The Urinary System

21 The Kidneys, the Ureters, the Bladder, and the Urethra

Chapter Outline

THE KIDNEYS

Renal Mobility

The kidneys are maintained in their normal position by intraabdominal pressure and by their connections with the perirenal fat and renal fascia. Each kidney moves slightly with respiration. The right kidney lies at a slightly lower level than the left kidney, and the lower pole may be palpated in the right lumbar region at the end of deep inspiration in a person with poorly developed abdominal musculature. Should the amount of perirenal fat be reduced, the mobility of the kidney may become excessive and produce symptoms of renal colic caused by kinking of the ureter. Excessive mobility of the kidney leaves the suprarenal gland undisturbed because the latter occupies a separate compartment in the renal fascia.

Kidney Trauma

The kidneys are well protected by the lower ribs, the lumbar muscles, and the vertebral column. However, a severe blunt

injury applied to the abdomen may crush the kidney against the last rib and the vertebral column. Depending on the severity of the blow, the injury varies from a mild bruising to a complete laceration of the organ. Penetrating injuries are usually caused by stab wounds or gunshot wounds and often involve other viscera. Because 25% of the cardiac outflow passes through the kidneys, renal injury can result in rapid blood loss. A summary of the injuries to the kidneys is shown in CD Fig. 21-1.

Kidney Tumors

Malignant tumors of the kidney have a strong tendency to spread along the renal vein. The left renal vein receives the left testicular vein in the male, and this may rarely become blocked, producing left-sided **varicocele**.

Renal Pain

Renal pain varies from a dull ache to a severe pain in the flank that may radiate downward into the lower abdomen. Renal pain can result from stretching of the kidney capsule or spasm of the smooth muscle in the renal pelvis. The afferent nerve fibers pass through the renal plexus around the renal artery and ascend to the spinal cord through the lowest splanchnic nerve in the thorax and the sympathetic trunk. They enter the spinal cord at the level of T12. Pain is commonly referred along the distribution of the subcostal nerve (T12) to the flank and the anterior abdominal wall.

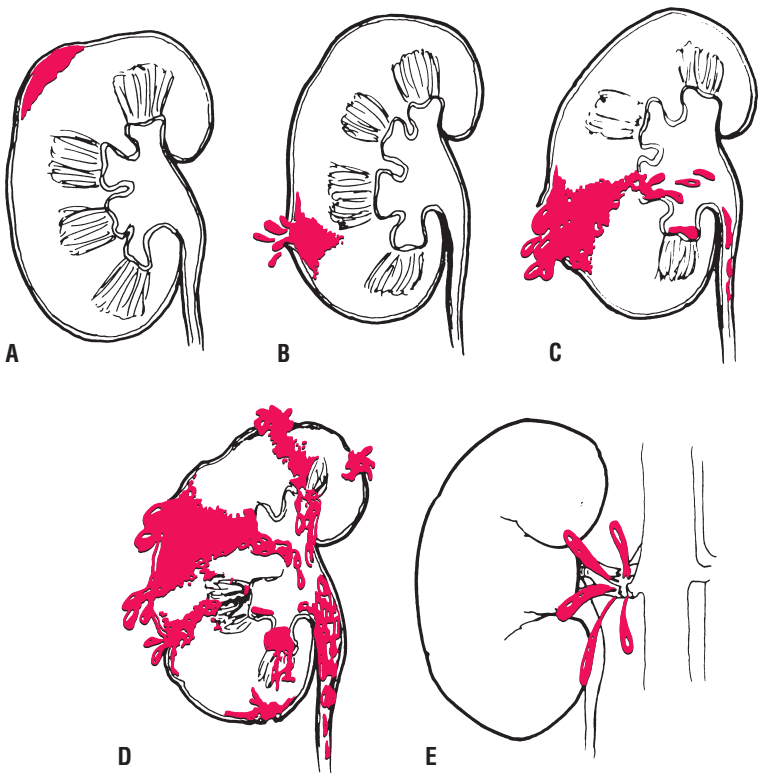
Transplanted Kidneys

The iliac fossa on the posterior abdominal wall is the usual site chosen for transplantation of the kidney. The fossa is exposed through an incision in the anterior abdominal wall just above the inguinal ligament. The iliac fossa in front of the iliacus muscle is approached retroperitoneally. The kidney is positioned and the vascular anastomosis constructed. The renal artery is anastomosed end to end to the internal iliac artery and the renal vein is anastomosed end to side to the external iliac vein (CD Fig. 21-2). Anastomosis of the branches of the internal iliac arteries on the two sides is sufficient so that the pelvic viscera on the side of the renal arterial anastomosis are not at risk. Ureterocystostomy is then performed by opening the bladder and providing a wide entrance of the ureter through the bladder wall.

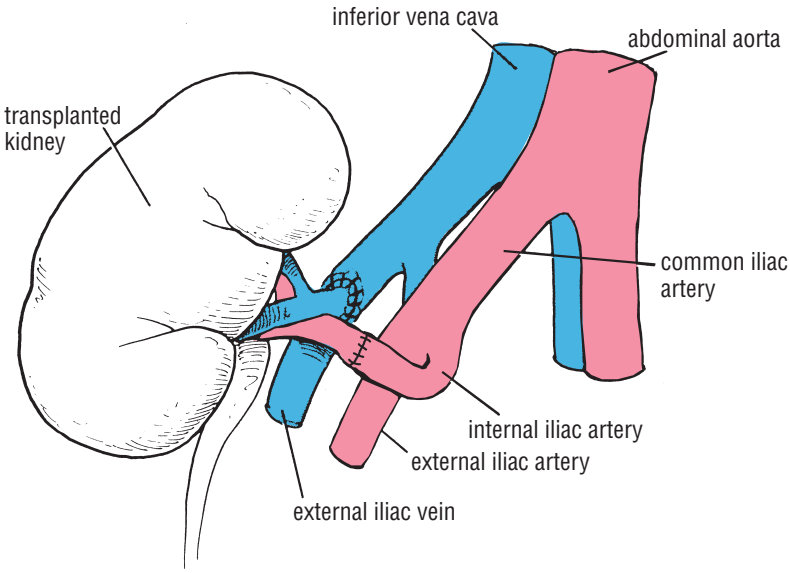
THE URETERS

Traumatic Ureteral Injuries

Because of its protected position and small size, injuries to the ureter are rare. Most injuries are caused by gunshot



CD Figure 21-1 Injuries to the kidney. **A.** Contusion, with hemorrhage confined to the cortex beneath the intact fibrous capsule. **B.** Tearing of the capsule and cortex with bleeding occurring into the perirenal fat. **C.** Tearing of the capsule, the cortex, and the medulla. Note the escape of blood into the calyces and therefore the urine. Urine as well as blood may extravasate into the perirenal and pararenal fat and into the peritoneal cavity. **D.** Shattered kidney with extensive hemorrhage and extravasation of blood and urine into the perirenal and pararenal fat; blood also enters the calyces and appears in the urine. **E.** Injury to the renal pedicle involving the renal vessels and possibly the renal pelvis.



CD Figure 21-2 The transplanted kidney.

wounds and, in a few individuals, penetrating stab wounds. Because the ureters are retroperitoneal in position, urine may escape into the retroperitoneal tissues on the posterior abdominal wall.

Ureteric Stones

There are three sites of anatomic narrowing of the ureter where stones may be arrested, namely, the pelviureteral junction, the pelvic brim, and where the ureter enters the bladder. Most stones, although radiopaque, are small enough to be impossible to see definitely along the course of the ureter on plain radiographic examination. An intravenous pyelogram is usually necessary. The ureter runs down in front of the tips of the transverse processes of the lumbar vertebrae, crosses the region of the sacroiliac joint, swings out to the ischial spine, and then turns medially to the bladder.

Renal Colic

The renal pelvis and the ureter send their afferent nerves into the spinal cord at segments T11 and 12 and L1 and 2. In renal colic, strong peristaltic waves of contraction pass down the ureter in an attempt to pass the stone onward. The spasm of the smooth muscle causes an agonizing colicky pain, which is referred to the skin areas that are supplied by these segments of the spinal cord, namely, the flank, loin, and groin.

When a stone enters the low part of the ureter, the pain is felt at a lower level and is often referred to the testis or the tip of the penis in the male and the labium majus in the female. Sometimes ureteral pain is referred along the femoral branch of the genitofemoral nerve (L1 and 2) so that pain is experienced in the front of the thigh. The pain is often so severe that afferent pain impulses spread within the central nervous system, giving rise to nausea.

CONGENITAL ANOMALIES OF THE KIDNEYS

Polycystic Kidney

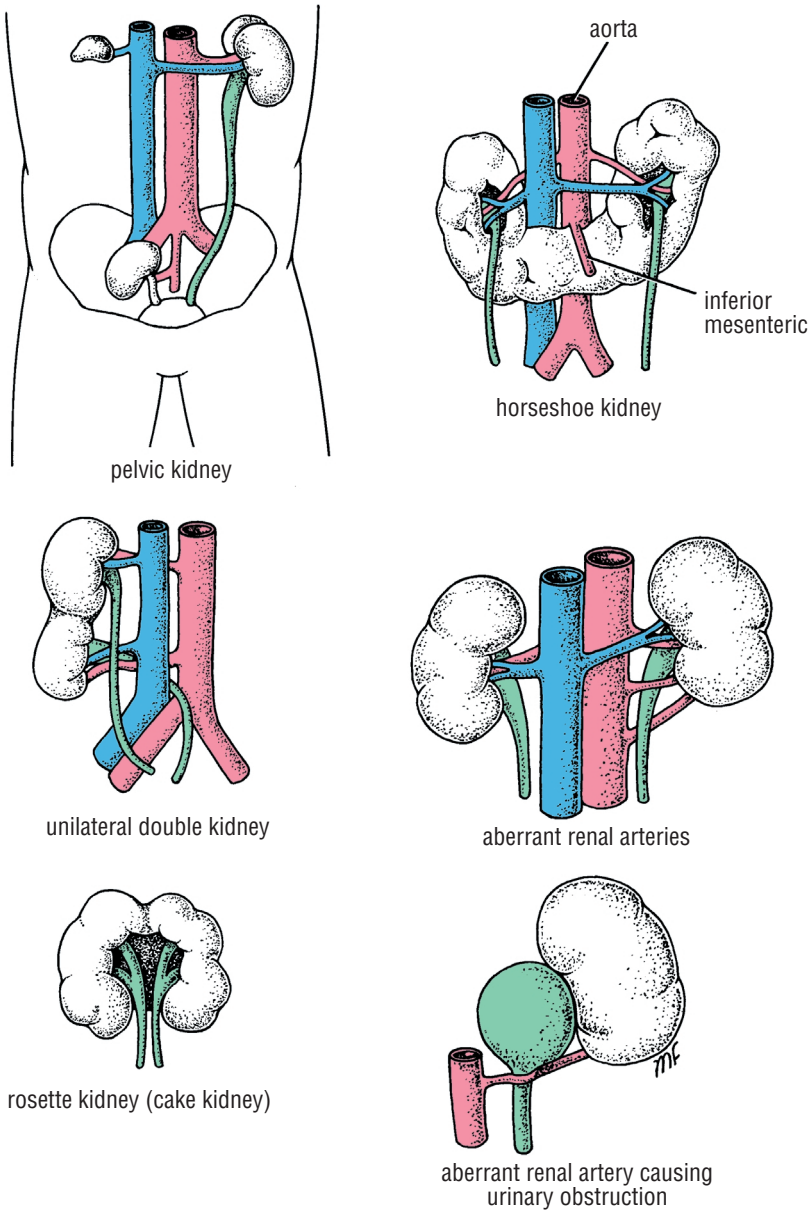
A hereditary disease, polycystic kidney can be transmitted by either parent. It may by associated with congenital cysts of the liver, pancreas, and lung. Both kidneys are enormously enlarged and riddled with cysts. Polycystic kidney is thought to be caused by a failure of union between the developing convoluted tubules and collecting tubules. The accumulation of urine in the proximal tubules results in the formation of retention cysts.

Pelvic Kidney

In pelvic kidney, the kidney is arrested in some part of its normal ascent; it usually is found at the brim of the pelvis (CD Fig. 21-3). Such a kidney may present with no signs or symptoms and may function normally. However, should an ectopic kidney become inflamed, it may—because of its unusual position—give rise to a mistaken diagnosis.

Horseshoe Kidney

When the caudal ends of both kidneys fuse as they develop, the result is horseshoe kidney (see CD Fig. 21-3). Both kidneys commence to ascend from the pelvis, but the interconnecting bridge becomes trapped behind the



CD Figure 21-3 Some common congenital anomalies of the kidney.

inferior mesenteric artery so that the kidneys come to rest in the low lumbar region. Both ureters are kinked as they pass inferiorly over the bridge of renal tissue, producing urinary stasis, which may result in infection and stone formation. Surgical division of the bridge corrects the condition.

Unilateral Double Kidney

The kidney on one side may be double, with separate ureters and blood vessels. In unilateral double kidney, the ureteric bud on one side crosses the midline as it ascends, and its upper pole fuses with the lower pole of the normally placed kidney (see CD Fig. 21-3). Here again, angulation of the ureter may result in stasis of the urine and may require surgical treatment.

Rosette Kidney

Both kidneys may fuse together at their hila, and they usually remain in the pelvis. The two kidneys together form a rosette (see CD Fig. 21-3). This is the result of the early fusion of the two ureteric buds in the pelvis.

Supernumerary Renal Arteries

Supernumerary renal arteries are relatively common. They represent persistent fetal renal arteries, which grow in

sequence from the aorta to supply the kidney as it ascends from the pelvis. Their occurrence is clinically important because a supernumerary artery may cross the pelviureteral junction and obstruct the outflow of urine, producing dilation of the calyces and pelvis, a condition known as **hydronephrosis** (see CD Fig. 21-3).

CONGENITAL ANOMALIES OF THE URETERS

Double Pelvis

Double pelvis of the ureter is usually unilateral (CD Fig. 21-4). The upper pelvis is small and drains the upper group of calyces; the larger lower pelvis drains the middle and lower groups of calyces. The cause is a premature division of the ureteric bud near its termination.

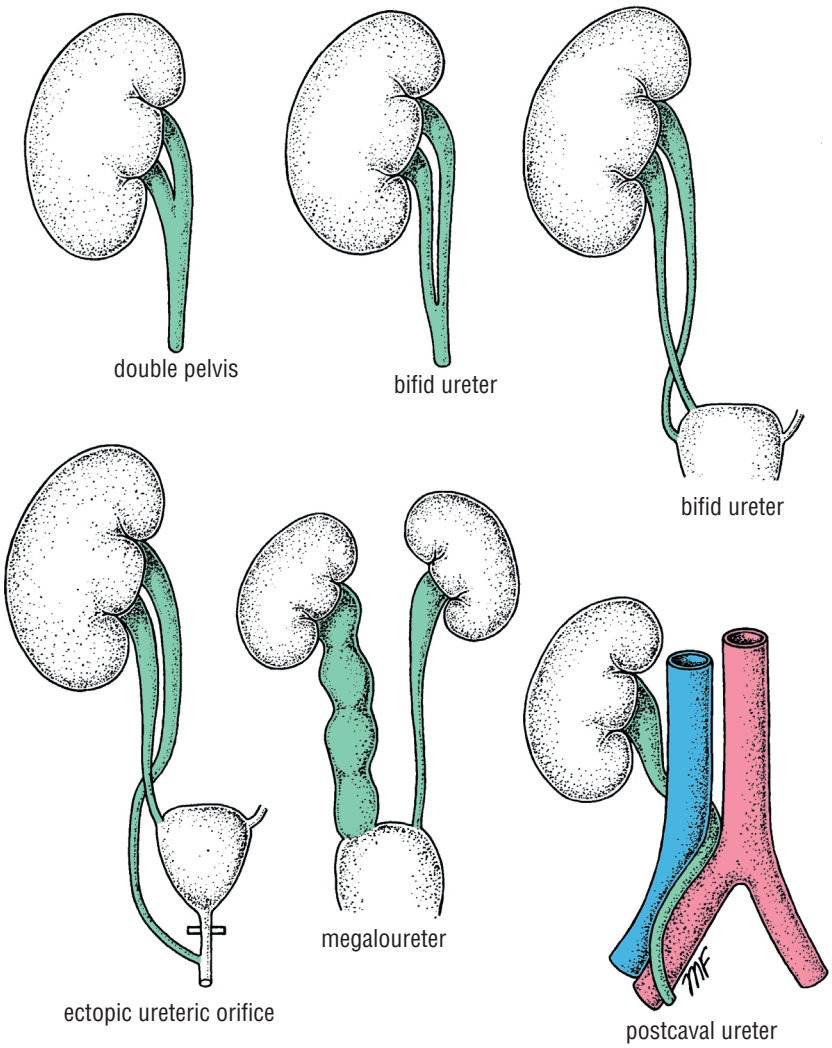
Bifid Ureter

In bifid ureter, the ureters may join in the lower third of their course, may open through a common orifice into the bladder, or may open independently into the bladder (see CD Fig. 21-4). In the latter case, one ureter crosses its fellow and may produce urinary obstruction. The cause of bifid ureter is a premature division of the ureteric bud.

Cases of double pelvis and double ureters may be found by chance on radiologic investigation of the urinary tract. They are more liable to become infected or to be the seat of calculus formation than is a normal ureter.

Megaloureter

Megaloureter may be unilateral or bilateral and shows complete absence of motility (see CD Fig. 21-4). The cause is unknown. Because of the urinary stasis, the ureter is prone



CD Figure 21-4 Some common congenital anomalies of the ureter.

to infection. Plastic surgery is required to improve the rate of drainage.

Postcaval Ureter

The right ureter may ascend posterior to the inferior vena cava and may be obstructed by it (see CD Fig. 21-4). Surgical rerouting of the ureter with reimplantation of the distal end into the bladder is the treatment of choice.

THE URINARY BLADDER

Palpation of the Urinary Bladder

The full bladder in the adult projects up into the abdomen and may be palpated through the anterior abdominal wall above the symphysis pubis.

Bimanual palpation of the empty bladder with or without a general anesthetic is an important method of examining the bladder. In the male, one hand is placed on the anterior abdominal wall above the symphysis pubis, and the gloved index finger of the other hand is inserted into the rectum. From their knowledge of anatomy, students can see that the bladder wall can be palpated between the examining fingers. In the female, an abdominovaginal examination can be similarly made. In the child, the bladder is in a higher position than in the adult because of the relatively smaller size of the pelvis.

Bladder Distension

The normal adult bladder has a capacity of about 500 mL. In the presence of urinary obstruction in males, the bladder may become greatly distended without permanent damage to the bladder wall; in such cases, it is routinely possible to drain 1,000 to 1,200 mL of urine through a catheter.

Urinary Retention

In adult males, urinary retention is commonly caused by obstruction to the urethra by a benign or malignant enlargement of the prostate. An acute urethritis or prostatitis can also be responsible. Acute retention occurs much less frequently in females. The only anatomic cause of urinary retention in females is acute inflammation around the urethra (e.g., from herpes).

Suprapubic Aspiration

As the bladder fills, the superior wall rises out of the pelvis and peels the peritoneum off the posterior surface of the anterior abdominal wall. In cases of acute retention of urine, when catheterization has failed, it is possible to pass a needle into the bladder through the anterior abdominal wall above the symphysis pubis, without entering the peritoneal cavity. This is a simple method of draining off the urine in an emergency.

Cystoscopy

The mucous membrane of the bladder, the two ureteric orifices, and the urethral meatus can easily be observed by means of a cystoscope. With the bladder distended with fluid, an illuminated tube fitted with lenses is introduced into the bladder through the urethra. Over the trigone, the mucous membrane is pink and smooth. If the bladder is partially emptied, the mucous membrane over the trigone remains smooth, but it is thrown into folds elsewhere. The ureteric orifices are slit-like and eject a drop of urine at intervals of about 1 minute. The interureteric ridge and the uvula vesicae can easily be recognized.

Bladder Injuries

The bladder may rupture intraperitoneally or extraperitoneally. Intraperitoneal rupture usually involves the superior wall of the bladder and occurs most commonly when the bladder is full and has extended up into the abdomen. Urine and blood escape freely into the peritoneal cavity. Extraperitoneal rupture involves the anterior part of the bladder wall below the level of the peritoneal reflection; it most commonly occurs in fractures of the pelvis when bony fragments pierce the bladder wall. Lower abdominal pain and blood in the urine (hematuria) are found in most patients.

In young children, the bladder is an abdominal organ, so abdominal trauma can injure the empty bladder.

Difficulty with Micturition after Spinal Cord Injury

After injuries to the spinal cord, the nervous control of micturition is disrupted.

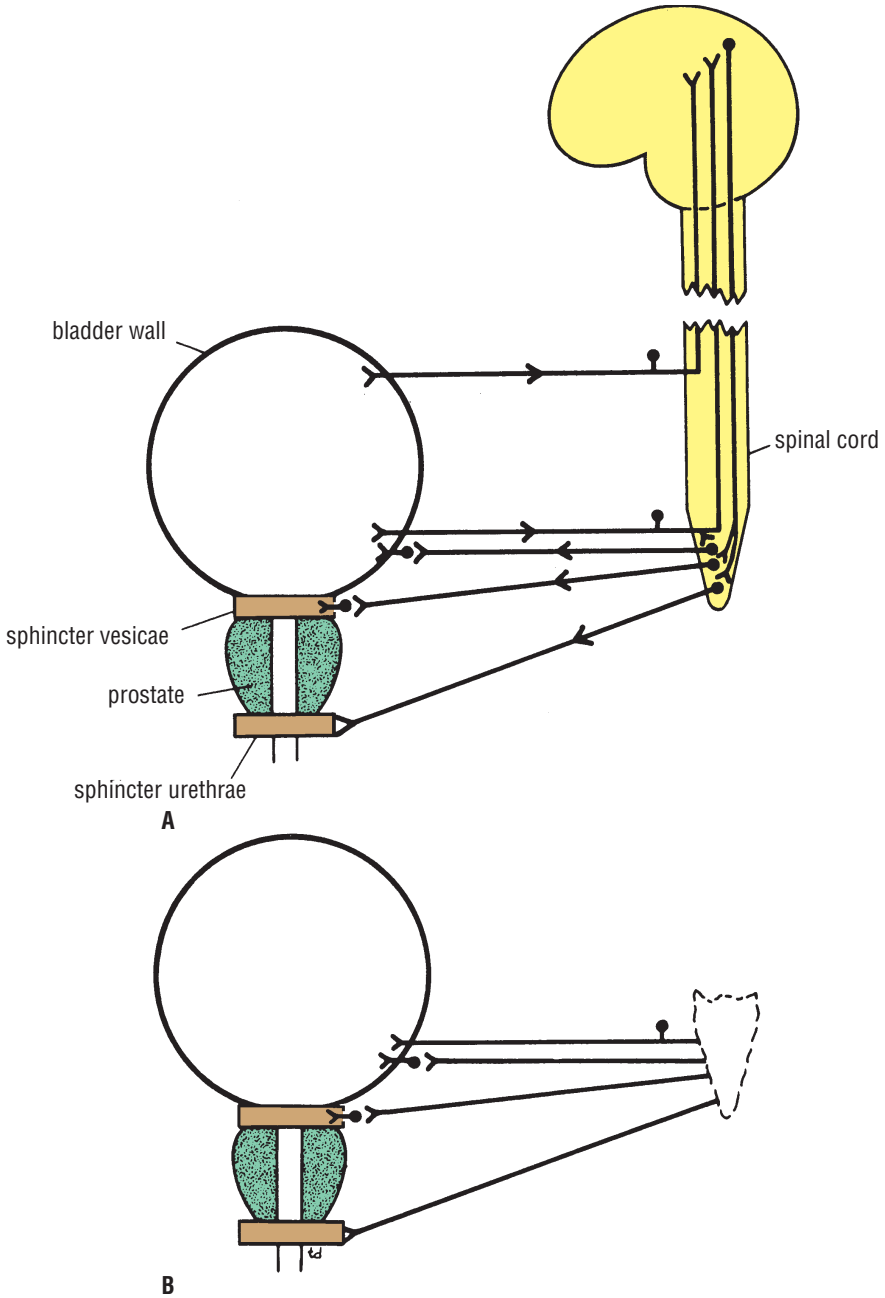
The **normal bladder** is innervated as follows:

- **Sympathetic outflow** is from the first and second lumbar segments of the spinal cord. The sympathetic nerves (see the footnote on text p. 819) inhibit contraction of the detrusor muscle of the bladder wall and stimulate closure of the sphincter vesicae.
- **Parasympathetic outflow** is from the second, third, and fourth sacral segments of the spinal cord. The parasympathetic nerves stimulate the contraction of the detrusor muscle of the bladder wall and inhibit the action of the sphincter vesicae.

- **Sensory nerve fibers** enter the spinal cord at the above segments. The normal process of micturition is described on text page 819.

Disruption of the process of micturition by spinal cord injuries may produce the following types of bladder:

- The **atonic bladder** occurs during the phase of spinal shock, immediately after the injury, and may last for a few days to several weeks. The bladder wall muscle is relaxed, the sphincter vesicae tightly contracted, and the sphincter urethrae relaxed. The bladder becomes greatly distended and finally overflows. Depending on the level of the cord injury, the patient either is or is not aware that the bladder is full.
- The **automatic reflex bladder** (CD Fig. 21-5) occurs after the patient has recovered from spinal shock, provided that the cord lesion lies above the level of the parasympathetic outflow (S2, 3, and 4). It is the type of bladder normally found in infancy. The bladder fills and empties reflexly. Stretch receptors in the bladder wall are stimulated as the bladder fills, and the afferent impulses pass to the spinal cord (segments S2, 3, and 4). Efferent impulses pass down to the bladder muscle, which contracts; the sphincter vesicae and the urethral sphincter both relax. This simple reflex occurs every 1 to 4 hours.
- The **autonomous bladder** (see CD Fig. 21-5) is the condition that occurs if the sacral segments of the spinal cord are destroyed. The sacral segments of the spinal cord are



CD Figure 21-5 **A.** Nervous control of the bladder after section of the spinal cord in the upper thoracic region. Destruction of the sacral segments of the spinal cord. **B.** The afferent sensory fibers from the bladder entering the central nervous system and the parasympathetic efferent fibers passing to the bladder are shown; the sympathetic fibers have been omitted for clarity.

situated in the upper part of the lumbar region of the vertebral column. The bladder is without any external reflex control. The bladder wall is flaccid, and the capacity of the bladder is greatly increased. It merely fills to capacity and overflows; continual dribbling is the result. The bladder may be partially emptied by manual compression of the lower part of the anterior abdominal wall, but infection of the urine and backpressure effects on the ureters and kidneys are inevitable.

THE MALE URETHRA

Urethral Infections

The most dependent part of the male urethra is that which lies within the bulb. Here, it is subject to chronic inflammation and stricture formation.

The many glands that open into the urethra—including those of the prostate, the bulbourethral glands, and many small penile urethral glands—are commonly the site of chronic gonococcal infection.

Injuries to the Penis

Injuries to the penis may occur as the result of blunt trauma, penetrating trauma, or strangulation. Amputation of the entire penis should be repaired by anastomosis using microsurgical techniques to restore continuity of the main blood vessels.

Rupture of the Urethra

Rupture of the urethra may complicate a severe blow on the perineum. The common site of rupture is within the bulb of the penis, just below the perineal membrane. The urine extravasates into the superficial perineal pouch and then passes forward over the scrotum beneath the membranous layer of the superficial fascia, as described on CD page 313. If the membranous part of the urethra is ruptured, urine escapes into the deep perineal pouch and can extravasate upward around the prostate and bladder or downward into the superficial perineal pouch.

Catheterization

The following anatomic facts should be remembered before passing a catheter or other instrument along the male urethra:

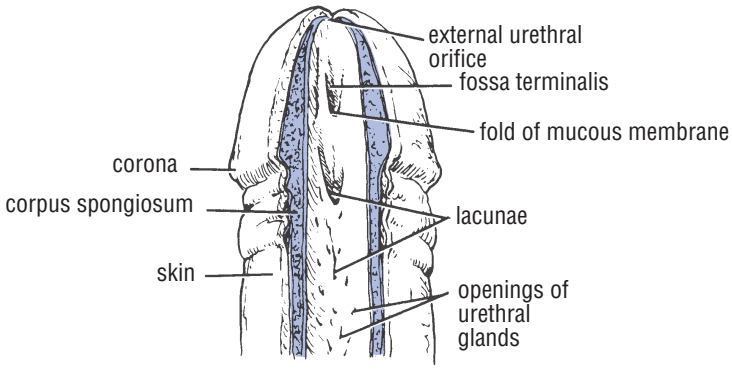
- The external orifice at the glans penis is the narrowest part of the entire urethra.
- Within the glans, the urethra dilates to form the **fossa terminalis** (navicular fossa).
- Near the posterior end of the fossa, a fold of mucous membrane projects into the lumen from the roof (CD Fig. 21-6).
- The membranous part of the urethra is narrow and fixed.
- The prostatic part of the urethra is the widest and most dilatable part of the urethra.
- By holding the penis upward, the S-shaped curve to the urethra is converted into a J-shaped curve.

If the point of the catheter passes through the external orifice and is then directed toward the urethral floor until it has passed the mucosal fold, it should easily pass along a normal urethra into the bladder.

Anatomy of the Procedure of Catheterization

The procedure is as follows:

1. The patient lies in a supine position.
2. With gentle traction, the penis is held erect at right angles to the anterior abdominal wall. The lubricated catheter is passed through the narrow external urethral meatus. The catheter should pass easily along the penile urethra. On reaching the membranous part of the



CD Figure 21-6 The penile urethra slit open to show the folds of mucous membrane and glandular orifices in the roof of the urethra.

urethra, a slight resistance is felt because of the tone of the urethral sphincter and the surrounding rigid perineal membrane.

3. The penis is then lowered toward the thighs, and the catheter is gently pushed through the sphincter.
4. Passage of the catheter through the prostatic urethra and bladder neck should not present any difficulty.

THE FEMALE URETHRA

Urethral Infections

The short length of the female urethra predisposes to ascending infection; consequently, **cystitis** is more common in females than in males.

Urethral Injuries

Because of the short length of the urethra, injuries are rare. In fractures of the pelvis, the urethra may be damaged by shearing forces as it emerges from the fixed urogenital diaphragm.

Catheterization

Because the female urethra is shorter, wider, and more dilatable, catheterization is much easier than in males. Moreover, the urethra is straight, and only minor resistance is felt as the catheter passes through the urethral sphincter.

CONGENITAL ANOMALIES OF THE BLADDER

Exstrophy of the Bladder (Ectopia Vesicae)

Exstrophy of the bladder occurs three times more commonly in males than in females. The posterior bladder wall protrudes through a defect in the anterior abdominal wall below the umbilicus (CD Fig. 21-7). The condition is caused by a failure of the embryonic mesenchyme to invade the embryonic disc caudal to the cloacal membrane (CD Fig. 21-7). The absence of intervening mesenchyme between the ectoderm and entoderm produces an unstable state, which is followed by breakdown of this area.

Because of the urinary incontinence and almost certain occurrence of ascending urinary infection, surgical reconstruction of the bladder is attempted.

CONGENITAL ANOMALIES OF THE URETHRA

Meatal Stenosis

The external urinary meatus normally is the narrowest part of the male urethra, but occasionally the opening is excessively small and may cause back pressure effect on the entire urinary system. In severe cases, dilatation of the orifice by incision is necessary.

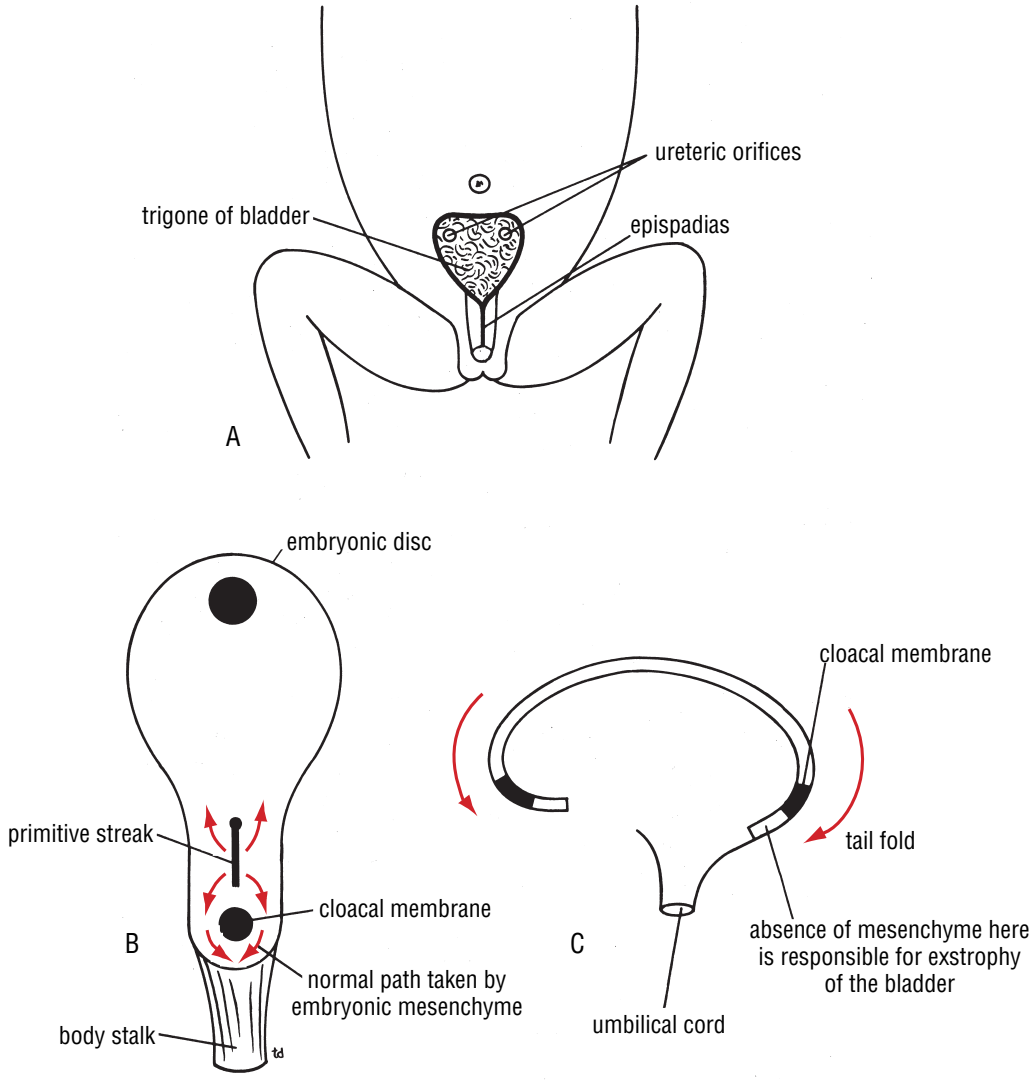
Hypospadias

Hypospadias is the most common congenital anomaly affecting the male urethra. The external meatus is situated on the ventral or undersurface of the penis anywhere between the glans and the perineum. Five degrees of severity may occur, the first of which is the most common: (1) glandular, (2) coronal, (3) penile, (4) penoscrotal, and (5) perineal (CD Fig. 21-8). In all except the first type, the penis is curved in a downward or ventral direction, a condition referred to as **chordee.**

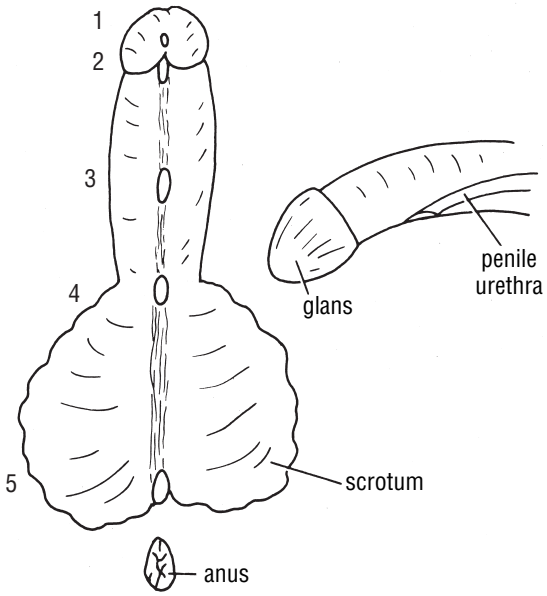
Types 1 and 2 are caused by a failure of the bud of ectodermal cells from the tip of the glans to grow into the substance of the glans and join the entodermal cells lining the penile urethra. Types 3, 4, and 5 are caused by a failure of the genital folds to unite on the undersurface of the developing penis and convert the urethral groove into the penile urethra. In the penoscrotal variety, the genital swellings fail to fuse completely, so that the meatal orifice occurs in the midline of the scrotum. Type 1 requires no treatment; for the remainder, plastic surgery is necessary.

Epispadias

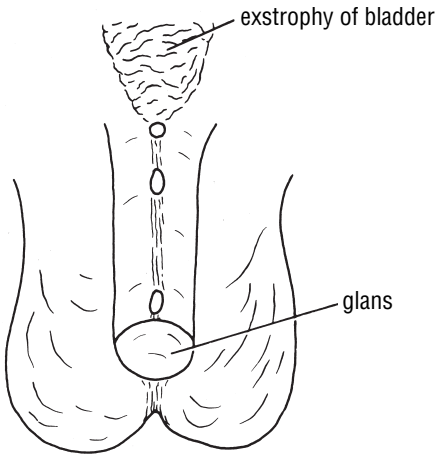
Epispadias is a relatively rare condition and is more commonly found in the male. In the male, the external meatus is situated on the dorsal or upper surface of the penis between the glans and the anterior abdominal wall (CD Fig. 21-9). The most severe type is associated with exstrophy of the bladder. In the female, the urethra is split dorsally and is associated with a double clitoris. It is thought that epispadias is caused by failure of the embryonic mesenchyme to develop in the lower part of the anterior abdominal wall, so that when the cloacal membrane breaks down, the urogenital sinus opens onto the surface of the cranial aspect of the penis. Plastic surgery is the required treatment.



CD Figure 21-7 **A.** Exstrophy of the bladder. **B.** Dorsal view of the embryonic disc. The normal path taken by the growing embryonic mesenchyme in the region of the cloaca is shown. **C.** Fetus as seen from the side. The head and tail folds have developed, but the mesenchyme has failed to enter the ventral body wall between the cloaca and the umbilical cord.



CD Figure 21-8 Types of hypospadias: (1) glandular, (2) coronal, (3) penile, (4) penoscrotal, and (5) perineal. Ventral flexion (chordee) of the penis also is present.



CD Figure 21-9 Types of epispadias.

Clinical Problem Solving Questions

Read the following case histories/questions and give the best answer for each.

A 16-year-old boy received a severe kick in the right flank while playing football at school. On examination in the emergency department, his right flank was severely bruised, and his right costovertebral angle was extremely tender on palpation. A specimen of urine showed microscopic hematuria. A diagnosis of damage to the right kidney was made.

1. The following statements concerning blunt trauma to the kidney are correct **except** which?
   A. The kidney tends to be crushed between the twelfth rib and the vertebral column.
   B. The kidney can be injured by fractures of the twelfth rib (right kidney) or eleventh and twelfth ribs (left kidney).
   C. In most patients the kidney damage is mild and results in nothing more than microscopic hematuria, as in this patient.
   D. In severe kidney lacerations, extensive hemorrhage and extravasation of blood and urine into the pararenal fat occurs.
   E. In severe kidney lacerations, a mass caused by extravasated blood and urine behind the peritoneum may be palpated, especially on the right side.
   F. Both kidneys lie on the posterior abdominal wall and are at the same vertebral level.

A 19-year-old boy was involved in a gang fight. It started as an argument but quickly worsened into a street brawl with the use of knives. He was examined in the emergency department and found to have a bleeding stab wound in his left flank. A urine specimen revealed frank blood.

2. Stab wounds of the kidneys involve other abdominal organs in a high percentage of cases. Of the organs listed, which one is least likely to be damaged in this patient?
   A. Stomach
   B. Spleen
   C. Inferior vena cava
   D. Left colic flexure
   E. Left suprarenal gland
   F. Coils of jejunum
   G. Body of the pancreas

An inebriated 40-year-old man was involved in a fight over a woman. The woman's husband gave the man a severe blow to the lower part of the anterior abdominal wall, whereupon he doubled up with pain and collapsed on the floor. On admission to the emergency department of the local hospital, the man was in a state of shock and

complaining of severe pain in the lower abdominal region. He was unable to pass urine since the fight. A diagnosis of ruptured urinary bladder was made.

3. The following statements concerning this patient are correct **except** which?
   A. Rectal examination revealed a bulging backward of the rectovesical fossa.
   B. Although the patient had consumed a considerable volume of liquor, dullness was not present on percussion of the anterior abdominal wall above the symphysis pubis.
   C. The urine accumulated in the rectovesical pouch.
   D. A full bladder is more likely to be ruptured by a blow to the anterior abdominal wall than an empty bladder.
   E. In the adult, as the normal bladder fills, its superior wall extends upward into the abdomen, leaving the covering of parietal peritoneum behind.

   A 39-year-old woman was admitted to the local hospital after experiencing a gunshot wound to the lower part of her back. Radiographic examination revealed that the bullet was lodged in the vertebral canal at the level of the third lumbar vertebra. A comprehensive neurologic examination indicated that a complete lesion of the cauda equina had occurred.

4. The following statements concerning this patient are likely to be true **except** which?
   A. The cauda equina, which consists of anterior and posterior nerve roots below the level of the first lumbar segment, was sectioned at the level of the third lumbar vertebra.
   B. The preganglionic sympathetic nerve fibers to the vesical sphincter that descend in the anterior roots of the fourth and fifth lumbar nerves were sectioned.
   C. The preganglionic parasympathetic fibers to the detrusor muscle that descend in the anterior roots of the second, third, and fourth sacral nerves were sectioned.
   D. The patient would have an autonomous bladder.
   E. The bladder would fill to capacity and then overflow.
   F. Micturition could be activated by powerful contraction of the abdominal muscles and manual pressure on the anterior abdominal wall in the suprapubic region.

   A 15-year-old boy was taking part in a bicycle race when, on approaching a steep hill, he stood up on the pedals to increase the speed. His right foot slipped off the pedal and he fell violently, his perineum hitting the bar of the bicycle. Several hours later he was admitted to the hospital unable to micturate. On examination, he was found to have extensive swelling of the penis and scrotum. A diagnosis of ruptured urethra was made.

5. The following statements concerning this case are correct **except** which?
   A. Rupture of the bulbous part of the urethra had taken place.
   B. The urine had escaped from the urethra and extravasated into the superficial perineal pouch.
   C. The urine had passed forward over the scrotum and penis to enter the anterior abdominal wall.
   D. The urine had extended posteriorly into the ischiorectal fossae.
   E. The urine was located beneath the membranous layer of superficial fascia.

   A 34-year-old man was suffering from postoperative retention of urine after an appendectomy. The patient's urinary tract was otherwise normal. Because the patient was in considerable discomfort, the resident decided to pass a catheter.

6. The following statements concerning the catheterization of a male patient are correct **except** which?
   A. Because the external urethral orifice is the narrowest part of the urethra, once the tip of the catheter has passed this point, further passage should be easy.
   B. Near the posterior end of the fossa terminalis, a fold of mucous membrane projects from the roof and may catch the end of the catheter.
   C. The membranous part of the urethra is narrow and fixed and may produce some resistance to the passage of the catheter.
   D. The prostatic part of the urethra is the widest and most easily dilated part of the urethra and should cause no difficulty to the passage of the catheter.
   E. The bladder neck is surrounded by the sphincter vesicae and always strongly resists the passage of the tip of the catheter.

7. An explorer in the Amazon jungle was found alive after having lost contact with the outside world for 6 months. On physical examination, he was found to be in an emaciated condition. On palpation of the abdomen, a rounded, smooth swelling appeared in the right loin at the end of inspiration. On expiration, the swelling moved upward and could no longer be felt. What anatomic structure could produce such a swelling?

8. An intravenous pyelogram revealed that a patient's left kidney was in its normal position, but the right kidney was situated in front of the right sacroiliac joint. Can you explain this on embryologic grounds?

9. An examination of a patient revealed that she had a horseshoe kidney. What anatomic structure prevents a horseshoe kidney from ascending to a level above the umbilicus?

10. An intravenous pyelogram revealed that the calyces and pelvis of a patient's right kidney were grossly dilated (a condition known as hydronephrosis). What embryologic anomaly may be responsible for this condition?
11. A 55-year-old woman was found rolling on her kitchen floor, crying out from agonizing pain in her abdomen. The pain came in waves and extended from the right loin to the groin and to the front of the right thigh. An anteroposterior radiograph of the abdomen revealed a calculus in the right ureter. What causes the pain when a ureteral calculus is present? Why is the pain felt in such an extensive area? Where does one look for the course of the ureter in a radiograph? Where along the ureter is a calculus likely to be held up?
12. Which congenital anomaly of the ureter is likely to present as a case of urinary incontinence?
13. Renal pain is a common symptom faced by medical professionals. Describe the course taken by pain nerve fibers from the kidneys. In which regions of the body is pain commonly referred to?
14. In relation to abdominal trauma, can you explain the differences between the bladder position in a child compared with that of an adult? Does the degree of filling of the adult bladder affect the signs and symptoms presented by the patient with a ruptured bladder? Can you explain how it is possible to pass an aspirating needle through the anterior abdominal wall into the full bladder in an adult without entering the peritoneal cavity?
15. Why is acute cystitis more common in females than in males? In anatomic terms explain stress incontinence.

Answers and Explanations

1. **F** is the correct answer. Because of the large size of the right lobe of the liver, the right kidney lies at a lower level than the left kidney.
2. **C** is the correct answer. The inferior vena cava lies at some distance from the left flank.
3. **E** is the correct answer. In the adult, as the normal bladder fills, its superior wall bulges upward into the abdomen, peeling off the peritoneum from the posterior surface of the anterior abdominal wall (see text Fig. 21-17).
4. **B** is the correct answer. The preganglionic sympathetic nerve fibers to the vesical sphincter descend in the anterior roots of the first and second lumbar nerves and were left intact.
5. **D** is the correct answer. The superficial perineal pouch is closed off posteriorly by the attachment of the membranous layer of superficial fascia to the posterior margin of the urogenital diaphragm (see text Fig. 21-15). Because of this attachment, the extravasated urine cannot enter the ischiorectal fossae.
6. **E** is the correct answer. The bladder neck does not cause obstruction to the passage of the catheter. In this patient, the sphincter may provide some minor resistance that is easily overcome.
7. The right kidney was felt. It is the only normal kidney that can be palpated. The lower pole may be felt in a thin person at the end of inspiration, when the contracted diaphragm has pushed it down to its lowest level. When the diaphragm relaxes on expiration, the kidney returns to its original position.
8. Both kidneys originate in the pelvis and with development rise up on the posterior abdominal wall until the hili lie opposite the second lumbar vertebra. Occasionally, one of the kidneys fails to reach its normal position.
9. The bridge of renal tissue, which unites the lower poles of the two kidneys to form the horseshoe, becomes trapped behind the inferior mesenteric artery (see CD Fig. 21-3). The artery arrests the ascent of the kidneys.
10. An aberrant renal artery may cross the pelviureteric junction and obstruct the flow of urine (see CD Fig. 21-3).
11. Spasm of the smooth muscle in the wall of the pelvis and ureter occurs as it attempts to move the calculus down the urinary tract. Afferent pain nerve fibers enter the spinal cord in the first and second lumbar segments. The anterior rami of the first lumbar nerves are distributed in the skin in the lumbar region and groin as the iliohypogastric and ilioinguinal nerves. The pain experienced in the front of the thigh was referred along the femoral branch of the genitofemoral nerve (L1and 2). One could look for the course of the ureter in front of the tips of the transverse processes of the lumbar vertebrae, in front of the sacroiliac joint, and in the region of the spine of the ischium. A calculus is likely to be held up at the pelviureteric junction, where the ureter crosses the pelvic brim and where it enters the bladder.

12. The congenital anomaly is a case of bifid ureters in which one ureter opens into the urinary tract below the bladder sphincter in the male, or into the vagina in the female (see CD Fig. 21-4).

13. Renal pain may result from stretching the renal capsule or spasm of the smooth muscle in the pelvis or the ureter. The afferent nerve fibers pass through the renal plexus around the renal artery and ascend to the spinal cord through the lowest thoracic splanchnic nerve and the sympathetic trunk. They enter the twelfth thoracic spinal nerve through the white rami communicantes and the twelfth thoracic segment of the spinal cord through the posterior root of the spinal nerve. The pain fibers are then believed to ascend to the brain in the lateral spinal thalamic tracts. The pain is referred along the distribution of the subcostal nerve (T12) to the flank and the anterior abdominal wall.

14. In young children, the empty bladder lies in the abdomen; later, as the pelvis enlarges, the bladder sinks to become a pelvic organ.

    In adults, the full bladder lies behind the lower part of the anterior abdominal wall. Severe trauma to the lower abdomen in patients with a full bladder may cause the superior wall of the bladder to rupture into the peritoneal cavity. The blood and urine irritates the peritoneum, causing lower abdominal tenderness and later muscle rigidity.

    When the bladder is empty, the anterior wall of the bladder lies behind the symphysis pubis. Trauma to the lower abdomen in these circumstances may not damage the bladder. However, if the pubic bones are fractured, the anterior wall of the bladder may be damaged by bone fragments, and urine escapes below the reflection of the peritoneum and does not enter the peritoneal cavity. Lower abdominal pain and hematuria are present in the majority of such patients.

    It is possible to pass an aspirating needle through the lower part of the anterior abdominal wall into the full bladder in an adult without entering the peritoneal cavity. This can be explained because as the bladder fills, the superior wall rises and strips the peritoneum off the lower part of the anterior abdominal wall. Thus, the aspirating needle will enter the bladder below the peritoneal reflection and avoid the peritoneal cavity.

15. Acute cystitis is much more common in females than males because the urethra is much shorter. In females the urethra measures 1.5 in. long, whereas in males the urethra measures about 8 in. long, and thus bacteria have a shorter distance to travel in the female.

    Stress incontinence usually follows a difficult childbirth, where there has been injury to the pelvic floor. This results in an alteration in the position of the bladder neck relative to the urethra.