Surgery of the Urinary Tract

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ABSTRACT

Although wound healing and tissue handling principles for surgery of the urinary tract are similar to those for other tissues, there are several unique considerations when performing surgery on the urinary tract. Surgical procedures may compromise one or more of the functions of the urinary system. Vascular compromise during renal surgery, loss of bladder capacity, and stricture formation within the ureters or urethra may all have devastating consequences. The choice of suture material in achieving closure of the urethra, bladder, or ureter has been studied extensively; recommendations resulting from this research are outlined. This article discusses various techniques for surgery of the kidneys (biopsies, nephrotomy, pyelolithotomy, and nephrectomy), ureters (ureteral anastomosis, neoureterostomy, and ureteroneocystostomy to treat ureteral ectopia), urinary bladder (removal of urinary calculi, partial cystectomy), urethra (urethrotomy, urethral trauma, and urinary diversion for urethral injuries), and urethral sphincter mechanism (cystourethropexy, colposuspension).

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The process of wound healing and the principles of tissue handling in surgery of the urinary tract are similar to those for other tissues. There are, however, several unique considerations when performing surgery on this system.[1] The functions of the urinary system are to form, store, and void urine. Surgical procedures may compromise one or all of these functions. Vascular compromise during renal surgery, loss of bladder capacity, and stricture formation within the ureters or urethra may all have devastating consequences.

It is well recognized that urine has a detrimental effect on wound healing, especially in the presence of infection.[1] Delayed healing, increased inflammatory responses, and stricture formation are common sequelae of urine leakage. It is extremely important to obtain a watertight seal of incisions to avoid these consequences. Where this is not possible, urinary diversion techniques should be used to bypass the urethra or ureter following surgical repair.[2–8]

The choice of suture material in achieving closure of the urethra, bladder, or ureter has been studied extensively. Results of these studies are not uniform, but several statements can be made. Prolonged intraluminal exposure of suture material may provide a nidus for mineral deposition and formation of calculi.[9] Normally, however, suture material is covered by urinary epithelium within 3 days of implantation.[10] Chromic gut is associated with a more severe inflammatory response and has a less predictable duration of tensile strength than synthetic absorbable sutures. Non-absorbable suture material, such as polypropylene and nylon, have been used successfully in urinary surgery, but a heightened inflammatory response has been reported with their use for ureteral repair.[11] Non-absorbable suture material is not required as tissues of the urinary tract typically heal rapidly. Polydioxanone, polyglactin 910, and polyglycolic acid have all been used successfully. However, prolonged intraluminal exposure of polydioxanone has been reported following urethral repair.[12] Polyglycolic acid suture retains tensile strength longer than polyglactin 910 in acid urine, while the reverse is true in neutral or alkaline urine.[13]

Urinary epithelium has a remarkable regenerative ability. Total re-epithelialization of epithelium-denuded bladders occurs within 30 days. Functional reformation of both ureteral and urethral defects occurs where an epithelial bridge of at least 25% circumference is present across the defect, and urinary diversion is used to bypass urine flow from the defect.

RENAL SURGERY

Kidney stones and neoplasia are the two most common indications for renal surgery. Surgical removal of renal calculi is indicated in the presence of renal pelvic obstruction (as evidenced by hydronephrosis), uncontrolled pyelonephritis, progressive enlargement of the calculus, or deteriorating renal function.[14] Progressive deterioration of renal function is expected with chronic renal calculi. Both primary and secondary renal neoplasia can be seen, although the kidney is a relatively uncommon site for primary neoplasia. An in-depth discussion of renal neoplasia is beyond the scope of this article, but it is imperative that the veterinary surgeon forms a definitive diagnosis of tumor type, accurately stages the disease, and understands the natural behavior and treatment options for the disease before embarking on a surgical course of therapy.

Renal biopsy

Kidney biopsy may be performed using open, closed, or keyhole techniques.[15] Closed techniques are generally preferred where the kidneys are easily palpated and immobilized and where a diffuse disease process is sus-

Figure 1
The cutting end of a needle biopsy instrument. The biopsy needle consists of a notch recessed into an obturator specimen rod (arrows). After advancing the specimen rod into the tissue, the outer cannula (arrowheads) is advanced over the rod. The biopsy specimen is entrapped within the notch of the specimen rod.

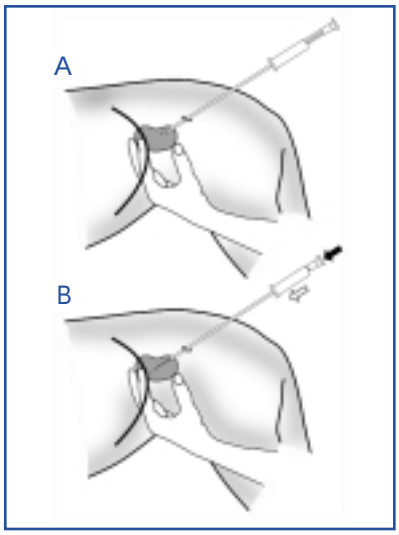


Figure 2
(**A**) To perform percutaneous renal biopsy, the kidney is first immobilized against the body wall. A needle biopsy instrument, with the specimen rod retracted, is inserted through a cutaneous stab incision and advanced until it rests on the renal capsule. (**B**) The specimen rod is advanced into the renal parenchyma (black arrow). The specimen rod is then held in position while the outer cannula is advanced (open arrow). The entire unit is withdrawn, and the kidney is held against the body wall for 2–3 minutes to control potential hemorrhage.

pected. Ultrasound-guided percutaneous biopsy may be employed for localized disease processes or where kidneys are difficult to localize on palpation.

Percutaneous needle biopsy

Needle biopsy instruments are formed of an obturator specimen rod ensleeved in an outer cannula (Figure 1). The specimen rod has a sharpened needle tip with a notch cut into its shaft immediately behind the tip. The rod is manufactured such that it may be advanced beyond the distal end of the outer cannula, exposing the notch.

To perform a percutaneous needle biopsy, the kidney is first stabilized by transabdominal palpation. A stab incision is made through the skin overlying the kidney and the biopsy needle, with the specimen rod retracted into the sleeve, is advanced until it rests on the renal capsule (Figure 2). The rod is advanced beyond the cannula into the renal parenchyma, allowing the notch to fill with tissue as it conforms to the shape of the needle. The outer cannula is advanced over the rod, leaving a small sample entrapped within the notch. The biopsy needle is withdrawn, keeping the specimen rod within the cannula.

Biopsy needles should not be directed at right angles to the renal long axis as iatrogenic damage to the ureter or renal artery and vein can occur. After completing needle biopsy, the kidney should be immobilized against the body wall for several minutes to reduce the risk of hemorrhage. Animals should be monitored closely for evidence of hemorrhage for several hours after biopsy.

Percutaneous needle biopsy is contraindicated in animals with bleeding disorders, suspected pyelonephritis, large renal cysts, or obstructive uropathy.

Keyhole technique

The procedure is identical to that for percutaneous biopsy, with the exception of the approach to the kidney. Following induction of general anesthesia, a 2 to 3 cm incision is performed over the lateral abdominal wall at the level of the kidney. The surgeon's index finger is advanced into the abdomen and the kidney is immobilized. The biopsy needle is directed to the kidney and the point of entry is verified by digital palpation. After completing the biopsy and withdrawing the needle, digital pressure is applied over the biopsy tract for several minutes. The abdominal incision is sutured in a routine fashion.

Open technique

In many instances, renal biopsy is indicated in animals undergoing exploratory laparotomy. Needle biopsy is often used in this setting because of the minimal invasiveness of the technique and ease with which it is performed.

Transverse wedge biopsy should be considered where larger specimens are required. An incision is made transversely into the renal parenchyma using a No. 10 or 15 scalpel blade. A second incision is made at a converging angle such that a wedge of renal parenchyma is excised. The defect is closed using 1 or 2 mattress sutures of 3-0 absorbable suture material. Direct pressure is applied as needed to control hemorrhage.

Nephrotomy

Nephrotomy refers to incision into the kidney and is indicated for exploration of the renal pelvis for tumors or sources of hemorrhage. Nephrolithotomy refers to an incision made through the renal parenchyma for the purpose of removing calculi within the renal pelvis.

Nephrotomy temporarily decreases renal function by 30% to 50%.[16] This is generally well tolerated, but in animals with pre-existing renal disease it may prove significant. Where bilat-

eral nephrotomy is required for patients with compromised renal function, the procedures should be staged. Nephrotomy should be avoided in patients with advanced hydronephrosis.

Nephrotomy is generally performed through a midline laparotomy incision, although a flank incision may be performed for unilateral nephrotomy where exploration of the abdomen is not necessary. The peritoneum immediately cranial to the kidney is grasped and incised. Continued blunt finger dissection of the peritoneum allows elevation of the kidney from its retroperitoneal location. Elevating the kidney and retracting it medially facilitates identification of the vascular structures on the dorsal surface of the hilus. The renal artery is identified, minimally dissected, and temporarily occluded using an atraumatic vascular clamp or digital compression by the assistant surgeon (Figure 3). The kidney is immobilized between the surgeon's fingers, and the renal capsule is sharply incised along the longitudinal midline of the convex surface. The length of incision should be adequate to allow identification and removal of the renal calculus. Blunt dissection through the renal parenchyma is continued, using the handle of the scalpel, until the renal pelvis is identified.

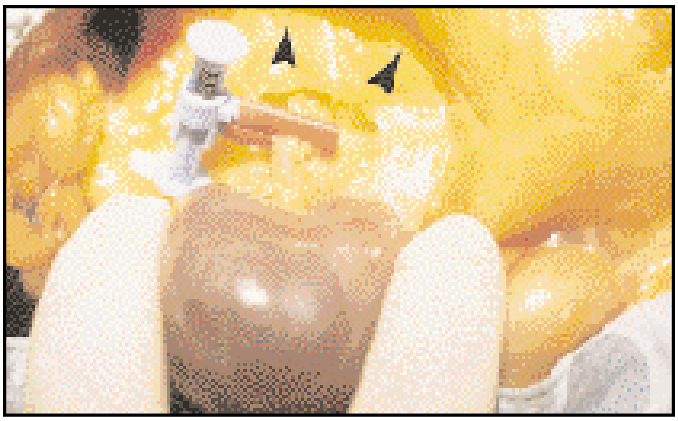
After removing the calculus, a soft rubber or polyvinyl catheter is placed into the renal pelvis and sterile saline solution is flushed vigorously to remove any remaining calculi, blood clots, or tissue debris. The catheter is then advanced into the proximal ureter and saline solution gently flushed to ensure patency. The renal artery is released and the opposing sides of the incised kidney are held in apposition using digital pressure for approximately 5 minutes to provide hemostasis. The renal capsule is closed using a simple continuous pattern of 3-0 absorbable suture material. Tacking sutures are placed between the kidney and body wall to prevent rotation of the kidney.

Intravenous fluid support must be given perioperatively to ensure adequate renal perfusion. Postoperative diuresis assists in flushing cellular debris and blood clots from the renal pelvis. Calculi should be submitted for quantitative chemical analysis, and the renal pelvis and calculus should be cultured.

Pyelolithotomy

Pyelolithotomy refers to incision directly into the renal pelvis for retrieval of calculi. In the normal kidney, pyelolithotomy is not possible because parenchymal tissue surrounds the renal pelvis. Where chronic partial obstruction has resulted in dilation of the proximal ureter and renal pelvis, however, exposure and direct incision into the pelvis is possible. Pyelolithotomy is preferable to nephrotomy in these situations because nephrotomy will decrease function of an already compromised kidney.

To perform pyelolithotomy, the kidney is elevated from its peritoneal attachments and retracted medially as described for nephrotomy. The dilated renal pelvis and proximal ureter are identified and incised longitudinally (Figure 4). After identifying



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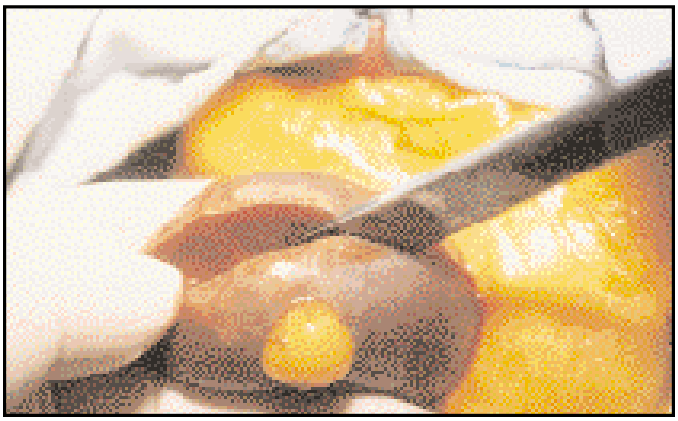

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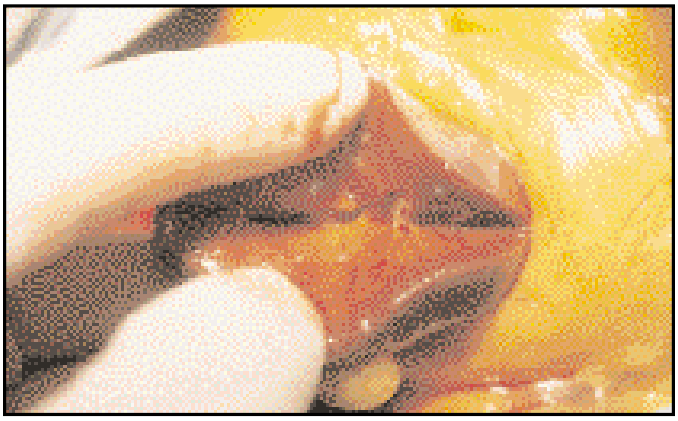

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Figure 3

(**A**) In preparation for nephrotomy, the kidney is elevated from its retroperitoneal location (arrowheads) and retracted medially. The renal artery is identified, exposed, and clamped with an atraumatic vascular clamp. (**B**) Incision is made through the renal capsule, and blunt dissection is continued through the parenchyma to the level of the renal pelvis. (**C**) The renal pelvis is exposed and nephroliths are identified and removed. The renal pelvis and proximal ureter are flushed with saline solution to ensure patency and removal of all calculi.

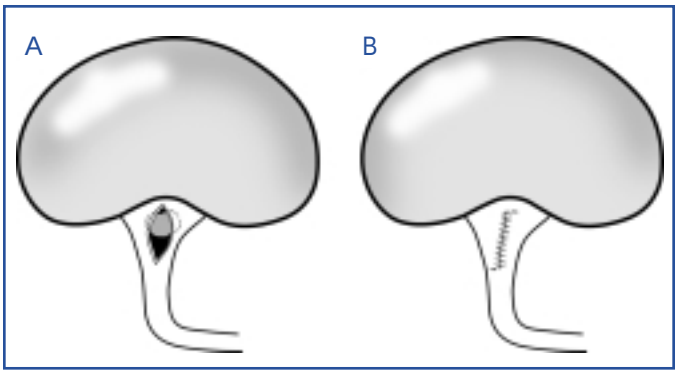


Figure 4
(**A**) Renal calculi can be removed by direct incision into the renal pelvis in cases in which significant hydronephrosis is present. (**B**) Closure is achieved using a simple continuous suture pattern of fine absorbable suture material.

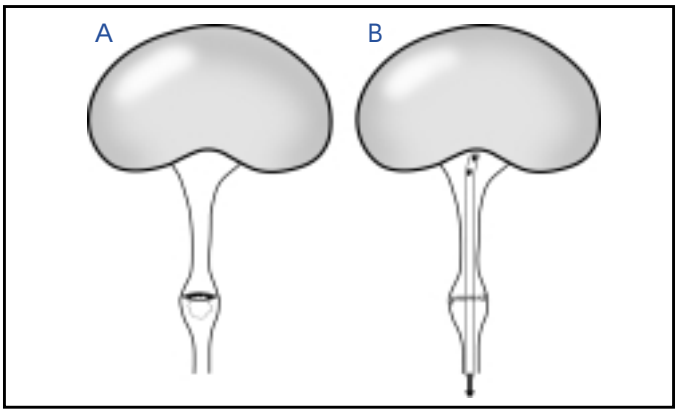


Figure 6
(**A**) Transverse ureterotomy is indicated for the removal of ureteroliths. Incision should be made into the dilated ureteral segment immediately proximal to the calculus. (**B**) Closure is achieved using a simple continuous pattern of fine absorbable suture material. A ureteral stent is placed for 3–4 days to provide urinary diversion.

and removing the calculus, the renal pelvis is copiously flushed with saline solution. The proximal ureter is catheterized and flushed to ensure patency. The incision into the renal pelvis is meticulously closed using a simple continuous suture pattern of 4-0 or 5-0 absorbable suture material.

Nephrectomy

Nephrectomy refers to the surgical removal of a kidney and is most often performed for the treatment of renal neoplasia or end-stage hydronephrosis or pyelonephritis. Adequate function of the opposite kidney must be established prior to surgery.

The kidney is elevated from its peritoneal attachments, and the renal artery and vein are identified on the dorsal surface of the hilus. The renal artery is dissected and double ligated near its origin from the aorta and divided. The renal vein is subsequently identified, ligated, and divided. The hilus is inspected to ensure that there are no anomalous vascular structures such as a double renal artery or vein. The ureter is dissected, ligated, and transected near its insertion into the urinary bladder. The entire kidney and ureter are then dissected from any remaining peritoneal attachments and removed (Figure 5). Appropriate diagnostic tests, such as histopathology and culture, are performed on the excised specimen.

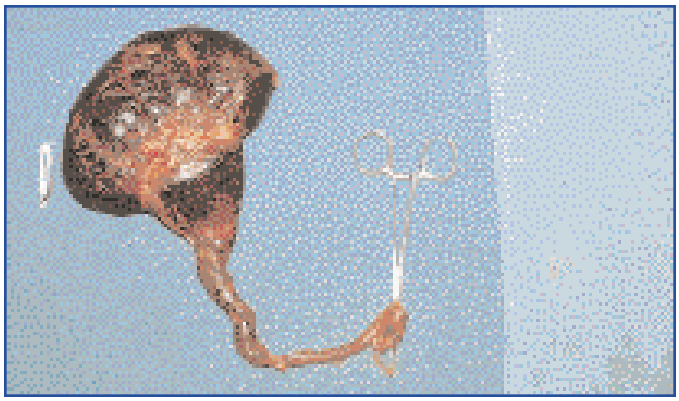


Figure 5
Nephrectomy, in this case for the removal of an end-stage hydronephrotic kidney, should include the entire length of the ureter.

URETERAL SURGERY

Surgical diseases of the ureter include traumatic disruption of the ureter, ureteral ectopia, and, rarely, ureteral calculi. The most frequent complication associated with ureteral surgery is stricture and the subsequent development of hydroureter and hydronephrosis. Complete resolution of hydroureter can be expected if ureteral obstruction is alleviated within 10 weeks.[17] Accurate apposition of ureteral mucosa, provision of a watertight seal, minimal tissue trauma, and provision of a ureteral stent and urinary diversion will decrease the risk of postoperative stricture.

Ureterotomy

Ureterotomy refers to a planned incision into the ureter, usually for removal of a lodged ureteral calculus. A transverse incision is performed in the dilated portion of the ureter immediately proximal to the calculus (Figure 6). Longitudinal ureterotomy has been used successfully, but transverse incisions are subject to less tension.[18,19] A sufficient circumference is incised to allow gentle extraction of the calculus. The ureter is gently flushed to assist in removal of debris and to ensure ureteral patency. The ureteral incision can be closed using a simple continuous or interrupted pattern of 5-0 to 7-0 absorbable suture material. Loupe magnification is extremely beneficial when performing ureteral surgery.

Ureteral stents and urinary diversion remain controversial but are generally accepted as beneficial.[20] A soft rubber or

polyvinyl catheter is inserted into the distal ureter via a ventral cystotomy. The size of the catheter should be small enough to allow easy insertion into the ureter. The catheter is advanced to the renal pelvis, and the distal end is passed into the urethra and exited to the outside. A small absorbable tacking suture can be placed within the bladder lumen to secure the catheter. Ureteral incisions are usually epithelialized within 3 to 4 days, allowing removal of ureteral stents at that time.

Ureteral anastomosis

Ureteral anastomosis is recommended where segmental resection of the ureter is required for the management of ureteral calculi and for the treatment of traumatic ureteral discontinuity. Stricture remains a significant postoperative complication. Ureters must be anatomically apposed without tension, tissue at the anastomosis must be well vascularized, and closure must be meticulous to provide a watertight seal. Direct end-to-end and spatulated end-to-end techniques have been recommended (Figure 7), and there is no clear evidence to support one technique over the other.[21] The spatulated technique has a potential advantage in that it provides a greater luminal diameter at the anastomosis. Direct end-to-end repair, however, is likely to yield more accurate anatomical apposition of tissues.

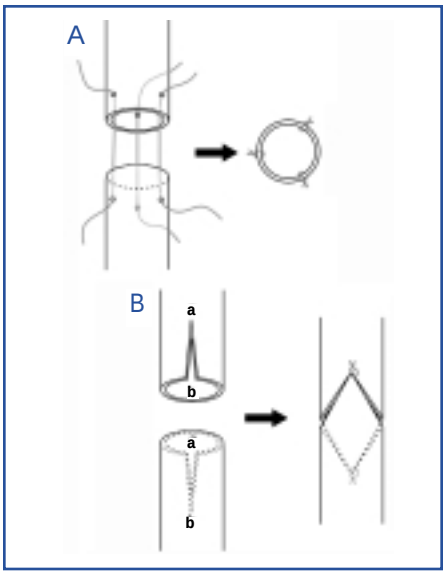


Figure 7
(**A**) Direct end-to-end ureteral anastomosis is performed by first triangulating the anastomosis. Three sutures are placed at equidistant points around the ureteral circumference and interpositional sutures are used to complete the repair. Care should be taken to provide accurate apposition of ureteral mucosa. (**B**) Full-thickness longitudinal incisions are made on opposing sides of the ureter where performing a spatulated end-to-end repair. Point "a" is sutured to point "a" and point "b" to point "b." Simple continuous or simple interrupted sutures are used to complete the anastomosis.

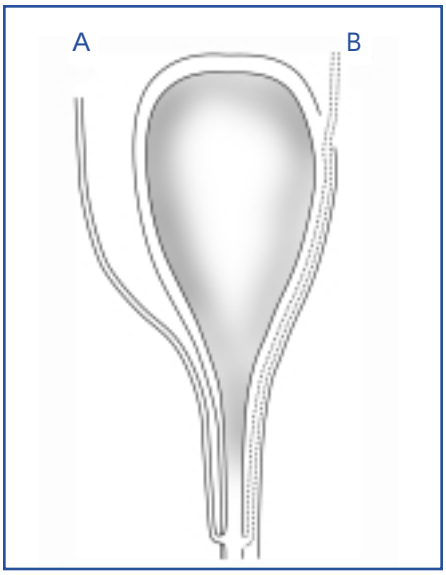


Figure 8
Ectopic ureters are classified as extramural (**A**) or intramural (**B**). Extramural ectopic ureters bypass the bladder wall and enter directly into the urethra or vagina. Intramural ectopic ureters traverse the serosal surface of the bladder at a normal location and tunnel submucosally to enter into the urethra.

Ureteral repair should be performed under loupe or operating microscope magnification. Either simple interrupted or continuous closures can be used.[22] Simple continuous repair is completed more rapidly, provides a better seal against leakage of urine, and causes less vascular disruption to tissues. Continuous suture patterns, where used for anastomosis, can result in the formation of a purse-string effect.

Postoperative care includes provision of a ureteral stent, as described for ureterotomy, and diuresis accomplished through adequate intravenous fluid administration. Normal peristalsis returns within 1 to 3 weeks of primary ureteral repair.[23,24]

Ureteral ectopia

Ectopic ureter refers to a congenital anatomical abnormality where one or both ureters fail to open into the bladder trigone. Affected animals present with a history of urinary incontinence that is usually continuous but may be intermittent. There is a strong female:male sex predilection of greater than 10:1, and the majority of dogs are affected unilaterally.[25,26] The diagnosis and medical management of ureteral ectopia is discussed elsewhere (see "Workup of the urinary incontinent dog," pages 90–96).

Ectopic ureters may be intramural or extramural (Figure 8). Intramural ones traverse the serosal surface of the bladder at a normal location, continue beneath the bladder mucosa, and ultimately open into the urethra or vagina. Extramural ones pass outside the bladder wall and ultimately open into the urethra or vagina. Most dogs affected with ureteral ectopia have additional abnormalities including hydroureter, hydronephrosis, incompetence of the urethral sphincter, and urinary tract infection.[25]

Surgical correction is recommended for all patients diagnosed with ureteral ectopia. Two procedures are commonly employed: neoureterostomy (intravesicular ureteric transplantation) for the management of intramural ectopic ureters and neoureterocystostomy (extravesicular ureteric transplantation) for the correction of extramural ectopic ureters.

Significant postoperative complications include continued urinary incontinence and dysuria. Dysuria occurs if closure of the bladder neck or proximal urethra compromises urine flow. This complication is often self-limiting but may require intermittent catheterization until accommodation of the tissues

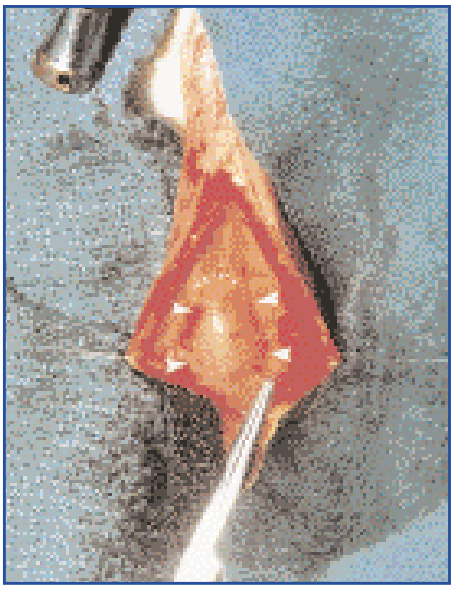


Figure 9
Intramural ectopic ureters are identified as a raised submucosal ridge at the level of the bladder trigone (arrowheads). If the position of the ectopic ureter is not evident, digital pressure distally is used to obstruct urine flow until distension of the ureter occurs.

occurs. Approximately 50% of dogs with surgically corrected ectopic ureters have resolution of their clinical signs. The remainder continue to suffer some degree of incontinence but often benefit from long-term treatment using α-adrenergic drugs to increase urethral tone.

Neoureterostomy

The urinary bladder is approached through a caudal midline abdominal incision. Ureters are examined bilaterally to determine whether they enter the bladder wall or bypass the bladder; neoureterostomy is appropriate only for the former. Stay sutures are placed in the cranial pole as well as medially and laterally in the bladder wall, and a ventral midline cystotomy is performed. Incision into the bladder should be carried into the proximal urethra along the ventral midline. Bladder mucosa must be handled very gently to avoid bruising and edema. Sterilized cotton swabs should be used rather than gauze sponges for control of hemorrhage in the surgical field. Intramural ectopic ureters may be identified by the absence of a normal ureteral opening into the bladder trigone. The submucosal location of the ureter is usually identifiable as a slight submucosal ridge running toward and into the urethra (Figure 9). If the ureter is not readily identified, it can be digitally compressed distally until distension occurs.

Once identified, a 4 to 5 mm elliptical excision of bladder mucosa is performed directly over the ureter at the level of the trigone (Figure 10). A 4 to 5 mm longitudinal incision is made into the ureter, and entry is confirmed by the presence of urine flow through the opening. Simple interrupted absorbable sutures of size 5-0 to 7-0 are used to approximate ureteral mucosa to bladder mucosa, forming a new opening between the ureter and bladder lumen.

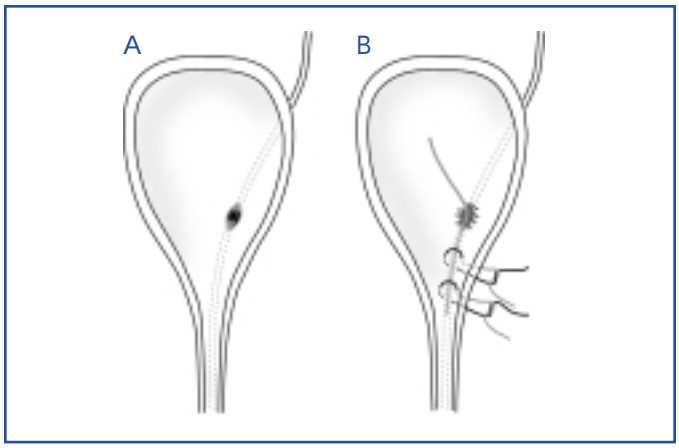


Figure 10
(**A**) Neoureterostomy is indicated for the correction of intramural ectopic ureters. An elliptical excision of bladder mucosa is made overlying the submucosal ureter at the level of the bladder trigone. The ureter is identified and incised longitudinally for a length of 4–5 mm. (**B**) Ureteral mucosa is apposed to bladder mucosa using simple interrupted absorbable sutures. The distal continuation of the ureter is catheterized, and several non-absorbable ligatures are placed. Ligatures are placed such that knots are tied on the serosal surface of the bladder.

The distal continuation of the ureter into the urethra can be managed in one of two ways. The most frequently described method entails catheterization of the ureter distal to the neoureterostomy. Several non-absorbable sutures of size 3-0 to 4-0 are passed from the serosal surface around the cannulated ureter and tied, resulting in functional ligation of the distal ureteral extension. The author prefers to transect the ureter completely at the level of the neoureterostomy.

The distal ureteral extension is opened longitudinally 1 to 2 cm into the proximal urethra using fine dissection scissors. The ureteral mucosa is excised and the resulting defect closed in a simple continuous pattern using 4-0 or 5-0 absorbable suture material. Urine flow through the neoureterostomy is visually confirmed. The proximal urethra and bladder wall are closed using a simple continuous pattern of 3-0 or 4-0 absorbable suture material in either a single or double layer. Inverting suture patterns should be avoided at the bladder neck and proximal urethra because they may result in functional obstruction to urine flow.

Ureteroneocystostomy

Extramural ectopic ureters are identified prior to entry into the bladder. The ectopic ureter is ligated distally and transected, and a stay suture is placed into the distal end to facilitate handling (Figure 11). A ventral cystotomy is performed at the level of the bladder trigone and a 3 to 4 mm elliptical excision of bladder mucosa is performed as described for neoureterostomy. A fine hemostat is placed through the mucosal opening and is passed submucosally for 7 to 10 mm

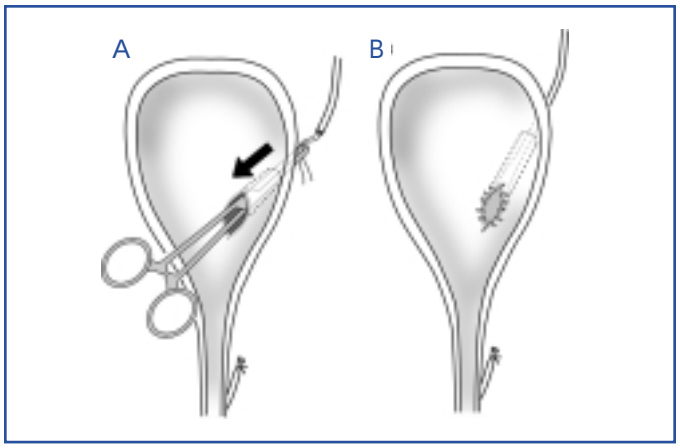


Figure 11
(**A**) Ureteroneocystostomy is indicated for the correction of extramural ectopic ureters. An elliptical excision of bladder mucosa is made at the trigone, and hemostats are advanced submucosally to exit the serosal surface. The length of the submucosal tunnel should be approximately three times the thickness of the bladder wall. The ureter is pulled back through the submucosal tunnel by grasping a stay suture placed into its end. (**B**) The end of the ureter is spatulated and sutured into apposition with bladder mucosa.

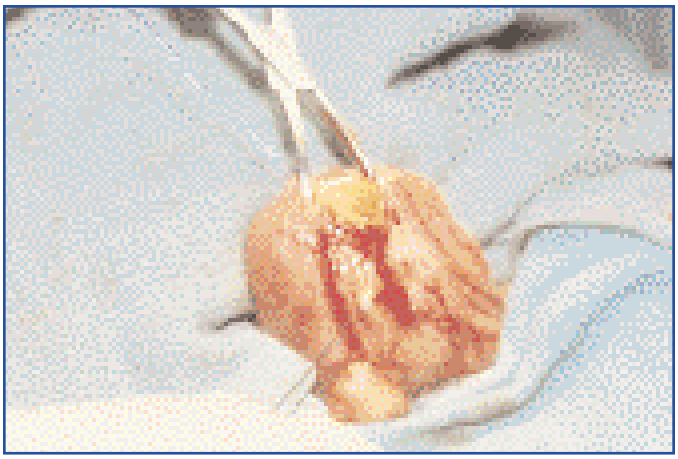
toward the cranial pole of the bladder before exiting through the serosal surface. A ratio of tunnel length to bladder wall thickness of approximately 3:1 is preferred.[27] The ureteral stay suture is grasped and the hemostat is withdrawn, pulling the ureter through the submucosal tunnel. The ureter is spatulated and apposed to bladder mucosa as described for neoureterostomy.

URINARY BLADDER

Surgery of the urinary bladder is most frequently employed for the removal of urinary calculi or for the treatment of bladder tumors. Cystotomy may be performed using either a dorsal or ventral incision through the bladder wall. There is no difference in the incidence of urine leakage or postoperative adhesion formation, but exposure is more limited and ureteral encroachment during closure is more likely to occur with dorsal than with ventral incisions.[28] Ventral cystotomy, therefore, is recommended.

Removal of urinary calculi

Prior to surgery an indwelling catheter is placed into the bladder and urine is withdrawn. The catheter is then pulled back so that its tip lies in the proximal urethra. The bladder is approached using a standard caudal midline laparotomy. Stay sutures are placed in the cranial pole and medially and laterally in the bladder wall to facilitate manipulation. A ventral cystotomy incision, of adequate length to allow thorough inspection of the bladder mucosa, is performed (Figure 12). Urinary calculi are gently extracted from the bladder using a large curette or sterilized stainless steel spoon.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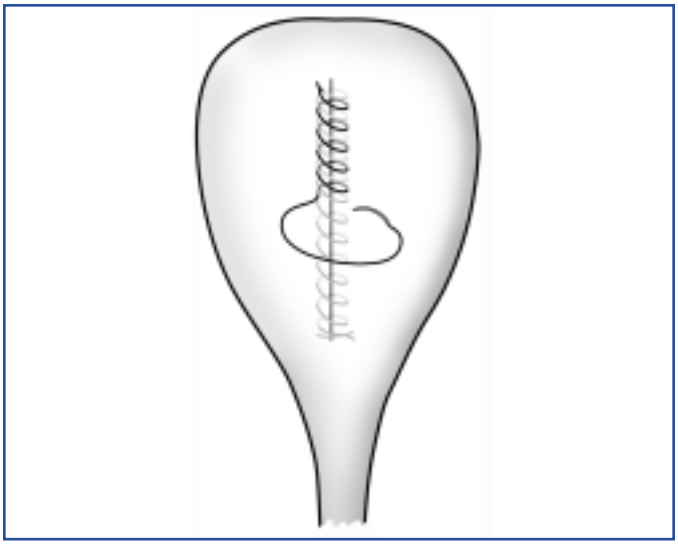
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Figure 12
(**A**) Removal of urinary calculi is performed through a ventral cystotomy incision. The length of incision must be adequate to allow inspection of the bladder lumen. Towels or sponges are used to isolate the retracted bladder from the abdominal cavity. (**B**) Appositional closure is recommended for cystotomy incisions, using either a single or double simple continuous suture pattern.

Sterile saline solution is vigorously flushed through the urethral catheter. Fluid is suctioned as it enters the bladder, and any calculi that may have been forced into the proximal urethra are identified and removed. The urethral catheter is then passed to the level of the bladder and withdrawn into the urethra several times to ensure patency of the urethra. Calculi should be submitted for bacterial culture and for quantitative chemical analysis to determine appropriate postoperative medical treatment.

Several techniques have been recommended for closure of cystotomy incisions. Appositional closure using a single or double layer simple continuous suture pattern results in earlier and more advanced healing than a traditionally recommended

Figure 13
Prescrotal urethrotomy is indicated for the removal of urethral calculi lodged at the base of the os penis. The incision must be maintained on the ventral midline to prevent excessive hemorrhage from cavernous tissues. The retractor penis muscle (arrowheads) is retracted and the longitudinal incision is extended into the urethra. Catheterization of the urethra facilitates its identification (arrows).

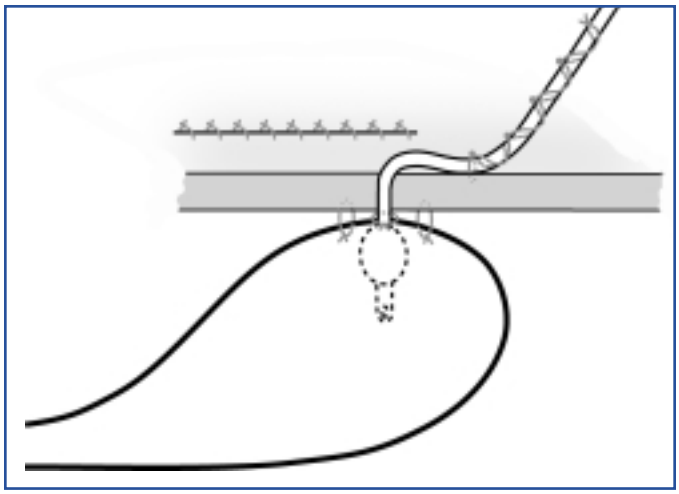

Figure 14
Prepubic urinary catheterization is used to provide urinary diversion from the urethra. The bladder is approached through a caudal midline incision. A 6–12 French Foley catheter is passed through the body wall adjacent to the laparotomy incision. The tip of the Foley catheter is secured into the cranial pole of the bladder using a purse-string suture and the bladder is tacked to the abdominal wall using several simple interrupted sutures.

double inverting suture pattern.[29] Also, where dealing with chronic cystitis, the bladder wall is usually thickened making tissue inversion difficult or impossible. Absorbable 3-0 to 4-0 suture should be used.

Partial cystectomy

Partial cystectomy is occasionally recommended for the management of bladder tumors localized to the cranial pole. It should be recognized, however, that surgery is not routinely recommended and is of no established benefit in the treatment of transitional cell carcinoma. Bladder regeneration and accommodation occurs following resection of up to 75% of the bladder wall, with good recovery of storage capacity and function within 3 months.[30]

URETHRA

Urethral surgery is most often required for the management of lodged urethral calculi or traumatic injury. The urethra is capable of complete regeneration and repair of urethral defects given two conditions: There must be an intact "strip" of urethral mucosa bridging the proximal and distal segments, and urine must be diverted from the defect.[31] Urethral mucosa tends to retract into the lumen of the urethra following transection. Care must be taken to identify and accurately appose urethral mucosa during repair.

Urethrotomy

Urethrotomies are most frequently performed for removal of urethral calculi. The level of urethrotomy is determined by the location of the calculus. Urethral calculi seldom occur in females; in males, they most often lodge at the proximal base of the os penis. Urethrotomy is reserved for those patients in which attempts to flush calculi into the urinary bladder have failed.

Prescrotal urethrotomy is performed with the dog in dorsal recumbency. A soft catheter is placed from the distal end of the penis to the level of the urethral obstruction. A midline incision is made between the scrotum and the base of the os penis (Figure 13). The retractor penis muscle is elevated and retracted, and a scalpel blade is used to make a longitudinal incision into the urethra. Care should be taken to remain on midline to avoid excessive hemorrhage from cavernous tissues. Calculi are identified and gently extracted. Warm saline solution is flushed through the catheter to ensure removal of all calculi.

Prescrotal urethrotomy incisions may be left to heal by second intention, but hemorrhage is expected for several days and is occasionally of clinical significance. Primary urethral closure has been found to result in decreased hemorrhage without an increase in stricture formation.[32] Where dealing with healthy urethral mucosa, primary closure using a simple continuous pattern of 5-0 absorbable suture material is recommended.

Urethral trauma

When presented with a urethral injury, the surgeon must determine whether there is complete disruption of the urethra. Incomplete transections and lacerations can be managed by debriding necrotic tissue from the site of injury and diverting urine from the site. Urethral integrity is assessed periodi-

Figure 15
Cystourethropexy is performed by placing 6–10 simple interrupted non-absorbable sutures through the caudal abdominal body wall and into opposing sides of the urethra. Sutures are tied from caudal to cranial.

Figure 16
Colposuspension involves a pexy of the vagina to the ventral abdominal wall in such a manner that it surrounds, or entraps, the proximal urethra. Two or three non-absorbable sutures are placed into the cranially retracted vagina on either side of the proximal urethra. Sutures are exited through the body wall and are tied under tension. Excessive compression or kinking of the urethra must be avoided.

cally by contrast radiography. Complete urethral disruptions require identification of the defect, surgical debridement of non-viable tissue, primary repair, and urinary diversion. If extensive necrosis is present due to vascular injury or urine extravasation, tissues should be debrided and urinary diversion implemented. Staged urethral repair is performed once tissue necrosis is controlled.

Urinary diversion for urethral injuries

Although soft indwelling urethral catheters can be used for urinary diversion, chronic catheterization can result in injury to the urethral mucosa. It is likely, also, that at least some urine travels extraluminally and is exposed to the urethra. Prepubic catheterization is recommended where urinary diversion is required for longer periods. Prepubic catheters are placed through a limited caudal midline incision (Figure 14). A purse-string suture is placed into the ventral aspect of the urinary bladder near the cranial pole and a stab incision is made in its center. A 6 to 12 French Foley catheter is passed through a stab incision in the abdominal wall immediately adjacent to the laparotomy incision, and the tip of the catheter is placed within the bladder lumen and secured by tying the purse-string suture. The catheter is withdrawn to bring the urinary bladder into contact with the body wall and tacked to it with several sutures.

URETHRAL SPHINCTER MECHANISM INCOMPETENCE

Incontinence due to failure of the urethral sphincter mechanism is frustrating for both the owner and veterinarian. Accurate diagnosis and medical management are the mainstays of managing these patients and are described in pages 90–96. Surgical intervention should be considered in dogs that respond poorly to medical management. Two techniques, designed to increase functional urethral length and urethral resistance, have been described.

Cystourethropexy

Cystourethropexy is performed through a caudal midline abdominal incision (Figure 15). The urinary bladder is retracted cranially and the ventral bladder neck and proximal urethra are exposed. Six to ten non-absorbable 3-0 to 4-0 sutures are placed bilaterally through the seromuscular layers of the urethra and bladder neck. Sutures are placed at the 9 o'clock and 3 o'clock positions as viewed from a transverse plane. Both suture ends are then passed through the abdominal wall immediately adjacent to the laparotomy incision. Cranial sutures pass through the muscular layers of the abdominal wall while caudal sutures are placed through the prepubic tendon. The sutures are tied beginning caudally and progressing cranially. The laparotomy incision is closed in a routine fashion.

Reported results of cystourethropexy are disappointing. In a study of 10 dogs, short-term resolution of incontinence was seen in two dogs and incontinence was improved in two dogs.[33] Resolution of incontinence tended to be temporary, with recurrence noted after several months.

Colposuspension

The technique of colposuspension has been modified from a similar procedure employed in women.[34–36] A Foley catheter is placed retrograde into the urinary bladder to drain urine and facilitate identification of the urethra. The bladder is approached through a caudal midline incision and retracted cranially to facilitate exposure of the ventral bladder neck and proximal urethra. A finger is passed through the vestibule and into the vagina and digital pressure applied to move the vagina cranially. Periurethral fat is bluntly dissected away from the vagina, following its identification dorsal and lateral to the urethra, and the vaginal wall is grasped with forceps. The vagina is then displaced to the contralateral side of the urethra and the procedure repeated.

Two non-absorbable No. 0 or 1 sutures are placed full thickness through the vagina on either side of the urethra and passed through the prepubic tendon on either side of the laparotomy incision (Figure 16). Sutures are tied under tension to avoid excessive compression of the urethra, which is entrapped between the vagina and the body wall. The urethra is inspected to ensure that it is freely moveable and that it is not kinked or compressed. If excessive compression is present, the offending suture(s) are removed and the procedure is repeated. Closure of the abdominal incision is routine.

Approximately 50% of dogs treated using colposuspension are continent after surgery and only 10% fail to respond.[35] Dysuria is the most common postoperative complication and is reported in less than 10% of dogs. Dysuria resolves within 1 week in nearly all instances but may require intermittent or indwelling urinary catheterization in the short term.

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