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Functional Anatomy of the Pelvic Floor and Lower Urinary Tract

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Introduction and Terminology

Pelvic floor disorders, including pelvic organ prolapse and urinary incontinence, are debilitating conditions that result in surgery in 1 of 9 women.[1] They arise because of injuries and deterioration of the muscles, nerves, and connective tissue that support and control normal pelvic function. Although it is clear that incontinence and prolapse increase with age,[1] there is no hour during a woman's life when these structures are more vulnerable than during childbirth. Vaginal delivery confers a four- to elevenfold higher risk of prolapse that increases with parity.[2] In contrast to classic anatomy, this chapter addresses the *functional* anatomy of the pelvic floor in women and specifically focuses on how the pelvic organs are supported by the surrounding muscle and fasciae, and how pelvic visceral function relates to the clinical conditions of urinary incontinence and pelvic organ prolapse.

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In the past, gynecologists and urologists have relied on the terms "cystocele" (anterior prolapse), "urethrocele," "rectocele" (posterior prolapse), or "enterocele" to refer to bulging or protrusion of the vagina below the pelvic floor that involves the bladder, urethra, rectum, or small bowel, respectively. The use of these terms implied assumptions concerning which organs were causing the vaginal bulge; however, since an accurate diagnosis is possible only by imaging or surgical dissection, these terms may be inappropriate. A recent National Institutes of Health (NIH) Terminology Workshop for Researchers in Female Pelvic Floor Disorders defined terms for anatomic description and surgical therapy. Prolapse was described by three categories: uterine or apical, anterior, and posterior prolapse.[3] This framework has permitted a uniform dialogue among clinicians and will be applied in this chapter.

Support of the Pelvic Organs

The pelvic organs rely on their attachments to the pubic bones, muscles, and connective

tissue for support, with control provided through connections to the peripheral and central nervous systems. In this chapter, the term "pelvic floor" is used broadly to include all the structures supporting the pelvic cavity rather than the restricted use of this term to refer to the levator ani group of muscles.

The pelvic floor consists of several components lying between the peritoneum and the vulvar skin. From above downward, these are the peritoneum, pelvic viscera and endopelvic fascia, levator ani muscles, perineal membrane, and superficial genital muscles. The support for all these structures comes from connections to the bony pelvis and its attached muscles. The viscera are often thought of as being supported by the pelvic floor, but are actually a part of it. The viscera play an important role in forming the pelvic floor through their connections with structures, such as the cardinal and uterosacral ligaments.

In 1934, Bonney pointed out that the vagina is in the same relationship to the abdominal cavity as the in-turned finger of a surgical glove is to the rest of the glove (Figure 1).[4] If the pressure in the glove is increased, it forces the finger to protrude downwards in the same way that increases in abdominal pressure force the vagina to prolapse. Figure 2a and Figure 2b provide a schematic illustration of this prolapse phenomenon. In Figure 2c, the lower end of the vagina is held closed by the pelvic floor muscles, preventing prolapse by constriction. Figure 2d shows suspension of the vagina to the pelvic walls. Figure 2e demonstrates that spatial relationships are important. This is a flap-valve closure where the suspending fibers hold the vagina in a position against the supporting walls of the pelvis; increases in pressure force the vagina against the wall, thereby pinning it in place. Vaginal support is a combination of constriction, suspension, and structural geometry.

Because of the way the supportive tissues attach the pelvic organs to the pelvic walls, the female pelvis can naturally be divided

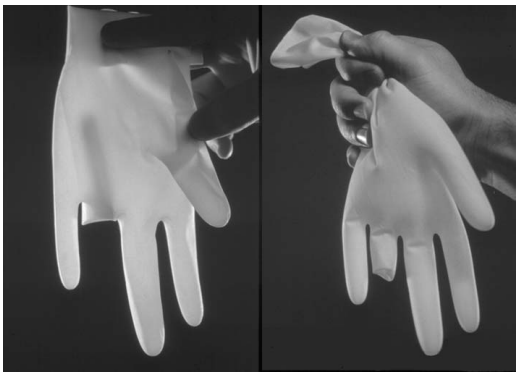

FIGURE 1. Bonney's analogy of vaginal prolapse. The eversion of an intussuscepted surgical glove finger by increasing pressure within the glove is analogous to prolapse of the vagina (DeLancey 2002, with permission).

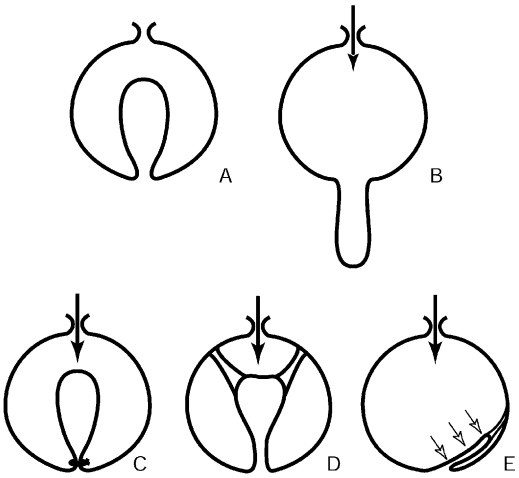

FIGURE 2. Diagrammatic display of vaginal support. A, Invaginated area in a surrounding compartment; (B) The prolapse opens when the pressure (arrow) is increased; (C) Closing the bottom of the vagina prevents prolapse by constriction; (D) Ligament suspension; (E) Flap valve closure where suspending fibers hold the vagina in a position against the wall allowing increases in pressure to pin it in place (DeLancey 2002, with permission).

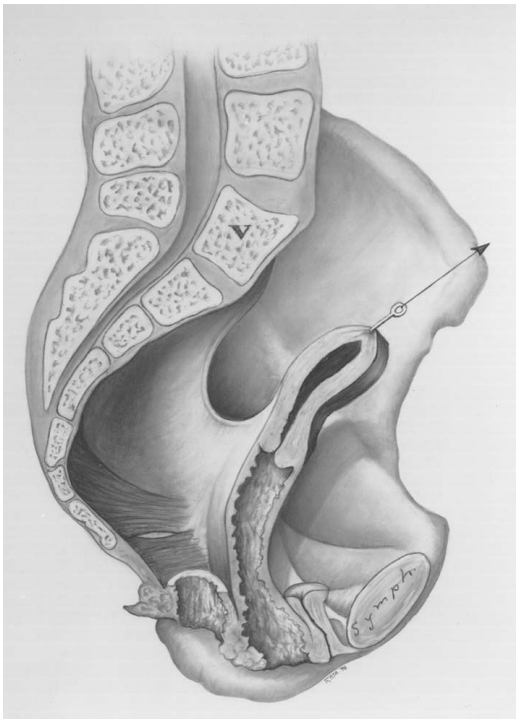

FIGURE 3. Compartments of the pelvis. The vagina, connected laterally to the pelvic walls, divides the pelvis into an anterior and posterior compartment (DeLancey 1998, with permission; based on SEARS 1933).

into anterior and posterior compartments (Figure 3). The levator ani muscles form the bottom of the pelvis. The organs are attached to the levator ani muscles when they pass through the urogenital hiatus and are supported by these connections.

Endopelvic Fascia

On each side of the pelvis, the endopelvic fascia attaches the cervix and vagina to the pelvic wall (Figure 4). This fascia forms a continuous sheet-like mesentery, extending from the uterine artery at its cephalic margin to the point at which the vagina fuses with the levator ani muscles below. The part of the fascia that attaches to the uterus is called the parametrium and that which attaches to the vagina, the paracolpium.[5] The vagina is attached laterally to the pelvic walls forming a single divider in the middle of the pelvis that determines the nature of prolapse. Anterior and posterior prolapse occur from the front or the back, respectively. There are no "lateroceles." The division of clinical problems into anterior, posterior, and apical prolapse reflects the nature of these lateral connections. Therefore, three types of movement can occur in patients with pelvic organ prolapse: 1) the cervix or vaginal apex can move downward between the anterior and posterior supports; 2) the anterior vagina can protrude through the introitus; and 3) the posterior wall can protrude through the introitus. The types of support loss are related to the location of the genital tract's connection to the pelvis. The location of connective

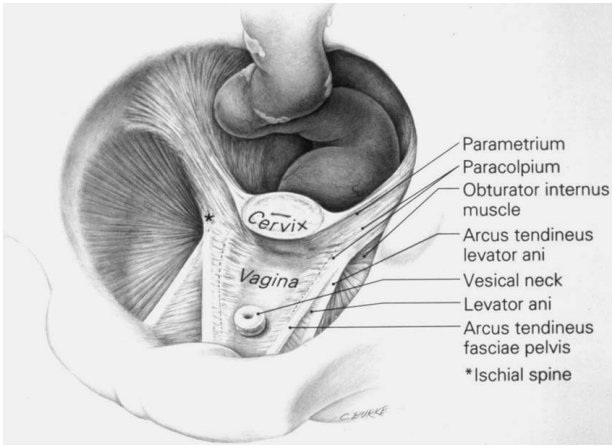

FIGURE 4. Attachments of the cervix and vagina to the pelvic walls demonstrating different regions of support with the uterus in situ. Note that the uterine corpus and the bladder have been removed (Delancey 2002, with permission).

tissue damage determines whether a woman has anterior, posterior, or vault prolapse. Understanding the different characteristics of support helps us to understand the types of prolapse that can occur.

Uterovaginal Support

The cardinal and uterosacral ligaments (parametrium) attach the cervix and uterus to the pelvic walls.[6,7] This tissue continues downward over the upper vagina to attach it to the pelvic walls and is called the paracolpium here.[5] These tissues provide support for the vaginal apex following hysterectomy (Figure 5). The paracolpium has two portions from the pelvic inlet toward the pelvic outlet. The uppermost portion of the paracolpium consists of a relatively long sheet of tissue that suspends the superior aspect of the vagina (level I) by attaching it to the pelvic wall. This is true whether or not the cervix is present. In the midportion of the vagina (level II), the paracolpium attaches the vagina laterally and more directly to the pelvic walls. This attachment stretches the vagina transversely between the bladder and rectum and has functional significance. The structural layer that supports the bladder ("pubocervical fascia") does not exist as a separate layer from the vagina, as is often incorrectly depicted, but rather is composed of the anterior vaginal wall and its attachment through the endopelvic fascia to the pelvic wall (Figure 6). Similarly, the posterior vaginal wall and endopelvic fascia ("rectovaginal fascia") form the restraining layer that prevents the rectum from protruding forward, blocking formation of posterior prolapse. In the distal vagina (level III), the vaginal wall is directly attached to surrounding structures without any intervening paracolpium. Anteriorly, the vagina fuses with the urethra, posteriorly with the perineal body, and laterally with the levator ani muscles.

Prolapse of the Uterus or Vaginal Apex

Damage to level I support can result in uterine or vaginal prolapse (Figure 7). The nature of uterine support can be understood when the cervix is pulled downward with a tenaculum during dilation and curettage or pushed downward during laparoscopy. After a certain amount of descent, the parametria become tight and arrest further cervical descent. Similarly, downward descent of the vaginal apex after hysterectomy is resisted

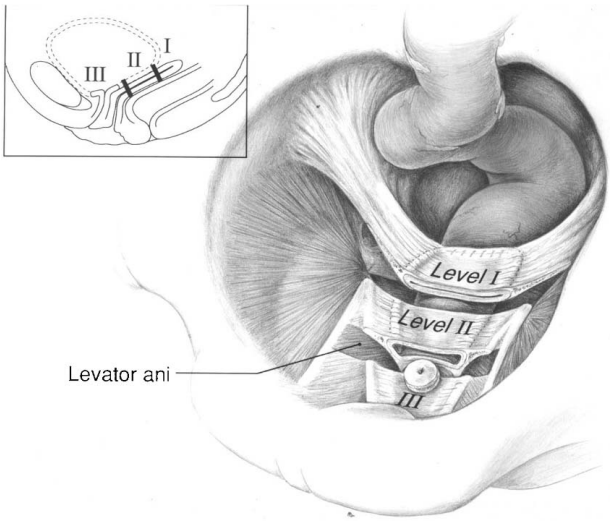

FIGURE 5. Levels of vaginal support after hysterectomy. *Level I* (suspension) and *level II* (attachment). In *level I,* the paracolpium suspends the vagina from the lateral pelvic walls. Fibers of *level I* extend both vertically and also posteriorly towards the sacrum. In *level II,* the vagina is attached to the arcus tendineus fasciae pelvis and the superior fascia of levator ani (DeLancey 1992, with permission).

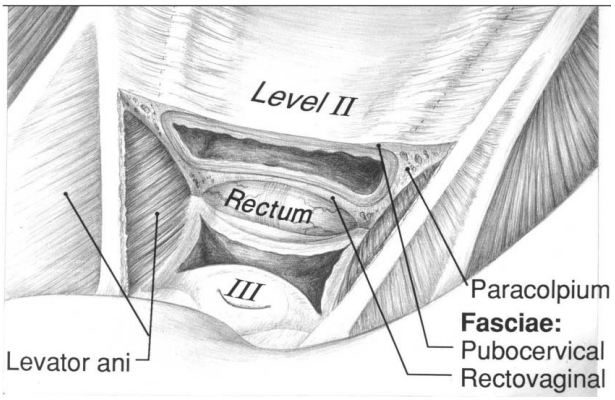

FIGURE 6. Close up of the lower margin of *level II* after a wedge of vagina has been removed *(inset)*. Note how the anterior vaginal wall, through its connections to the arcus tendineus fascia pelvis, forms a supportive layer clinically referred to as the pubocervical fascia (DeLancey 1992, with permission).

by the paracolpia. The parametria do not determine the resting position of the cervix in normal healthy women, since the cervix can be drawn to the hymen with little difficulty.[8] The same can be said of the vaginal apex after hysterectomy. Damage to the upper suspensory fibers of the paracolpium allows uterine or vaginal vault prolapse (Figure 8). Damage to the level II and III portions of vaginal support results in anterior and posterior prolapse. The varying combinations of these defects are responsible for the diversity of clinically encountered problems.

Anterior Vaginal and Urethral Support

The position and mobility of the anterior vagina, bladder, and urethra are important to urinary continence and anterior prolapse.[9] By fluoroscopy, the urethra and vesical neck are normally mobile structures while the dis-

FIGURE 7. Uterine prolapse showing the cervix protruding from the vaginal opening and vaginal prolapse where the puckered scar indicates where the cervix used to be and upper vagina are prolapsed (DeLancey 2002, with permission).

FIGURE 8. Damage to the suspensory ligaments that can lead to eversion of the vaginal apex when subjected to downward forces (DeLancey 2002, with permission).

tal urethra remains fixed in location.[10,11] Both pelvic muscles and fasciae determine the support of the urethra.[12] Disruption of this supportive system will result in downward descent of the anterior vaginal wall. Anterior vaginal support depends on the connections of the vagina and periurethral tissues to the muscles and fascia of the pelvic wall; it does not depend on attachments of the urethra itself to adjacent structures (Figure 9). On both sides of the pelvis, the arcus tendineus fascia pelvis is a band of connective tissue attached at one end to the lower sixth of the pubic bone, one centimeter from the midline, and at the other end to the ischium, just above the spine.

The layer of tissue that provides urethral support has two lateral attachments: fascial and muscular.[13] The fascial attachment of the urethral supports connects the periurethral tissues and anterior vaginal wall to the arcus tendineus fascia pelvis and has been called the paravaginal fascial attachments by Richardson et al.[14] Lateral detachment of the paravaginal fascial connections from the pelvic wall is associated with stress incontinence and anterior prolapse (Figure 10). The muscular attachment connects these same periurethral tissues to the medial border of the levator ani muscle. These attachments allow the levator ani muscle's normal resting tone to maintain the position of the vesical neck, supported by the fascial attachments. When the muscle relaxes at the onset of micturition, it allows the vesical neck to rotate downward to the limit of the elasticity

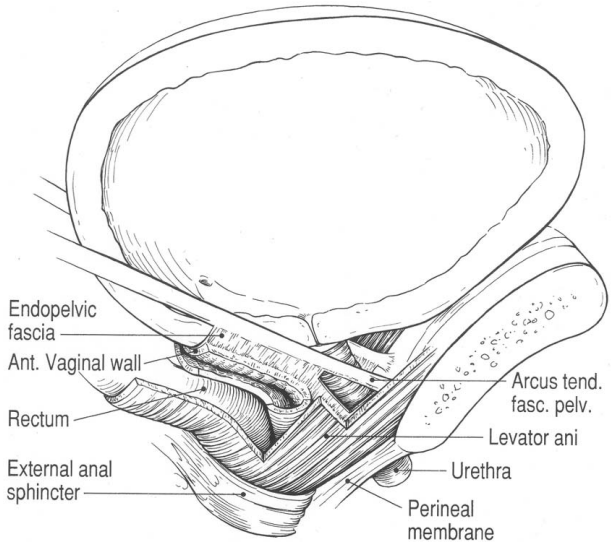

FIGURE 9. Lateral view of the pelvic floor structures related to urethral support seen from the side in the standing position, cut just lateral to the midline. Note that windows have been cut in the levator ani muscles, vagina, and endopelvic fascia so that the urethra and anterior vaginal walls can be seen. (DeLancey 2002, with permission; redrawn after DeLancey 1994)

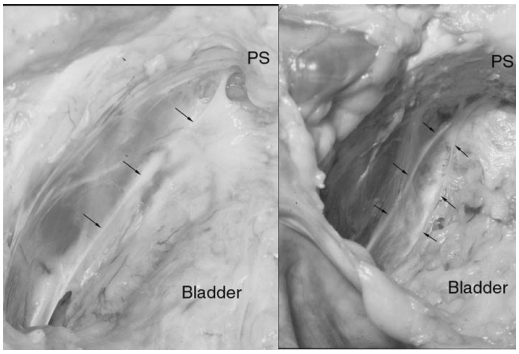

FIGURE 10. *Left panel* shows the attachment of the arcus tendineus fascia pelvis to the pubic bone [arcus tendineus fascia pelvis, *black arrow*]. *Right panel* shows a paravaginal defect where the cervical fascia has separated from the arcus tendineus (*black arrow* points to the sides of the split) (*PS* = pubic symphysis) (DeLancey 2002, with permission).

FIGURE 11. *Left:* Displacement "cystocele" where the intact anterior vaginal wall has prolapsed downward due to paravaginal defect. Note that the right side of the patient's vagina and cervix has descended more than the left because of a larger defect on this side. *Right:* Distension "cystocele" where the anterior vaginal wall fascia has failed and the bladder is distending the epithelium (DeLancey 2002, with permission).

of the fascial attachments; contraction at the end of micturition brings the vesical neck back to its normal position.

Anterior prolapse can occur either because of lateral detachment of the anterior vaginal wall at the pelvic side wall, referred to as a displacement "cystocele", or as a central failure of the vaginal wall itself that results in distension "cystocele" (Figure 11). Although various grading schemes have been described for anterior vaginal prolapse, they are often focused on the degree of prolapse rather than the anatomic perturbation that results in this descent; therefore, it is important to describe anterior prolapse with regard to the location of the fascial failure (lateral detachment versus central failure).

It has been postulated that urethral support influences stress incontinence, not by determining how high or how low the urethra is, but by how it is supported. The urethra lies on the anterior vagina, which is supported by its connections to the arcus tendineus fascia pelvis and the levator ani muscles. Simulated increases in abdominal pressure compress the urethra against the vaginal wall, which acts as a supporting hammock (Figure 12).[13] It is the relative elasticity of this support rather than the absolute position of the urethra that results in stress incontinence. With a firm supportive layer, the urethra is compressed between abdominal pressure and the pelvic fascia, in much the same way that you can stop the flow of water through a garden hose by stepping on it and compressing it against an underlying sidewalk. If, however, the layer under the urethra becomes unstable and does not provide a firm backstop against abdominal pressure, the opposing force that causes closure is lost and the occlusive action diminished. This latter situation is similar to trying to stop the flow of water through a garden hose by stepping on it while it lays on soft soil.

Posterior Support

The posterior vagina is supported by connections between the vagina, the bony pel-

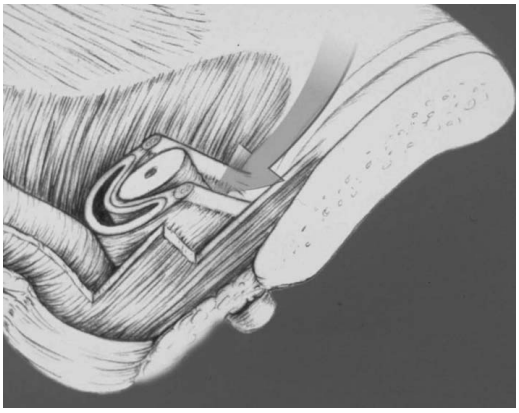

FIGURE 12. Lateral view of pelvic floor with the urethra and fascial tissues transected at the level of the proximal urethra. The arrow indicates compression of the urethra by a downward force against the supportive tissues and illustrates the influence of abdominal pressure on the urethra (DeLancey 1994, with permission).

vis, and the levator ani muscles.[15] The lower one-third of the vagina is fused with the perineal body (level III), (Figure 13) which joins the perineal membranes on either side. This connection prevents downward descent of the rectum in this region. If the fibers that connect one side with the other rupture, the bowel may protrude downward resulting in posterior vaginal prolapse. (Figure 14) The mid-posterior vagina (level II) is connected to the inside of the levator ani muscles by sheets of endopelvic fascia (Figure 15). These connections prevent vaginal descent during increases in abdominal pressure. The most medial aspects of these paired sheets are the rectal pillars. In its upper one-third, the posterior vagina is connected laterally by the paracolpium. Separate systems for anterior and posterior vaginal support do not exist at level I.

The attachment of the levator ani muscles to the perineal body is important. Using magnetic resonance imaging (MRI), up to 20% of primiparous women have a visible defect in the levator ani muscle.[16] Moreover, these defects were found to occur more

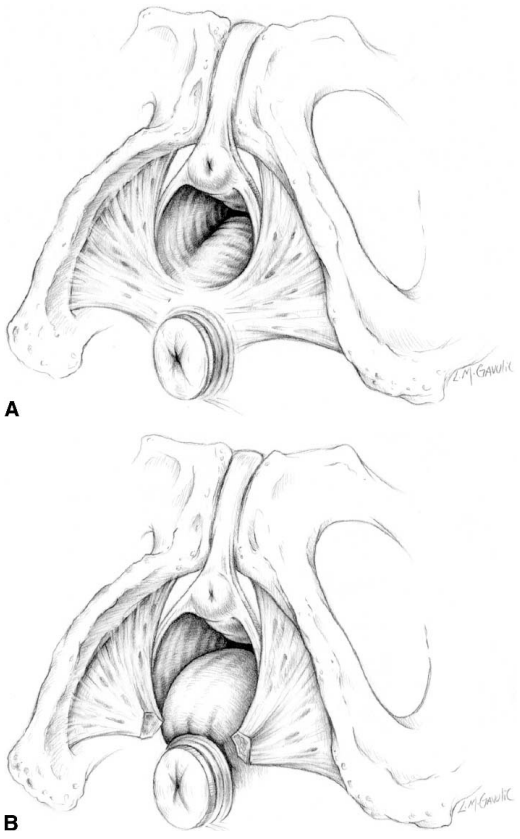

FIGURE 13. The perineal membrane spans the arch between the ischiopubic rami with each side attached to the other through their connection in the perineal body. Note that separation of the fibers in this area leaves the rectum unsupported and results in a low posterior prolapse (DeLancey 1999, with permission).

frequently in women with stress incontinence.[16] An individual with muscles that do not function properly has a problem that is not surgically correctable.

Levator Ani Muscles

The levator ani muscles play a critical role in supporting the pelvic organs.[17–19] Not only has evidence of this been seen in magnetic resonance scans[20,21] but histologic evidence of muscle damage has been found as well[22] and tied to operative failure.[23] Any connec-

FIGURE 14. Posterior prolapse due to separation of the perineal body. Note the end of the hymenal ring that lies laterally on the side of the vagina, no longer united with its companion on the other side (DeLancey, with permission).

tive tissue within the body may be stretched by subjecting it to a constant force. Skin expanders used in plastic surgery stretch the dense and resistant dermis to extraordinary degrees and flexibility exercises practiced by dancers and athletes elongate leg ligaments with as little as 10 minutes of stretching a day. Both of these observations underscore the malleable nature of connective tissue when subjected to force over time. If the ligaments and fasciae within the pelvis were subjected to the continuous stress imposed on the pelvic floor by the great force of abdominal pressure, they would stretch. This stretching does not normally occur because the constant tonic activity of the pelvic muscles[24] closes the pelvic floor and carries the weight of the abdominal and pelvic organs, preventing constant strain on the connective tissue.

Below the fascial layer are the levator ani muscles.[25] (Figure 17). The connective tissue covering on both superior and inferior surfaces are called the superior and inferior fascia of the levator ani. When these muscles and their associated fascia are considered together, the combined structures make up the pelvic diaphragm. The opening between the levator ani muscles through which the urethra, vagina, and rectum pass (and through which prolapse occurs) is the urogenital hiatus. The urogenital hiatus is supported anteriorly by the pubic bones and the levator ani muscles, and posteriorly by the perineal body and external anal sphincter. The normal baseline activity of the levator ani muscle keeps the urogenital hiatus closed by compressing the urethra, vagina, and rectum against the pubic bone, pulling the pelvic floor and organs in a cephalic direction.[26]

There are two basic regions of the levator ani muscle. The iliococcygeal and coccygeal portions form a relatively flat, horizontal shelf that spans the potential gap from one pelvic sidewall to the other. The second portion of the levator ani muscle is the pubococcygeus, the pubovisceral component that arises from the pubic bone on either side, forming a sling around and behind the pelvic organs. It also attaches to the walls of the pelvic organs and includes the puborectalis portion. The constant muscle tone of the pubococcygeal portion is responsible for holding the pelvic floor closed by coapting the urogenital hiatus. This continuous contraction, similar to the external anal sphincter, closes the lumen of the vagina much as the anal sphincter closes the anus. This constant action eliminates any opening within the pelvic floor through which prolapse could occur and forms a relatively horizontal shelf on which the pelvic organs are supported.[27]

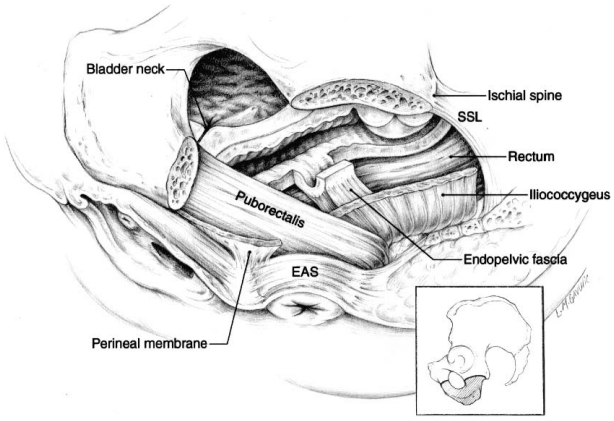

FIGURE 15. Lateral view of the pelvis showing the relationships of the puborectalis, iliococcygeus, and pelvic floor structures after removal of the ischium below the spine and sacrospinous ligament. The bladder and vagina have been cut in the midline yet the rectum left intact. Note how the endopelvic fascial "pillars" hold the vaginal wall dorsally preventing its downward protrusion [*SSL* = sacrospinous ligament; *EAS* = external anal sphincter) (DeLancey 1999, with permission).

Interactions Between the Pelvic Muscles and Endopelvic Fascia

Interaction between the pelvic muscles and the supportive connective tissue is critical to pelvic organ support. As long as the levator ani muscles function properly, the urogenital hiatus is closed and the connective tissue is under minimal tension, acting to stabilize the organs in their position above the levator ani muscles. When the pelvic muscles relax or are damaged, the urogenital hiatus opens and the vagina lies between the high abdominal pressure and low atmospheric pressure. In this situation, the vagina must be held in place by the fascia. Although the fascia can sustain these loads for short periods of time, if the pelvic muscles do not close the urogenital hiatus, the connective tissue eventually fails, resulting in prolapse. The support of the vagina has been likened to a ship in its berth, floating on the water and attached by ropes on either side to a dock.[28] The ship is analogous to the vagina, the ropes to the ligaments, and the water to the supportive layer formed by the pelvic muscles. The ropes function to hold the ship

FIGURE 16. Mid-vaginal posterior prolapse that protrudes through the introitus despite a normally supported perineal body (DeLancey, with permission).

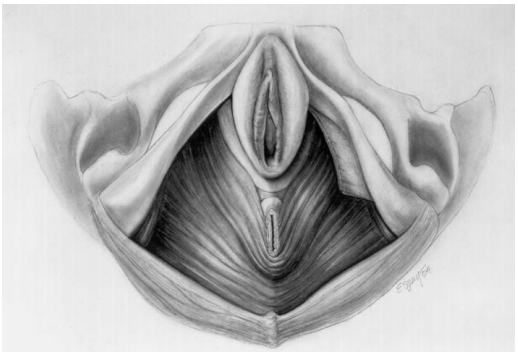

FIGURE 17. Levator ani muscles seen from below the edge of the perineal membrane ("urogenital diaphragm") can be seen on the left of the specimen (DeLancey, with permission).

(vagina) in the center of its berth as it rests on the water (pelvic muscles). If, however, the water level were to fall far enough that the ropes would be required to hold the ship without the supporting water, the ropes would all break. The analogous situation in the pelvic floor involves the pelvic muscles supporting the vagina, stabilized in position by the fascia. Once the pelvic musculature becomes damaged and no longer holds the organs in place, the connective tissue fails.

Perineal Membrane (Urogenital Diaphragm) and External Genital Muscles

In the anterior pelvis, below the levator ani muscles, there is a dense triangular membrane called the perineal membrane. The term "perineal membrane" replaces the old term "urogenital diaphragm," reflecting the fact that this layer is not a single muscle layer with a double layer of fascia ("diaphragm") but rather a set of connective tissues that surround the urethra.[29] The orientation consists of a single connective tissue membrane, with muscle lying immediately above. The perineal membrane lies at the level of the hymen and attaches the urethra, vagina, and perineal body to the ischiopubic rami (Figure 18). The compressor urethrae and urethrovaginal sphincter muscles are associated with the upper surface of the perineal membrane. This anatomy explains the observation that pressures during a cough are greatest in the distal urethra[30,31] where the compressor urethra and urethrovaginal sphincter compress the lumen in anticipation of a cough.[32,33]

Functional Anatomy of the Lower Urinary Tract

Urinary continence is maintained by a complex relationship that involves neurophysiology and structural support to the lower urinary tract. The lower urinary tract can be divided into the bladder and urethra (Figure 19, Figure 20), joined at the vesical neck.

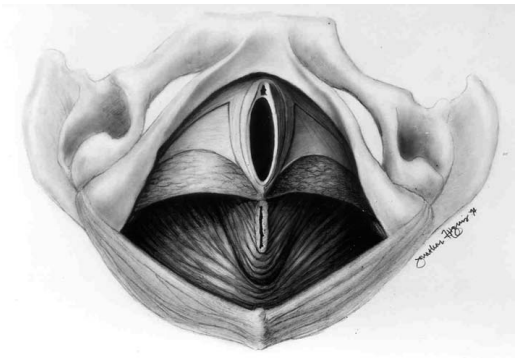

FIGURE 18. Position of the perineal membrane and its associated components of the striated urogenital sphincter, the compressor urethra and the urethrovaginal sphincter (DeLancey, with permission).

Bladder

The bladder is a hollow organ composed of epithelium surrounded by layers of smooth muscle. The bladder has two primary functions: storage and evacuation of urine (voiding), for which the detrusor muscle has a "storage phase" and an "emptying phase." During the storage phase, the muscular layers relax to accommodate urine so that increasing volumes are stored without appreciable increases in intravesical pressure. The emptying phase occurs when the bladder reaches its physiological capacity or when a woman voluntarily voids. After urethral relaxation, tonic inhibition of the detrusor is released and reflex voiding contraction is initiated. Increased post-void residual urine in some women with anterior vaginal prolapse supports the premise that proper location of the bladder relative to the vesical neck is important for efficient voiding.

Vesical Neck

The term "vesical neck" is both regional and functional; it does not refer to a single ana-

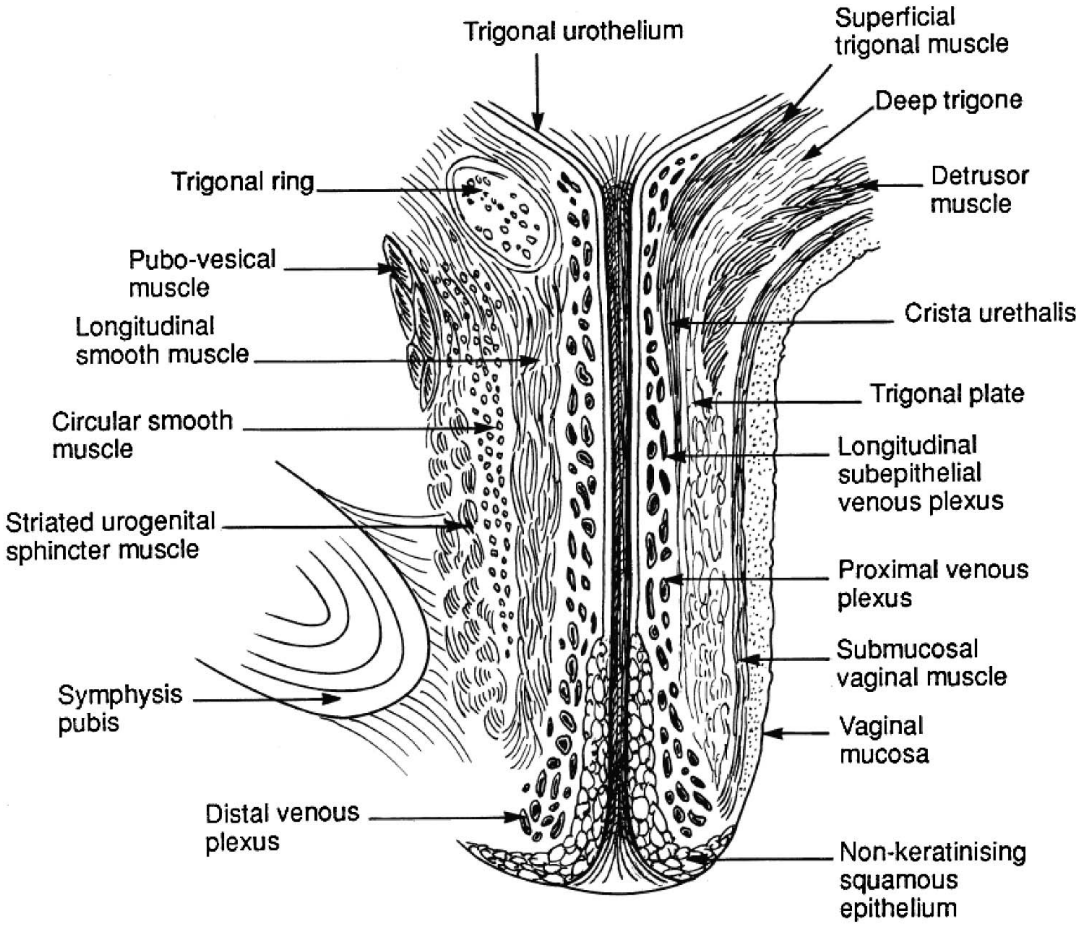

FIGURE 19. Cross-section of the urethra modified from Huisman (1983) [from Strohbehn and DeLancey (Saunders, with permission)].

tomic entity. It denotes that area at the base of the bladder where the urethral lumen passes through the thickened detrusor musculature of the bladder base that surrounds the trigone and urethral meatus.[34]

Urethra

The urethra is a complex tubular organ extending below the bladder. In its upper third, it is clearly separable from the adjacent vagina, but its lower portion is fused with the vaginal wall. The urethra is associated with several structures that are relevant for understanding lower urinary tract dysfunction.[35]

Striated Urogenital Sphincter

The striated urogenital sphincter muscle, often referred to as the external urethral sphincter, encircles the urethra in its midportion. Distally, under the arch of the pubic bone, these fibers diverge to insert into the walls of the vagina and the perineal membrane (the compressor urethrae and urethrovaginal sphincter muscles) (Figure 18). These muscles are responsible for increasing intraurethral pressure during times of need and contribute about one-third of the resting tone of the urethra. The muscle fibers, which are primarily slow-twitch and fatigue-resistant, are constantly active.

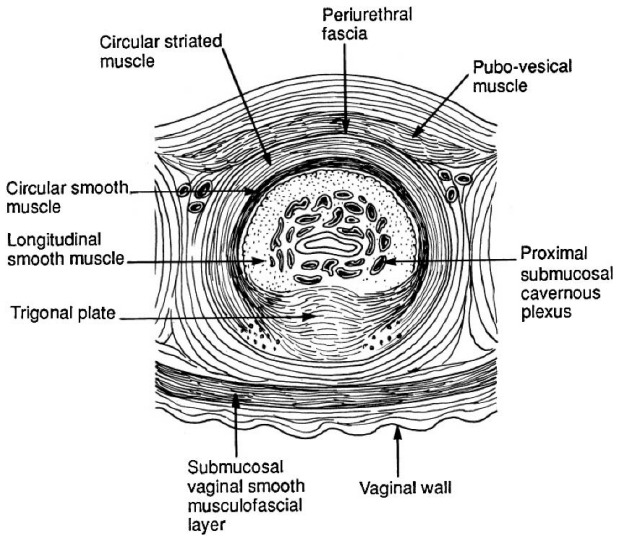

FIGURE 20. Sagittal section of the mid-urethra modified from Huisman (1983) [from Strohbehn and DeLancey (Saunders, with permission)].

Urethral Smooth Muscle

The urethral smooth muscle has two layers: outer circular and inner longitudinal layers. Smooth muscle blockade reduces resting urethral closure pressure by about one-third. The circular fibers contribute to urethral constriction. The function of the longitudinal muscle is not understood. Although there is considerably more longitudinal muscle than circular muscle, the reasons for this have yet to be determined.

Submucosal Vasculature

The submucosal vasculature is remarkably prominent, far more extensive than expected for such a small organ. The vasculature is probably responsible in part for the hermetic seal that maintains urethral closure. Occlusion of arterial flow to the urethra decreases resting urethral closure pressure.

Glands

The submucosa contains a variable number of glands, primarily along the vaginal side of the urethra,[36] and concentrated in the distal and middle thirds of the urethra. The location of urethral diverticula, cystic dilation of these glands, follows this distribution.

References

1. Olsen AL, Smith VJ, Bergstrom JO, et al. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. *Obstet Gynecol*. 1997;89:501–506.
2. Mant J, Painter R, Vessey M. Epidemiology of genital prolapse: observations from the Oxford Family Planning Association Study. *Br J Obstet Gynaecol.* 1997;104:579–585.
3. Weber AM, Abrams P, Brubaker L, et al. The standardization of terminology for researchers in female pelvic floor disorders. *International Urogynecology Journal*. 2001;12:178–186.
4. Bonney V. The principles that should underlie all operations for prolapse. *Obstet Gynaecol Br Emp*. 1934;41:669.
5. DeLancey JO. Anatomic aspects of vaginal eversion after hysterectomy. *Am J Obstet Gynecol.* 166:1992.
6. Campbell RM. The anatomy and histology of the sacrouterine ligaments. *Am J Obstet Gynecol*. 1950;59:1.
7. Range RL, Woodburne RT. The gross and microscopic anatomy of the transverse cer-

vical ligaments. *Am J Obstet Gynecol*. 1964; 90:460.

8. Bartscht KD, DeLancey JO. A technique to study the passive supports of the uterus. *Obstet Gynecol*. 1988;72:940–943.
9. Ala-Ketola L. Roentgen diagnosis of female stress urinary incontinence. Roentgenological and clinical study. *Acta Obstet Gynecol Scand Suppl*. 1973;23:1.
10. Muellner SR. Physiology of micturition. *J Urol*. 1951;65:805.
11. Westby M, Asmussen M, Ulmsten U. Location of maximum intraurethral pressure related to urogenital diaphragm in the female subject as studied by simultaneous urethrocystometry and voiding urethrocystography. *Am J Obstet Gynecol*. 1982;144:408–412.
12. Miller JM, Perucchini D, Carchidi LT, et al. Pelvic floor muscle contraction during a cough and decreased vesical neck mobility. *Obstet Gynecol*. 2001;97:255.
13. DeLancey JO. Structural support of the urethra as it relates to stress urinary incontinence: the hammock hypothesis. [comment] *Am J Obstet Gynecol.* 1994;170:1713.
14. Richardson AC, Edmonds PB, Williams NL. Treatment of stress urinary incontinence due to paravaginal fascial defect. *Obstet Gynecol*. 1981;57:357.
15. DeLancey JO. Structural anatomy of the posterior pelvic compartment as it relates to rectocele. [comment] *Am J Obstet Gynecol*. 1999;180:815.
16. 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: 46–53.
17. Porges RF, Porges JC. After office hours: the anatomy and etiology of genital prolapse in women (translated by Halban and Tandler). *Obstet Gynecol*. 1960;15:790.
18. Halban J, Tandler I. Anatomie und Aetiologie der Genitalprolapse beim Weibe. Vienna: 1907.
19. Berglas B, Rubin IC. Study of the supportive structures of the uterus by levator myography. *Surg Gynecol Obstet*. 1953;97:677.
20. Kirschner-Hermanns R, Wein B, Niehaus S, et al. The contribution of magnetic resonance imaging of the pelvic floor to the understanding of urinary incontinence. *Br J Urol.* 72: t, 1993
21. Tunn R, Paris S, Fischer W, et al. Static magnetic resonance imaging of the pelvic floor muscle morphology in women with stress urinary incontinence and pelvic prolapse. *Neurourol Urodyn*. 1998;17:579–589.
22. Koelbl H, Strassegger H, Riss PA, et al. Morphologic and functional aspects of pelvic floor muscles in patients with pelvic relaxation and genuine stress incontinence. *Obstet Gynecol*. 1989;74:789–795.
23. Hanzal E, Berger E, Koelbl H. Levator ani muscle morphology and recurrent genuine stress incontinence. *Obstet Gynecol.* 1993; 81:426.
24. Parks AG, Porter NH, Melzak J. Experimental study of the reflex mechanism controlling muscles of floor. *Dis Colon Rectum*. 1962;5:407.
25. Lawson JO. Pelvic anatomy. I. Pelvic floor muscles. *Ann R Coll Surg Engl*. 1974;54: 244.
26. Taverner D. An electromyographic study of the normal function of the external anal sphincter and pelvic diaphragm. *Dis Colon Rectum*. 1959;2:153.
27. Nichols DH, Milley PS, Randall CL. Significance of restoration of normal vaginal depth and axis. *Obstet Gynecol*. 1970;36: 251.
28. Paramore RH. The uterus as a floating organ. In: The statics of the female pelvic viscera. Edited by Lewis: London: p. 12, 1918.
29. Oelrich TM. The striated urogenital sphincter muscle in the female. Anatomical Record, 223, 1983
30. Hilton P, Stanton SL. Urethral pressure measurement by microtransducer: the results in symptom-free women and in those with genuine stress incontinence. *Br J Obstet Gynaecol*. 1983;90:919–933.
31. Constantinou CE. Resting and stress urethral pressures as a clinical guide to the mechanism of continence in the female pa-

tient. *Urol Clin North Am*. 1985;12:247–258.
32. DeLancey JO. Structural aspects of the extrinsic continence mechanism. *Obstet Gynecol*. 1988;72:296–301.
33. DeLancey JO. Correlative study of paraurethral anatomy. *Obstet Gynecol*. 1986;68: 91–97.
34. Gil Vernet S. Morphology and function of the vesicoprostato-urethral musculature. Edizioni Canova, Treviso, 1968.
35. Huisman AB. Aspects on the anatomy of the female urethra with special relation to urinary continence. *Contributions to Gynecology & Obstetrics*. 1983;10:1–31.
36. Huffman J. Detailed anatomy of the paraurethral ducts in the adult human female. *Am J Obstet Gynecol*. 1948;55:86.