Surgical female urogenital anatomy

AUTHOR: Matthew D Barber, MD, MHS
SECTION EDITOR: Linda Brubaker, MD, FACOG
DEPUTY EDITOR: Kristen Eckler, MD, FACOG

All topics are updated as new evidence becomes available and our peer review process is complete.

Literature review current through: **Sep 2023.**
This topic last updated: **Feb 11, 2021.**

INTRODUCTION

Gynecologic and urologic surgery is frequently performed using a vaginal or perineal approach. Pelvic surgery requires a comprehensive knowledge of the pelvic anatomy to safely attain access, maximize exposure, ensure hemostasis, and avoid injury to viscera, blood vessels, and nerves.

The anatomy of the female lower genital and urinary tract that is clinically pertinent to the pelvic surgeon when operating from a vaginal or perineal approach is reviewed here. Also included is a discussion of the contemporary understanding of female pelvic organ support, with an emphasis on the functional and surgical anatomy of the vagina, urethra, and pelvic floor. The anatomy of the female genital tract and lower urinary and gastrointestinal tracts relevant to the surgeon performing laparotomy or laparoscopy is discussed separately. (See "Surgical female pelvic anatomy: Uterus and related structures".)

SURGICAL PEARLS

Anatomic features that are clinically applicable to female pelvic surgery are indented and bulleted throughout the text.

PELVIC BONES

At birth, the bones that make up the pelvis are the ilium, ischium, pubis, sacrum, and coccyx. The ilium, ischium and pubis fuse by age 16 to 18 years to form a single bone, referred to as the pelvic bone. Thus, in an adult, the bones of the pelvis consist of the right and left pelvic

bones, the sacrum and the coccyx (figure 1 and picture 1). The bony pelvis is the rigid foundation to which all of the pelvic ligaments and muscles are anchored.

Ilium — The most superior component of the pelvic bone is the ilium. The upper part of the ilium expands to form a flat fan-shaped "wing," which provides support for the lower abdomen, and is also called the false pelvis. The medial surface of the ilium has two concavities forming the lateral borders of the pelvic outlet (the inferior opening of the pelvis). The superior and larger of these two concavities is the greater sciatic notch (boundaries are the sacrum, ilium, and ischial spine).

Ischium — The ischium is the posterior and inferior part of the pelvic bone. The posterior margin of the bone is marked by prominent projection called the ischial spine, an important surgical landmark. (See 'Ischial spine' below.)

Sacrum — The sacrum is composed of five sacral vertebrae that are fused together. Nerve foramina are positioned anterior and laterally, through which run the sacral nerves. Overlying the middle of the sacrum is a rich neurovascular bed. The coccyx is attached inferiorly and is the posterior border of the pelvic outlet.

Pubis — The anterior and inferior part of the pelvic bone is the pubis. The superior and inferior pubic rami are located anteriorly and articulate in the midline at the pubic symphysis.

- During pregnancy, there is increased mobility at the pubic symphysis, which may result in pain. Pubic symphysis is an uncommon peripartum complication. (See "Maternal adaptations to pregnancy: Musculoskeletal changes and pain", section on 'Pelvic girdle pain'.)

Orientation of the bony pelvis — Although pelvic surgeons often visualize the orientation of the pelvis in the supine or dorsal lithotomy position, it is important to understand and discuss the bony pelvis from the perspective of a standing woman. In the standing woman, the pelvis is oriented such that the anterior superior iliac spines and the front edge of the pubic symphysis are in the same vertical plane, perpendicular to the floor (figure 2). As a consequence, the pelvic inlet is tilted anteriorly and ischiopubic rami and urogenital hiatus (the gap between the anteromedial borders of the pubococcygeus muscle through which the vagina and urethra pass) (figure 3) are parallel to the ground. In the upright position, the bony arches of the pelvic inlet are oriented in an almost vertical plane. This directs the pressure of the intraabdominal and pelvic contents toward the bones of the pelvis instead of toward the muscles and endopelvic fascia attachments of the pelvic floor. Thus, in the standing position, the bony pelvis is oriented such that forces are dispersed to minimize the pressures on the pelvic viscera and musculature and transmit the forces to the bones that are better suited to the long-term, cumulative stress of daily life. Where the pubic rami

articulate in the midline, they are nearly horizontal. Much of the weight of the abdominal and pelvic viscera is supported by this bony articulation inferiorly.

Surgical landmarks of the bony pelvis — The bones of the pelvis provide a number of important fixed anatomic landmarks that are important to the pelvic surgeon, including the ischial spine, coccyx, pubic arch, pectineal line, and obturator foramen.

Ischial spine — The ischial spine is a sharp bony projection on the medial surface of the ischium that separates the greater sciatic notch from the lesser sciatic notch. The ischial spine is important clinically and anatomically, as it can be palpated easily via the vagina, rectum, or retropubic space and serves as a point of fixation for many structures that are important for pelvic organ support. The tendinous lateral attachments of the levator ani muscle (arcus tendineus levator ani) and the vagina (arcus tendineus fascia pelvis) insert posteriorly onto the ischial spine (figure 3); these tendinous structures overlap, but are distinct structures. Similarly, the ischial spine represents the lateral attachment site of the sacrospinous ligament (figure 1). (See 'Arcus tendineus levator ani' below and 'Endopelvic fascia' below.)

- The sacrospinous ligament attaches to the ischial spine, and the spine is an important landmark during sacrospinous ligament suspension for the repair of prolapse of the vaginal apex. (See "Pelvic organ prolapse in women: Surgical repair of apical prolapse (uterine or vaginal vault prolapse)", section on 'Sacrospinous ligament suspension'.)

- When performing a paravaginal repair, either vaginally or retropubically, the ischial spine can be palpated to identify the proximal location of the lateral vaginal attachment (arcus tendineus fascia pelvis), which is also the most proximal location of the repair.

- When a pudendal block is administered, the ischial spine is palpated and the anesthetic is injected medial and posterior to it (figure 4). (See "Pudendal and paracervical block".)

- During labor and delivery, the ischial spine is palpated to determine the station of the presenting fetal part.

Coccyx — The coccyx is the terminal portion of the sacrum and consists of four fused coccygeal vertebrae. It is palpable transvaginally or transrectally and is a useful landmark surgically during sacrospinous ligament suspension for repair of prolapse of the vaginal apex, since it marks the inferior-medial border of the sacrospinous ligament (figure 1).

Pubic arch — The two pubic bones form an arch beneath the pubic symphysis. The pubic arch serves as the upper and lateral borders of the urogenital triangle under which the distal urethra and vagina exit (figure 5). The mean pubic arch angle is 75 degrees (plus/minus 12 degrees); however, wide variability can be seen (range 44 to 110 degrees) [1].

- A narrow pubic arch is a recognized risk factor for failed vaginal hysterectomy [2]. (See "Hysterectomy: Vaginal".)

Pectineal line — The ridge along the superior, medial surface of the superior pubic rami is called the pectineal line. Anteriorly, this line is continuous with the pubic crest. Overlying the pectineal line is the pectineal ligament, also called Cooper's ligament.

- The pectineal ligament is an important point of attachment for the Burch colposuspension procedure, a surgery to correct female stress urinary incontinence. (See "Female stress urinary incontinence: Choosing a primary surgical procedure".)

Obturator foramen — The obturator foramen is bordered superiorly by the grooved obturator surface of the superior pubic ramus, medially by the body and inferior ramus of the pubis, inferiorly by the ramus of the ischium, and laterally by the anterior border of the body of the ischium. In women, its shape is nearly triangular. The area of the obturator foramen is on average 12.2 cm^2, but can vary considerably (range 7.4 to 18.2 cm^2) [1]. The obturator vessels and nerve pass through the obturator foramen.

Transobturator midurethral slings for treatment of stress urinary incontinence are inserted through the obturator foramens bilaterally and exit through the skin of the groin area. (See "Surgical management of stress urinary incontinence in females: Transobturator midurethral slings".)

PELVIC LIGAMENTS

Two major ligaments link the pelvic bones to the sacrum and coccyx, the sacrotuberous ligament and the sacrospinous ligament (figure 1). These ligaments also convert the two notches on the pelvic bones into foramina on the lateral pelvic walls, the greater and lesser sciatic foramen. The ligaments of the sacro-iliac joint are rarely encountered during pelvic surgery and are not addressed here.

Sacrospinous ligament — The sacrospinous ligament is a strong, triangular-shaped ligament; the apex attaches to the ischial spine laterally and the base attaches to the distal sacrum and coccyx medially. Its average length is 5.3 cm (range 4.4 to 6.6 cm) [3]. This ligament divides the lateral pelvic outlet into two foramina, the greater sciatic foramen superiorly and the lesser sciatic foramen inferiorly. The coccygeus muscle is located on the superior surface of the sacrospinous ligament.

- The sacrospinous ligament is a common attachment point for the vaginal apex for procedures that treat prolapse of the vaginal apex (ie, sacrospinous ligament fixation). Similarly, several commercially available "mesh kits" for treating apical vaginal prolapse place trocars or other fixation devices through the sacrospinous ligament. (See "Pelvic

organ prolapse in women: Surgical repair of apical prolapse (uterine or vaginal vault prolapse)", section on 'Sacrospinous ligament suspension' and "Transvaginal synthetic mesh: Use in pelvic organ prolapse", section on 'Transvaginal mesh kits'.)

There are a number of neurovascular structures in close proximity to the sacrospinous ligament. These must be avoided when placing sutures or trocars in the ligament (figure 6). The pudendal neurovascular bundle passes behind the ischial spine and lateral aspect of the sacrospinous ligament as it exits the pelvis and enters the ischioanal fossa (see 'Pudendal neurovascular bundle' below). The S3 sacral nerve root and/or the pudendal nerve course parallel over the superior border of the sacrospinous ligament. The inferior gluteal artery, a branch of the anterior trunk of the internal iliac, is located, on average, 2.4 cm from the ischial spine and a mean vertical distance of 3.4 mm (range 1 to 5 mm) above the superior border of the sacrospinous ligament [3,4].

Given the close proximity of these structures, the recommended location for suture or trocar placement is at least two fingerbreadths medial to the ischial spine and ideally in the lateral one-third of the ligament safely below its superior border (figure 7). (See "Pelvic organ prolapse in women: Surgical repair of apical prolapse (uterine or vaginal vault prolapse)", section on 'Sacrospinous ligament suspension' and "Pelvic organ prolapse in women: Surgical repair of apical prolapse (uterine or vaginal vault prolapse)", section on 'Iliococcygeus suspension'.)

Sacrotuberous ligament — The sacrotuberous ligament is also a triangular-shaped ligament (figure 1). It has a broad base that extends from the posterior superior iliac spine along the lateral margin of the sacrum and coccyx. The apex of the ligament is attached to the medial margin of the ischial tuberosity. The sacrotuberous ligament forms the lateral-inferior border of the lesser sciatic foramen.

PELVIC MUSCLES

The pelvic muscles include the muscles of the pelvic sidewall and of the pelvic floor.

Muscles of the pelvic sidewall — The obturator internus and piriformis are the muscles of the pelvic sidewalls (figure 3).

Obturator internus muscle — The obturator internus muscle lies on the superior (intrapelvic) side of the obturator membrane. The obturator internus origin is on the inferior margin of the superior pubic ramus and the pelvic surface of the obturator membrane. Its tendon passes through the lesser sciatic foramen to insert onto the greater trochanter of the femur to laterally rotate the thigh. The obturator internus is innervated by the obturator nerve, which originates from L5 to S2.

Piriformis muscle — The piriformis muscle is part of the pelvic sidewall and is located dorsal and lateral to the coccygeus. It extends from the anterolateral sacrum to pass through the greater sciatic foramen and insert on the greater trochanter. Lying on top of the piriformis is a particularly large neurovascular plexus, the lumbosacral plexus.

Muscles of the pelvic floor — The skeletal muscles of the pelvic floor include the levator ani muscles, the coccygeus muscle, the external anal sphincter, the striated urethral sphincter and the deep and superficial perineal muscles (figure 3). The levator ani muscle complex consists of the pubococcygeus (also called pubovisceral), the puborectalis, and iliococcygeus muscles [5,6].

The fusion of levator ani in the midline creates the so-called "levator plate." The urogenital hiatus is the space between the levator ani musculature through which the urethra, vagina, and rectum pass.

The muscles of the pelvic floor, particularly the levator ani muscles, provide support to the pelvic visceral organs and play an integral role in urinary, defecatory, and sexual function.

Arcus tendineus levator ani — There is a linear thickening of the fascial covering of the obturator internus muscle called the arcus tendineus levator ani. This thickened fascia forms an identifiable line from the ischial spine to the posterior surface of the ipsilateral superior pubic ramus. The muscles of the levator ani originate from this musculofascial attachment.

Puborectalis muscle — The puborectalis muscle originates on the pubic bone, and its fibers pass posteriorly, forming a sling around the vagina, rectum and perineal body. This results in the anorectal angle and promotes closure of the urogenital hiatus.

Pubococcygeus muscle — The pubococcygeus muscle originates on the posterior inferior pubic rami and inserts on the midline-visceral organs and the anococcygeal raphe.

Iliococcygeus muscle — The iliococcygeus originates from the arcus tendineus levator ani and inserts in the midline onto the anococcygeal raphe and coccyx.

- Like the sacrospinous ligament, the fascia overlying the iliococcygeus muscle can be used as a fixation point for suspension of the vaginal apex in the treatment of vaginal vault prolapse. Sutures are typically placed 1 to 2 cm medial and 1 cm inferior to the ischial spine in the iliococcygeus fascia bilaterally (figure 7) [7].

Pelvic floor muscle function and shape — Pelvic floor muscles have a constant resting tone except during voiding, defecation, and the Valsalva maneuver. This activity serves to close the urethral and anal sphincters, narrow the urogenital hiatus, and provide a constant support for the pelvic viscera. The levator muscles and the skeletal components of the urethral and anal sphincters all have the ability to contract quickly at the time of an acute

intraabdominal pressure, such as a cough or sneeze, in order to maintain continence and to relax during evacuation.

The levator ani muscles are depicted in most anatomy figures shaped like a bowl or "funnel-shaped," but this is the uncontracted state of the muscles as might be seen in a cadaver dissection. In a woman with normal pelvic floor function, the levator ani muscle complex is in a tonically contracted state and has an intricate three-dimensional structure. The anterior portion of the muscle complex (pubococcygeus and puborectalis muscles) is oriented vertically as a sling around the mid-urethra, vagina and anorectum, and the posterior portion (iliococcygeus muscle) has a horizontal upwardly biconvex shape resembling the appearance of a "butterfly wing" (figure 8) [8]. Thus, the anterior portion of the levator ani complex serves to close the urogenital hiatus and pull the urethra, vagina, perineum and anorectum toward pubic bone, while the horizontally oriented posterior portion (levator plate) serves as a supportive diaphragm or "backstop" behind the pelvic viscera.

Loss of normal levator ani tone, through denervation or direct muscle trauma, results in a more open urogenital hiatus, loss of the horizontal orientation of the levator plate, and a more bowl-like configuration. These changes can be bilateral or asymmetric [9]. Such configurations are seen more often in women with pelvic organ prolapse than in women with normal pelvic organ support [8].

PELVIC NERVES AND VASCULATURE

Levator ani nerve — The levator ani nerve originates from S3, S4, and/or S5 and innervates both the coccygeus muscle and the levator ani muscle complex [3,10]. After exiting the sacral foramina, it travels 2 to 3 cm medial to the ischial spine and arcus tendineus levator ani across the superior (intrapelvic) surface of the coccygeus, iliococcygeus, pubococcygeus, and puborectalis muscles (figure 9). In some women, a separate nerve comes directly from S5 to innervate the puborectalis muscle independently [10]. There is some controversy about whether the pelvic floor muscles also receive some of their innervation from branches from the pudendal nerve [10-15].

- Given its location, the levator ani nerve is susceptible to injury through parturition and some pelvic reconstructive surgery. Specifically, the fixation points used in the sacrospinous ligament fixation and the iliococcygeus vaginal vault suspensions are in close proximity to the course of the levator ani nerve. However, the impact that potential injury has on the long-term anatomic and functional success of these procedures is currently unknown. (See "Pelvic organ prolapse in women: Surgical repair of apical prolapse (uterine or vaginal vault prolapse)", section on 'Vaginal surgical approach'.)

Pudendal neurovascular bundle — The pudendal nerve innervates the striated urethral and anal sphincters, as well as the deep and superficial perineal muscles, and provides sensory innervation to the external genitalia. The pudendal nerve originates from S2 to S4 (with S3 providing the largest contribution) sacral nerve trunks.

The internal pudendal artery is the main arterial supply of the perineum. The pudendal artery courses inferiorly from its origins in the anterior trunk of the internal iliac artery (figure 6). The internal pudendal artery and a contribution from the external pudendal artery, which originates from the femoral artery, provide a rich blood supply to the perineum (figure 10).

- It is this rich collateral anastomosis that allows a Martius flap to be utilized by pelvic surgeons. (See "Urogenital tract fistulas in females" and "Rectovaginal and anovaginal fistulas", section on 'Modified Martius graft'.)

Together, the pudendal vessels and nerve follow a complex course as they leave the pelvis. With the nerve oriented medially and the vessels laterally, the pudendal neurovascular bundle travels behind the sacrospinous ligament just medial to the ischial spine to exit the pelvis through the greater sciatic foramen (figure 1). The nerves and vessels then enter the ischioanal fossa through the lesser sciatic foramen, travel through the pudendal canal (Alcock canal) on the medial aspect of the obturator internus muscles before emerging in the perineum, where each separates into several branches that terminate within the muscles and skin of the perineum and the clitoris.

The anterior branches of the pudendal nerve include the perineal nerve and the dorsal nerve of the clitoris (figure 11). These anterior branches enter the perineum just medial to the ischial tuberosity on either side. The dorsal nerve of the clitoris and associated artery can consistently be found posterior to the midsegment of the clitoral crus. They emerge into the anterior perineal triangle by piercing the perineal membrane adjacent to the medial surface of the ischiopubic rami. The posterior branch, the inferior rectal nerve, provides innervation to the external anal sphincter and perianal skin. The inferior rectal nerve and vessels traverse the ischioanal fossa medially as they course toward the anus.

OBTURATOR ANATOMY

There is an increasing number of procedures used to correct female stress urinary incontinence and pelvic organ prolapse that access the pelvis using a transobturator approach. As such, it is important that the surgeons using these techniques have a thorough understanding of the anatomy of this region. The obturator foramen has been described above.

Obturator membrane — The obturator membrane is a thick, flat connective tissue membrane that spans the obturator foramen. A small opening in the membrane, known as the obturator canal, is found in the anterior-superior edge of the obturator foramen.

Obturator canal — At the top of the obturator foramen is the obturator canal. The obturator canal is bordered anteriorly by the inferior surface of the superior pubic ramus and elsewhere by the obturator membrane and adductor muscles of the thigh. The obturator neurovascular bundle passes from the pelvic cavity to the medial compartment of the thigh via the obturator canal.

Muscles of the obturator space — The muscles of the medial thigh and adductor compartment are, from superficial to deep: the gracilis, adductor longus, adductor brevis, adductor magnus, and obturator externus muscles (figure 12) [16]. Deep to this is the obturator membrane. The obturator internus muscle lies on the superior (intrapelvic-pelvic) side of the obturator membrane (see above). The adductor longus tendon originates from a triangular depression just inferior to the pubic crest and lateral to the pubic symphysis. This tendon is readily palpable when a patient is in dorsal lithotomy position and serves as an important landmark for the placement of transobturator slings for treatment of stress urinary incontinence. Transobturator sling trocars are inserted just lateral to the inferior pubic ramus in the area just below the adductor longus tendon.

Obturator neurovascular bundle — The obturator artery and vein originate as branches of the internal iliac vessels. As they emerge from the cranial side of the obturator membrane via the obturator canal and enter the obturator space, they divide into many small branches supplying the muscles of the adductor compartment of the thigh. The vessels are predominantly small (<5 mm diameter) and splinter into variable courses [16]. In contrast to the vessels, the obturator nerve emerges from the obturator membrane and bifurcates into anterior and posterior divisions traveling distally down the thigh to supply the muscles of the adductor compartment. With the patient in the dorsal lithotomy position, the nerves and vessels follow the thigh and course laterally away from the ischiopubic ramus [16]. The distance from the mid-point of the ischiopubic ramus to the obturator canal ranges from 4.2 to 5.5 cm [16]. Variability in obturator foramen size and shape likely has a direct effect on this distance [1].

PERINEUM

The area between the vagina and anus is often clinically referred to as the "perineum"; however, anatomically, the perineum is the entirety of the pelvic outlet inferior to the pelvic floor. The area between the vagina and anus is more aptly termed "the perineal body."

The borders of the anatomic female perineum are the ischiopubic rami, ischial tuberosities, sacrotuberous ligaments, and coccyx. An imaginary line connecting the ischial tuberosities divides the perineum into the urogenital triangle anteriorly and the anal triangle posteriorly. In the standing position, the urogenital triangle is oriented horizontally and the anal triangle is tilted upward so that it faces more posteriorly (figure 13).

Perineal membrane — The perineal membrane is a thick fibrous sheet that spans the urogenital triangle (figure 14). It attaches laterally to the pubic arch and has a free posterior margin anchored in the midline by the perineal body. Although anatomists and clinicians have historically used the term urogenital diaphragm to describe this structure, this term has been abandoned, as it erroneously implies a muscular diaphragm rather than a thick sheet of connective tissue [17,18].

The urethra and vagina penetrate through a hiatus in the perineal membrane (the urogenital hiatus) to exit at the vestibule. The perineal membrane, therefore, provides fixation of distal urethra, distal vagina and perineal body to the pubic arches.

Urogenital triangle — The urogenital triangle is divided into a superficial and deep perineal space by the perineal membrane. The superficial perineal space contains the superficial perineal muscles (ischiocavernosus, bulbospongiosus, superficial transverse perineal muscles), the erectile tissue of the clitoris, the vestibular bulbs, and Bartholin glands (figure 13). The deep perineal space lies just deep to the perineal membrane and inferior to the levator ani muscles.

Within the deep perineal space lie the external urethral sphincter and the urethrovaginalis, compressor urethrae, and deep transverse perineal muscles (figure 15) [17,19]. The urethrovaginalis and compressor urethrae muscles provide accessory sphincter function to the urethra [19]. The urethrovaginalis muscles surround the distal urethra and vagina without passing between them, and therefore act as a sphincter to the vagina as well the distal urethra [17].

The deep transverse perineal muscle, along with its superficial counterpart, serves to stabilize the position of the perineal body and inferior border of the perineal membrane. However, there is some dispute as to whether the deep transverse perineal muscle is present in females [17].

Perineal body — The perineal body marks the point of convergence of the bulbospongiosus muscles, superficial and deep transverse perinei, perineal membrane, external anal sphincter, posterior vaginal muscularis and fibers from the puborectalis and pubococcygeus muscles. The perineal body plays an important role in support of the distal vagina and in normal anorectal function. The vascular and nerve supply to the perineum, including the deep and superficial perineal spaces, is provided by the pudendal neurovascular bundle.

Anal triangle — The anal triangle is formed laterally by the medial margins of the sacrotuberous ligaments, anteriorly by the inferior edge of the perineal membrane and perineal body, and posteriorly by the coccyx. The superior extent of the anal triangle is the levator ani muscles. The anal canal and anal sphincter muscles are located in the middle of the anal triangle. Lateral to the anal sphincter, complex on each side, is the ischioanal fossa.

Ischioanal fossa — The ischioanal fossa, previously termed the ischiorectal fossa, is the space inferior to the levator ani muscles and superior to the perineum [20]. This fossa resembles two inverted wedge-shaped gutters, filled primarily with adipose tissue, that lie on either side of the anal aperture and urogenital hiatus. The lateral wall of each fossa is formed by the ischium, obturator internus muscle, and sacrotuberous ligament. The medial wall is the levator ani muscle. The ischioanal fossa allows movement of the pelvic floor and expansion of the anal canal during defecation. Along the lateral border of the ischioanal fossa is the pudendal canal, a fascial tunnel approximately 4 cm in length along the obturator internus muscle [10].

- Clinically, infections of the anal canal sinuses or crypts can spread into the ischioanal fossa, resulting in large abscesses. Additionally, some commercially available kits for correction of pelvic organ prolapse use trocars that pass through this space toward the sacrospinous ligament to suspend the vaginal apex.

LOWER GENITAL TRACT

The female lower genital tract consists of the vulva and vagina.

The anatomy of the upper genital tract, comprised of the cervix, uterine corpus, fallopian tubes, and ovaries, is discussed separately. (See "Surgical female pelvic anatomy: Uterus and related structures", section on 'Genital tract viscera'.)

Vulva (external female genitalia) — The vulva, or external female genitalia, includes the labia majora, labia minora, clitoris, vulvar vestibule, external urethral meatus, and vaginal orifice (figure 16).

The labia minora bifurcate anteriorly to form medial and lateral folds. The lateral folds unite ventrally over the clitoris to form the prepuce of the clitoris. The components of the clitoris include the glans, body, and paired crura. The clitoral body is comprised of paired erectile tissue structures, which originate from each crus. The proximal clitoral body is found cephalad to the midpubic arch on the anterior surface of the pubic symphysis. The crura run bilaterally along the ischiopubic rami. The mean length of the clitoral body is 2.9 cm (range 1.3 to 5.9 cm), and the length of the crura is on average 5.0 cm (range 2.5 to 6.8 cm) [21].

The vulvar vestibule is the area enclosed by the labia minora into which the urethra and vagina open. Within the vestibule, the ducts of the Skene (paraurethral) glands open on each side of the lateral margin of the urethra. The ducts of the Bartholin glands (greater vestibular glands) open on the posterior lateral margin of the vaginal opening at the four and eight o'clock positions (figure 17). Blockage of the Skene or Bartholin glands ducts can result in cysts or abscesses. (See "Bartholin gland masses".)

The hymen is a ring-like membrane that surrounds the vaginal orifice and typically has one or more central perforations (figure 18). After rupture of the hymen, from sexual intercourse or trauma, fringe-like hymenal remnants persist surrounding the vaginal opening. Congenital anomalies of the hymen, such as imperforate hymen, can occur which may require surgical correction. (See "Congenital anomalies of the hymen and vagina".)

Vagina — The vagina is a hollow, distensible, fibromuscular tube with rugal folds that extends from the vestibule to the uterine cervix. The longitudinal shape of the vagina resembles a trapezoid, narrowest at the introitus and becoming progressively wider as it approaches the vaginal apex and cervix. In the transverse plane, the vagina has a box-like configuration at its distal end (toward the introitus) and is flattened proximally. In the sagittal plane, the vagina has a distinct angulation. The upper two-thirds of the vagina angles toward the third and fourth sacral vertebrae and is almost horizontal in the standing position (figure 19). In contrast, the lower one-third is nearly vertical as it passes through the perineal membrane to the vestibule. The angle between the upper and lower axis of the vagina is approximately 130° [22].

There is considerable variability in the length, size, and width of the vagina among women. Based on magnetic resonance imaging studies of women with normal support, the average length of the anterior vaginal wall is 6.3 cm with a wide range: 4.4 to 8.4 cm. Similarly, the average length of the posterior vaginal wall is 9.8 cm with a range of 5.1 to 14.4 cm [23]. The vaginal width is largest at its cranial portion and decreases as it passes through the pelvic diaphragm to be smallest at the introitus. There are large variations in transverse dimensions, and, in one study, as much as a fivefold variation seen in total vaginal surface area (34 to 164 cm^2).

Histologically, the vaginal wall is composed of three layers: mucosa, muscularis, and adventitia [24,25]. The vaginal mucosa is the inner layer and consists of stratified squamous epithelium and a lamina propria. The lamina propria contains no glands. Coursing through the lamina propria are small blood vessels. Vaginal lubrication is via a transudate from the vessels, cervix, and from the Bartholin and Skene glands. The vaginal muscularis is a well-developed fibromuscular layer consisting primarily of interdigitating smooth muscle bundles with smaller amounts of collagen, elastin, and vascular tissue [24,25]. The outermost adventitia is a mixed layer of collagen, elastin, and adipose tissue containing blood vessels,

lymphatics, and nerves. The adventitia represents an extension of the visceral endopelvic fascia that surrounds the vagina and adjacent pelvic organs and allows for their independent expansion and contraction.

The terms pubocervical fascia and rectovaginal fascia have been used to describe the layer separating the vagina from the bladder and rectum, respectively. Although these terms are widely used, the use of the term "fascia" is a misnomer, as it does not accurately reflect the histology of the vagina. Numerous histological analyses of the vaginal wall have failed to identify a distinct "fascial" layer [18,24,25]. Between the adjacent pelvic organs is primarily vaginal muscularis. The "fascia" often noted by pelvic surgeons during vaginal dissection, in fact, refers to layers that are developed as a result of separating the vaginal epithelium from the muscularis, or by splitting the vaginal muscularis layer [24]. The only area in which there does appear to be dense connective tissue separating the vagina from an adjacent organ is the distal posterior vaginal wall. The connective tissue of the perineal body extends 2 to 4 cm cephalad from the hymenal ring along the posterior vaginal wall between the smooth muscle layers of the vagina and the rectum [18]. This layer does not, however, extend the full length of the posterior vaginal wall.

LOWER URINARY TRACT

The structures of the urinary system located within the pelvis include the urethra, bladder, and distal portion of the ureters (figure 20).

Urethra — The female urethra connects the bladder to the vulva (figure 21). It averages approximately 2 to 3 cm in length and 6 mm in diameter. The junction of the urethra to the bladder is called the bladder neck, or vesical neck. The urethra then continues its course fused to the vagina for its distal two-thirds, and terminates at the external urethral meatus in the vulvar vestibule directly above the vaginal introitus. The female urethra is slightly curved as it passes from the bladder in the retropubic space, through the perineal membrane, to the vestibule.

Histologically, the urethra has four distinct layers: mucosa, submucosa, internal urethral sphincter (smooth muscle) and striated external urethral sphincter. The submucosal layer is highly vascular. The blood supply of the urethra derives from extensions of the pudendal vessels and the vesical vessels [26]. These vascular cushions, along with the urethral mucosa, account for approximately a third of the urethral resting tone, while the internal and external urethral sphincters account for the remainder [27].

The internal urethral sphincter is primarily composed of oblique and longitudinal smooth muscle fibers, with a few circularly oriented outer fibers. The precise function of this longitudinal smooth muscle is not known, however, it has been suggested that these

longitudinal fibers serve as "filler volume" within the circular smooth muscle and striated urethral sphincter, whose presence improves the efficiency of the sphincter mechanism by allowing closure of the urethral lumen with only a small amount of circular muscle shortening [28].

The skeletal muscle component of the urethral sphincter consists of the external urethral sphincter (also called sphincter urethrae), as well as the compressor urethrae and the urethrovaginalis muscle described previously (figure 22). These three muscles, which function as a single unit, have been called the striated urogenital sphincter [19]. Together, they are approximately 2.5 cm in length and encircle the urethra in its mid-portion from just below the bladder neck to the perineal membrane within the deep perineal space. The striated urogenital sphincter provides approximately one-third of urethral resting tone and is responsible for the voluntary and reflex increases in intraurethral pressure needed to maintain continence. The smooth muscle portion of the urethra is innervated by the autonomic nerves of the pelvic plexus, while the striated urethral sphincter is innervated by branches of the pudendal nerve [29].

Normal urethral function depends upon normal support of the urethra, as well as its intrinsic sphincter mechanism. As with vaginal support, dynamic interaction between the levator ani muscle complex and the connective tissue supports of the urethra is essential. The urethra lies on a hammock-like supportive layer composed of periurethral endopelvic fascia and anterior vaginal wall [30]. Increased intraabdominal pressure, as with a cough or sneeze, causes compression of the urethra against this hammock-like layer thereby compressing and closing the urethral lumen. The stability of the suburethral layer depends upon the intact connection of the anterior vaginal wall and its connective tissue attachments to the arcus tendineus fascia pelvis and levator ani muscles. These attachments allow the pelvic floor muscle's normal resting tone to maintain the position of the urethra and bladder neck. They are also responsible for the posterior movement of the vesical neck seen at the onset of micturition (when the pelvic floor relaxes) and for the elevation noted when a patient is instructed to arrest the urinary stream. Defects in these attachments can result in proximal urethral support defects (urethral hypermobility) and anterior vaginal prolapse (cystocele), and contribute to stress urinary incontinence. (See "Female urinary incontinence: Evaluation" and "Pelvic organ prolapse in women: Surgical repair of anterior vaginal wall prolapse".)

Bladder — The bladder is located in the midline, posterior to the pubic bone. The bladder is separated from the pubic bone by a potential space, called the retropubic space, or the space of Retzius, which contains the venous plexus of Santorini.

The boundaries of the bladder include the pubic symphysis anteriorly, the pelvic sidewalls laterally, and the lower uterine segment and vagina posteriorly. The inferior boundary of the bladder is the lower uterine segment and anterior cervix. The superior border of the bladder

roughly corresponds to the obliterated umbilical arteries and urachus. In the fetus, the urachus connects the developing bladder to the umbilicus. Postnatally, the urachus involutes and becomes the median umbilical ligament, which anchors the apex of the bladder to the anterior abdominal wall. Occasionally, the urachus remains patent. (See "Care of the umbilicus and management of umbilical disorders", section on 'Urachal anomalies'.)

The dome of the bladder is contiguous with the parietal peritoneum of the anterior abdominal wall. Inferiorly, the peritoneum sweeps off the bladder into the vesicouterine pouch. The remainder of the bladder is retroperitoneal.

The bladder is quite distensible. When empty, the bladder is pyramid-shaped, with the apex pointed toward the pubic bone. When full, the bladder is spherical, with normal capacities ranging from 400 to 500 mL, and can transform from being a pelvic organ to an abdominal one, rising above the pubic bone.

- When the bladder is distended, the musculature of the dome can become relatively thin. Thus, prior to initiating a pelvic surgical procedure, decompression of the bladder using a bladder catheter can help avoid injury.

The regions of the bladder include the dome, superiorly, and the base, inferiorly. The base of the bladder lies directly on the anterior vaginal wall and consists of the trigone and detrusor loop, a thickening of the detrusor muscle, the thickness of which does not vary with filling of the bladder.

The bladder trigone is a triangular area at the base of the bladder bounded by the internal urethral meatus and the two ureteric orifices. The ureteric orifices and the internal urethral meatus are equidistant from each other with each side of the trigone measuring approximately 3 cm (figure 23) [31]. The superior border of the trigone between the ureteric orifices is raised and known as the intraureteric ridge. During hysterectomy, inadvertent bladder injury may occur during dissection of the vesicovaginal space. Such injuries are commonly located just superior to the intraureteric ridge in the midline.

- Injury to the bladder dome may occur during peritoneal entry for laparotomy or suprapubic port placement during a laparoscopy.

- Injury to the inferior regions of the bladder may occur during hysterectomy when the bladder is dissected off the lower uterine segment and cervix. The most common site of injury during this dissection is in the midline just superior to the intraureteric ridge. Risk factors for this type of injury include conditions that cause scar tissue in the vesicouterine pouch, such as cesarean delivery, bladder surgery (eg, anterior colporrhaphy), pelvic infection, endometriosis, distorted anatomy from fibroids or malignancy, or prior pelvic radiation. An elongated cervix may also predispose the

patient to bladder injury, as the surgeon may not dissect the bladder as far caudally as necessary prior to performing the colpotomy or placing the vaginal cuff sutures, or by necessitating repeat dissections of the vesicovaginal space.

Histologically, the bladder is lined by three layers: mucosa, muscle, and adventitia. The bladder mucosa consists of a transitional cell epithelium and underlying lamina propria, and is also known as the urothelium. The muscular layer, or the detrusor muscle, consists of interlacing bundles of smooth muscle. This plexiform arrangement of detrusor muscle bundles is ideally suited to reduce all dimensions of the bladder lumen on contraction. The outer adventitial layer primarily consists of adipose tissue and loose connective tissue.

The blood supply to the bladder includes the superior and inferior vesical arteries, which are branches of the anterior trunk of the internal iliac artery. Bladder innervation is provided by the parasympathetic and sympathetic autonomic fibers of the pelvic and hypogastric nerve plexuses, respectively.

Ureters — The ureters are retroperitoneal structures that run from the renal pelvis to the bladder. They are approximately 25 to 30 cm in length from the renal pelvis to the trigone of the bladder. The pelvic brim divides them into abdominal and pelvic segments, each of which is approximately 12 to 15 cm in length.

The pelvic ureters can be injured during pelvic surgery (figure 24). The pelvic course of the ureters and most common sites of injury from superior to inferior can be summarized as follows [32-34]:

- The ureters enter the pelvis at the pelvic brim where they cross from lateral to medial, as well as anterior to the bifurcation of the common iliac arteries (picture 2). The left ureter is often obscured by the sigmoid colon, and visualization can be facilitated by sharply incising the sigmoid colon attachments to the left pelvic sidewall.

  The ureters travel into the pelvis along with the ovarian vessels (picture 3), making the identification of the ureter imperative prior to performing an oophorectomy [35].

  - The ureter usually lies posterior and medial to the infundibulopelvic ligament, but in cases where it lies in close proximity to the ovarian vessels, it may be necessary to open the retroperitoneal space lateral to the infundibulopelvic ligament and create a window between the ovarian vessels and the ureter in order to safely secure the ovarian vascular pedicle.

  - In the case of salpingo-oophorectomy at the time of hysterectomy, opening the broad ligament between the round ligament and the infundibulopelvic ligament provides excellent retroperitoneal access and opportunity to identify the ureter.

- The ureters then descend into the pelvis within a peritoneal sheath (ureteric fold) attached to the medial leaf of the uterine broad ligament and the lateral pelvic sidewall (figure 25 and figure 26).

- Just inferior to the internal cervical os, the ureter passes under the uterine arteries ("water under the bridge"), along the lateral side of the uterosacral ligament, approximately 1.5 cm lateral to the internal cervical os (figure 24). The ureter then courses medially as the uterosacral ligament is traced from the sacrum toward the vagina. At the level of the ischial spine, the ureter is approximately 2.3 cm lateral to the uterosacral ligament [36]. The ureter is closest to the uterosacral ligament at its distal end, approximately 1 cm.

- The ureter passes through the areolar tissue of the tunnel of Wertheim (ie, the cardinal ligament/anterior bladder pillar) to the anterolateral surface of the cervix (figure 27).

- The ureters then pass close to the anterolateral fornix of the vagina and enter the posterior aspect of the bladder 5 to 6 cm apart and run obliquely through the bladder wall for 1.5 cm before terminating at the trigone.

The ureter is supplied by the blood vessels it crosses (ie, the ovarian, internal iliac, superior vesical, and inferior vesical arteries). Above the pelvic brim, the blood supply enters from the medial side while below the pelvic brim the blood supply enters laterally.

- During ureterolysis, the surgeon can avoid ischemic injuries by staying outside of the adventitial sheath surrounding the ureter, although this may be difficult to do in the setting of malignancy, or significant scarring or fibrosis as a result of endometriosis or prior pelvic radiation.

Partial or complete duplication of the ureter may be present in approximately 1 percent of patients [37]. Duplications may be partial or complete. Partial duplications are characterized by the duplicate ureters joining before entering the bladder. (See "Overview of congenital anomalies of the kidney and urinary tract (CAKUT)", section on 'Duplication'.)

- The existence of a urinary tract anomaly may not even be known prior to undertaking pelvic surgery, but every effort should be made to identify the ureter in the normal location. If the patient has a history of a müllerian or urinary tract anomaly (eg, a solitary kidney), preoperative imaging with an intravenous pyelogram may prepare expectations of what or where the surgeon may find the ureters intraoperatively [38].

Prevention, evaluation, and management of ureteral injury during gynecologic surgery are discussed in detail separately. (See "Urinary tract injury in gynecologic surgery: Epidemiology and prevention" and "Urinary tract injury in gynecologic surgery: Identification and management".)

MECHANISMS OF PELVIC ORGAN SUPPORT

Support of the vagina and uterus — The normal axis of the pelvic organs in the standing woman places the upper two-thirds of the vagina directly over the levator plate.

Endopelvic fascia — The endopelvic fascia is the loose connective tissue network that envelops all of the organs of the pelvis and connects them loosely to the supportive musculature and bones of the pelvis. Histologically, it is composed of collagen, elastin, adipose tissue, nerves, vessels, lymph channels, and smooth muscle. This connective tissue network tethers the vagina and uterus in their normal anatomic location, yet allows for the mobility of the viscera to permit storage of urine and stool, coitus, parturition, and defecation.

Several areas of the endopelvic fascia (and its associated peritoneum) have been named by anatomists. These are really condensations of the endopelvic fascia and not true ligaments: uterosacral ligament, cardinal ligament, broad ligament, mesovarium, mesosalpinx, and the round ligament. The broad ligament, mesovarium, mesosalpinx, and round ligament do not play a role in support of the pelvic organs.

Level I support — Three levels of connective tissue supports of the vagina have been described (figure 28A-B) [39]. The uterosacral/cardinal ligament complex, which comprises level I support, is an intricate three-dimensional connective tissue structure that originates at the cervix and upper vagina and inserts at the pelvic sidewall and sacrum. Magnetic resonance images of healthy women reveal that the uterosacral ligament inserts in the area of the coccygeus muscle and sacrospinous ligament in most women, with only 7 percent actually inserting into the sacrum [40]. The uterosacral/cardinal ligament complex suspends the uterus and upper vagina in its normal orientation. It serves to maintain vaginal length and keep the vaginal axis nearly horizontal in a standing woman so that it can be supported by the levator plate. Loss of Level I support contributes to prolapse of the uterus and/or vaginal apex.

Level II support — Contiguous with the uterosacral/cardinal ligament complex at the location of the ischial spine is Level II support, the paravaginal attachments. The anterior vaginal wall is suspended laterally to the arcus tendineus fascia pelvis (ATFP) or "white line," which is a thickened condensation of fascia overlying the iliococcygeus muscle. The ATFP originates on the ischial spine and inserts on the inferior aspect of the pubic symphysis. The ATFP overlaps the arcus tendineus levator ani proximally from the ischial spine, but they diverge distally as they approach the pubic symphysis. The anterior Level II supports suspend the mid-portion of the anterior vaginal wall creating the anterior lateral vaginal sulci. Detachment of these lateral supports can lead to paravaginal defects and prolapse of the anterior vaginal wall.

Similar to the anterior paravaginal supports, there are posterior lateral supports at Level II, as well. The posterior vaginal wall is attached laterally to the pelvic sidewall in a slightly more complex arrangement than the anterior vaginal wall. The distal half of the posterior vaginal wall fuses with the aponeurosis of the levator ani muscle from the perineal body along a line referred to as the arcus tendineus rectovaginalis. It converges with the ATFP at a point approximately midway between the pubic symphysis and the ischial spine [41]. Along the proximal half of the vagina, the anterior and posterior vaginal walls are both supported laterally to the ATFP. Thus, in the proximal vagina, the lateral supports for the anterior and posterior vaginal wall are identical. This arrangement accounts for the H-shape or box-like configuration of distal vagina when viewed in cross-section and the flattened tube configuration seen in upper vagina (figure 28A-B).

Level III support — Level III support is provided by the perineal membrane, the muscles of the deep perineal space and the perineal body. These structures support and maintain the normal anatomical position of the urethra and distal one-third of the vagina, which, in a standing woman, is perpendicular to the floor. Anteriorly, the vagina fuses with the urethra at Level III, and posteriorly, with the perineal body. Disruption of Level III support anteriorly can result in urethral hypermobility and stress incontinence, and disruption posteriorly may result in distal rectoceles and/or perineal descent.

Interactions between the muscular and connective tissue supports — Normal pelvic organ support and function depend upon dynamic interaction between the pelvic floor musculature and the endopelvic fascia. In a standing woman, the endopelvic fascia suspends the upper vagina, the bladder, and the rectum over the levator plate while the pelvic floor muscles close the urogenital hiatus and provide a stable platform on which the pelvic viscera rests. Intraabdominal and gravitational forces are applied perpendicular to the vagina and pelvic floor while the pelvic floor musculature counters those forces with its constant tone by closing. With proper tone of the pelvic floor muscles, stress on the connective tissue attachments is minimized. Furthermore, in times of acute stress, such as a cough or sneeze, there is a reflex contraction of the pelvic floor musculature countering and further stabilizing the viscera. The urogenital hiatus also responds by narrowing to maintain Level III support. With pelvic floor weakness, such as neuropathic injury or mechanical muscular damage, there is loss of the horizontal orientation of the levator plate, the urogenital hiatus opens, and pelvic floor assumes a more bowl-like configuration. The endopelvic fascia then becomes the primary mechanism of support. Over time, this stress can overcome the endopelvic fascial attachments and result in loss of the normal anatomical position through breaks, stretching, or attenuation of these connective tissue supports. This can result in changes in the vector forces applied to the viscera and may lead to pelvic organ prolapse and/or dysfunction.

SUMMARY

- Pelvic surgery in women requires a comprehensive knowledge of the pelvic anatomy to safely attain access, maximize exposure, ensure hemostasis, and avoid injury to viscera, blood vessels, and nerves. (See 'Introduction' above.)

- The bones of the pelvis consist of the right and left pelvic bones, the sacrum and the coccyx (figure 1 and picture 1). The bony pelvis is the rigid foundation to which all of the pelvic ligaments and muscles are anchored. (See 'Pelvic bones' above.)

- The obturator internus and piriformis are the muscles of the pelvic sidewalls (figure 3). (See 'Muscles of the pelvic sidewall' above.)

- The skeletal muscles of the pelvic floor include the levator ani muscles, the coccygeus muscle, the external anal sphincter, the striated urethral sphincter and the deep and superficial perineal muscles (figure 3). The levator ani muscle complex consists of the pubococcygeus (also called pubovisceral), the puborectalis, and iliococcygeus muscles. (See 'Muscles of the pelvic floor' above.)

- The levator ani nerve originates from S3, S4, and/or S5 and innervates both the coccygeus muscle and the levator ani muscle complex (figure 9). The pudendal nerve innervates the striated urethral and anal sphincters, as well as the deep and superficial perineal muscles, and provides sensory innervation to the external genitalia. The pudendal nerve originates from S2 to S4 (with S3 providing the largest contribution) sacral nerve trunks (figure 6). (See 'Pelvic nerves and vasculature' above.)

- The female lower genital tract consists of the vulva and vagina. (See 'Lower genital tract' above.)

- The structures of the urinary system located within the pelvis include the urethra, bladder, and distal portion of the ureters (figure 20). The ureters are retroperitoneal structures that run from the renal pelvis to the bladder. Knowledge of their course is important to avoid injury during pelvic surgery. (See 'Lower urinary tract' above.)

REFERENCES

1. Ridgeway BM, Arias BE, Barber MD. Variation of the obturator foramen and pubic arch of the female bony pelvis. Am J Obstet Gynecol 2008; 198:546.e1.
2. Harmanli OH, Khilnani R, Dandolu V, Chatwani AJ. Narrow pubic arch and increased risk of failure for vaginal hysterectomy. Obstet Gynecol 2004; 104:697.

3. Roshanravan SM, Wieslander CK, Schaffer JI, Corton MM. Neurovascular anatomy of the sacrospinous ligament region in female cadavers: Implications in sacrospinous ligament fixation. Am J Obstet Gynecol 2007; 197:660.e1.
4. Netter FH. Atlas of Human Anatomy, 6, Saunders, 2014.
5. Kearney R, Sawhney R, DeLancey JO. Levator ani muscle anatomy evaluated by origin-insertion pairs. Obstet Gynecol 2004; 104:168.
6. Lawson JO. Pelvic anatomy. I. Pelvic floor muscles. Ann R Coll Surg Engl 1974; 54:244.
7. Meeks GR, Washburne JF, McGehee RP, Wiser WL. Repair of vaginal vault prolapse by suspension of the vagina to iliococcygeus (prespinous) fascia. Am J Obstet Gynecol 1994; 171:1444.
8. Singh K, Jakab M, Reid WM, et al. Three-dimensional magnetic resonance imaging assessment of levator ani morphologic features in different grades of prolapse. Am J Obstet Gynecol 2003; 188:910.
9. DeLancey JO, Kearney R, Chou Q, et al. The appearance of levator ani muscle abnormalities in magnetic resonance images after vaginal delivery. Obstet Gynecol 2003; 101:46.
10. Barber MD, Bremer RE, Thor KB, et al. Innervation of the female levator ani muscles. Am J Obstet Gynecol 2002; 187:64.
11. Snooks SJ, Swash M. The innervation of the muscles of continence. Ann R Coll Surg Engl 1986; 68:45.
12. Percy JP, Neill ME, Swash M, Parks AG. Electrophysiological study of motor nerve supply of pelvic floor. Lancet 1981; 1:16.
13. Pierce LM, Reyes M, Thor KB, et al. Innervation of the levator ani muscles in the female squirrel monkey. Am J Obstet Gynecol 2003; 188:1141.
14. Bremer RE, Barber MD, Coates KW, et al. Innervation of the levator ani and coccygeus muscles of the female rat. Anat Rec A Discov Mol Cell Evol Biol 2003; 275:1031.
15. Grigorescu BA, Lazarou G, Olson TR, et al. Innervation of the levator ani muscles: description of the nerve branches to the pubococcygeus, iliococcygeus, and puborectalis muscles. Int Urogynecol J Pelvic Floor Dysfunct 2008; 19:107.
16. Whiteside JL, Walters MD. Anatomy of the obturator region: relations to a trans-obturator sling. Int Urogynecol J Pelvic Floor Dysfunct 2004; 15:223.
17. Mirilas P, Skandalakis JE. Urogenital diaphragm: an erroneous concept casting its shadow over the sphincter urethrae and deep perineal space. J Am Coll Surg 2004; 198:279.
18. DeLancey JO. Structural anatomy of the posterior pelvic compartment as it relates to rectocele. Am J Obstet Gynecol 1999; 180:815.

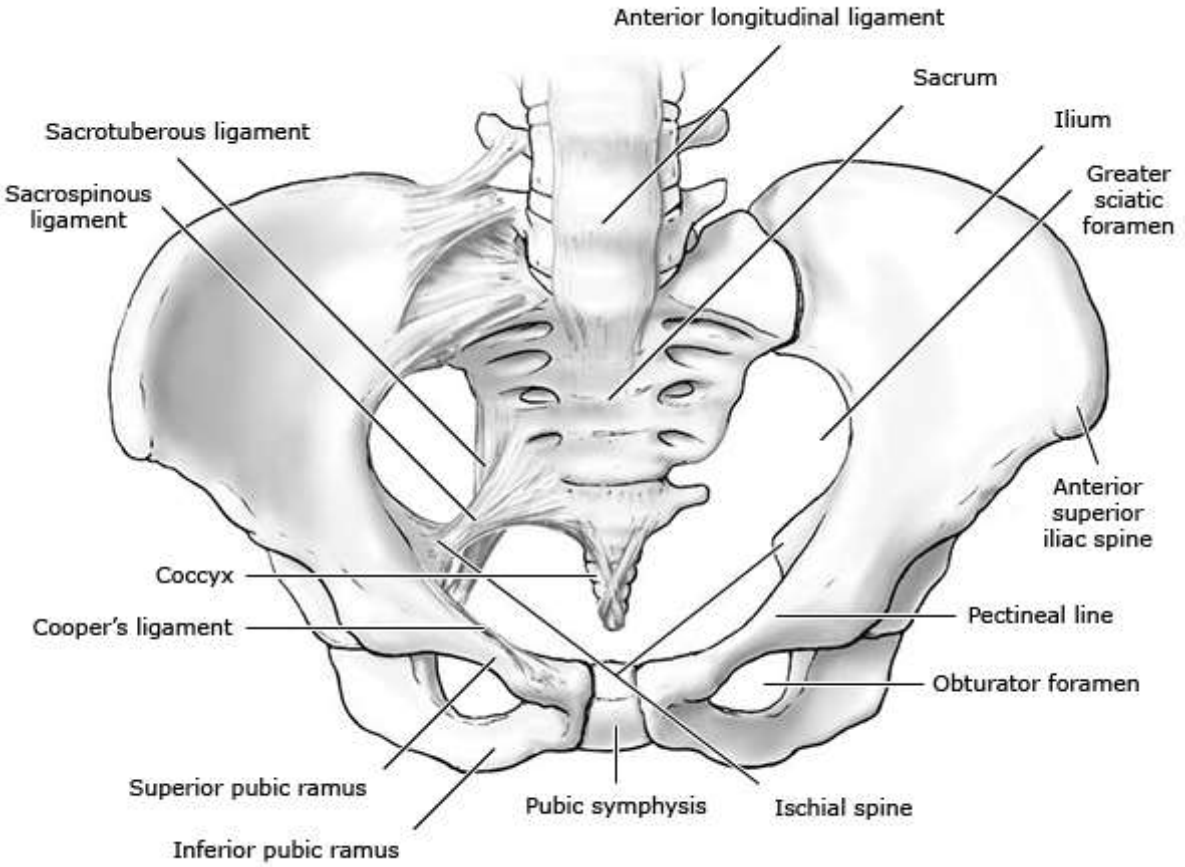
19. Oelrich TM. The striated urogenital sphincter muscle in the female. Anat Rec 1983; 205:223.
20. Federative Committee on Anatomical Terminology. Terminologia Anatomica: Internation al Anatomic Terminology. Thieme, New York 2000.
21. Jackson LA, Hare AM, Carrick KS, et al. Anatomy, histology, and nerve density of clitoris and associated structures: clinical applications to vulvar surgery. Am J Obstet Gynecol 2019; 221:519.e1.
22. Funt MI, Thompson JD, Birch H. Normal vaginal axis. South Med J 1978; 71:1534.
23. Luo J, Betschart C, Ashton-Miller JA, DeLancey JO. Quantitative analyses of variability in normal vaginal shape and dimension on MR images. Int Urogynecol J 2016; 27:1087.
24. Weber AM, Walters MD. Anterior vaginal prolapse: review of anatomy and techniques of surgical repair. Obstet Gynecol 1997; 89:311.
25. Boreham MK, Wai CY, Miller RT, et al. Morphometric analysis of smooth muscle in the anterior vaginal wall of women with pelvic organ prolapse. Am J Obstet Gynecol 2002; 187:56.
26. Rahn DD, Bleich AT, Wai CY, et al. Anatomic relationships of the distal third of the pelvic ureter, trigone, and urethra in unembalmed female cadavers. Am J Obstet Gynecol 2007; 197:668.e1.
27. Bump RC, Friedman CI, Copeland WE Jr. Non-neuromuscular determinants of intraluminal urethral pressure in the female baboon: relative importance of vascular and nonvascular factors. J Urol 1988; 139:162.
28. Schäfer W. Some biomechanical aspects of continence function. Scand J Urol Nephrol Suppl 2001; :44.
29. Colleselli K, Stenzl A, Eder R, et al. The female urethral sphincter: a morphological and topographical study. J Urol 1998; 160:49.
30. DeLancey JO. Structural support of the urethra as it relates to stress urinary incontinence: the hammock hypothesis. Am J Obstet Gynecol 1994; 170:1713.
31. Rahn DD, Bleich AT, Wai CY, et al. Anatomic relationships of the distal third of the pelvic ureter, trigone, and urethra in unembalmed female cadavers. Am J Obstet Gynecol 2007; 197:668.e1.
32. Sorinola O, Begum R. Prevention and management of ureteric injuries. Hosp Med 2005; 66:329.
33. DeLancey J. Surgical anatomy of the female pelvis. In: Te Linde's Operative Gynecology, Rock JA, Thompson JD (Eds), Lippincott-Raven, 2011.
34. Underwood P. Operative injuries to the ureter. In: Te Linde's Operative Gynecology, Rock JA, Thompson JD (Eds), Lippincott-Raven, 2011.

35. Hofmeister FJ. Pelvic anatomy of the ureter in relation to surgery performed through the vagina. Clin Obstet Gynecol 1982; 25:821.
36. Buller JL, Thompson JR, Cundiff GW, et al. Uterosacral ligament: description of anatomic relationships to optimize surgical safety. Obstet Gynecol 2001; 97:873.
37. Fernbach SK, Feinstein KA, Spencer K, Lindstrom CA. Ureteral duplication and its complications. Radiographics 1997; 17:109.
38. Fernbach SK, Feinstein KA, Spencer K, Lindstrom CA. Ureteral duplication and its complications. Radiographics 1997; 17:109.
39. DeLancey JO. Anatomic aspects of vaginal eversion after hysterectomy. Am J Obstet Gynecol 1992; 166:1717.
40. Umek WH, Morgan DM, Ashton-Miller JA, DeLancey JO. Quantitative analysis of uterosacral ligament origin and insertion points by magnetic resonance imaging. Obstet Gynecol 2004; 103:447.
41. Leffler KS, Thompson JR, Cundiff GW, et al. Attachment of the rectovaginal septum to the pelvic sidewall. Am J Obstet Gynecol 2001; 185:41.

Topic 14186 Version 19.0

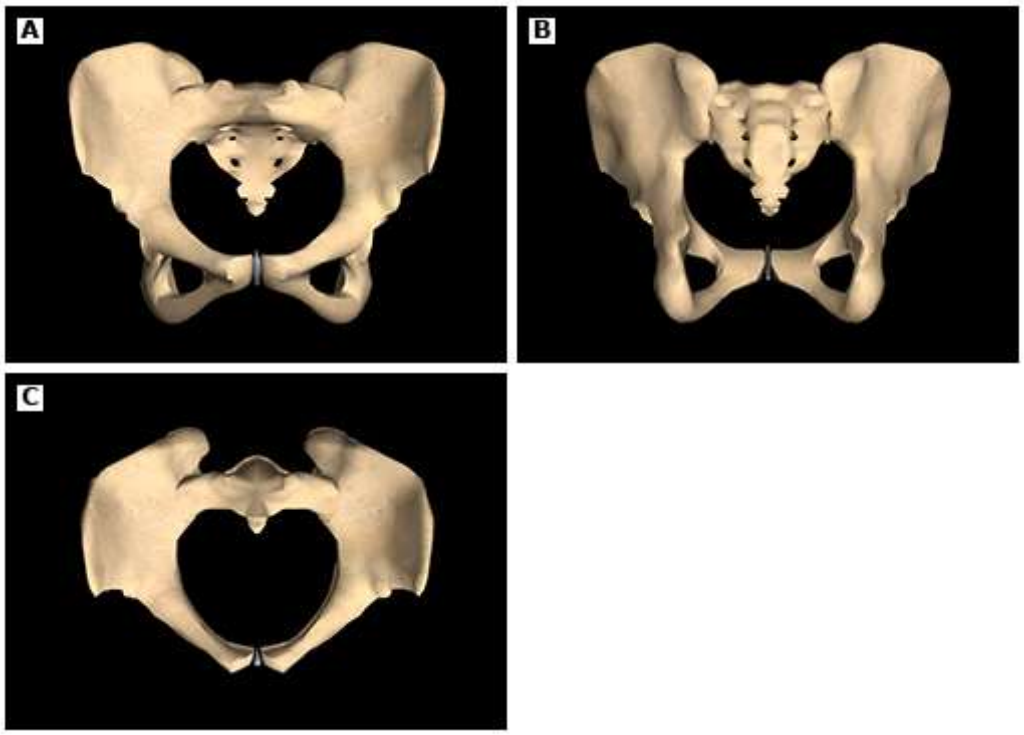
GRAPHICS

Female pelvic bones and ligaments



Graphic 87086 Version 1.0

Female pelvic bones



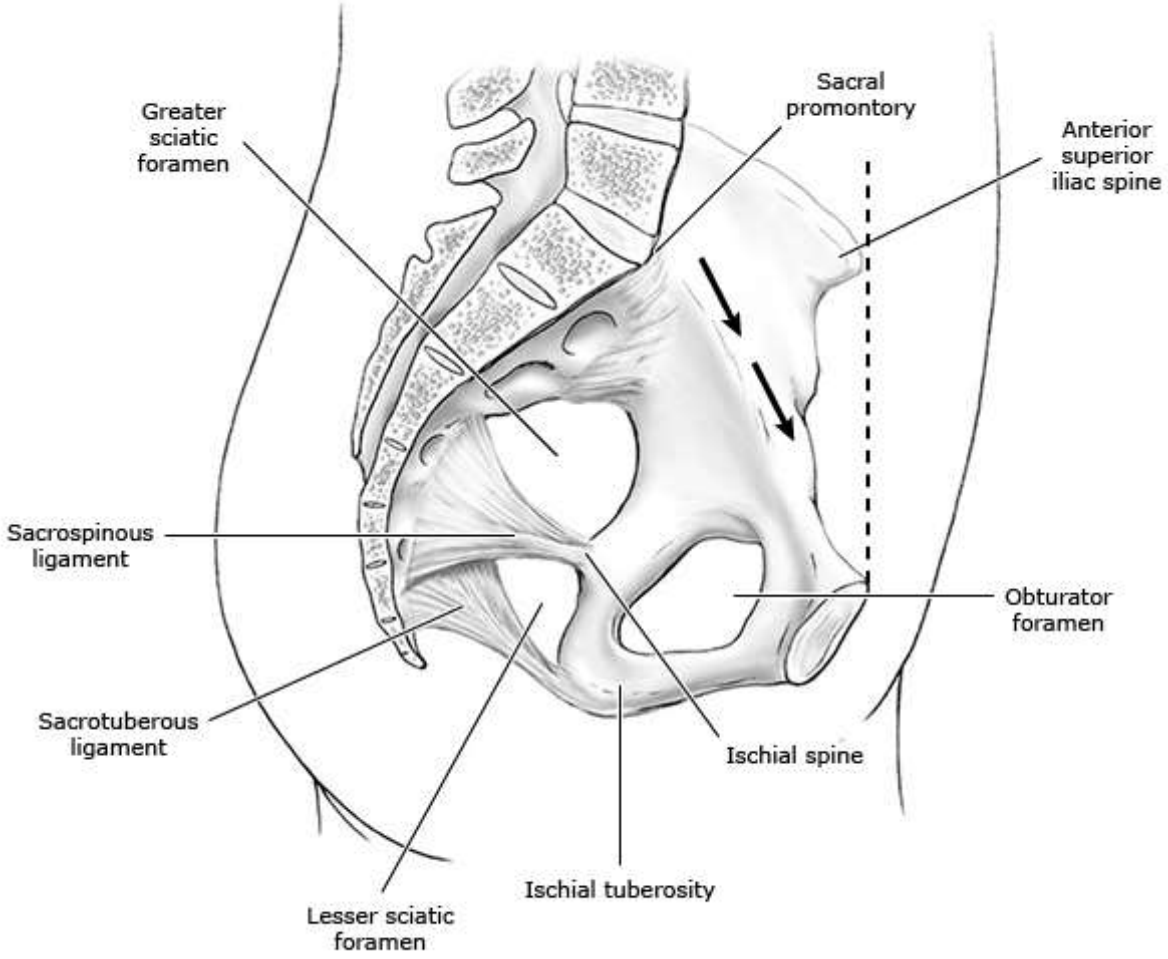
(A) Pelvis, female, anterior. Anterior view of the female pelvis.

(B) Pelvis, female, posterior. Posterior view of the female pelvis.

(C) Pelvis, female, superior. Superior view of the female pelvis.

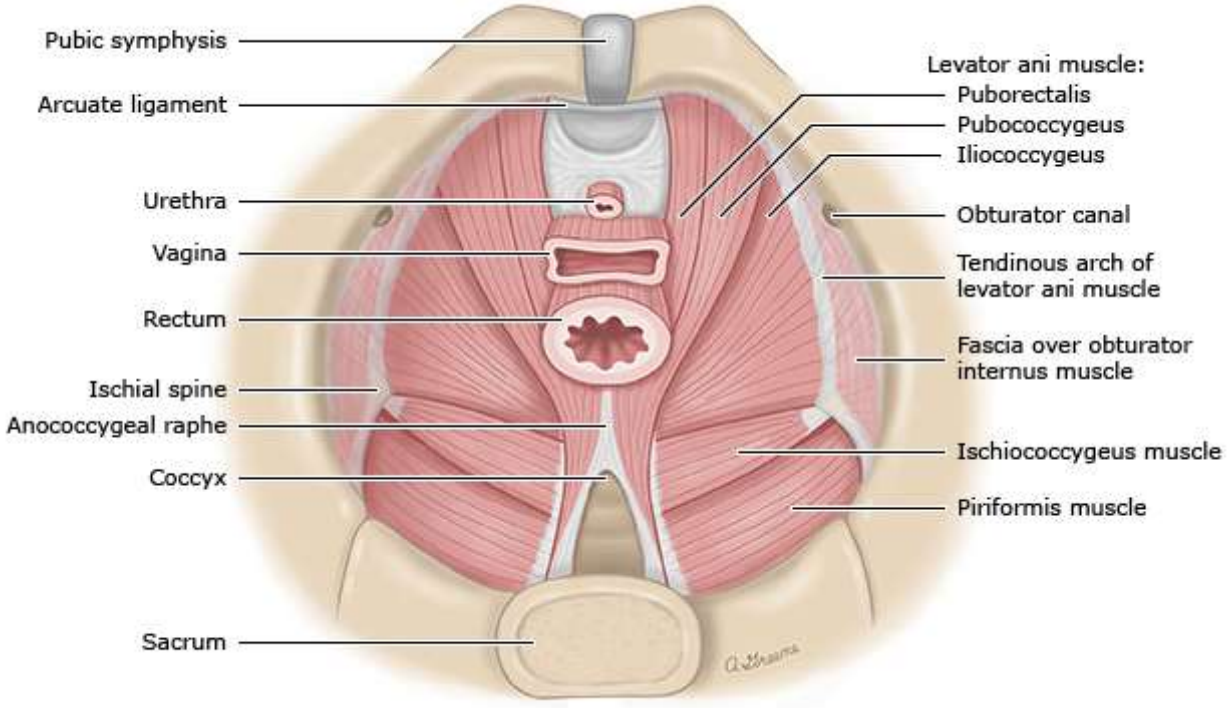
Graphic 87087 Version 1.0

Sagittal view of the female pelvic bones



Graphic 87092 Version 1.0

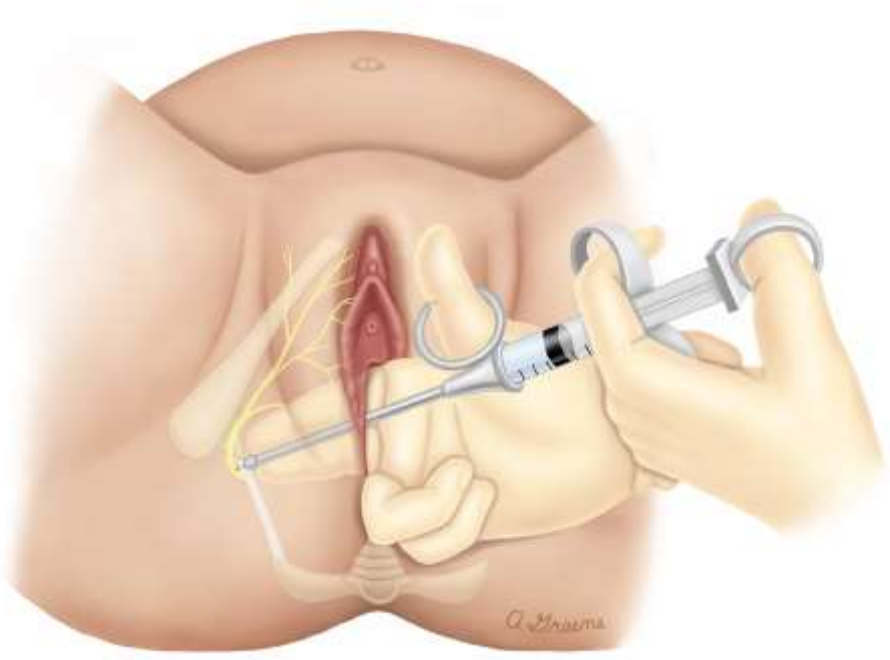
Female pelvic muscles at the level of the pelvic floor



This figure shows the muscles of the floor of the female pelvis as viewed from within the patient. Note the close proximity of the rectum to the vagina, the anococcygeal ligament that holds the rectum to the sacrum, and the pubococcygeus muscles.

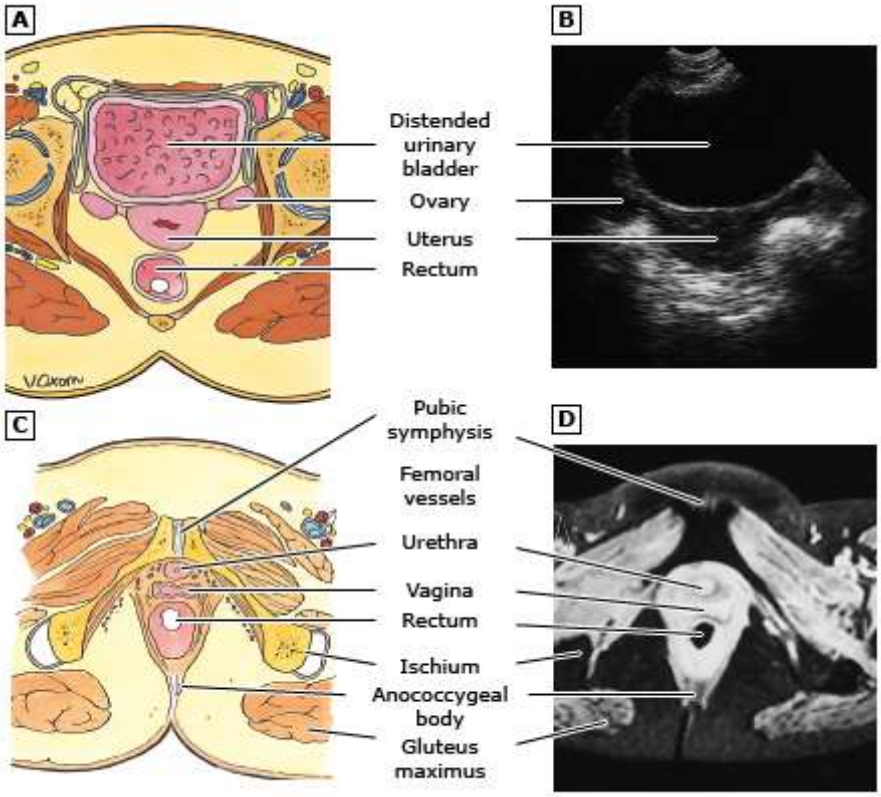
Graphic 62230 Version 3.0

Pudendal block



Graphic 57711 Version 5.0

Transverse sections of the female pelvis



Transverse sections of the female pelvis.

(A) Drawing of an anatomical section through the urinary bladder, uterus, and rectum.

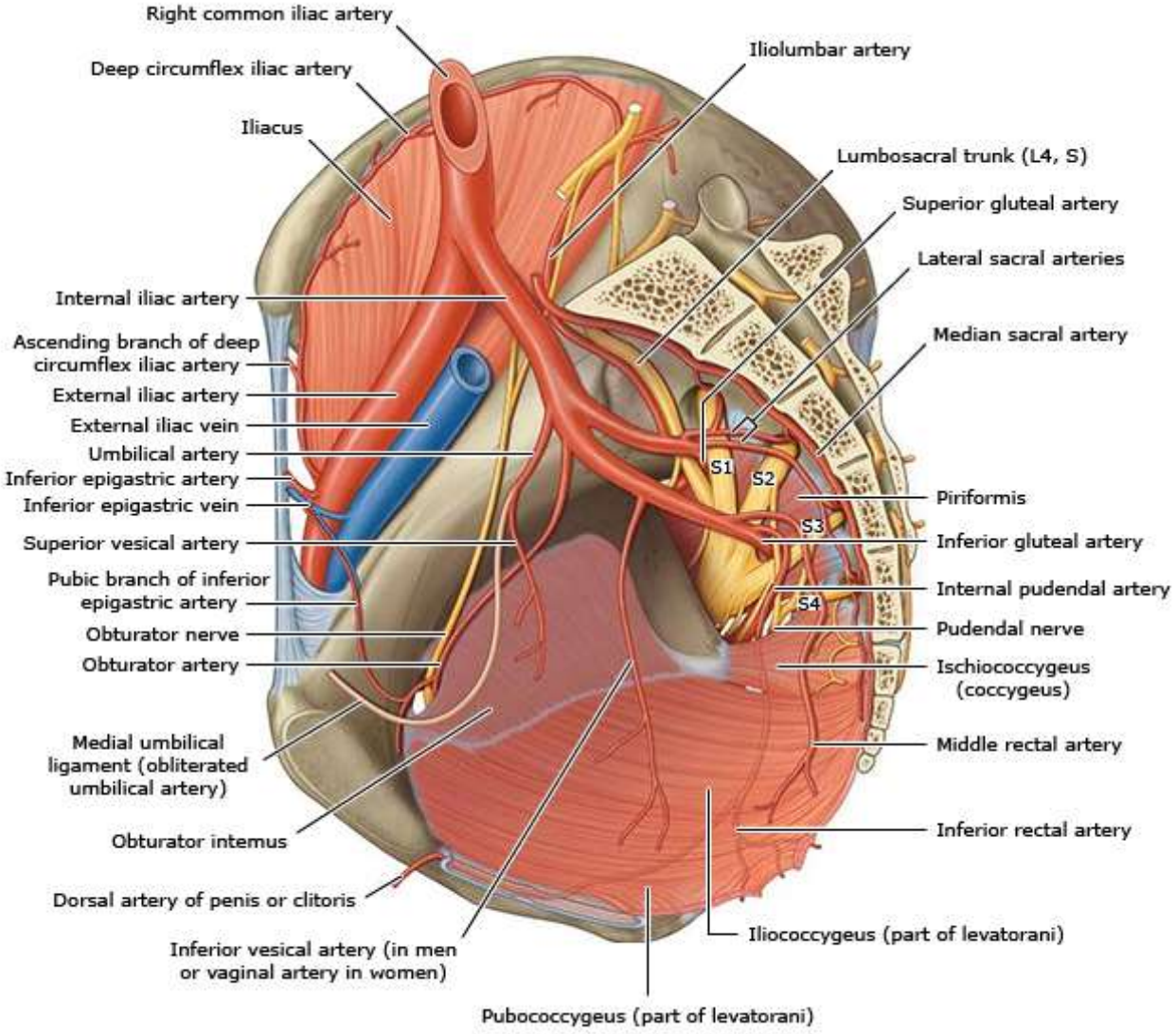
(B) Transverse ultrasound scan.

(C) Drawing of an anatomical section through the urethra, vagina, and rectum.

(D) Transverse magnetic resonance image (MRI).

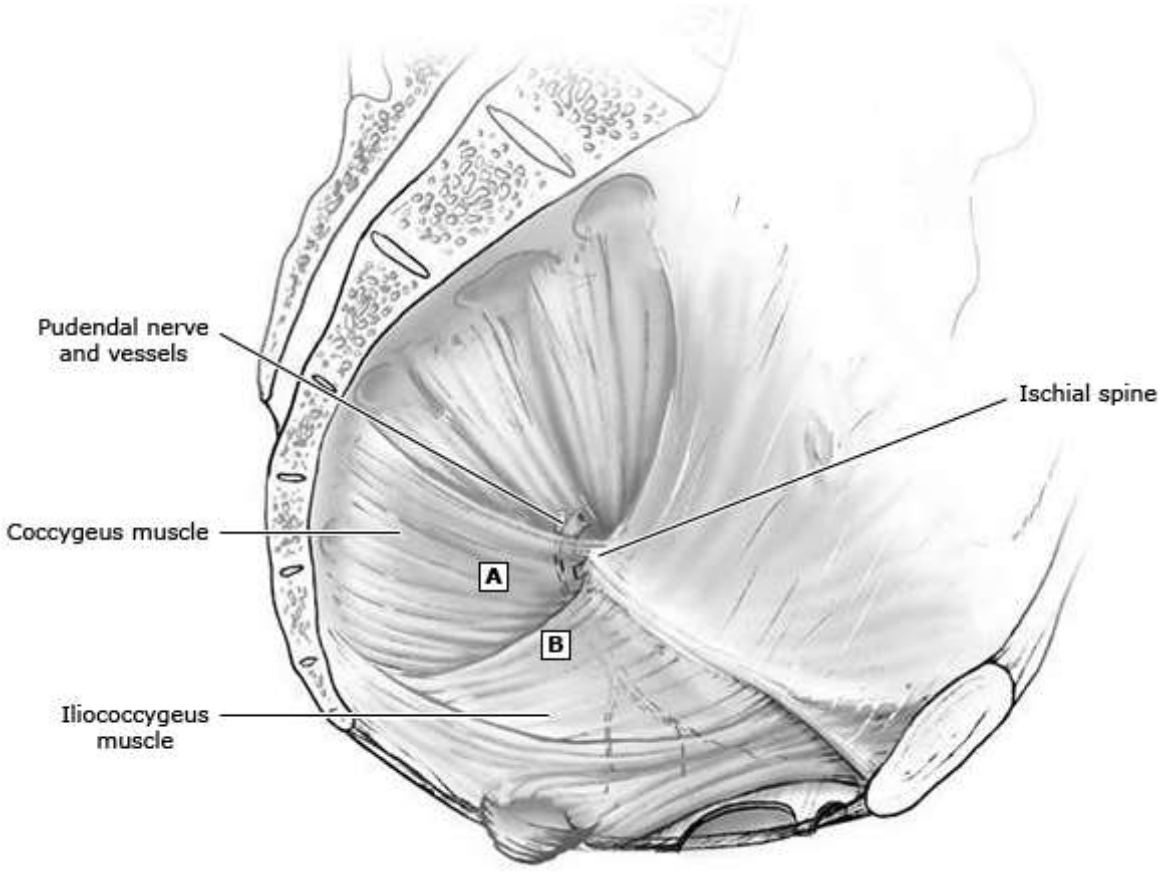
Graphic 87091 Version 1.0

Sagittal view of the female pelvic vessels and nerves



Graphic 87093 Version 1.0

Site of suture placement for transvaginal apical suspension procedures

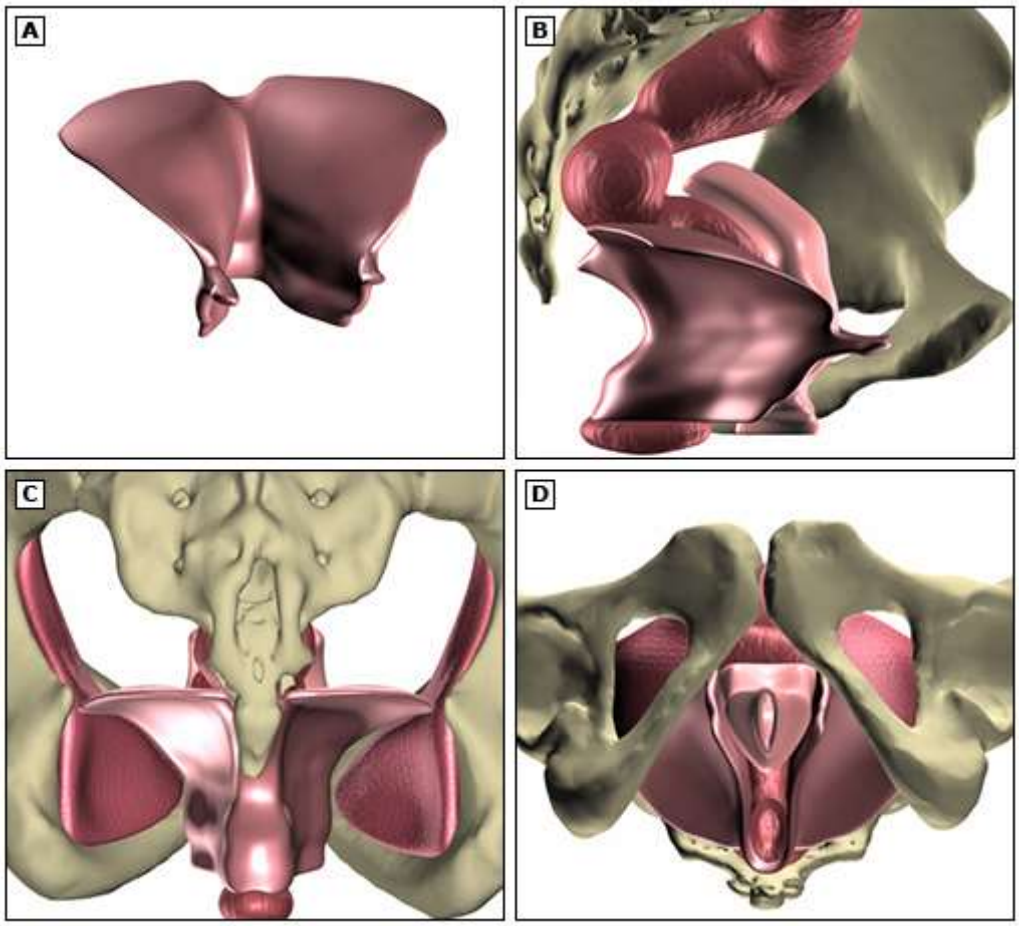


(A) Location of suture placement for sacrospinous ligament fixation.

(B) Location of suture placement for iliococcygeous vaginal vault suspension.

Graphic 87094 Version 1.0

Female levator muscles: three-dimensional form



Digitally enhanced three-dimensional reconstructions of the female pelvic floor from a magnetic resonance image of the pelvis in a normal nulliparous 23-year-old woman.

(A) Anterior view of the levator ani muscle with normal resting tone.

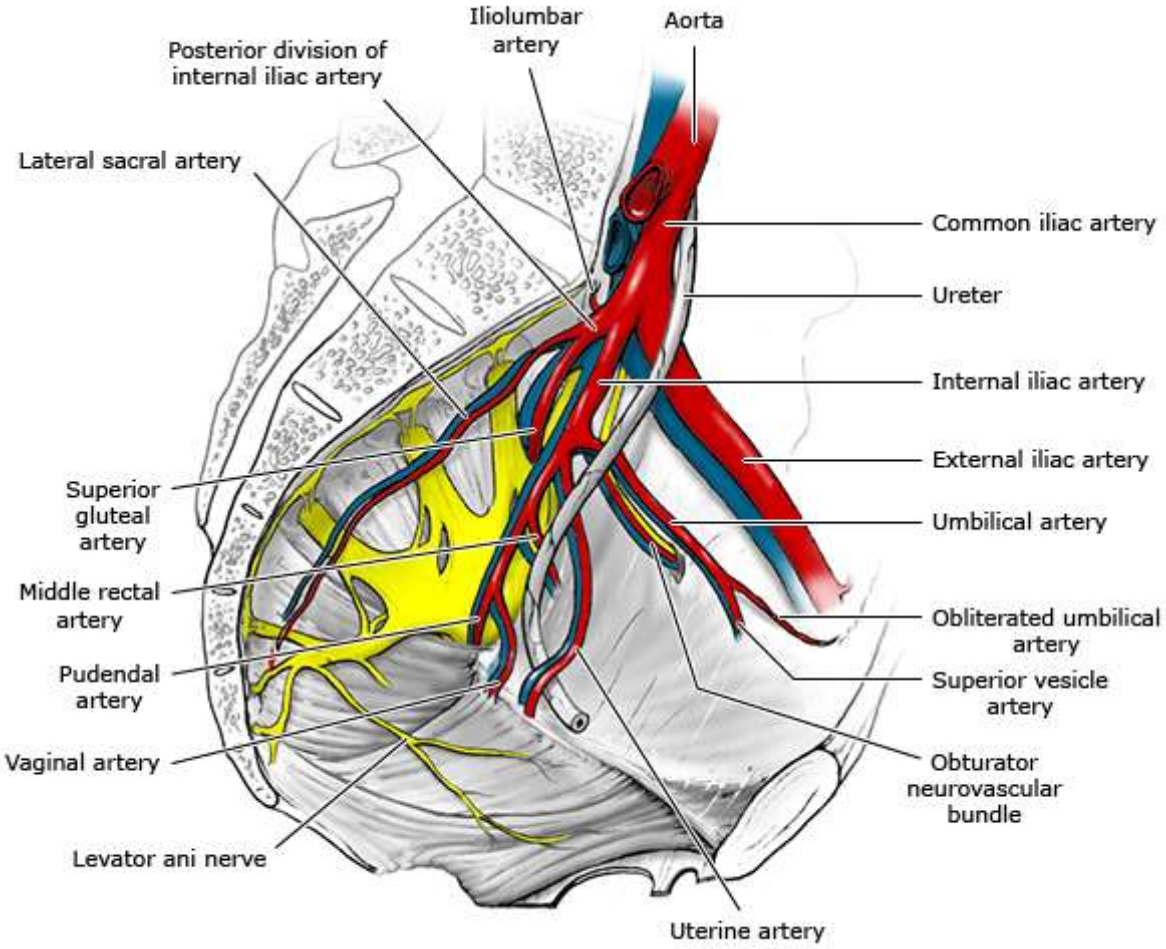
(B) Sagittal view of the levator ani muscle, bony pelvis, vagina, and rectum.

(C) Posterior view of the levator ani muscle, obturator internus muscles, and bony pelvis.

(D) Lithotomy view.

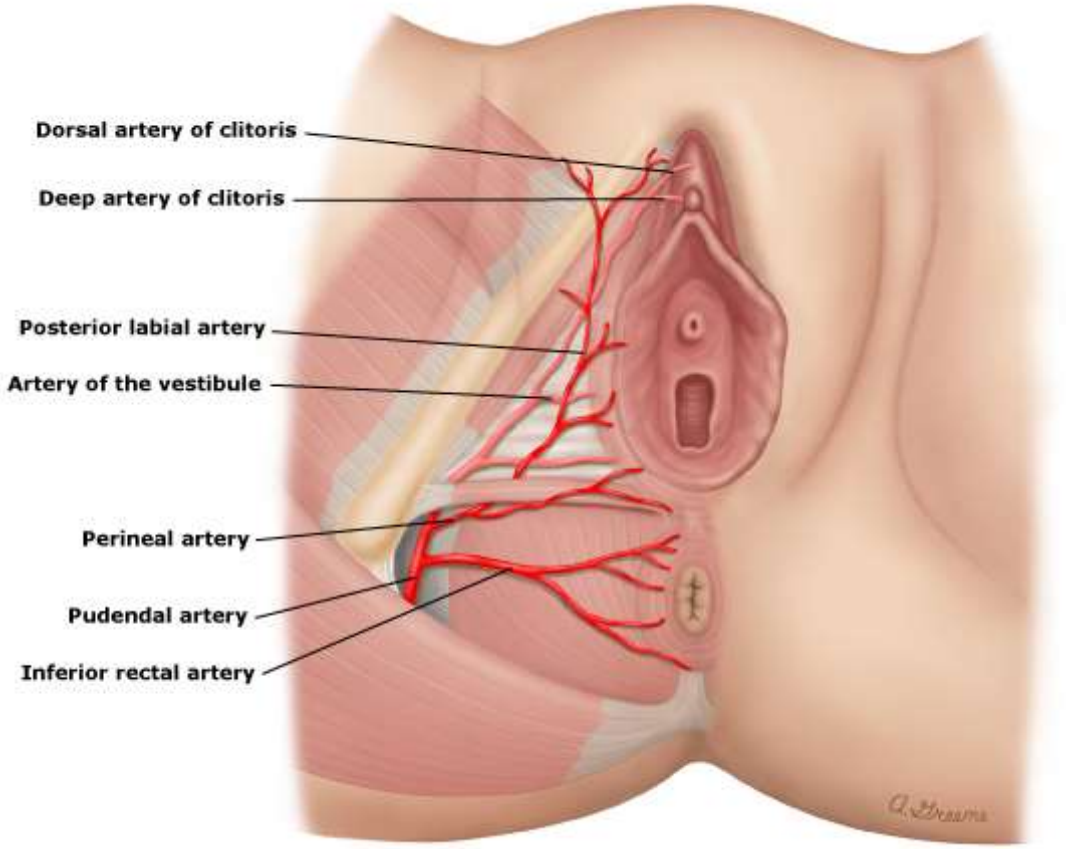
Graphic 87156 Version 1.0

Female levator ani nerve



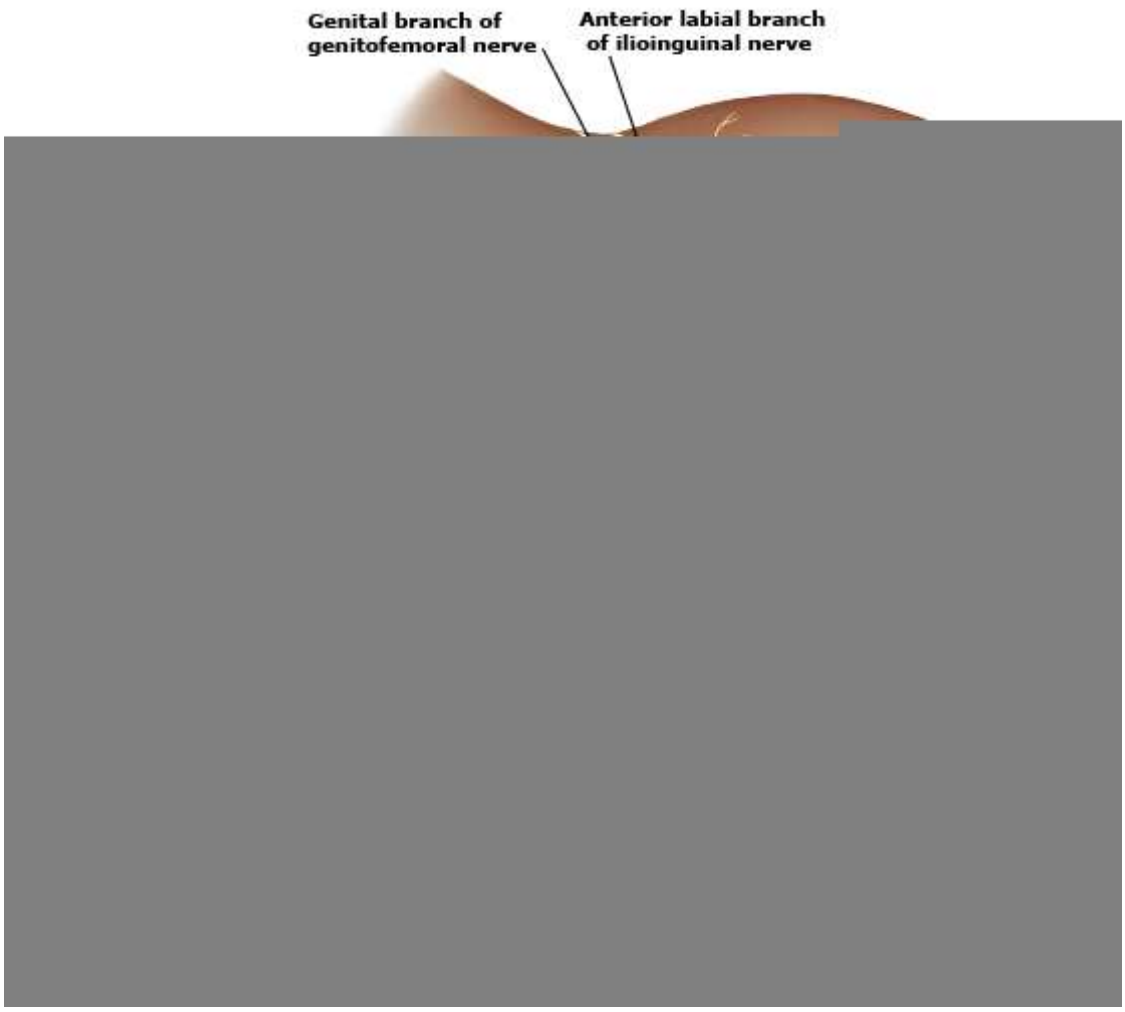
Graphic 87159 Version 1.0

Arteries of the female perineum



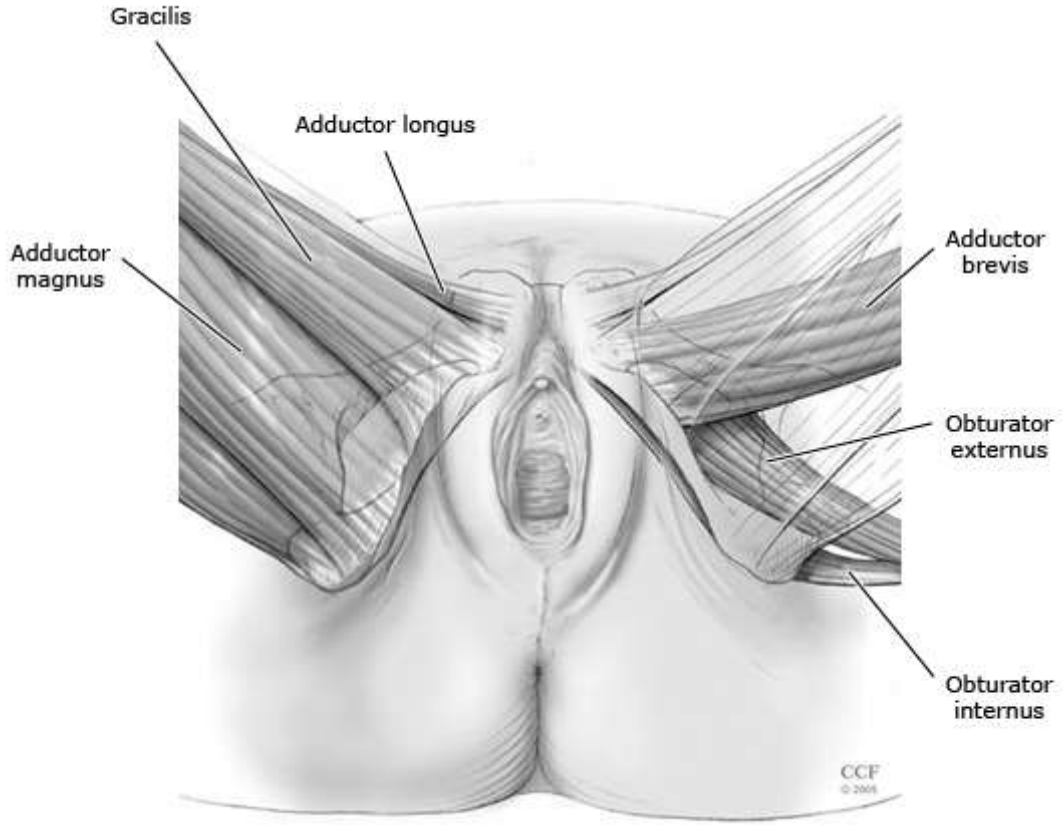
Graphic 81882 Version 1.0

Nerves of the female perineum



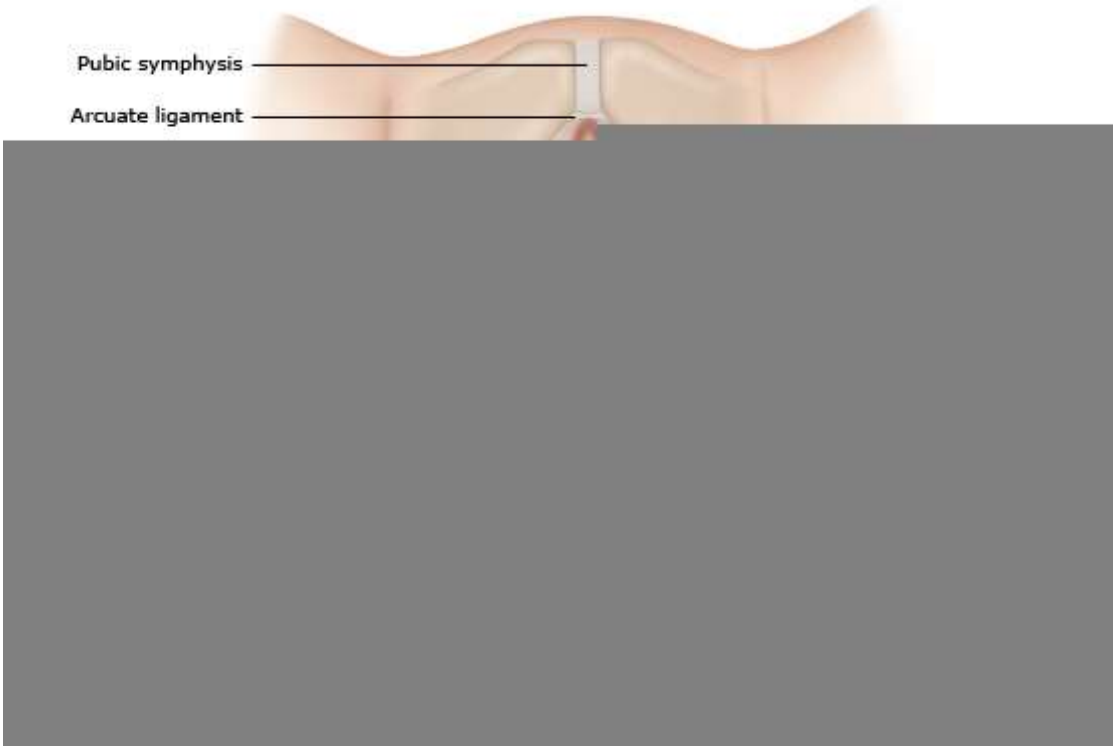
Graphic 74742 Version 5.0

Muscles of the obturator space



Graphic 87168 Version 1.0

Muscles of the female perineum



This figure illustrates the muscles of the female perineum. Note the location of the levator ani (iliococcygeus) muscles, the external anal sphincter, and the superficial transverse perineal muscle.

Graphic 74060 Version 2.0

Female perineal membrane

Inferior view of the urogenital diaphragm.

(A) Male; on the left, the inferior fascia of the deep transversus perineus (perineal membrane or inferior fascia of the urogenital diaphragm) is intact, but has been removed on the right to expose the musculature.

(B) Female; the fascia of the deep transverse perineus has been removed on both sides to expose the muscle fibers.

Graphic 87160 Version 1.0

Female urethral and urethrovaginal sphincters

Perineum. External urethral sphincter, urethrovaginal sphincter, and compressor urethrae.

Graphic 87161 Version 1.0

Anatomy of the vulva

Graphic 72614 Version 12.0

Location of the Bartholin glands and ducts

Each Bartholin gland is approximately 0.5 centimeter (cm) in size and drains into a duct 2.5 cm long. The ducts emerge onto the vestibule, one at each side of the vaginal orifice, in the groove (superficial perineal pouch) between the hymenal ring and the labia minora.

Graphic 66162 Version 2.0

Anatomic variations of the hymen

Modified from: Laufer MR. Structural abnormalities of the female reproductive tract. In: Emans, Laufer, Goldstein's Pediatric & Adolescent Gynecology, 7th ed, Emans SJ, Laufer MR, DiVasta AD (Eds), Wolters Kluwer, Philadelphia 2020.

Graphic 57977 Version 16.0

Female pelvic anatomy sagittal view

(A) Uterus and vagina. Median section of vagina.

(B) Magnetic resonance images (MRIs) of the female pelvis. Median (above) and coronal (below) MRIs showing the uriary bladder, body of the uterus, vagina, and intestine.

Graphic 87164 Version 1.0

Female genitourinary system

Female genitourinary system (GU). Anterior view of the female genitourinary system, including the ovaries, uterine tubes, uterus and bladder.

Graphic 87166 Version 1.0

Female pelvis - Sagittal view

This figure depicts the sagittal view of the female pelvis. Note the rectovaginal septum and the proximity of the uterus and bladder to the rectum.

Graphic 59561 Version 1.0

Urethral sphincter

Urethra.

(A) External urethral sphincter and compressor urethrae muscle of the male. Lateral view.

(B) External urethral sphincter, compressor urethrae, and urethrovaginal sphincter muscles of the female. Lateral view.

Graphic 87165 Version 1.0

Bladder trigone

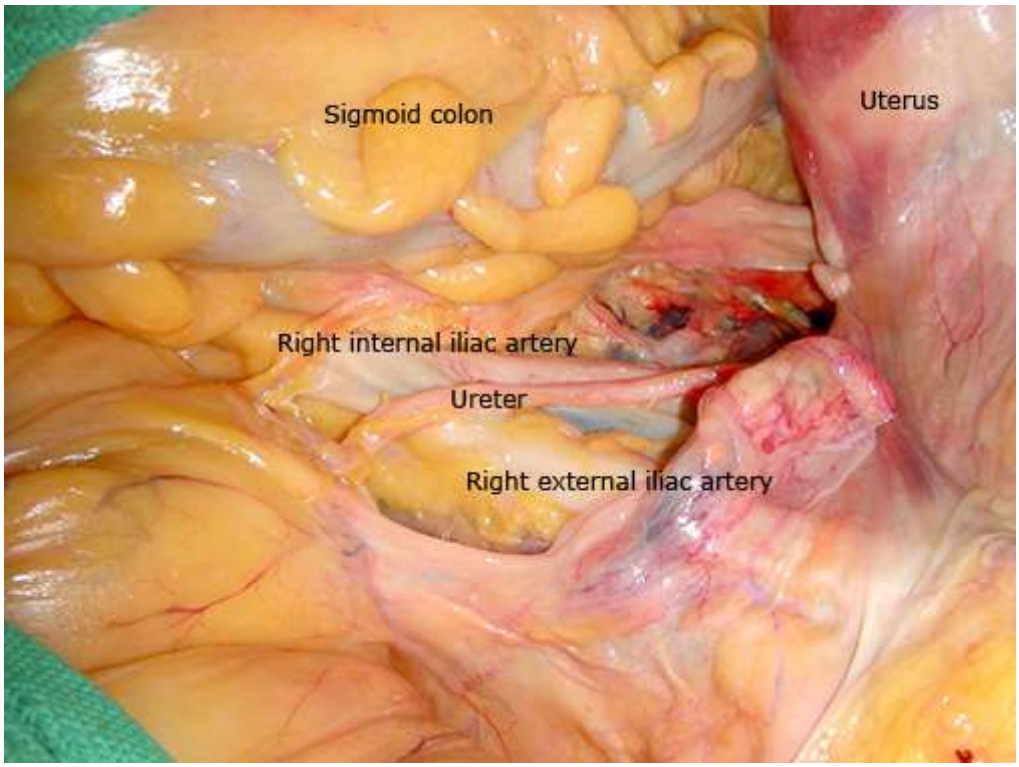
Graphic 87167 Version 3.0

Identification of the ureter during hysterectomy

The ureter is located on the medial leaf of the broad ligament and courses under the uterine artery. Prior to any surgical manipulation, it usually lies 2 cm lateral to the uterus, but may be nearer. The ureter must be identified before clamping and cutting the uterine artery to avoid injury.

Graphic 76515 Version 4.0

Ureter at female pelvic brim



The ureters are most easily identified at the pelvic brim, where they cross the bifurcation of the common iliac into the external and internal iliac vessels.

Graphic 83005 Version 1.0

Ureteral course: Laparoscopic view

Superior view of the ureter during laparoscopy. Dots represent the course of the ureter.

Courtesy of Thomas Lyons, MD.

Graphic 51215 Version 2.0

Identification of the ureter and ligating the uterine artery during hysterectomy

With sharp dissection, the ureter is dissected free of its soft tissue attachments from its point of entry into the pelvis to its insertion into the bladder. The uterine artery is then identified, divided at its origin, and reflected medially. Identification of the uterine artery can be facilitated by placing downward tension on the superior vesical artery on the ipsilateral side. This causes all of the branches of the internal iliac artery to be tensed and makes them more readily identified.

Courtesy of William J Mann, Jr, MD.

Graphic 76698 Version 3.0

Identification of the ureter and superior vesical artery during hysterectomy

The peritoneal reflection anterior to the uterus is incised and the bladder reflected inferiorly with sharp dissection. The ureter is identified on the medial aspect of the broad ligament during the development of the perivesical and perirectal spaces, as is the superior vesical artery.

Courtesy of William J Mann, Jr, MD.

Graphic 64999 Version 4.0

Ureteral insertion into the bladder

As the ureter is traced down through the parametrium, the parametrium is divided superior and lateral to the ureter and mobilized medially, until the actual insertion of the ureter into the bladder can be seen.

Courtesy of William J Mann, Jr, MD.

Graphic 57777 Version 3.0

DeLancey levels of female pelvic floor support: Level 1 (apical suspension) and level 2 (lateral attachment)

Level 1: Paracolpium suspends the vaginal apex from the lateral pelvic sidewall via the uterosacral-cardinal complex.

Level 2: The anterior vaginal wall is attached laterally to arcus tendinous fascia pelvis, and the posterior vaginal wall is attached laterally to the facia overlying the levator ani muscle.

Graphic 60888 Version 5.0

DeLancey levels of vaginal support

Level I consists of the cardinal and uterosacral ligaments and suspends the vaginal apex. Level II consists of the endopelvic fascia connections to the arcus tendineus fascia pelvis, which attaches the vagina to the aponeurosis of the levator ani. Level III consists of the perineal body and includes interlacing muscle fibers of the bulbospongiosus, transverse perinei, and external anal sphincter.

Graphic 61643 Version 6.0

Contributor Disclosures

Matthew D Barber, MD, MHS Other Financial Interest: Elsevier book royalties [Hysterectomy, Walters & Karram Urogynecology and Reconstructive Pelvic Surgery]. All of the relevant financial relationships listed have been mitigated. **Linda Brubaker, MD, FACOG** Grant/Research/Clinical Trial Support: National Institutes of Health [Prevention of lower urinary symptoms]. Other Financial Interest: Editor in Chief for Urogynecology journal [Urogynecology]; Journal of the American Medical Association [Women's health]. All of the relevant financial relationships listed have been mitigated. **Kristen Eckler, MD, FACOG** No relevant financial relationship(s) with ineligible companies to disclose.

Contributor disclosures are reviewed for conflicts of interest by the editorial group. When found, these are addressed by vetting through a multi-level review process, and through requirements for references to be provided to support the content. Appropriately referenced content is required of all authors and must conform to UpToDate standards of evidence.

Conflict of interest policy

→