of the stricture with the laboratory results could be made.

7) Epithelial changes, primarily infiltration of chronic mononuclear cells and flattening of the urethral mucosa, were observed in the majority of dogs. ~~These lesions may be due to infection, increased pressure, or another as yet undefined factor.~~ Histopathology demonstrated signs of chronic, ascending upper urinary tract disease in four out of twelve dogs.

8) Dilation of the urethra distal to the stricture was observed in the majority of the cases. The mechanism for this post-stricture dilation has not been defined in the current literature.

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# APPENDIX

## LABORATORY RESULTS

GROUP I: Dog 1

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 6.3 | 5.3 | 9.3 | 6.9 | 8.4 | 8.8 |
| RBC x $10^6$ | 5.6 | 6.3 | 7.1 | 7.1 | 8.0 | 7.5 |
| Hgb g/dl | 11.6 | 12.9 | 14.8 | 15.2 | 16.2 | 15.4 |
| Hct % | 32.1 | 37.1 | 40.5 | 40.7 | 45.8 | 43.4 |
| MCV | 57.0 | 59.0 | 58.0 | 57.0 | 57.0 | 58.0 |
| MCH | 20.7 | 20.4 | 20.9 | 2.12 | 20.1 | 20.5 |
| MCHC | 35.9 | 34.3 | 36.1 | 36.9 | 35.0 | 35.2 |
| Poly. | 3906 | 2968 | 5441 | 3933 | 4452 | 5632 |
| Stab. | -- | -- | -- | -- | 82 | 176 |
| Lymph. | 1134 | 1484 | 1488 | 1656 | 2100 | 1936 |
| Mono. | 630 | 159 | 372 | 621 | 840 | 176 |
| Eos. | 630 | 583 | 1999 | 690 | 924 | 880 |
| Baso. | -- | 106 | -- | -- | -- | -- |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | -- | -- | -- | -- | -- |
| NRBC/200 WBC | -- | -- | -- | -- | -- | -- |
| Anisocytosis | -- | -- | sl. | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 18.0 | 27.6 | 15.9 | 16.0 | 17.8 | 10.1 |
| Creat. mg. % | 0.9 | 1.3 | 0.8 | 0.8 | 0.9 | 1.1 |
| Glucose mg. % | 105.0 | | | | | |
| Inor. Phos. mg. % | 4.2 | | | | | |
| $Ca^{++}$ mg. % | 9.7 | | | | | |
| Alb. gm. % | 2.7 | | | | | |
| T.P. gm. % | 7.5 | 8.0 | 7.5 | 8.0 | 8.0 | 8.1 |
| SGPT I.U. | 43.0 | | | | | |
| $CO_2$ meq/1 | 24.0 | | | | | |
| C1 meq/1 | 120.0 | | | | | |
| $K^+$ meq/1 | 3.8 | | | | | |
| $Na^+$ meq/1 | 151.0 | | | | | |
| Alk. phos. I.U. | 81.0 | | | | | |

GROUP I: Dog 2

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 16.2 | 23.0 | 14.9 | 14.7 | 18.0 | 14.6 |
| RBC x $10^6$ | 7.3 | 5.2 | 8.7 | 8.4 | 9.0 | 8.4 |
| Hgb g/dl | 16.4 | 11.0 | 16.3 | 16.3 | 17.0 | 16.9 |
| Hct % | 43.7 | 33.0 | 45.7 | 43.6 | 46.6 | 45.1 |
| MCV | 60.0 | 63.0 | 53.0 | 52.0 | 53.0 | 55.0 |
| MCH | 22.2 | 21.1 | 18.8 | 19.4 | 18.9 | 20.3 |
| MCHC | 37.0 | 33.0 | 35.3 | 37.1 | 36.1 | 37.2 |
| Poly. | 9882 | 15985 | 9015 | 9996 | 9360 | 7957 |
| Stab. | 486 | 1150 | -- | 74 | -- | -- |
| Lymph. | 3807 | 3910 | 2533 | 1911 | 4050 | 2336 |
| Mono. | 891 | 1495 | 745 | 882 | 900 | 879 |
| Eos. | 1134 | 406 | 2384 | 1764 | 3420 | 3285 |
| Baso. | -- | -- | 223 | 73 | 270 | 146 |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | -- | -- | -- | -- | -- |
| NRBC/200 WBC | -- | 6 | -- | -- | -- | -- |
| Anisocytosis | -- | -- | -- | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | sl. |
| Platelets | Low N | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 14.0 | 31.1 | 13.0 | 16.0 | 13.7 | 10.9 |
| Creat. mg. % | 0.9 | 1.5 | 0.7 | 0.7 | 1.0 | 1.1 |
| Glucose mg. % | 118.0 | | | | | |
| Inor. Phos. mg. % | 3.8 | | | | | |
| $Ca^{++}$ mg. % | 10.4 | | | | | |
| Alb. gm. % | 3.2 | | | | | |
| T.P. gm. % | 6.8 | 6.7 | 7.43 | 7.3 | 8.4 | 7.9 |
| SGPT I.U. | 43.0 | | | | | |
| $CO_2$ meq/1 | 27.0 | | | | | |
| C1 meq/1 | 112.0 | | | | | |
| $K^+$ meq/1 | 4.3 | | | | | |
| $Na^+$ meq/1 | 152.0 | | | | | |
| Alk. phos. I.U. | 77.0 | | | | | |

GROUP I: Dog 3

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 9.5 | 19.0 | 13.9 | 26.6 | 18.5 | 20.9 |
| RBC x $10^6$ | 6.8 | 5.1 | 6.8 | 6.0 | 6.4 | 6.8 |
| Hgb g/dl | 15.5 | 11.3 | 15.1 | 12.0 | 13.3 | 13.8 |
| Hct % | 42.7 | 32.6 | 40.9 | 35.8 | 37.9 | 39.8 |
| MCV | 63.0 | 64.0 | 60.0 | 60.0 | 59.0 | 58.0 |
| MCH | 22.9 | 22.1 | 22.1 | 19.9 | 20.7 | 20.3 |
| MCHC | 36.0 | 34.1 | 36.5 | 33.2 | 34.6 | 34.9 |
| Poly. | 5700 | 14155 | 8966 | 22344 | 14153 | 14317 |
| Stab. | 95 | 475 | 347 | 1330 | 555 | 209 |
| Lymph. | 1710 | 1805 | 2502 | 798 | 2867 | 2821 |
| Mono. | 950 | 1425 | 626 | 1197 | 740 | 1254 |
| Eos. | 1045 | 1140 | 1459 | 931 | 2035 | 1672 |
| Baso. | -- | -- | -- | -- | -- | 627 |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | -- | -- | -- | -- | -- |
| NRBC/200 WBC | -- | -- | -- | -- | -- | -- |
| Anisocytosis | -- | -- | sl. | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 21.0 | 20.7 | 15.2 | 16.8 | 16.4 | 11.9 |
| Creat. mg. % | 1.4 | 1.1 | 0.9 | 0.6 | 1.0 | 1.3 |
| Glucose mg. % | 85.0 | | | | | |
| Inor. Phos. mg. % | 4.4 | | | | | |
| $Ca^{++}$ mg. % | 10.8 | | | | | |
| Alb. gm. % | 3.0 | | | | | |
| T.P. gm. % | 6.4 | 6.3 | 6.8 | 7.8 | 6.9 | 8.7 |
| SGPT I.U. | 36.0 | | | | | |
| $CO_2$ meq/1 | 22.0 | | | | | |
| C1 meq/1 | 129.0 | | | | | |
| $K^+$ meq/1 | 4.8 | | | | | |
| $Na^+$ meq/1 | 161.0 | | | | | |
| Alk. phos. I.U. | 57.0 | | | | | |

GROUP I: Dog 4

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 10.8 | 17.1 | 15.0 | 13.0 | 13.0 | 15.5 |
| RBC x $10^6$ | 7.7 | 6.4 | 7.0 | 7.5 | 7.2 | 6.3 |
| Hgb g/dl | 17.7 | 14.7 | 15.5 | 17.0 | 16.4 | 14.2 |
| Hct % | 48.1 | 40.7 | 43.1 | 45.7 | 44.6 | 38.8 |
| MCV | 63.0 | 63.0 | 62.0 | 61.0 | 62.0 | 62.0 |
| MCH | 23.0 | 22.7 | 22.2 | 22.6 | 22.8 | 22.6 |
| MCHC | 36.4 | 35.7 | 35.6 | 36.8 | 36.3 | 36.3 |
| Poly. | 7344 | 12141 | 10875 | 8190 | 8645 | 11238 |
| Stab. | 2052 | 171 | 150 | 65 | 65 | 199 |
| Lymph. | 548 | 2394 | 1575 | 2470 | 2210 | 3078 |
| Mono. | 754 | 1625 | 1425 | 1040 | 1300 | 387 |
| Eos. | -- | 769 | 975 | 1105 | 780 | 542 |
| Baso. | -- | -- | -- | 130 | -- | -- |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | -- | 2+ toxic | -- | sl.toxic | -- |
| NRBC/200 WBC | -- | -- | -- | 1 | -- | -- |
| Anisocytosis | sl. | -- | -- | -- | -- | sl. |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 19.0 | 16.7 | 16.8 | 16.6 | 13.4 | 31.1 |
| Creat. mg. % | 0.9 | 0.8 | 0.7 | 1.0 | 1.3 | 1.3 |
| Glucose mg. % | 111.0 | | | | | |
| Inor. Phos. mg. % | 4.4 | | | | | |
| $Ca^{++}$ mg. % | 10.5 | | | | | |
| Alb. gm. % | 3.0 | | | | | |
| T.P. gm. % | 6.7 | 7.8 | 7.7 | 8.1 | 7.5 | 6.8 |
| SGPT I.U. | 28.0 | | | | | |
| $CO_2$ meq/1 | 20.0 | | | | | |
| C1 meq/1 | 120.0 | | | | | |
| $K^+$ meq/1 | 4.7 | | | | | |
| $Na^+$ meq/1 | 152.0 | | | | | |
| Alk. phos. I.U. | 24.0 | | | | | |

GROUP II: Dog 5

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 14.3 | 12.1 | 14.9 | 14.5 | 19.7 | 19.3 |
| RBC x $10^6$ | 7.6 | 7.1 | 7.9 | 8.1 | 7.8 | 7.3 |
| Hgb g/dl | 16.3 | 13.9 | 14.5 | 15.5 | 15.3 | 14.9 |
| Hct % | 44.0 | 39.8 | 41.5 | 42.9 | 42.9 | 41.7 |
| MCV | 58.0 | 56.0 | 53.0 | 53.0 | 55.0 | 57.0 |
| MCH | 21.3 | 19.4 | 18.5 | 19.1 | 19.6 | 20.4 |
| MCHC | 36.5 | 34.5 | 34.7 | 35.8 | 35.2 | 35.5 |
| Poly. | 7865 | 6292 | 9909 | 8845 | 11820 | 9554 |
| Stab. | 286 | 60 | 74 | -- | 197 | 96 |
| Lymph. | 3361 | 3872 | 3800 | 3190 | 3645 | 3860 |
| Mono. | 1641 | 1150 | 447 | 1015 | 1773 | 1254 |
| Eos. | 1144 | 484 | 670 | 1378 | 2265 | 3571 |
| Baso. | -- | 272 | -- | 72 | -- | 965 |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | occ. react.ly. | -- | -- | -- | -- | sl.toxic |
| NRBC/200 WBC | -- | 1 | -- | 1 | -- | -- |
| Anisocytosis | -- | sl. | sl. | -- | -- | sl. |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 19.0 | 16.3 | 27.0 | 13.3 | 15.2 | 14.0 |
| Creat. mg. % | 0.7 | 1.2 | 1.1 | 0.8 | 1.1 | 1.1 |
| Glucose mg. % | 79.0 | | | | | |
| Inor. Phos. mg. % | 5.5 | | | | | |
| $Ca^{++}$ mg. % | 10.9 | | | | | |
| Alb. gm. % | 3.2 | | | | | |
| T.P. gm. % | 7.6 | 7.2 | 7.4 | 7.8 | 8.3 | 8.1 |
| SGPT I.U. | 27.0 | | | | | |
| $CO_2$ meq/1 | 25.0 | | | | | |
| C1 meq/1 | 112.0 | | | | | |
| $K^+$ meq/1 | 4.9 | | | | | |
| $Na^+$ meq/1 | 148.0 | | | | | |
| Alk. phos. I.U. | 70.0 | | | | | |

GROUP II: Dog 6

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 7.0 | 10.4 | 10.3 | 10.2 | 12.8 | 10.3 |
| RBC x $10^6$ | 6.5 | 5.5 | 6.1 | 6.2 | 5.7 | 5.1 |
| Hgb g/dl | 15.3 | 12.8 | 14.5 | 13.9 | 13.0 | 11.3 |
| Hct % | 41.2 | 35.4 | 39.4 | 39.2 | 35.9 | 32.4 |
| MCV | 63.0 | 65.0 | 65.0 | 64.0 | 63.0 | 64.0 |
| MCH | 23.5 | 23.2 | 23.6 | 22.5 | 22.5 | 22.3 |
| MCHC | 36.7 | 35.6 | 36.4 | 35.0 | 35.8 | 34.6 |
| Poly. | 4480 | 7592 | 6283 | 7344 | 8448 | 6180 |
| Stab. | -- | -- | -- | -- | 128 | -- |
| Lymph. | 1120 | 728 | 1957 | 1224 | 1472 | 1236 |
| Mono. | 910 | 832 | 670 | 1020 | 1472 | 1442 |
| Eos. | 490 | 1248 | 1390 | 612 | 1216 | 1339 |
| Baso. | -- | -- | -- | -- | 64 | 103 |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | react.ly. | -- | -- | -- | -- | -- |
| NRBC/200 WBC | -- | -- | -- | -- | -- | -- |
| Anisocytosis | -- | -- | -- | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 11.0 | 7.9 | 14.4 | 12.7 | 10.6 | 8.9 |
| Creat. mg. % | 0.7 | 0.7 | 0.6 | 0.9 | 0.9 | 1.1 |
| Glucose mg. % | 100.0 | | | | | |
| Inor. Phos. mg. % | 4.8 | | | | | |
| $Ca^{++}$ mg. % | 9.5 | | | | | |
| Alb. gm. % | 2.9 | | | | | |
| T.P. gm. % | 6.5 | 6.7 | 7.4 | 8.4 | 8.4 | 8.1 |
| SGPT I.U. | 58.0 | | | | | |
| $CO_2$ meq/1 | 33.0 | | | | | |
| C1 meq/1 | 109.0 | | | | | |
| $K^+$ meq/1 | 4.4 | | | | | |
| $Na^+$ meq/1 | 152.0 | | | | | |
| Alk. phos. I.U. | 88.0 | | | | | |

GROUP II: Dog 7

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 13.5 | 15.9 | 12.6 | 10.8 | 13.4 | 13.4 |
| RBC x $10^6$ | 5.4 | 6.9 | 6.9 | 7.2 | 7.5 | 7.4 |
| Hgb g/dl | 11.6 | 13.6 | 14.0 | 14.8 | 15.8 | 15.9 |
| Hct % | 32.8 | 38.7 | 38.9 | 41.0 | 43.4 | 43.7 |
| MCV | 61.0 | 56.0 | 56.0 | 58.0 | 58.0 | 59.0 |
| MCH | 21.6 | 19.7 | 20.2 | 20.7 | 20.9 | 21.4 |
| MCHC | 35.1 | 34.8 | 35.8 | 35.8 | 36.0 | 36.0 |
| Poly. | 5400 | 9302 | 6363 | 8694 | 6901 | 7839 |
| Stab. | -- | 159 | 63 | -- | 67 | 67 |
| Lymph. | 5535 | 3975 | 4285 | 3294 | 3953 | 4221 |
| Mono. | 945 | 954 | 694 | 972 | 801 | 201 |
| Eos. | 1620 | 1510 | 1197 | 1080 | 1407 | 1072 |
| Baso. | -- | -- | -- | -- | 268 | -- |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | 2+ toxic | -- | -- | -- | -- |
| NRBC/200 WBC | 2 | -- | -- | -- | -- | 1 |
| Anisocytosis | -- | sl. | -- | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 14.0 | 13.1 | 15.2 | 15.1 | 21.4 | 21.0 |
| Creat. mg. % | 0.8 | 1.0 | 0.9 | 0.8 | 1.3 | 1.6 |
| Glucose mg. % | 116.0 | | | | | |
| Inor. Phos. mg. % | 7.3 | | | | | |
| $Ca^{++}$ mg. % | 11.1 | | | | | |
| Alb. gm. % | 2.8 | | | | | |
| T.P. gm. % | 6.0 | 6.4 | 7.2 | 6.8 | 6.9 | 6.6 |
| SGPT I.U. | 34.0 | | | | | |
| $CO_2$ meq/1 | 26.0 | | | | | |
| C1 meq/1 | 119.0 | | | | | |
| $K^+$ meq/1 | 4.7 | | | | | |
| $Na^+$ meq/1 | 155.0 | | | | | |
| Alk. phos. I.U. | 185.0 | | | | | |

GROUP II: Dog 8

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 10.7 | 16.3 | 14.6 | 12.4 | 11.6 | 13.8 |
| RBC x $10^6$ | 7.0 | 5.8 | 5.6 | 6.4 | 7.1 | 7.3 |
| Hgb g/dl | 17.5 | 14.0 | 13.8 | 15.7 | 16.9 | 17.8 |
| Hct % | 47.8 | 39.2 | 38.2 | 43.9 | 46.9 | 47.9 |
| MCV | 69.0 | 68.0 | 68.0 | 68.0 | 66.0 | 66.0 |
| MCH | 25.1 | 24.3 | 24.6 | 24.3 | 23.6 | 24.4 |
| MCHC | 36.1 | 35.4 | 35.8 | 35.4 | 35.6 | 36.9 |
| Poly. | 6741 | 12479 | 10804 | 7874 | 6903 | 7590 |
| Stab. | 107 | 163 | -- | -- | 59 | 69 |
| Lymph. | 2515 | 2771 | 1825 | 2728 | 2891 | 3795 |
| Mono. | 749 | 407 | 949 | 620 | 826 | 759 |
| Eos. | 588 | 489 | 1022 | 1178 | 1121 | 1587 |
| Baso. | -- | -- | -- | -- | -- | -- |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | -- | -- | -- | -- | -- | -- |
| NRBC/200 WBC | -- | -- | -- | -- | -- | -- |
| Anisocytosis | sl. | -- | -- | -- | -- | sl. |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 16.0 | 18.1 | 11.0 | 17.0 | 17.8 | 12.0 |
| Creat. mg. % | 0.7 | 1.1 | 0.9 | 0.9 | 0.7 | 1.1 |
| Glucose mg. % | 105.0 | | | | | |
| Inor. Phos. mg. % | 4.5 | | | | | |
| $Ca^{++}$ mg. % | 10.2 | | | | | |
| Alb. gm. % | 3.2 | | | | | |
| T.P. gm. % | 7.7 | 7.2 | 7.0 | 7.0 | 7.1 | 7.0 |
| SGPT I.U. | 62.0 | | | | | |
| $CO_2$ meq/1 | 25.0 | | | | | |
| C1 meq/1 | 119.0 | | | | | |
| $K^+$ meq/1 | 4.8 | | | | | |
| $Na^+$ meq/1 | 152.0 | | | | | |
| Alk. phos. I.U. | 62.0 | | | | | |

GROUP III: Dog 9

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 16.4 | 11.9 | 11.6 | 13.7 | 19.6 | 12.6 |
| RBC x $10^6$ | 7.4 | 6.5 | 8.1 | 7.5 | 7.0 | 7.7 |
| Hgb g/dl | 16.6 | 13.7 | 16.3 | 15.4 | 15.0 | 16.8 |
| Hct % | 44.7 | 38.5 | 45.8 | 42.7 | 40.8 | 45.4 |
| MCV | 61.0 | 59.0 | 57.0 | 58.0 | 58.0 | 59.0 |
| MCH | 22.5 | 21.0 | 20.2 | 20.6 | 21.3 | 21.9 |
| MCHC | 36.9 | 35.1 | 35.2 | 35.7 | 36.4 | 36.7 |
| Poly. | 10086 | 9163 | 7192 | 9864 | 14112 | 7182 |
| Stab. | -- | 59 | 58 | -- | 98 | 63 |
| Lymph. | 4264 | 1428 | 2900 | 2192 | 2548 | 2898 |
| Mono. | 738 | 833 | 290 | 891 | 882 | 189 |
| Eos. | 1148 | 417 | 1160 | 753 | 1960 | 1323 |
| Baso. | 164 | -- | -- | -- | -- | 945 |
| Meta. | -- | -- | -- | -- | -- | -- |
| WMC morph. | react.ly. | -- | -- | -- | 1+ toxic | 1+ toxic |
| NRBC/200 WBC | -- | -- | -- | -- | -- | -- |
| Anisocytosis | -- | sl. | sl. | -- | -- | -- |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. | Adeq. |
| BUN mg. % | 13.0 | 25.5 | 17.6 | 12.7 | 12.9 | 12.9 |
| Creat. mg. % | 0.7 | 1.3 | 0.9 | 0.9 | 1.1 | 1.2 |
| Glucose mg. % | 85.0 | | | | | |
| Inor. Phos. mg. % | 4.4 | | | | | |
| $Ca^{++}$ mg. % | 10.6 | | | | | |
| Alb. gm. % | 3.4 | | | | | |
| T.P. gm. % | 6.8 | 7.0 | 7.7 | 7.8 | 8.7 | 8.7 |
| SGPT I.U. | 47.0 | | | | | |
| $CO_2$ meq/1 | 24.0 | | | | | |
| C1 meq/1 | 120.0 | | | | | |
| $K^+$ meq/1 | 6.2 | | | | | |
| $Na^+$ meq/1 | 152.0 | | | | | |
| Alk. phos. I.U. | 84.0 | | | | | |

GROUP III: Dog 10

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 12.2 | 22.6 | 15.2 | 18.0 | 22.6 | 13.0 |
| RBC x $10^6$ | 4.5 | 2.4 | 3.4 | 4.5 | 5.6 | 5.3 |
| Hgb g/dl | 9.0 | 4.7 | 5.2 | 5.9 | 8.7 | 9.3 |
| Hct % | 25.9 | 15.5 | 16.0 | 20.2 | 26.4 | 27.4 |
| MCV | 57.0 | 64.0 | 46.0 | 45.0 | 47.0 | 51.0 |
| MCH | 20.0 | 19.5 | 15.3 | 13.2 | 15.5 | 17.5 |
| MCHC | 34.5 | 29.9 | 32.5 | 29.1 | 32.7 | 33.9 |
| Poly. | 6161 | 16611 | 9880 | 11700 | 16016 | 5070 |
| Stab. | 366 | 1695 | 304 | 270 | 226 | -- |
| Lymph. | 5063 | 2712 | 4180 | 4950 | 4181 | 5590 |
| Mono. | 427 | 1356 | 836 | 990 | 1356 | 1040 |
| Eos. | 183 | 226 | -- | -- | 678 | 910 |
| Baso. | -- | -- | -- | -- | 113 | 390 |
| Meta. | -- | -- | -- | 90 | -- | -- |
| WMC morph. | -- | H-G occ. bodies | 1+ toxic | 2+ toxic | -- | -- |
| NRBC/200 WBC | -- | 4 | -- | -- | -- | -- |
| Anisocytosis | sl. | mod. | sl. | sl. | -- | sl. |
| Poikilocytosis | -- | -- | -- | -- | -- | -- |
| Platelets | reduced | reduced | Adeq. | Adeq. | Adeq. | reduced |
| BUN mg. % | 15.0 | 21.8 | 18.9 | 29.8 | 55.7 | 18.0 |
| Creat. mg. % | 0.8 | 1.0 | 0.9 | 1.2 | 1.8 | 1.3 |
| Glucose mg. % | 91.0 | | | | | |
| Inor. Phos. mg. % | 3.8 | | | | | |
| $Ca^{++}$ mg. % | 8.3 | | | | | |
| Alb. gm. % | 1.6 | | | | | |
| T.P. gm. % | 7.2 | 7.5 | 9.8 | 12.3 | 10.4 | 10.1 |
| SGPT I.U. | 96.0 | | | | | |
| $CO_2$ meq/1 | 24.0 | | | | | |
| Cl meq/1 | 117.0 | | | | | |
| $K^+$ meq/1 | 4.2 | | | | | |
| $Na^+$ meq/1 | 145.0 | | | | | |
| Alk. phos. I.U. | 142.0 | | | | | |

GROUP III: Dog 11

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 6.4 | 14.6 | 15.6 | 6.6 | | |
| RBC x $10^6$ | 7.5 | 6.7 | 6.5 | 6.8 | | |
| Hgb g/dl | 17.6 | 15.1 | 14.9 | 15.4 | | |
| Hct % | 47.6 | 42.2 | 40.1 | 42.7 | | |
| MCV | 64.0 | 63.0 | 62.0 | 63.0 | | |
| MCH | 23.4 | 22.5 | 23.1 | 22.5 | | |
| MCHC | 36.6 | 35.4 | 36.8 | 35.7 | | |
| Poly. | 4096 | 11899 | 11388 | 4356 | | |
| Stab. | -- | 584 | 78 | 66 | | |
| Lymph. | 1088 | 2117 | 1950 | 1518 | | |
| Mono. | 448 | -- | 1404 | 396 | | |
| Eos. | 768 | -- | 780 | 264 | | |
| Baso. | -- | -- | -- | -- | | |
| Meta. | -- | -- | -- | -- | | |
| WMC morph. | -- | -- | sl.toxic | -- | | |
| NRBC/200 WBC | -- | -- | -- | -- | | |
| Anisocytosis | -- | -- | sl. | -- | | |
| Poikilocytosis | -- | -- | -- | -- | | |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | | |
| BUN mg. % | 19.0 | 45.6 | 27.4 | 40.0 | | |
| Creat. mg. % | 1.6 | 1.6 | 1.2 | 1.4 | | |
| Glucose mg. % | 110.0 | | | | | |
| Inor. Phos. mg. % | 4.4 | | | | | |
| $Ca^{++}$ mg. % | 11.4 | | | | | |
| Alb. gm. % | 3.8 | | | | | |
| T.P. gm. % | 8.1 | 8.6 | 8.3 | 7.4 | | |
| SGPT I.U. | 49.0 | | | | | |
| $CO_2$ meq/1 | 23.0 | | | | | |
| C1 meq/1 | 125.0 | | | | | |
| $K^+$ meq/1 | 5.2 | | | | | |
| $Na^+$ meq/1 | 160.0 | | | | | |
| Alk. phos. I.U. | 36.0 | | | | | |

GROUP III: Dog 12

| | Pre-Op. | 2 weeks | 6 weeks | 10 weeks | 14 weeks | 20 weeks |
|---|---|---|---|---|---|---|
| WBC x $10^3$ | 11.3 | 17.8 | 11.2 | 10.5 | | |
| RBC x $10^6$ | 7.3 | 7.4 | 7.7 | 8.1 | | |
| Hgb g/dl | 17.3 | 17.2 | 17.7 | 17.1 | | |
| Hct % | 46.8 | 46.7 | 47.3 | 50.0 | | |
| MCV | 64.0 | 64.0 | 62.0 | 62.0 | | |
| MCH | 23.7 | 23.3 | 23.0 | 21.2 | | |
| MCHC | 36.6 | 36.5 | 37.1 | 33.9 | | |
| Poly. | 7000 | 15041 | 6608 | 4095 | | |
| Stab. | -- | -- | -- | 105 | | |
| Lymph. | 3270 | 2225 | 1904 | 3570 | | |
| Mono. | 220 | -- | 448 | 525 | | |
| Eos. | 900 | 534 | 2128 | 2100 | | |
| Baso. | 110 | -- | 112 | 105 | | |
| Meta. | -- | -- | -- | -- | | |
| WMC morph. | -- | -- | -- | -- | | |
| NRBC/200 WBC | -- | -- | -- | -- | | |
| Anisocytosis | -- | sl. | sl. | -- | | |
| Poikilocytosis | -- | -- | -- | -- | | |
| Platelets | Adeq. | Adeq. | Adeq. | Adeq. | | |
| BUN mg. % | 18.0 | 27.7 | 20.0 | 23.7 | | |
| Creat. mg. % | 1.0 | 1.1 | 1.1 | 1.0 | | |
| Glucose mg. % | 97.0 | | | | | |
| Inor. Phos. mg. % | 4.6 | | | | | |
| $Ca^{++}$ mg. % | 10.8 | | | | | |
| Alb. gm. % | 3.1 | | | | | |
| T.P. gm. % | 7.6 | 7.0 | 7.3 | 7.6 | | |
| SGPT I.U. | 31.0 | | | | | |
| $CO_2$ meq/1 | 28.0 | | | | | |
| C1 meq/1 | 115.0 | | | | | |
| $K^+$ meq/1 | 4.2 | | | | | |
| $Na^+$ meq/1 | 153.0 | | | | | |
| Alk. phos. I.U. | 43.0 | | | | | |

FIGURE 2

Post-operative, positive contrast, retrograde urethrograph of dog 2 demonstrating essentially normal radiographic anatomy with no sign of intrapelvic urethral stricture. Dog 2 had a 68.4 percent reduction of lumen size according to dynamic radiography.

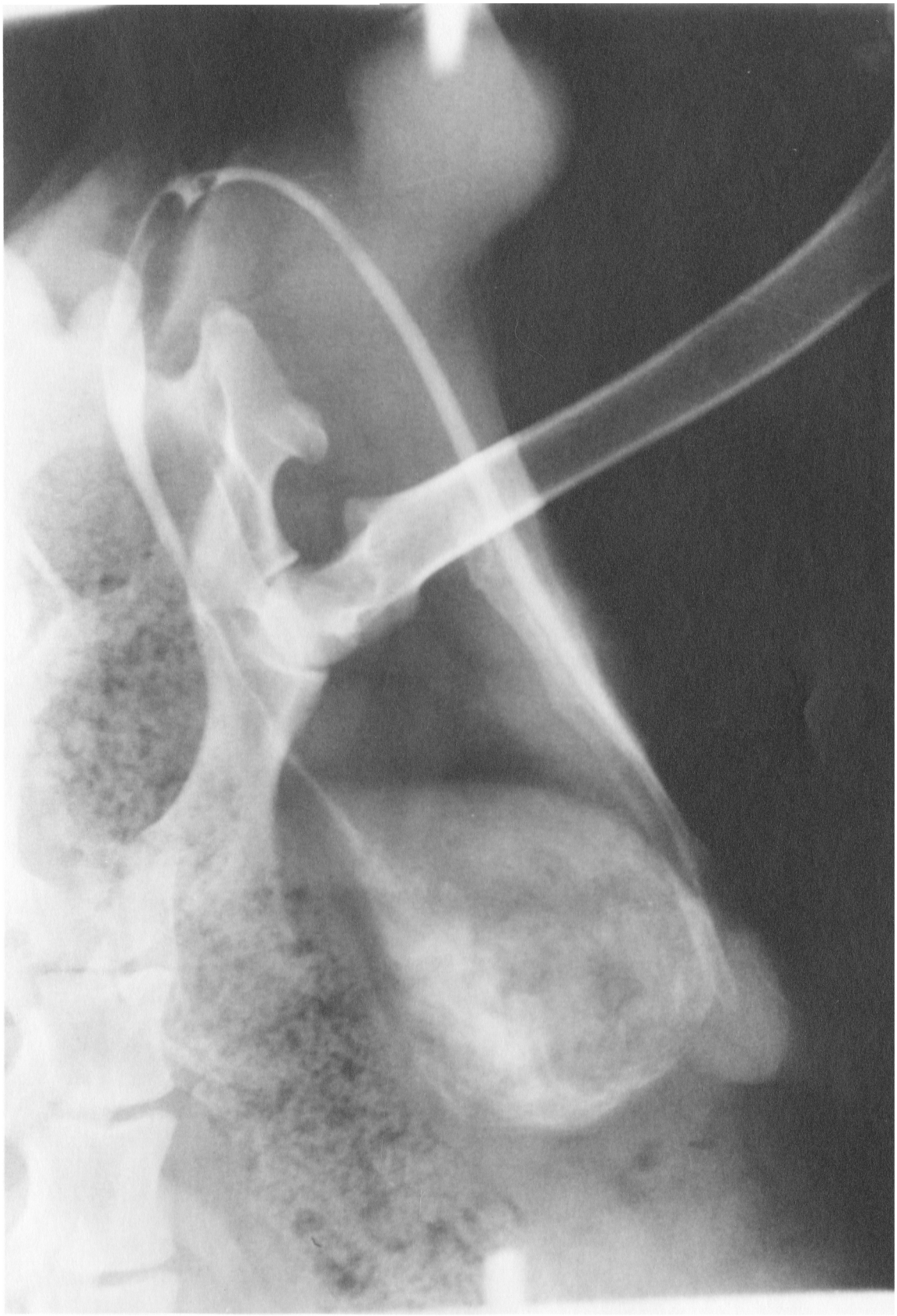


FIGURE 3

Post-operative, positive contrast, retrograde urethrograph of dog 10 demonstrating severe dilation distal to the intrapelvic urethral stricture. Dog 10 had 84 percent reduction of lumen diameter. Note the urethral dilation present at the perineal urethrostomy site.

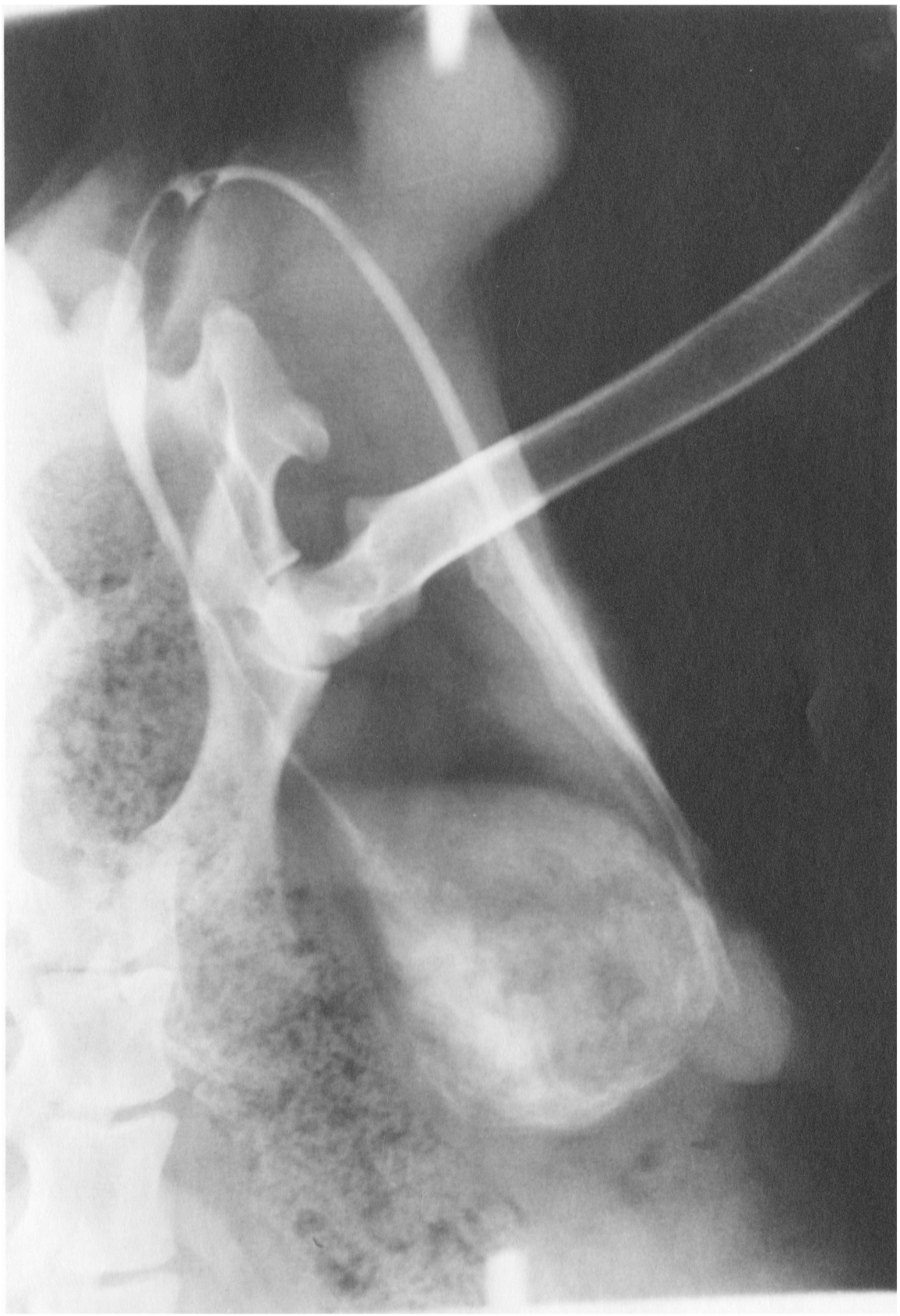


FIGURE 4

Dynamic, positive contrast urethrographs of Group I. Some degree of urethral stricture is present in all dogs, with dog 2 having the greatest lumen reduction. Dilation of the prostatic urethra (to the right of the film) is due to the high injection pressures.

Films are numbered: 1 3

2 4

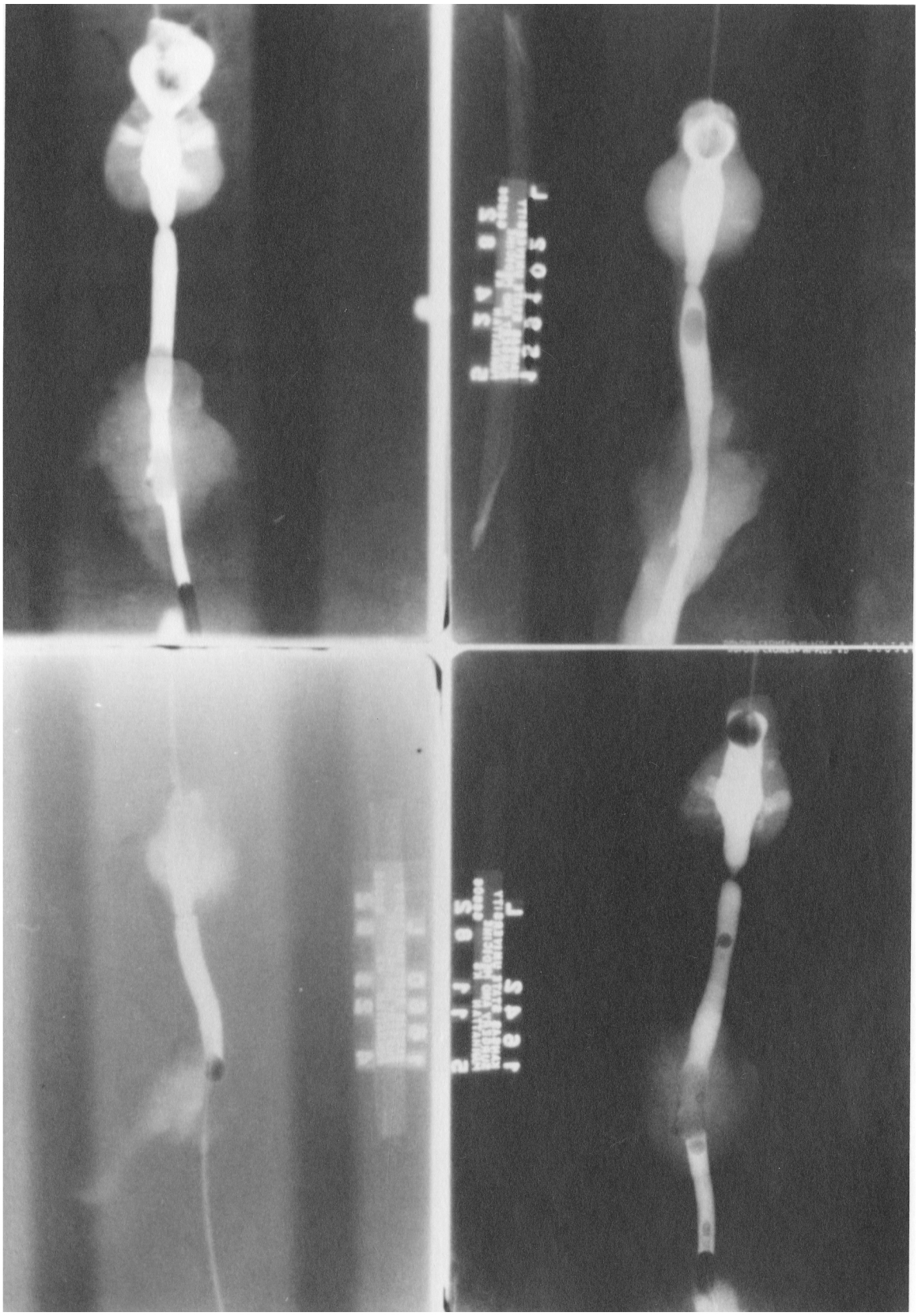


FIGURE 5

Dynamic, positive contrast urethrographs of Group II. Urethral strictures, just caudal to prostate gland, are very pronounced.

Films are numbered: 5 7

6 8

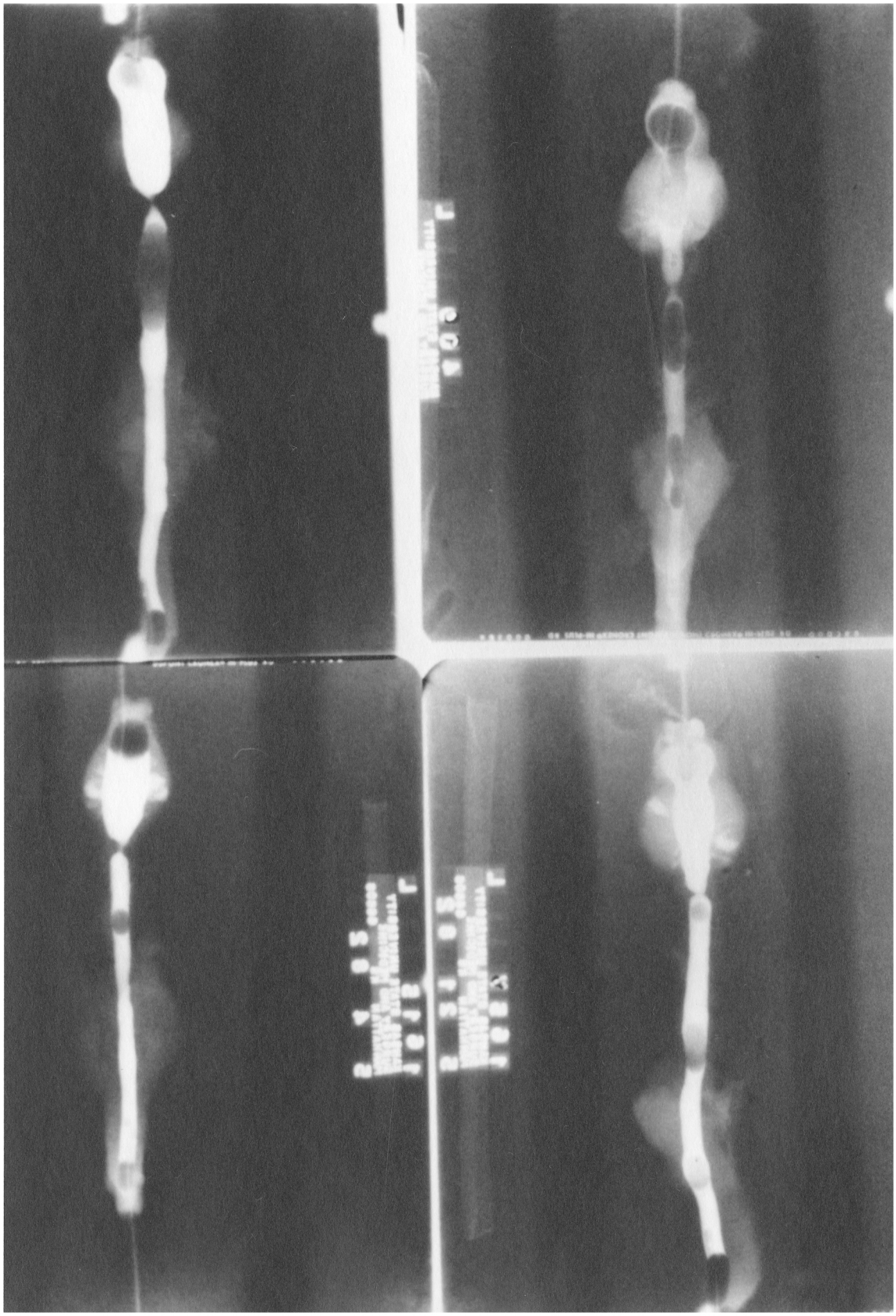


FIGURE 6

Dynamic, positive contrast urethrographs of Group III demonstrating pronounced intrapelvic urethral stricture caudal to the prostate gland. Note urethral dilation at the perineal urethrostomy sites of dogs 10, 11, and 12.

Films are numbered: 9 11

10 12

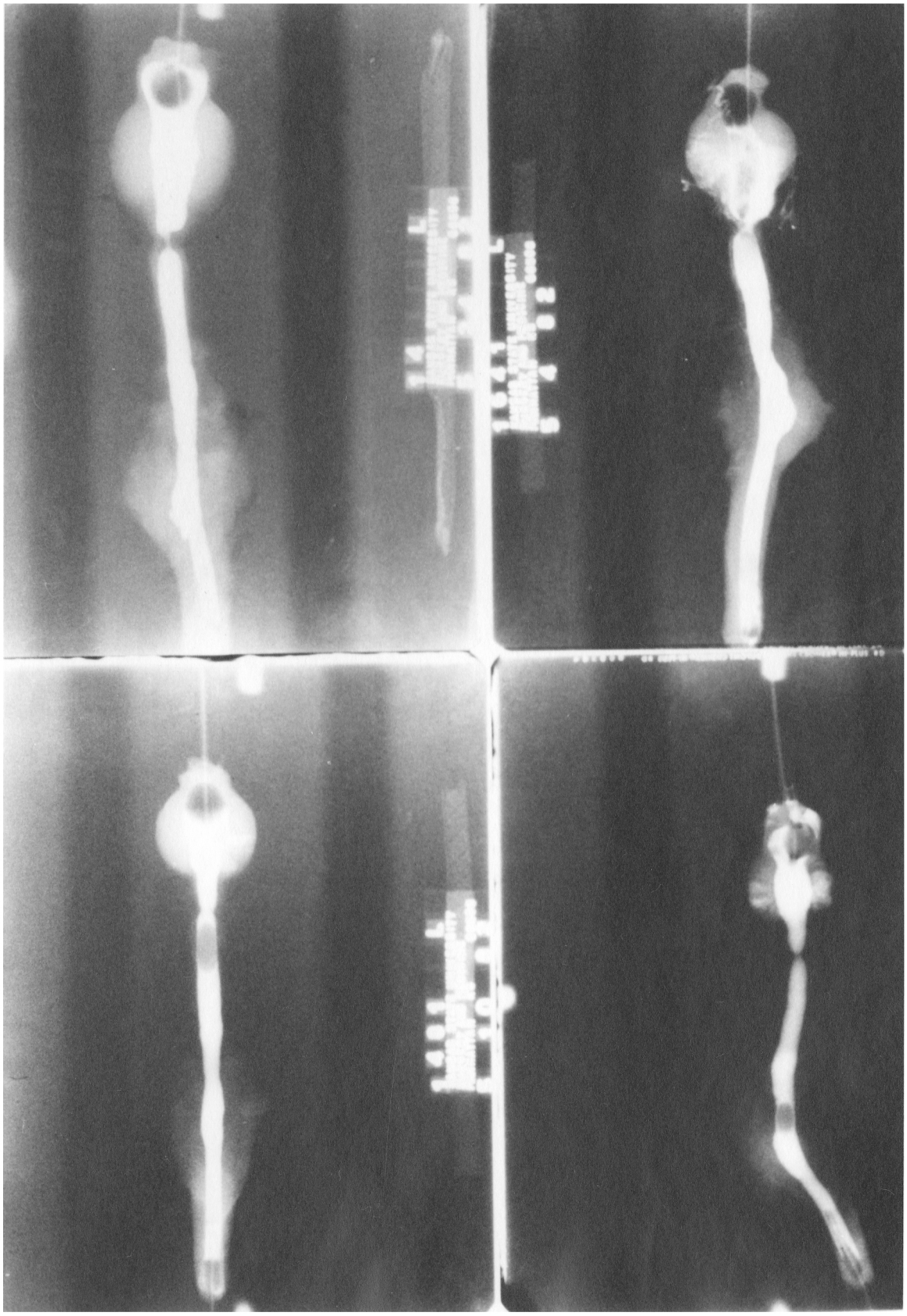
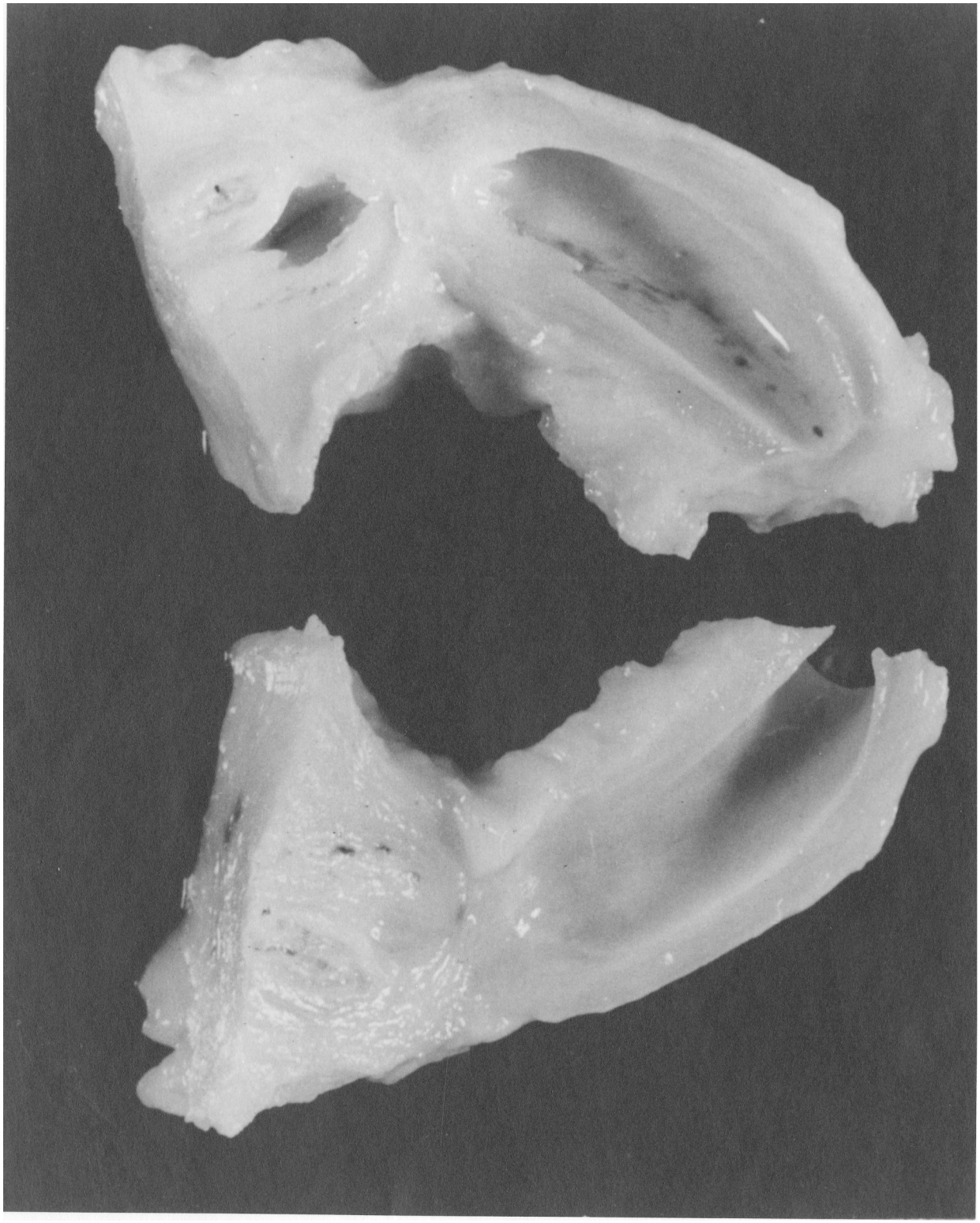


FIGURE 7

Intrapelvic urethra caudal to the prostate of dog 3 demonstrating no dilation or sign of severe urethral stricture.

FIGURE 8

Intrapelvic urethra caudal to the prostate of dog 10 demonstrating severe stricture at dilation of the urethral proximal and distal to the simulated rupture site.



# INTRAPELVIC URETHRAL ANASTOMOSIS:

## A Comparison of Three Techniques

by

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B.S., Kansas State University, 1975
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**AN ABSTRACT OF A MASTER'S THESIS**

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Rupture of the intrapelvic or membranous urethra in man and dog is usually associated with fracture of the pelvis. Mortality is low, but patient morbidity can be high with devastating long-term effects. Stricture formation is a frequent sequela of complete transection of the intrapelvic urethra. With stricture and subsequent increase in urine volume and back pressure, a syndrome of post-renal obstructive uropathy develops. This syndrome ultimately affects the function of the upper urinary tract.

Several techniques for anastomosis of the membranous urethra have been described, both in the human and veterinary literature. The purpose of this study was to compare three different anastomostic techniques and to correlate clinical, radiographic, and pathological signs with the degree of stricture and the presence of upper urinary tract disease.

Twelve dogs were randomly divided into three groups of four. A ventral midline approach was performed on all dogs, as was a perineal urethrostomy, to allow placement of a large-guage Foley catheter. All urethrostomy sites healed by granulation without stricture formation. After transection of the membranous or intrapelvic urethra one centimeter distal to the prostate, three techniques were employed to anastomose the urethra.

Group I: Urethral anastomosis was performed using interrupted, absorbable sutures placed in the membranous urethra over an indwelling Foley catheter. The catheter was left in place for two weeks.

Group II: Urethral anastomosis was performed using interrupted absorbable stutures as in Group I. The Foley catheter was used as a guide during suturing of the urethra and was removed immediately after surgery was completed.

Group III: Apposition of the membranous urethra was maintained with a traction Foley catheter, without sutures. The indwelling traction catheter was left in place for two weeks.

Following surgery, all dogs were evaluated using four criteria: 1) clinical observation of urinary patterns, 2) serial renal function tests and complete blood counts, 3) static and dynamic, positive contrast urethrography, and 4) histopathology.

Results of the study demonstrated good correlation of degree of stricture with clinical changes in urinary patterns. Renal function tests exhibited moderate flucuations during the course of the study, but were within acceptable normal limits at the termination of the projects. There was a tendency for increased numbers of white blood cells on urinalysis of Group I and III. All three groups demonstrated pH values of 7.0 or greater along with many triple phosphate crystals.

Static, positive contrast urethrography was nonconclusive as to the presence or degree of stricture. Only three dogs out of twelve had definite radiographic signs of stricture. Dynamic positive contrast urethrography on the dissected tract demonstrated reduction of urethral lumens ranging from 25.0 to 84.0 percent. Group I had the least amount of stricture.

All dogs exhibited signs of chronic inflammatory changes on histopathology. No correlation could be made concerning the degree of stricture, the surgical technique used, or the histopathological changes. With severe urethral dilation, flattening of the epithelium was noted. Four of the twelve dogs demonstrated signs of chronic, ascending upper urinary tract disease.