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CURRENT CONCEPTS IN PELVIC ANATOMY AND RECONSTRUCTIVE SURGERY

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Supplement 4 to Volume 72, December 2005

Supplement Editor

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Preface:

Sizing up the evolution of reconstructive pelvic surgery

Reconstructive pelvic surgery is undergoing an evolution from art to science. This evolution has been a gradual one, stemming from increasing knowledge about normal and altered anatomy as well as from technological advances in surgical materials and techniques. It also has been well timed, as the aging of our population has resulted in growing numbers of women presenting to gynecologists' offices with genital prolapse and urinary incontinence. This supplement aims to reflect this evolution in practical terms by updating readers on the currently prevailing concepts about pelvic floor anatomy and on new techniques for repair of the two most challenging areas of reconstructive surgery: the vaginal apex and the anterior vaginal wall.

Normal anatomic support of the pelvic floor structures is based on the delicate interrelationship between the bony skeleton, intact neuromuscular function, and adequate ligamentous and fibromuscular fascial support structures. It is on the two areas of the female pelvis most likely to be affected by weakness in support—the apex (due to torn support ligaments) and the anterior wall (due to deficient endopelvic fascia)—that this supplement will focus.

Anatomic dissections and radiologic imaging techniques have been invaluable in improving our understanding of the pathophysiology of prolapse. Surgical correction approaches have evolved through a series of steps beginning with traditional reparative techniques and progressing to the development of specific tools and minimally invasive techniques, the increased acceptance of synthetic and biologic grafts, and the subsequent development of surgical kits that are applicable to most patients with prolapse regardless of the site of support weakness (Figure).

This evolution of surgical approaches has been swift, owing primarily to technological advances in materials and techniques. As a result, new potential complications, such as graft-related healing difficulties, have become apparent. Being prepared to address these complications is of great importance for the reconstructive surgeon in a referral practice. To that end, the final article in this supplement reviews accepted means of optimizing surgical outcomes, from both prophylactic and therapeutic perspectives.

Future progress in this field can be expected to lead to further innovation, with its associated benefits and drawbacks. Reconstructive surgeons should familiarize themselves with new techniques as they become available, and evaluate the utility of each with a critical, yet open, mind.

Evolution of reconstructive surgery

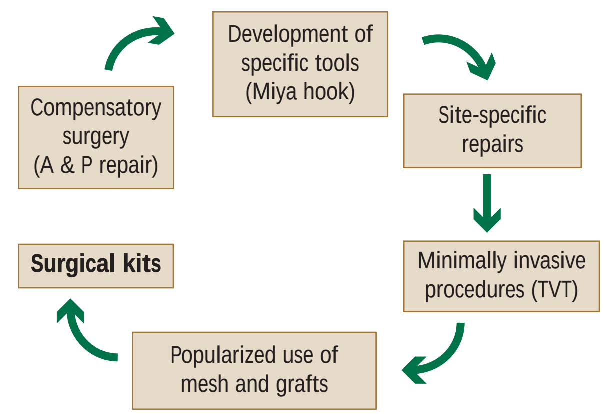

FIGURE. Schematic of the evolution of surgical techniques. A & P repair = anterior and posterior colporrhaphy; TVT = tension-free vaginal tape.

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Contemporary views on female pelvic anatomy

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The durable surgical repair of pelvic organ prolapse and its related disorders remains a significant challenge. The pelvic reconstructive surgeon needs an intimate knowledge of relevant surgical landmarks as well as a fundamental understanding of the biomechanics of pelvic organ support in order to successfully restore normal visceral anatomy and function. Rather than presenting a detailed description of female pelvic anatomy, this review provides a discussion of the contemporary understanding of female pelvic organ support, with emphasis on the functional and surgical anatomy of the vagina, urethra, and pelvic floor, as well as a discussion of obturator anatomy, as several new innovative procedures now use the transobturator approach.

ORIENTATION OF THE BONY PELVIS

The pelvic bones are the ilium, ischium, pubic rami, sacrum, and coccyx. The bony pelvis is the rigid foundation to which all of the pelvic structures are ultimately anchored. Although pelvic surgeons often visualize the orientation of the pelvis in the supine or 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 spine and the front edge of the pubic symphysis are in the same vertical plane, perpendicular to the floor (Figure 1). As a consequence, the pelvic inlet is tilted anteriorly and the ischiopubic rami and genital hiatus 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 intra-abdominal and pelvic contents toward the bones of the pelvis instead of 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 will 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 the bony articulation inferiorly.

Varied shape, orientation associated with prolapse

Variations in the orientation and shape of the bony pelvis have been associated with the development of pelvic organ prolapse. Specifically, a loss of lumbar lordosis and a pelvic inlet that is less vertically oriented is more common in women who develop genital prolapse than in those who do not.[1,2] A less vertical orientation of the pelvic inlet is thought to result in an alteration of the intra-abdominal vector forces that are normally directed anteriorly to the pubic symphysis such that a greater proportion is directed toward the pelvic viscera and their connective tissue and muscular supports. Similarly, women with a wide transverse pelvic inlet appear to be at increased risk of developing pelvic organ prolapse.[3,4] Some have theorized that a wider pelvic inlet provides a larger hiatus for abdominal pressure transmission to the pelvic floor, which leads to loss of pelvic visceral support over time.[3] Variations in the shape and orientation of the bony pelvis are also an important factor that influences maternal soft-tissue damage and nerve injury during parturition.

PELVIC FLOOR MUSCULATURE

The skeletal muscles of the pelvic floor include the levator ani muscles, the coccygeus, the external anal sphincter, the striated urethral sphincter, and the deep and superficial perineal muscles. The muscles of

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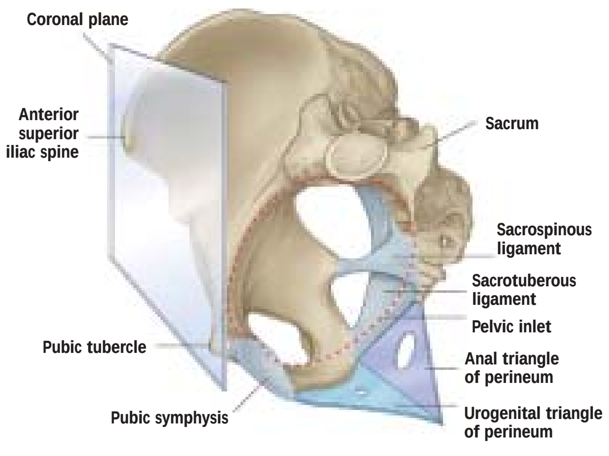

FIGURE 1. Orientation of the bony pelvis in the standing position. In this position, the anterior superior iliac spine and the pubic tubercle are perpendicular to the floor, whereas the urogenital triangle of the perineum is horizontal. Reprinted from Drake RL et al, eds, Gray's Anatomy for Students, copyright 2005, with permission from Elsevier.

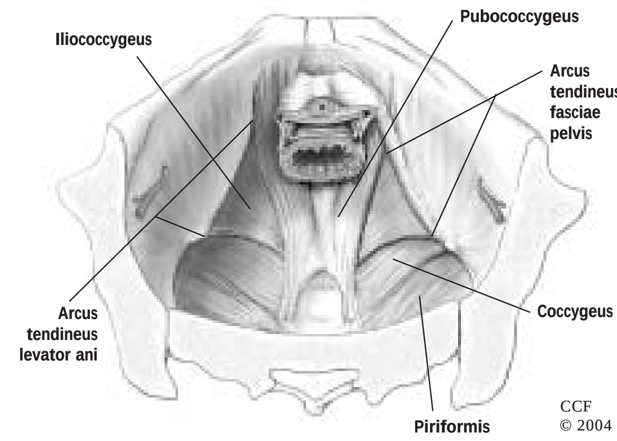

FIGURE 2. Illustration of the female pelvic floor showing relationships of the muscles of the pelvic floor and sidewalls and their attachments from an abdominal view. The arcus tendineus fasciae pelvis has been removed on the left, showing the origins of the levator ani muscles. On the right, the arcus tendineus fasciae pelvis remains intact, showing the attachment of the lateral vagina via the endopelvic fascia (cutaway).

the pelvic floor, particularly the levator ani muscles, have a critical role in supporting the pelvic visceral organs and play an integral role in urinary, defecatory, and sexual function. The levator ani muscle complex consists of the pubococcygeus (also called pubovisceral), the puborectalis, and the iliococcygeus (Figure 2).[5,6] The pubococcygeus originates on the posterior inferior pubic rami and inserts on the midline-visceral organs and the anococcygeal raphe. The puborectalis also originates on the pubic bone, but its fibers pass posteriorly and form a sling around the vagina, rectum, and perineal body, resulting in the anorectal angle and promoting closure of the urogenital hiatus. The iliococcygeus originates from the arcus tendineus levator ani (ATLA), a linear thickening of the fascial covering of the obturator internus that runs from the ischial spine to the posterior surface of the ipsilateral superior pubic ramus. It inserts in the midline onto the anococcygeal raphe. The space between the levator ani musculature through which the urethra, vagina, and rectum pass is called the urogenital hiatus. The fusion of levator ani where they meet in the midline creates the so-called levator plate.

Constant resting tone, quick contraction ability

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

Three-dimensional structure for levator ani complex

Although most anatomy and surgical texts depict the levator ani muscles as a bowl or funnel-shaped, this reflects the uncontracted state of the muscles as might be seen in a cadaver dissection and not that of a normally functioning levator. In a woman with normal pelvic floor function, the levator ani muscle complex in its tonically contracted state has an intricate three-dimensional structure in which its anterior portion (pubococcygeus and puborectalis) is oriented vertically as a sling around the mid-urethra, vagina, and anorectum and its posterior portion (the iliococcygeus) has a horizontal upwardly biconvex shape resembling a butterfly wing (Figure 3).[7] Thus, the anterior portion of the levator ani complex serves to close the urogenital hiatus and pull the urethra, vagina, perineum, and anorectum toward the pubic bone, whereas 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 laxity of the urogenital hiatus, loss of the horizontal orientation of the levator plate, and a more bowl-like configuration. These changes can be bilateral or asymmetric.[8]

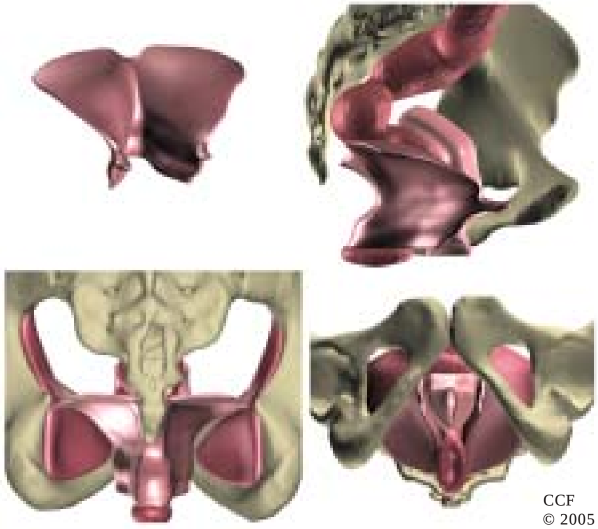

FIGURE 3. Digitally enhanced three-dimensional reconstructions of the female pelvic floor from a magnetic resonance image of the pelvis in a normal nulliparous 23-year-old woman. Upper left: anterior view of the levator ani muscle with normal resting tone. Upper right: sagittal view of the levator ani muscle, bony pelvis, vagina, and rectum. Lower left: posterior view of the levator ani muscle, obturator internus muscles, and bony pelvis. Lower right: lithotomy view.

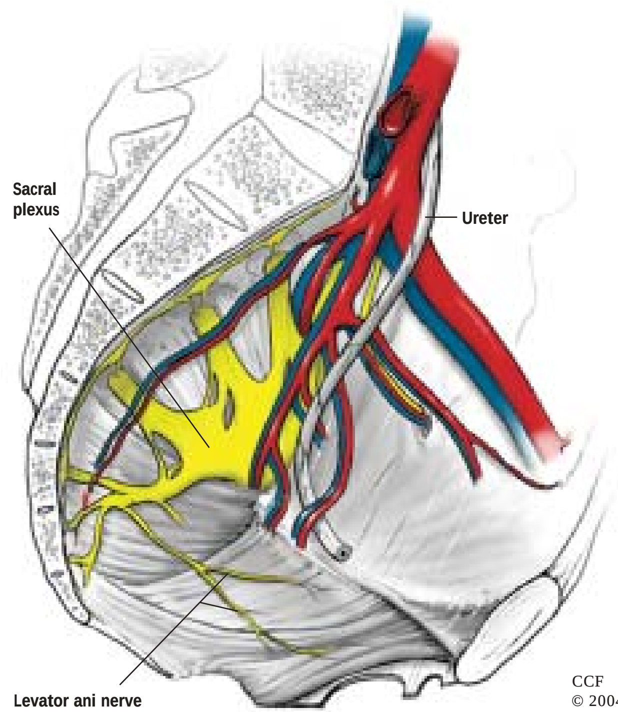

FIGURE 4. Sagittal view of the pelvis showing the arterial (red) and venous (blue) blood supply and nerves.

Such configurations are seen more often in women with pelvic organ prolapse than in those with normal pelvic organ support.[7]

INNERVATION OF THE PELVIC FLOOR MUSCLES

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. This nerve follows a complex course that originates from S2–S4 (with S3 providing the largest contribution) and travels behind the sacrospinous ligament just medial to the ischial spine, exiting the pelvis through the greater sciatic foramen. It then enters the ischiorectal fossa through the lesser sciatic foramen and travels through the pudendal canal (Alcock's canal) on the medial aspect of the obturator internus muscles before separating into several terminal branches that terminate within the muscles and skin of the perineum.

New insights into levator ani innervation

Many anatomic and surgical texts suggest that the levator ani muscles are dually innervated from (1) the pudendal nerve on the perineal surface and (2) direct branches of the sacral nerves on the pelvic surface. However, recent anatomic,[9] neurophysiologic,[10,11] and experimental evidence[12–14] indicates that these standard descriptions are inaccurate and that the levator ani muscles are innervated solely by a nerve traveling on the superior (intrapelvic) surface of the muscles without contribution of the pudendal nerve. This nerve, referred to as the levator ani nerve, originates from S3, S4, and/or S5 and innervates both the coccygeus and the levator ani muscle complex.[9] After exiting the sacral foramina, it travels 2 to 3 cm medial to the ischial spine and arcus tendineus levator ani across the coccygeus, iliococcygeus, pubococcygeus, and puborectalis **(Figure 4)**. Occasionally, a separate nerve comes directly from S5 to innervate the puborectalis muscle independently.

Given its location, the levator ani nerve is susceptible to injury through parturition and pelvic 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.

PERINEUM

Although the area between the vagina and anus is described clinically as the "perineum," anatomical-

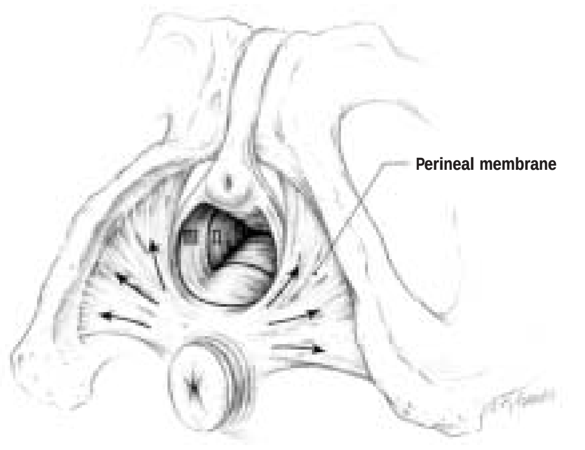

FIGURE 5. Perineal membrane with its attachments to the inferior pubic rami and direction of tension on fibers uniting through the perineal body (arrows). Reprinted from reference 16, copyright 1999, with permission from Elsevier.

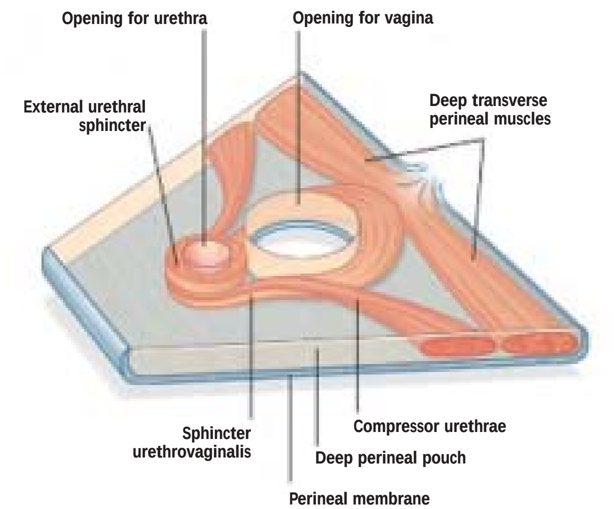

FIGURE 6. Muscles of the deep perineal space. The perineal membrane is in the horizontal plane in the standing position. The muscles of the deep perineal space lie cephalad to the perineal membrane and below the levator ani muscles. Reprinted from Drake RL et al, eds, Gray's Anatomy for Students, copyright 2005, with permission from Elsevier.

ly 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 female perineum are the ischiopubic rami, ischial tuberosities, sacrotuberous ligaments, and coccyx. A 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, whereas the anal triangle is tilted upward so that it faces more posteriorly (Figure 1).

The perineal membrane is a thick fibrous sheet that spans the urogenital triangle (Figure 5). It attaches laterally to the pubic arch and has a free posterior margin anchored in the midline by the perineal body. Although historically anatomists and clinicians have used the term *urogenital diaphragm* to describe this structure, this term has been abandoned because it erroneously implies a muscular diaphragm rather than a thick sheet of connective tissue.[15,16] 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.

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's glands. The deep perineal space lies just deep to the perineal membrane and inferior to the levator ani muscles. Within this thin space lie the external urethral sphincter and the urethrovaginalis, compressor urethrae, and deep transverse perineal muscles (Figure 6).[15,17] The urethrovaginalis and compressor urethrae muscles provide accessory sphincter function to the urethra.[17] The urethrovaginalis muscle surrounds the distal urethra and vagina without passing between them and therefore acts as a sphincter to the vagina as well as to the distal urethra.[15] 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. There is some dispute as to whether the deep transverse perineal muscle is present in females, however.[15]

The perineal body marks the point of convergence of the bulbospongiosus muscle, superficial and deep transverse perinei, perineal membrane, external anal sphincter, posterior vaginal muscularis, and fibers from the puborectalis and pubococcygeus. 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.

VAGINA

The vagina is a hollow, distensible, fibromuscular tube with rugal folds that extends from the vestibule to the uterine cervix. Its longitudinal shape resembles a trapezoid, as it is narrowest at the introitus and grows progressively wider as it approaches the vaginal apex and cervix. In the transverse dimension, the vagina is H-shaped at its distal end (toward the introitus) and flattened proximally. In the sagittal plane, the vagina has a distinct angulation so that its upper two thirds is directed toward the third and fourth sacral vertebrae and is almost horizontal in the standing position. In contrast, the lower third is nearly vertical as it passes through the perineal membrane to the vestibule. The angle between the upper and lower axes of the vagina is approximately 130°.[18]

Three layers of vaginal wall

Histologically, the vaginal wall is composed of three layers: mucosa, muscularis, and adventitia.[19,20] The vaginal mucosa is the most superficial layer and consists of stratified squamous epithelium and a lamina propria. 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.[19,20] The outermost adventitia is a variably discrete 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.

No 'fascial' layer

Some have used the terms *pubocervical fascia* and *rectovaginal fascia* to describe the layer separating the vagina from the bladder and rectum, respectively. Although these terms are widely used, "fascia" is a misnomer in this context, as it does not accurately reflect the histology of the vagina. Numerous authors have performed histologic analysis of the vaginal wall and have failed to identify a distinct "fascial" layer.[16,19,20] Between the adjacent pelvic organs is primarily vaginal muscularis. The "fascia" often noted by pelvic surgeons during vaginal dissection refers, in fact, to layers that are developed as a result of separating the vaginal epithelium from the muscularis, or by splitting the vaginal muscularis layer.[19] The one area where 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.[16] This layer does not, however, extend the full length of the posterior vaginal wall.

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. 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 while allowing 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 condensations of the endopelvic fascia and not true "ligaments": uterosacral ligament, cardinal ligament, broad ligament, mesovarium, mesosalpinx, and round ligament. The broad ligament, mesovarium, mesosalpinx, and round ligament do not play a role in support of the pelvic organs.

Three integrated levels of support

DeLancey described the connective tissue supports of the vagina in three levels[21] (Figure 7). 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 in healthy women reveal that the uterosacral ligament inserts in the area of the coccygeus and sacrospinous ligament in most women, with only 7% actually inserting into the sacrum.[22] 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.

Contiguous with the uterosacral/cardinal ligament complex at the location of the ischial spine is level II support—the paravaginal attachments. The anterior vagina is suspended laterally to the arcus tendineus fasciae pelvis (ATFP), or white line, which is a thickened condensation of fascia overlying the iliococ-

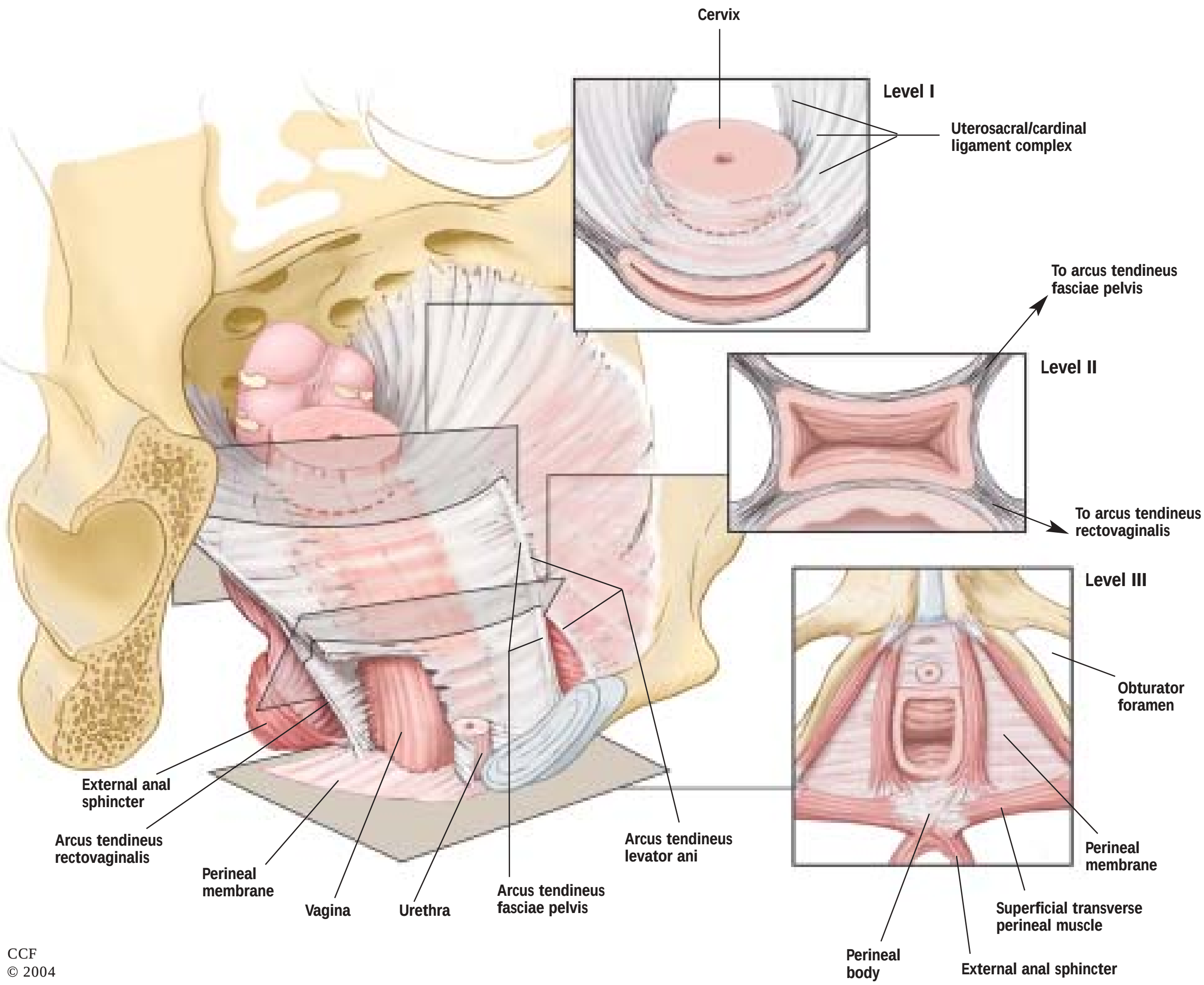

FIGURE 7. Integrated levels of support: illustration of the normal vaginal axis and the three levels of support of the vagina and uterus from the perspective of a standing woman. In level I, the endopelvic fascia suspends the upper vagina and cervix from the lateral pelvic walls. Fibers of level I extend both vertically and posteriorly toward the sacrum. In level II, the vagina is attached to the arcus tendineus fasciae pelvis and superior fascia of the levator ani muscles. In level III, the distal vagina is supported by the perineal membrane and muscles. The insets show transverse sections made through the vagina perpendicular to the normal vaginal axis at each level.

cygeus. The ATFP originates on the ischial spine and inserts on the inferior aspect of 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.

In addition 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.[23] 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 the distal vagina when viewed in cross-section and the flattened-tube configuration seen in the upper vagina (Figure 7).

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 the distal third of the vagina, which is perpendicular to the floor in a standing woman. At level III, the vagina fuses with the urethra anteriorly and with the perineal body posteriorly. 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 MUSCULAR AND CONNECTIVE TISSUE SUPPORTS

Normal pelvic organ support and function depends on 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. Intra-abdominal 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 a sneeze, there is a reflex contraction of the pelvic floor musculature, countering and further stabilizing the viscera. The genital 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 the 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 anatomic 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.

URETHRAL CONTINENCE MECHANISM

The urethra is about 3.5 to 4 cm long and averages 6 mm in diameter. Its lumen is slightly curved as it passes from the retropubic space, perforates the perineal membrane, and ends with its external orifice in the vestibule directly above the vaginal opening. Throughout most of its length, the urethra is fused to the anterior vaginal wall.

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. These vascular cushions, along with the urethral mucosa, account for approximately one third of the urethral resting tone, while the internal and external urethral sphincters account for the remainder.[24] The internal urethral sphincter is composed primarily 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, but Schafer makes a strong argument on biomechanical grounds that these longitudinal fibers serve as "filler volume" within the circular smooth muscle and striated urethral sphincter and that their presence improves the efficiency of the sphincter mechanism by allowing closure of the urethral lumen with only a small amount of circular muscle shortening.[25]

The skeletal muscle component of the urethral sphincter consists of the external urethral sphincter (also called sphincter urethrae) along with the previously described compressor urethrae and urethrovaginalis muscles. These three muscles, which function as a single unit, have been called by Oelrich the *striated urogenital sphincter*.[17] Together, they are approximately 2.5 cm long 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.

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.[26] Increased intra-abdominal pressure, as with a cough or sneeze, causes compression of the urethra against this hammock-like layer, thereby compressing the urethral lumen closed. The stability of the suburethral layer depends on the intact connection of the anterior vaginal wall and its connective tissue attachments to the ATFP 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 her urinary stream.

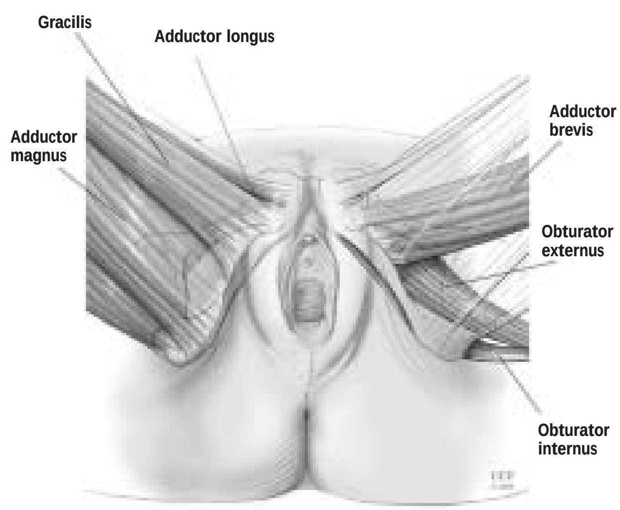

FIGURE 8. Muscles of the obturator compartment. The superficial muscles are illustrated on the left. On the right, the superficial muscles have been made transparent to allow depiction of the deeper muscles.

Defects in these attachments can result in proximal urethral support defects (urethral hypermobility) or anterior vaginal wall prolapse (cystocele), and can contribute to stress urinary incontinence.

OBTURATOR ANATOMY

The obturator *membrane* is a fibrous sheath that spans the obturator *foramen* through which the obturator neurovascular bundle penetrates via the obturator *canal*. The obturator internus muscle lies on the superior (intrapelvic) side of the obturator membrane. The origin of the obturator internus 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 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.

Recent cadaver work by Whiteside and Walters has contradicted previous reports that the obturator vessels bifurcate into medial and lateral branches.[27] Rather, the vessels are predominantly small (<5 mm in diameter) and splinter into variable courses. The muscles of the medial thigh and adductor compartment are (from superficial to deep): the gracilis, adductor longus, adductor brevis, adductor magnus, obturator externus, and obturator internus (Figure 8).

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.

CONCLUSIONS

Although human anatomy is unchanging, our understanding of the functional anatomy of the pelvic viscera and the biomechanics of pelvic organ support continues to evolve. Familiarity with the contemporary views of female pelvic organ support is essential as we refine established methods for surgically correcting pelvic organ prolapse or consider adopting new and innovative technologies. The fundamentals reviewed in this article should serve as a useful foundation for the practicing pelvic reconstructive surgeon.

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Vaginal vault prolapse:

Identification and surgical options

Daniel H. Biller, MD, and G. Willy Davila, MD

Maintenance of normal vaginal anatomy depends on the interrelationships of intact pelvic floor neuromusculature, ligaments, and fascia. This complexity of anatomic support is becoming better understood. Perhaps the least well understood area of vaginal support is the coalescence of ligaments and fascia at the vaginal apex or vault. As a result, identification of vaginal vault prolapse in a woman with an advanced degree of vaginal prolapse can be challenging. Surgical failure in any or all compartments is likely if support to the vaginal apex is not restored during operative therapy. This paper reviews the identification of vaginal vault prolapse by physical examination and the effective surgical options available to the reconstructive surgeon.

NORMAL VAULT SUPPORT ANATOMY

The vaginal apex represents a site where multiple important support structures coalesce.[1] If present, the cervix serves as an obvious strong attachment point. However, in a woman who has had a hysterectomy, the support structures lack a strong attachment site, resulting in support weakness and prolapse. The support structures include ligaments and endopelvic fascia (Figure 1), as detailed below.

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Ligaments

The uterosacral ligaments are peritoneal and fibromuscular tissue bands extending from the apex to the sacrum. They are considered the principal support structures for the vaginal apex, despite their apparent lack of significant strength.

The cardinal ligaments extend laterally from the apex to the pelvic sidewall adjacent to the ischial spine. Their role in support is less clear, as their course is less well understood. In addition, since they lie in proximity to the ureters, their use in restoring vault support by shortening or reattaching them to the apex is less attractive, unlike the uterosacral ligaments.

It is the coalescence of both ligaments, in the uterosacral-cardinal ligament complex (UCLC), that is likely crucial to maintaining vault support. In a woman who has had a hysterectomy, identifying the site of the UCLC attachment to the cuff (seen on vaginal examination as apical "dimples") is key to identifying the presence of vault prolapse.

Endopelvic fascia

The fibromuscular tissue layer that underlies the vaginal epithelium has been termed *endopelvic fascia*. Although its actual composition is somewhat controversial, it has been noted to envelop the entire vaginal canal, extending from apex to perineum and from arcus tendenius to arcus tendenius. Much like the abdominal wall aponeurosis, it maintains integrity of the anterior and posterior vaginal walls. A tear in this layer—along its lateral, inferior, or apical edges, or stretching along its central portion—will lead to herniation of the underlying tissues. If the fascial layer becomes detached from the vaginal apex, a true hernia can develop in the form of an enterocele, which can be anterior or posterior. This can lead, in turn, to further weakening of vaginal vault integrity.

Reconstructive surgeons recently have begun to espouse the concept that many cystoceles and rectoceles actually originate as a detachment of the endopelvic fascia from the vaginal apex. It is critical to restore

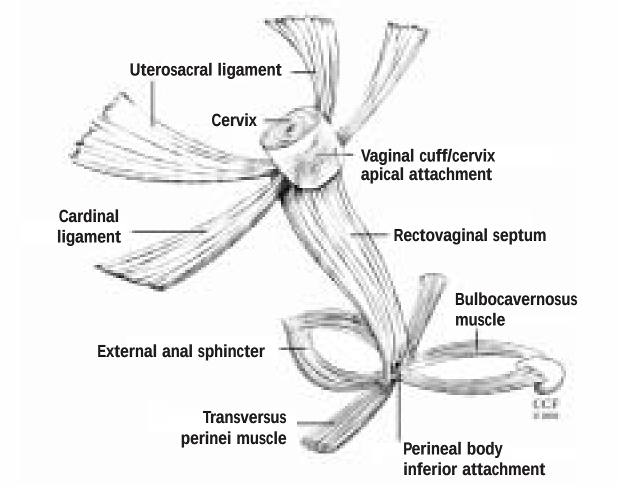


FIGURE 1. Ligamentous and fascial supports of the vaginal apex or cervix.

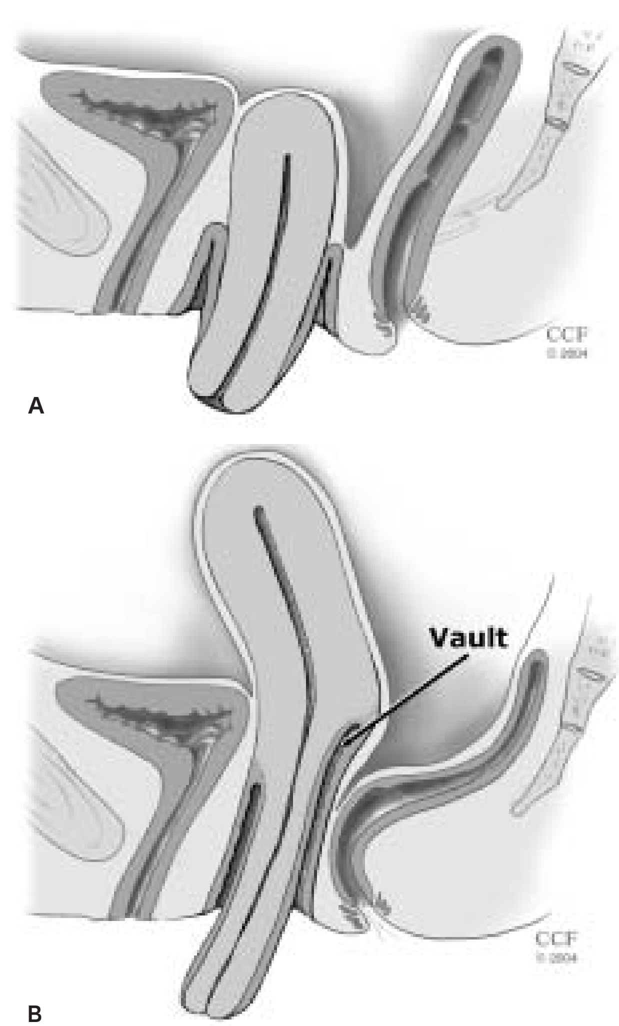


FIGURE 2. Cervical prolapse may be associated with vault prolapse (A) or may not (cervical hypertrophy without vault prolapse) (B).

anterior and posterior vaginal wall fascial integrity from apex to perineum by reattaching the patient's endogenous fascia to the vaginal apex, or augmenting the repair using a biologic or synthetic graft.

IDENTIFICATION OF VAGINAL VAULT PROLAPSE

When managing a patient with an advanced degree of vaginal prolapse, it is imperative to ascertain whether vaginal vault prolapse, with or without associated enterocele, is present. A careful and structured pelvic examination is therefore required. Whether the uterus is present or not, it may be difficult to evaluate the degree of vault support. The tools required include a bivalved speculum and a right-angled retractor, or the posterior blade of another gynecologic speculum.

When the uterus is present

The presence of an exteriorized cervix does not mean vault prolapse is present. In the presence of significant cervical hypertrophy or elongation, the cervix may be exteriorized while the apex is well supported (Figure 2). The right-angled speculum blade should be placed in the posterior fornix (behind the cervix) and inserted to its full extent. If vault prolapse is present, upon Valsalva efforts, as the speculum is removed slowly, the uterus will descend further. Reinsertion of the speculum will resuspend the uterus. If the vault is well supported, the cervix will remain in place despite Valsalva efforts. An approximation of the degree of vault prolapse can be made during this maneuver, and the effectiveness of a McCall culdoplasty in restoring vault support can be ascertained. If using the POP-Q prolapse quantification system, a patient with cervical hypertrophy and no vault prolapse will have a positive point C with a well-supported point D which will equal the total vaginal length (TVL). If a uterine suspension is performed in the face of significant cervical hypertrophy, cervical prolapse may persist, requiring partial amputation (ie, Manchester procedure).

When the patient has had a prior hysterectomy

It may be quite difficult to identify vault prolapse in a woman who has undergone a previous hysterectomy. The goal during physical examination will be to identify the apical scar tissue (cuff) resulting from the hysterectomy. In most patients, the cuff can be seen as a transverse band of tissue firmer than the adjacent vaginal walls. In a patient with extensive prolapse, the tissue is stretched and the cuff tissue is less obvi-

FIGURE 3. Vault prolapse associated with extensive exteriorized prolapse can be identified by the presence of scarring sites from previous uterosacral ligament attachments.

ous. Using a bivalved speculum can help visualize the apex, but in women with extensive prolapse the redundant vaginal tissue may make visualization difficult. Fortunately, the sites of previous UCLC attachment can usually be identified as "dimples" on either side of the midline at the cuff (Figure 3). Using both right-angled speculum blades, or one blade along the anterior vaginal wall and the examiner's index and middle fingers along the posterior vaginal wall, the dimples can usually be identified. The patient is asked to perform a Valsalva maneuver. The tip of the speculum can then be placed between the dimples, the vault elevated, and the degree of vault prolapse determined. This can then be confirmed during digital examination by identifying the dimples by tact and elevating them to their ipsilateral ischial spines.

Accuracy of the pelvic exam is key

The importance of an accurate pelvic examination cannot be overemphasized. In addition to assessing the degree and type of prolapse present, it is important to perform the examination with surgical planning in mind if the patient is considering surgical therapy. The presence of any fascial tears or defects can usually be predicted during careful vaginal examination, and usually identified by an area of abrupt change in vaginal wall thickness. A standing examination may be necessary to assess the full extent of the prolapse, and bimanual examination (one finger in the vagina and one finger in the rectum) can sometimes help to detect enterocele.

FACTORS THAT GUIDE THE SURGICAL APPROACH

The goals for repair of vaginal vault prolapse include normalizing support of all anatomic compartments, alleviating clinical symptoms, and optimizing sexual, bowel, and bladder function. Care must be taken to restore normal anatomy and function to all compartments, without precipitating new support or functional problems. A thorough evaluation as described above is necessary before surgical correction.

Currently, most surgeons prefer a vaginal approach to pelvic reconstruction. However, the choice of approach should be based on what is best for the patient's individual variables. The following factors are particularly important when planning a surgical approach for vault prolapse.

Importance of sexual function. If the patient reports that vaginal sexual function is of great importance to her (age may be an unrelated issue here), a sacrocolpopexy should be primarily considered, as it avoids vaginal incisions and associated potential vaginal narrowing/shortening.

Vaginal length. A patient whose vaginal apex (dimples) reaches the ischial spines with ease will do well with a vaginal procedure, whereas a patient whose dimples either do not reach or extend far above the ischial spines may be better served by an abdominal sacrocolpopexy or an obliterative procedure, if appropriate.

Previous reconstructive procedures. The degree of existent scarring and fibrosis must be kept in mind, as the area around the sacral promontory, or sacrospinous ligaments, may be difficult or risky to reach. This is especially important in this age of commonplace graft use.

Presence of large paravaginal defects. Although paravaginal defect repairs can be performed vaginally, they can be technically difficult and their long-term outcomes have not been reported. Thus, an abdominal approach may be better if significant paravaginal defects are present.

Medical comorbidities. For a medically delicate patient or a patient of advanced age, a vaginal, if not obliterative, procedure under regional anesthesia is preferable.

Tissue quality and presence of large fascial defects. Tissue quality will usually improve with preoperative local estrogen therapy (see final article in this supplement), but large fascial defects may require graft reinforcement, which can be routinely accomplished either abdominally or vaginally.

Associated colorectal problems. The frequent coexistence of colorectal dysfunction in women with vault prolapse requires that these problems be kept in mind during surgical planning. It may be best for a woman with extensive rectal prolapse to undergo a concomitant Ripstein rectopexy and sacrocolpopexy, or a perineal proctosigmoidectomy and vaginal-approach vault suspension.

VAGINAL PROCEDURE OPTIONS

McCall culdoplasty

The technique of plicating the uterosacral ligaments in the midline while reefing the peritoneum in the cul-de-sac, combined with a posterior culdoplasty, was introduced by McCall in 1957. This technique, most commonly performed at the time of vaginal hysterectomy, typically uses nonabsorbable sutures to incorporate both uterosacral ligaments, intervening cul-de-sac peritoneum, and full-thickness apical vaginal mucosa. Delayed absorbable sutures may also be used. Multiple sutures may be required if extensive prolapse is present. As a general rule, we try to place our uppermost suture on the uterosacral ligaments at a distance from the cuff equal to the amount of vault prolapse that is present (ie, POP-Q: TVL minus point D [or point C if uterus is absent]) **(Figure 4)**.

Care must be taken not to injure or kink the ureters when placing the suture through the uterosacral ligaments, as the ureters lie 1 to 2 cm lateral at the level of the cervix. We recommend cystoscopy with visualization of ureteral patency following the procedure. Intravenous indigo carmine, with attention to bilateral ureteral spill, is particularly helpful. Reported success rates are high,[2] but objective long-term data are limited.

Uterosacral ligament suspension

Excellent anatomic outcomes have been described with reattachment of the uterosacral ligaments to the vaginal apex, a procedure similar to the McCall technique. The physiologic nature of this technique makes it very attractive.

The technique involves opening the vaginal wall from anterior to posterior over the apical defect and identifying the pubocervical fascia, rectovaginal fascia, and uterosacral ligaments. One permanent 1-0 suture and one delayed absorbable 1-0 suture are placed in the posteromedial aspect of each uterosacral ligament, 1 to 2 cm proximal and medial to each ischial spine. One arm of each permanent suture is then placed through the pubocervical and rectovaginal fascia, and one arm of each delayed absorbable suture is placed in a similar fashion but also incorporating the vaginal epithelium. After all additional defects are repaired, the sutures are tied, suspending the vault. In cases of extensive prolapse, redundant peritoneum makes identifying the uterosacral ligaments and endopelvic fascia challenging. Success rates range from 87% to 90%, but ureteral injury is a limiting factor, with rates as high as 11%.[3] Therefore, cystoscopy is essential. Long-term results are lacking.

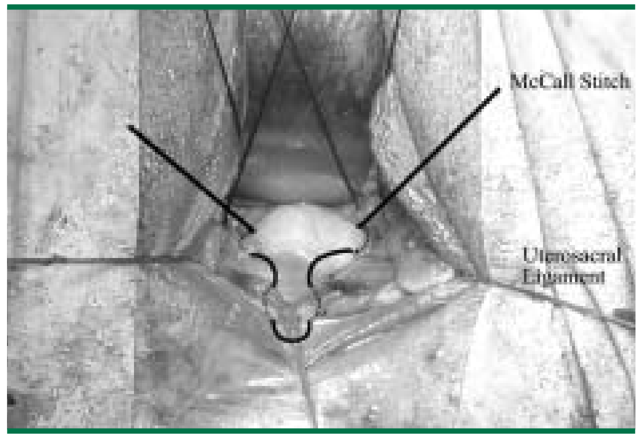


FIGURE 4. McCall culdoplasty at the time of vaginal hysterectomy. Monofilament sutures are placed through the uterosacral ligaments (at a distance from the cuff of total vaginal length [TVL] minus point D [cm]) and the full thickness of the apical vaginal wall.

Iliococcygeus suspension

Elevation of the vaginal apex to the iliococcygeus muscles along the lateral pelvic sidewall may be the simplest way of addressing vault prolapse. It can be performed without a vaginal incision by placing a monofilament permanent suture (ie, polypropylene) at full thickness through the vaginal wall into the muscle, either unilaterally or bilaterally to resuspend the apex. The main utility of this iliococcygeus suspension procedure is in the management of isolated unilateral vaginal vault prolapse, which can occur following an opposite-side unilateral sacrospinous fixation, or from a unilateral high paravaginal detachment. In a patient who is not sexually active, the presence of an intravaginal monofilament suture at the vaginal apex should not be associated with dyspareunia and should not cause significant granulation tissue. Therefore, this procedure is most useful as an adjunct or salvage procedure for a patient with an isolated apical unilateral defect.

Iliococcygeus suspension can also be performed following a posterior vaginal wall dissection and entering the pararectal space. The sutures are placed into the fascia overlying the iliococcygeus muscle, anterior to the ischial spine and inferior to the arcus tendineus fasciae pelvis, and incorporated into the pubocervical fas-

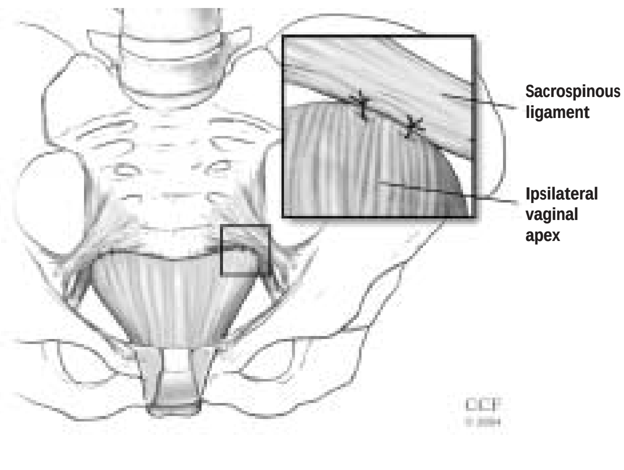


FIGURE 5. Bilateral sacrospinous fixation.

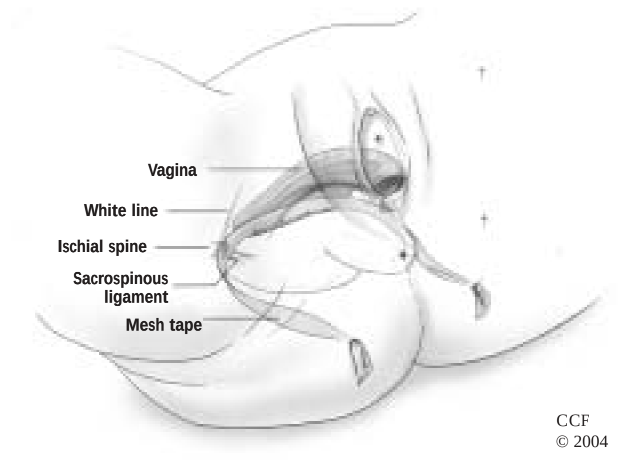


FIGURE 6. Schematic of the Apogee system for vault prolapse, which involves the creation of neo-cardinal ligaments.

cia anteriorly and the rectovaginal fascia posteriorly.

Shull et al[4] reported a 95% cure rate of the apical compartment following iliococcygeus suspension among 42 women who were followed up for 6 weeks to 5 years. However, 6 of the women (14%) had occurrence of prolapse at other sites during the follow-up period.[4] A randomized trial comparing iliococcygeus suspension with sacrospinous fixation demonstrated similar satisfactory outcomes.[5]

Sacrospinous fixation

Elevation of the vaginal apex to the sacrospinous ligament is one of the most commonly performed vaginal-approach vault suspension procedures. It can be performed unilaterally or bilaterally, depending on surgeon preference. The pararectal space is entered after a posterior wall dissection, after which the surgeon identifies the ischial spine and sacrospinous ligament extending from the spine to the sacrum. Anterior and mid-compartment approaches to the sacrospinous space have also been described. Two nonabsorbable sutures are placed *through* the ligament, rather than around it (Figure 5). Placement of the sutures in this fashion is important, as the pudendal nerve, artery, and vein are located immediately deep to the sacrospinous ligament, and damage to these structures can cause significant morbidity.

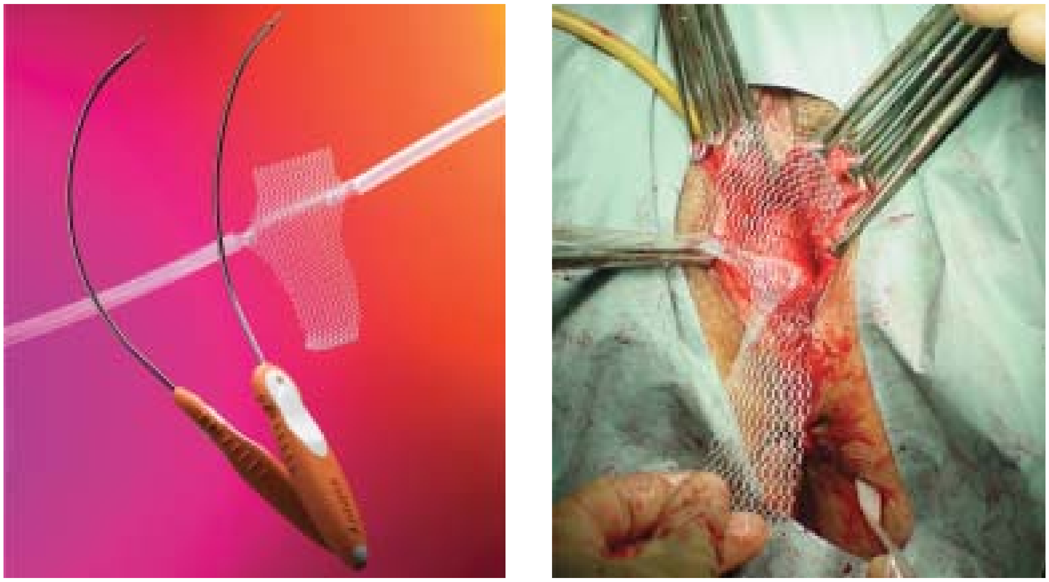
The first suture is placed 2 cm medial to the ischial spine, and the second 1 cm medial to the first. Each suture is then passed through the underside of the vaginal apex—in the midline if the procedure is done unilaterally, and under each apex if done bilaterally. When tied, the sutures suspend the vaginal apex by approximating the apex to the ligament, ideally without a suture bridge.[6] Any additional reconstructive procedures are then performed.

The bilateral approach (Figure 5) may provide a more physiologic correction of vaginal vault prolapse. Reinforcement of each vaginal apex with a graft does not appear to improve the success rate. The success rate of the sacrospinous fixation and restoration of vaginal vault support is greater than 90% in multiple series.[7] The main concern with this procedure is the fact that the vagina is placed in an exaggerated horizontal position, which increases force on the anterior compartment with increases in abdominal pressure. This is especially likely if a concomitant anti-incontinence procedure is performed. This nonphysiologic axis likely results in a higher rate of cystocele formation, reported at around 20% to 30%.[8] Other complications include hemorrhage, vaginal shortening, sexual dysfunction, and buttocks pain.

Posterior IVS vault suspension

Introduced as the infracoccygeal sacropexy, the posterior intravaginal slingplasty (Posterior IVS, Tyco/U.S. Surgical, Norwalk, CT) is a novel minimally invasive technique using a polypropylene tape for treating vaginal vault prolapse in a fashion analogous to the anti-incontinence tension-free vaginal tape procedure. This procedure recreates a central suspensory ligament at the level of the ischial spines, analogous to the cardinal ligaments, with a synthetic tape to restore vault support.

For the posterior intravaginal slingplasty, a posterior vaginal dissection is performed to the level of the vaginal apex. The tape is placed through bilateral pararec-



A B

FIGURE 7. (A) Apogee system. (B) System being placed with mesh arms through pararectal incisions and mesh secured to the vaginal apex. Panel A reproduced with permission from American Medical Systems, Inc.

tal incisions about 3 cm lateral and posterior to the anus. A metal tunneller is guided through the levator muscles and into the endopelvic fascia over the iliococcygeus muscle or immediately anterior to the ischial spine and sacrospinous ligament. The tape is secured to the vaginal apex and adjusted to provide vault support.

Concerns have been raised about the resultant vaginal length and risk of rectal injury. Our short-term experience is promising, with vaginal lengths of 7 to 8 cm and no rectal injuries.[9]

Apogee vaginal vault suspension

The Apogee system (American Medical Systems, Minnetonka, MN) represents the next generation in vault suspension. Neoligaments analogous to the cardinal ligaments are created by anchoring graft arms at sites adjacent to the ischial spines and under the arcus tendineus (Figure 6).

The pararectal space is accessed in a fashion similar to the sacrospinous ligament fixation. The ischial spine and arcus tendineus are then palpated. A modified SPARC needle is passed through bilateral pararectal incisions 3 cm lateral and 3 cm posterior to the anus, guided through the ipsilateral levators, and then passed laterally through the iliococcygeus muscle, anchoring to the white line at the level of the ischial spines. The insertion point for the polypropylene mesh arms with attached graft (polypropylene mesh or porcine dermis) is 0.5 to 1 cm anterior to the ischial spine through the white line. The graft arms are attached with small-profile connectors to the needles and are brought out through the para-anal incisions. The attached graft is then secured to the apex proximally and to the perineal body distally with interrupted delayed absorbable sutures (Figure 7). Central support of the vaginal apex running from ischial spine to ischial spine is thus recreated. The resultant vaginal axis is physiologic and vaginal length is normalized (Figure 8). The attached synthetic (soft polypropylene) or biologic (non–cross-linked porcine dermis) graft will provide posterior vaginal wall support.

Short-term experience from multicenter use has been very promising, with resultant vaginal lengths of 8 cm and no significant recurrence of apical or posterior wall prolapse.[10] Combining apical and posterior wall repairs allows for efficient use of operating room time. Concomitant use with the Perigee system (American Medical Systems, Minnetonka, MN) allows for correction of coexistent anterior vaginal wall prolapse.

Abdominal sacrocolpopexy

Suspension of the vaginal apex through an abdominal incision to the sacral promontory using a graft bridge (Figure 9) is considered by most surgeons to be the gold-standard procedure for vaginal vault prolapse. Although this procedure requires an abdominal incision, the resultant anatomy carries the greatest longevity and least risk of sexual dysfunction and dyspareunia.[11]

The procedure entails performing an abdominal incision and exposing the sacral promontory by incis-

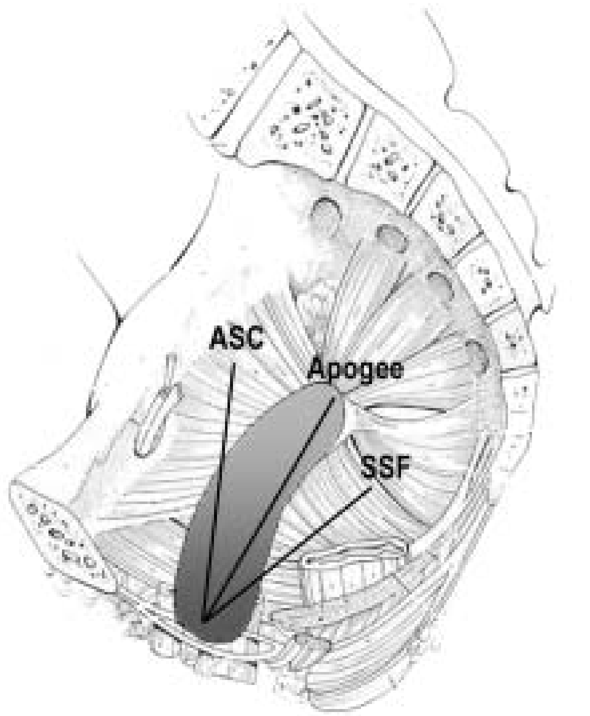


FIGURE 8. Differences in the vaginal axis following sacrocolpopexy (ASC), the Apogee procedure, and sacrospinous fixation (SSF).

FIGURE 9. Abdominal sacrocolpopexy. A polypropylene bridge is placed from the sacral promontory to the vaginal apex in continuity with anterior and posterior wall fascia.

ing the peritoneum between the right ureter and the sigmoid colon. The periosteum is cleared of any connective tissue. Two or three sutures (2-0 polypropylene) are then placed through the periosteum at the level of the L1 vertebra. The vaginal apex can be identified with the obturator of an end-to-end anastomosis rectal tool. We prefer the operator's hand for better identification of the vaginal apex. The peritoneum and bladder are dissected off of the anterior vaginal wall. Along the posterior vaginal wall, any fascial defects are identified and the rectal reflection is clearly noted.

Grafting for the vault suspension should be done with a synthetic polypropylene graft. It should have a long arm (4 to 5 cm) for the posterior wall and a shorter arm (2 to 3 cm) for the anterior vaginal wall. This can be fashioned from a standard 10 cm × 13 cm piece of polypropylene mesh folded in half. Typically, three rows of 2-0 polypropylene sutures are placed along the posterior wall of the vagina and two rows along the anterior wall. Once these are secured to the graft, the graft can be suspended to the sacral promontory with minimal tension. Before suspending the graft, the posterior cul-de-sac should be obliterated either by a uterosacral ligament plication or by the Halban/Moskowitz technique. If a biologic graft is used for this technique, the reported failure rate is significantly increased.[12]

Once the vault has been suspended, any additional necessary reconstructive procedures can be performed. These typically include paravaginal repair as well as posterior colporrhaphy.

Follow-up in most studies of abdominal sacrocolpopexy has ranged from 6 months to 3 years. The success rate ranged from 78% to 100% when defined as lack of apical prolapse postoperatively and from 58% to 100% when defined as no postoperative prolapse.[13]

The most concerning complications include life-threatening bleeding from the sacral promontory and postoperative ileus. The risk of bleeding can be minimized by the use of bone anchors on the sacral promontory (Straight-In System, American Medical Systems, Minnetonka, MN).

SUMMARY

Reconstructive surgeons should be familiar with the identification and treatment of vaginal vault prolapse. Most utilized techniques can be effective in terms of suspension of the vaginal apex. New technology has allowed for the performance of vaginal-approach techniques with increasingly physiologic anatomic and functional outcomes (Figure 8).

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Anterior vaginal wall prolapse:

Innovative surgical approaches

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Anterior vaginal wall prolapse occurs commonly and may coexist with disorders of micturition. Mild anterior vaginal wall prolapse often occurs in parous women but usually presents few problems. As prolapse progresses, symptoms may develop and worsen, and treatment becomes indicated. This article reviews the anatomy and pathology of anterior vaginal wall prolapse and describes traditional and innovative methods of vaginal prolapse repair.

ANATOMY AND PATHOLOGY

Anterior vaginal wall prolapse (cystocele) is defined as pathologic descent of the anterior vaginal wall and overlying bladder base. According to the International Continence Society standardized terminology for prolapse grading,[1] the term *anterior vaginal wall prolapse* is preferred over *cystocele*. This is because information obtained at the physical examination does not allow exact identification of structures behind the anterior vaginal wall, although it usually is in fact the bladder.

The etiology of anterior vaginal wall prolapse is not completely understood, but it is probably multifactorial, with different factors implicated in prolapse in individual patients. Normal support for the vagina and adjacent pelvic organs is provided by the interaction of the pelvic muscles and connective tissue.[2] The upper vagina rests on the levator plate and is stabilized by superior and lateral connective tissue attachments; the midvagina is attached to the arcus tendineus fasciae pelvis (white line) on each side.[3] Pathologic loss of that support may occur with damage to the pelvic muscles, connective tissue attachments, or both.

Theories of anterior vaginal wall prolapse

Nichols and Randall[4] described two types of anterior vaginal wall prolapse: distention and displacement. Distention was thought to result from overstretching and attenuation of the anterior vaginal wall, caused by overdistention of the vagina associated with vaginal delivery or atrophic changes associated with aging and menopause. The distinguishing physical feature of this type was described as diminished or absent rugal folds. The other type, displacement, was attributed to pathologic detachment or elongation of the anterolateral vaginal supports to the arcus tendineus fasciae pelvis, resulting in descent of the anterior segment with the rugae intact.

Another theory ascribes most cases of anterior vaginal wall prolapse to disruption or detachment of the lateral connective tissue attachments at the arcus tendineus fasciae pelvis, resulting in a paravaginal defect and corresponding to the displacement type discussed above. This was first described by White in 1909[5] and 1912[6] but was disregarded until redescribed by Richardson et al in 1976.[7] These latter researchers described transverse defects, midline defects, and defects involving isolated loss of integrity of pubourethral ligaments. Transverse defects were said to occur when the "pubocervical" fascia separated from its insertion around the cervix, whereas midline defects represented an anteroposterior separation of the fascia between the bladder and vagina.

Little clarifying evidence to date

There have been few systematic or comprehensive descriptions of anterior vaginal wall prolapse based on physical findings and correlated with findings at surgery to provide objective evidence for any of these theories of pathologic anatomy. In a study of 71 women with anterior vaginal wall prolapse and stress incontinence who underwent retropubic operations,

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DeLancey[8] described paravaginal defects on the left in 87% of patients and on the right in 89%. The arcus tendineus fasciae pelvis was usually attached to the pubic bone but detached from the ischial spine for a variable distance. The pubococcygeal muscle was visibly abnormal with localized or generalized atrophy in more than half of the women.

Progress in pelvic imaging

Recent improvements in pelvic imaging have led to a greater understanding of normal pelvic anatomy and the structural and functional abnormalities associated with prolapse. Magnetic resonance imaging (MRI) easily delineates the pelvic organs, pelvic muscles, and connective tissues. Various measurements can be made that may be associated with anterior vaginal wall prolapse or urinary incontinence, such as the urethrovesical angle, the descent of the bladder base, the quality of the levator muscles, and the relationship between the vagina and its lateral connective tissue attachments. Aronson et al[9] used an endoluminal surface coil placed in the vagina to image pelvic anatomy with MRI and compared four continent nulliparous women with four incontinent women with anterior vaginal wall prolapse. Lateral vaginal attachments were identified in all continent women. In the two subjects with clinically apparent paravaginal defects, lateral detachments were evident.

PATIENT EVALUATION

History

Patients with anterior vaginal wall prolapse report symptoms directly related to vaginal protrusion or associated symptoms such as urinary incontinence or voiding difficulty. Symptoms related to prolapse may include the sensation of a vaginal mass or bulge, pelvic pressure, low back pain, and sexual difficulty. Stress urinary incontinence commonly occurs in association with anterior vaginal wall prolapse. Voiding difficulty may result from advanced prolapse. Women may require vaginal pressure or manual replacement of the prolapse in order to accomplish voiding. Women may relate a history of urinary incontinence that has since resolved with worsening of their prolapse. This can occur with urethral kinking and obstruction to urinary flow; women in this situation are at risk for incomplete bladder emptying and recurrent or persistent urinary tract infections as well as for development of de novo stress incontinence after the prolapse is repaired.

Physical examination

The physical examination should be conducted with the patient in lithotomy position, as for a routine pelvic examination. The examination is first performed with the patient supine. A retractor or Sims speculum can be used to depress the posterior vagina to aid in visualizing the anterior vagina. After the resting examination, the patient is instructed to strain down forcefully or to cough vigorously. During this maneuver, the order of descent of the pelvic organs is noted, as is their relationship at the peak of straining. If physical findings do not correspond to symptoms or if the maximum extent of the prolapse cannot be confirmed, the woman is reexamined in the standing position. In some cases, late-day examination is useful to assess the full extent of prolapse, which typically progresses with straining and standing.

It may be possible to differentiate lateral defects, identified as detachment or effacement of the lateral vaginal sulci, from central defects, seen as midline protrusion but with preservation of the lateral sulci, by using a curved forceps placed in the anterolateral vaginal sulci directed toward the ischial spine. Bulging of the anterior vaginal wall in the midline between the forceps blades implies a midline defect; blunting or descent of the vaginal fornices on either side with straining suggests lateral paravaginal defects. Studies have shown that the physical examination technique to detect paravaginal defects is not particularly reliable or accurate. In a study by Barber et al[10] of 117 women with prolapse, the sensitivity of clinical examination for detecting paravaginal defects was good (92%), yet the specificity was poor (52%) and, despite an unexpectedly high prevalence of paravaginal defects, the positive predictive value was poor (61%). Less than two thirds of women believed to have a paravaginal defect on physical examination were confirmed to possess the same at surgery. Another study, by Whiteside et al,[11] demonstrated poor reproducibility of the clinical examination to detect anterior vaginal wall defects. Thus, the clinical value of determining the location of midline, apical, and lateral paravaginal defects remains unknown.

Anterior vaginal wall descent usually represents bladder descent with or without concomitant urethral hypermobility. In 1.6% of women with anterior vaginal prolapse, an anterior enterocele mimics a cystocele on physical examination.[12]

Diagnostic tests

After a careful history and physical examination, few diagnostic tests are needed to evaluate patients with anterior vaginal wall prolapse. A urinalysis should be performed to evaluate for urinary tract infection if the patient reports any lower urinary tract dysfunction. If

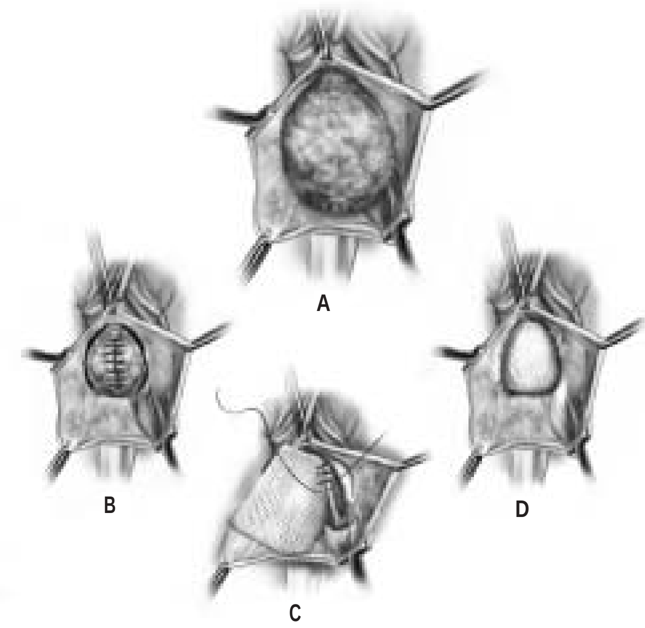

FIGURE 1. Cystocele repair with mesh. (A) The bladder is dissected bilaterally and off the vaginal apex. (B) Midline plication is completed. (C) After entering the left paravaginal space and exposing the arcus tendineus fasciae pelvis (white line), the prosthetic mesh is sewn to it. (D) The mesh is attached bilaterally and all sutures are tied, supporting the bladder. Reprinted from Walters and Karram, eds, Urogynecology and Reconstructive Pelvic Surgery, 2nd ed., copyright 1999, with permission from Elsevier.

urinary incontinence is present, further diagnostic testing is indicated to determine its cause. Urodynamic (simple or complex), endoscopic, or radiologic assessments of filling and voiding function are generally indicated only when symptoms of incontinence or voiding dysfunction are present. In women with severe prolapse, it is important to check urethral function after the prolapse is repositioned. Even if no urologic symptoms are noted, voiding function should be assessed to evaluate for completeness of bladder emptying. This procedure usually involves a timed, measured void followed by urethral catheterization or bladder ultrasonography to measure residual urine volume.

INNOVATIVE SURGICAL REPAIR TECHNIQUES

Anterior colporrhaphy with graft augmentation

The objective of anterior colporrhaphy is to plicate the layers of vaginal muscularis and adventitia overlying the bladder ("pubocervical fascia") or to plicate and reattach the paravaginal tissue in such a way as to reduce the protrusion of the bladder and vagina.

One modification of anterior colporrhaphy involves use of a prosthetic material to aid in support of the anterior vagina. This can be done in several ways, and the surgical techniques continue to evolve. One modification is to place a piece of polyglactin 910 mesh into the fold of imbricated bladder wall below the trigone and apical portion of the anterior colporrhaphy. In a second modification, after the plication sutures have been placed and tied, the prosthetic layer is placed over the stitches and anchored in place at the lateral limit of the previous dissection, using interrupted stitches of No. 2-0 absorbable or nonabsorbable suture. The anchor points are usually at or near the arcus tendineus fasciae pelvis or obturator fascia bilaterally, as shown in Figure 1. Biologic materials that have been used include segments of rectus fascia, fascia lata, cadaveric fascia, or other allograft or xenograft materials. Permanent (usually polypropylene) mesh may be used, although nonabsorbable material carries a risk of infection or erosion, with the need for subsequent revision or removal in 2% to 12% of cases (see Table).

Anti-incontinence operations are often performed at the same time as anterior vaginal wall prolapse repair to treat coexistent stress incontinence; sling placement may also improve the cure rate of the prolapse. Bladder neck suspension procedures (sling procedures or retropubic colposuspension) effectively treat mild anterior vaginal wall prolapse associated with urethral hypermobility and stress incontinence. More advanced anterior vaginal wall prolapse will not be treated adequately; in these cases, anterior segment repair should be performed, usually in conjunction with a midurethral sling. Surgical judgment is required to perform the bladder plication tightly enough to sufficiently reduce the anterior vaginal prolapse while preserving enough mobility of the anterior vagina to allow adequate urethral suspension. If anterior colporrhaphy with or without graft augmentation is combined with a sling procedure (midurethral or bladder neck), the cystocele should be repaired before the final tension is set for the sling. A midurethral sling, such as a tension-free vaginal tape (TVT) or transobturator sling (TOT), is best done through a separate midurethral incision after the cystocele repair is completed.

Vaginal paravaginal repair with and without graft augmentation

The objective of paravaginal defect repair for anterior vaginal wall prolapse is to reattach the detached lateral vagina to its normal place of attachment at the level of the white line or arcus tendineus fasciae pelvis.[13] This can be done using a vaginal or retropubic approach.

TABLE
Literature review of anterior vaginal wall prolapse repair with nonabsorbable mesh*

Study/researchers	Mesh	N	Follow-up (mo)	Success rate (%)	Vaginal erosions
Julian, 1996[19]	Marlex	12	24	100	1 (8.3%)
Nicita, 1998[20]	Polypropylene	44	14	93.2	1 (2.3%)
Flood et al, 1998[21]	Marlex	142	36	94.4	2 (1.4%)
Mage, 1999[22]	Mersuture†	46	26	100	1 (2.2%)
Migliari and Usai, 1999[23]	Mixed fiber‡	15	23.4	93	0
Migliari et al, 2000[24]	Polypropylene	12	20.5	75	0
Hardiman et al, 2000[25]	Polypropylene	18	1.5	100	2 (11.1%)
Salvatore et al, 2002[26]	Polypropylene	32	17	87	4 (13%)
de Tayrac et al, 2005[27]	Polypropylene	87	24	91.6	7 (8.3%)

* Definitions of success and surgical techniques varied among studies.
† Ethicon, Issy-Les-Moulineaux, France.
‡ 60% polyglactin 910 and 40% polyester.

Preparation for vaginal paravaginal repair begins as for an anterior colporrhaphy: vaginal flaps are developed by incising the vagina in the midline and dissecting the vaginal muscularis laterally. The dissection is performed bilaterally until the space is developed between the vaginal wall and retropubic space. Blunt dissection using the surgeon's index finger is employed to extend the space anteriorly along the ischiopubic rami, medially to the pubic symphysis, and laterally toward the ischial spine. After dissection is complete, midline plication of the bladder can be performed, either at this point or after placement and tying of the paravaginal sutures.

On the lateral pelvic sidewall, the obturator internus muscle and the arcus tendineus fasciae pelvis are identified by palpation and then visualization. Retraction of the bladder and urethra medially is best accomplished with a Breisky-Navratil retractor. Using No. 0 nonabsorbable suture, the first stitch is placed around the tissue of the white line just anterior to the ischial spine. A Capio device (Boston Scientific, Watertown, MA) works well to facilitate suture placement (Figure 2). If the white line is detached from the pelvic sidewall or clinically not believed to be durable, then the attachment should be to the fascia overlying the obturator internus muscle. Placement of subsequent sutures is aided by placing tension on the first suture. A series of four to six stitches are placed and held, working anteriorly along the white line from the ischial spine to the level of the urethrovesical junction. Starting with the most anterior stitch, the surgeon picks up the edge of the periurethral tissue (vaginal muscularis or pubocervical fascia) at the level of the urethrovesical junction and then tissue from the undersurface of the vaginal flap at the lateral fornix. After all stitches are placed on one side, the same procedure is carried out on the other side. If a biologic or synthetic implant is used for augmentation of the repair, the graft is incorporated into the stitch after the edge of the vaginal muscularis is included. A variation of vaginal paravaginal defect repair with graft augmentation is shown in Figure 1. The stitches are then tied in order from the urethra to the apex. This repair is a three-point closure involving the vaginal epithelium, the vaginal muscularis and endopelvic fascia (pubocervical fascia), and the lateral pelvic sidewall at the level of the arcus tendineus fasciae pelvis. Vaginal tissue should not be trimmed until all the stitches are tied. The vaginal flaps are trimmed and closed with a running subcuticular or interlocking delayed absorbable suture.

Transobturator tension-free vaginal mesh techniques for anterior vaginal wall prolapse

More recent innovative approaches for anterior vaginal wall repair anchor an allograft, xenograft, or polypropylene mesh without tension via strips placed through the obturator foramen with a special device (Perigee, American Medical Systems, Minnetonka, MN; and Anterior Prolift, Gynecare, Somerville, NJ). These techniques await safety and efficacy studies but are increasing in use. The advantage of this approach is that all defects (central, lateral, proximal, and distal) can be treated in a time-efficient manner. In an experienced

FIGURE 2. The Capio device, used to aid suture placement in vaginal paravaginal repair.

surgeon's pilot study of 11 patients, the average operative time for the Perigee procedure was 18.4 minutes (range, 11 to 26).[14] The goal of the procedure is to reestablish level II support of the vagina.

The Perigee procedure requires a dissection similar to that for the anterior colporrhaphy following an incision 4 cm from the bladder neck toward the apex of the vagina. The surgeon may or may not break through into the space of Retzius. When synthetic mesh is used, the plane of dissection of the anterior vaginal wall should be deeper, leaving muscularis on the vaginal epithelium in order to reduce risk of vaginal mesh extrusion. Plication sutures are placed in the midline to reduce the bulge and decrease risk of bladder perforation. External skin incisions are made at the medial border of the obturator foramen. The superior incisions are made at the base of the adductor longus tendon at the level of clitoris lateral to the ischiopubic ramus. The inferior incision is made 2 cm lateral and 3 cm inferior to the superior incision. A 5 cm × 10 cm biologic (porcine dermis) or synthetic (macroporous polypropylene) implant with four polypropylene arms (mesh identical to that used for SPARC or Monarc midurethral slings with tensioning suture) is introduced and secured in a tension-free manner using narrow-diameter helical needles. The four arms of the graft are fixed to four points in the arcus tendineus fasciae pelvis (proximally 1.5 to 2 cm distal to the ischial spine and distally at the bladder neck bilaterally). Figure 3 shows the kit for the procedure (3A) as well as the insertion of the helical needle at the level of the ischial spine in the space of Retzius (3B) and the anatomy of the pelvic floor after mesh placement (3C). The graft is secured distally and apically in the midline with No. 3-0 absorbable suture. Concomitant sling procedures may be performed with the plastic sheaths for the Perigee in place so that the superior arms of the procedure are not disrupted. Cystoscopy should be per-

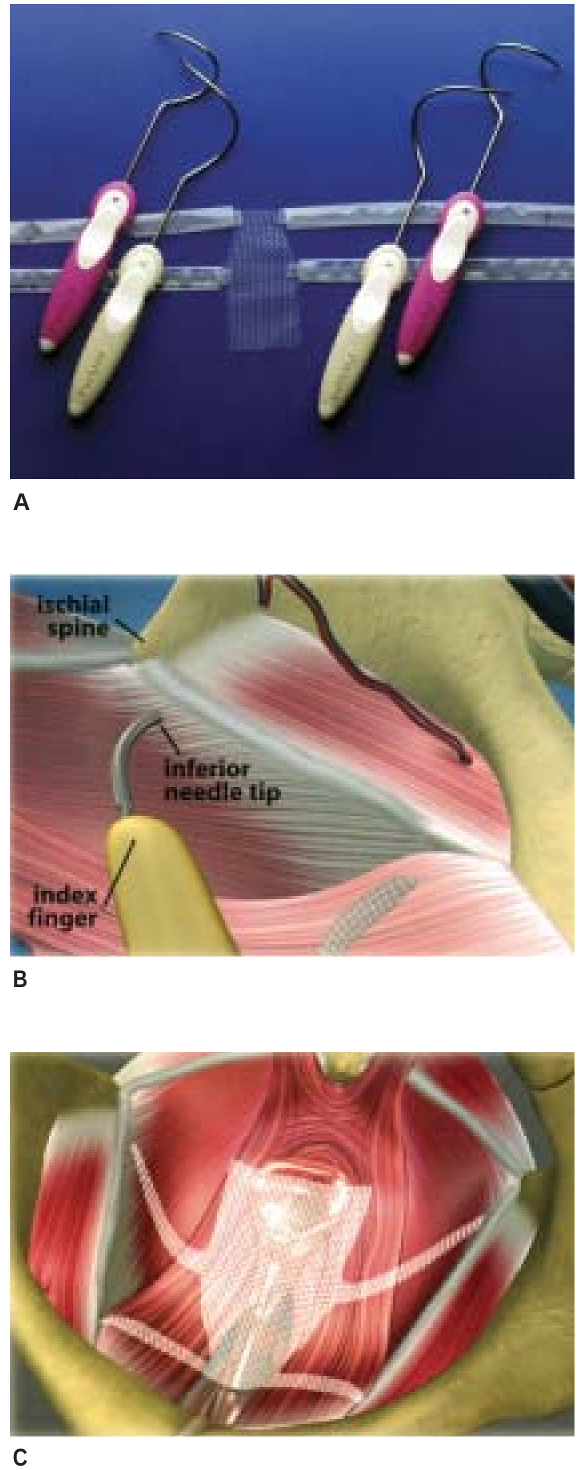

FIGURE 3. The Perigee procedure. (A) Procedure kit with mesh and helical trocars. (B) Anatomy of the retropubic space and insertion of the helical needle at the level of the ischial spine. (C) Mesh placement and anatomy of the pelvic floor. Reproduced with permission from American Medical Systems, Inc.

formed before removal of the plastic sheaths to ensure that the bladder and ureters have not been injured.

The Perigee procedure may be performed with or without the uterus in place. The procedure is contraindicated in pregnant women, in poor surgical candidates, and in the presence of active infection of the bladder or vagina.

Another alternative for mesh placement in prolapse repair is the Anterior Prolift procedure, which involves implantation of a large sheet of high-porosity monofilament polypropylene "tension-free" mesh featuring an anterior intervesicovaginal and/or posterior interrectovaginal prosthesis. The anterior prosthesis is retained by two nonsecured bilateral transobturator arms anteriorly at a point 1 to 2 cm from the proximal arcus tendineus fasciae pelvis and posteriorly at a point 1 to 2 cm distal from the arcus tendineus fasciae pelvis (Figure 4; mesh pictured in green). The diameter of the portion of the mesh used to support the anterior vaginal wall is greater in width in the Anterior Prolift procedure than in the Perigee procedure. Four cannulas are inserted at the fixation points with the use of a single trocar needle; the mesh arms are retrieved with a plastic loop and secured after implantation of the mesh and removal of the cannulas. Plication of the anterior vaginal wall and excision of excess vaginal epithelium are not recommended with the Anterior Prolift procedure. Concomitant anti-incontinence procedures are performed as indicated.

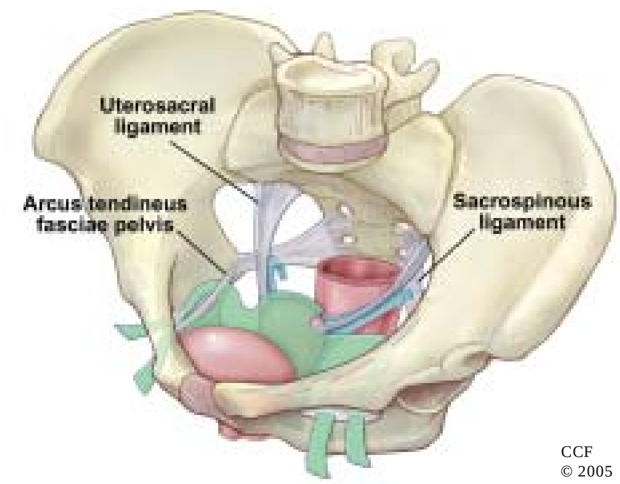

FIGURE 4. Prolift mesh (green) in the pelvis.

Cystoscopy

Cystoscopy is usually performed after cystocele repair, especially if slings or apical suspension procedures are also being done. The purpose is to ensure that no sutures or mesh have been placed in the bladder and to verify patency of both ureters.

RESULTS

The main indication for surgical repair of anterior vaginal wall prolapse is to relieve symptoms when they exist, or as part of a comprehensive pelvic reconstructive procedure for multiple sites of pelvic organ prolapse with or without urinary incontinence.

Few studies have addressed the long-term success of surgical treatments for anterior vaginal wall prolapse. Most published studies are uncontrolled series. Definitions of recurrence vary and sometimes are not stated, and loss to follow-up often is not stated. In our review of surgical techniques for the correction of anterior vaginal wall prolapse,[2] reported failure rates ranged from 0% to 20% for anterior colporrhaphy without graft augmentation and from 3% to 14% for paravaginal repair without graft augmentation.

Weber et al[15] studied three variations of anterior colporrhaphy using a prospective randomized design and a very strict definition of success (Aa and Ba points at −3 or −2 cm; Stage 0 or I). An optimal or satisfactory anatomic result was achieved in 30% of patients undergoing standard anterior colporrhaphy, 42% of those undergoing anterior colporrhaphy with polyglactin 910 mesh overlay, and 46% of those undergoing ultralateral plication under tension. No differences were seen in anatomic or functional outcomes, and most patients reported satisfaction with their symptom improvement. In another randomized controlled trial using a different staging system, Sand et al[16] reported fewer recurrent cystoceles when polyglactin 910 mesh was incorporated into the imbrication of the repair.

Prosthetic augmentation of cystocele repair is a promising although evolving innovation. There are many variations in techniques and materials used but few quality studies to date; two technique variations are shown in Figures 3 and 4. Biologic prosthetic materials have been placed over a midline cystocele plication as a simple overlay and anchored laterally, but this does not seem to offer significant lasting improvement over standard repair.[17] However, anchoring the mesh to the obturator fascia, the addition of suburethral slings,[18] and anchoring of the prosthesis to the apical portion of the repair may significantly improve long-term results.

Placement of nonabsorbable mesh into an anterior vaginal wall prolapse repair is a promising but more controversial variation. Polypropylene mesh has limited foreign body reaction in general and is probably the best choice. Technique variations include mesh overlays, modified four-corner attachments, transobturator attachments, and anterior flaps as part of an apical mesh procedure. Cure rates appear high (Table), but comparative trials with more traditional sutured repairs have not been done. Vaginal mesh erosions continue to be a problem; they occur in 2.1% to 13% of cases,[19–27] a significant number of which require reoperation for mesh removal. Analysis of the first 100 Prolift vaginal mesh procedures revealed a 17.5% erosion rate, which fell to 2.7% with limitation of the number and extent of colpotomies and avoidance of concomitant hysterectomy and perineal incisions.[28] Creation of vaginal flaps that are thicker with an attached fibromuscularis thus may reduce the mesh erosion rate. Efficacy and safety trials are paramount prior to widespread adoption. Emerging techniques must be compared with gold-standard procedures in well-designed, long-term trials for anatomic and functional outcomes.

For women with potential or occult stress incontinence in association with advanced prolapse, Meschia et al[29] reported that placement of a TVT results in a significantly higher objective postoperative continence rate compared with suburethral plication (92% vs 56%; $P < .01$). For this reason, placement of a TVT or perhaps a transobturator sling is recommended for all women with potential stress incontinence, except perhaps for very elderly patients and those with significant voiding dysfunction.

Paravaginal defect repair using the transvaginal approach results in excellent anatomic cure of anterior vaginal wall prolapse.[13] However, it has been used infrequently as an isolated procedure for treatment of stress urinary incontinence. Evidence suggests that it has less than satisfactory results when used in this capacity. Mallipeddi et al[30] reported that 57% of subjects with anterior vaginal wall prolapse and stress incontinence treated with a vaginal paravaginal repair and bladder neck plication had persistent urinary incontinence after an average of 1.6 years of follow-up. Thus, while the vaginal paravaginal repair is safe and relatively effective for correction of anterior vaginal wall prolapse, it has limited applicability in the surgical correction of stress incontinence.

Risk factors for repair failure

Risk factors for failure of anterior vaginal wall prolapse repair have not been specifically studied. Vaginal prolapse recurs with increasing age and length of follow-up, but the actual frequency is unknown. Recurrence of anterior prolapse is more likely with more severe initial prolapse[31] and probably with transvaginal, as opposed to abdominal, repairs.[32] Recurrence may represent a failure to identify and repair all support defects, or weakening, stretching, or breaking of patients' tissues, as occurs with advancing age and after menopause. Sacrospinous ligament suspension of the vaginal apex, with exaggerated retrosuspension of the vagina, may predispose patients to recurrence of anterior vaginal wall prolapse. Other factors that may increase the chances of recurrence are genetic predisposition, subsequent pregnancy, heavy lifting, chronic pulmonary disease, smoking, and obesity.

COMPLICATIONS

Intraoperative complications are uncommon with anterior vaginal wall prolapse repair. Excessive blood loss may occur, requiring blood transfusion, or a hematoma may develop in the anterior vagina; this is probably more common after vaginal paravaginal repair than after anterior colporrhaphy.[33] The lumen of the bladder or urethra may be entered in the course of dissection. Accidental cystotomy should be repaired in layers at the time of the injury. After repair of cystotomy, the bladder is generally drained for 7 to 14 days to allow adequate healing. Ureteral damage or obstruction occurs rarely (0% to 2% incidence),[34] usually with very large cystoceles or with apical prolapse.

Other rare complications include intravesical or urethral suture placement (and associated urologic problems) and fistula, either urethrovaginal or vesicovaginal. If permanent sutures or mesh material are used in the repair, erosion, draining sinuses, or chronic areas of vaginal granulation tissue can result. The incidence of these complications is unknown but may be as high as 13%.[21]

Urinary tract infections occur commonly, especially with concurrent catheter use, but other infections (eg, pelvic or vaginal abscesses) are less common.

Voiding difficulty can occur after anterior vaginal wall prolapse repair. In our hands, the average time to adequate voiding after cystocele repair with suburethral plication is 9 days.[35] This problem may occur more often in women with subclinical preoperative voiding dysfunction. The treatment is bladder drainage or intermittent self-catheterization until spontaneous voiding resumes, usually within 6 weeks.

Sexual function may be positively or negatively affected by vaginal operations for anterior vaginal wall prolapse. The current popularity of synthetic or allograft mesh to augment vaginal prolapse repairs could improve sexual function if cure rates improve or could worsen function if vaginal stiffness, mesh erosions, or draining sinuses result. More data with careful follow-up after surgery are needed.

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Optimizing pelvic surgery outcomes

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Perioperative problems can jeopardize the outcome of reconstructive procedures performed with the utmost technical skill. Since many of the factors behind such problems are within the surgeon's control, they must be kept in mind during surgical planning and postoperative care. The recent increase in use of biologic and synthetic grafts in reconstructive pelvic surgery has led to unique and specific healing abnormalities, many of which are preventable. This article reviews appropriate preoperative tissue preparation, intraoperative techniques to prevent postoperative healing difficulties, and management of graft-related healing abnormalities.

TISSUE PREPARATION

The problem of urogenital atrophy

Development of urogenital atrophy is an inevitable part of the aging process in women. Thought to be primarily a devascularization process, urogenital atrophy leads to thinning of the vaginal epithelium, mucosal dryness, increased sensitivity, and eventually an inflammatory infiltrate. There is a direct correlation between circulating estradiol levels and symptoms of urogenital atrophy.[1] Thus, the process of urogenital atrophy may begin even before the establishment of menopause. Symptomatic atrophy can also be seen in women of reproductive age with relative hypoestrogenism or decreased pelvic blood flow.

Posthysterectomy patients are particularly notable in this regard, owing to their reduced blood flow to the middle and upper vagina as a result of interruption of collateral blood flow from the uterine circulation. It is therefore not uncommon for these patients to have a pale and thin vaginal epithelium in the upper vagina and a well-estrogenized lower vagina. This is less commonly seen in women with an intact uterus, in whom apical vaginal blood flow is maintained.

Identifying urogenital atrophy

Surgeons cannot rely on symptoms alone to initiate therapy for urogenital atrophy. For unclear reasons, many women with significant atrophy are asymptomatic, even lacking signs and symptoms typically associated with atrophy, such as vaginal dryness and irritation.[2] For this reason, identification of urogenital atrophy during the physical examination is crucial for appropriate initiation of therapy. A pale, dry, and thin vaginal mucosa typically heralds urogenital atrophy. If the vagina is well vascularized but demonstrates lack of rugation only in specific areas, a subepithelial fascial tear should be suspected and is frequently found in patients with an enterocele.

The most objective means for identifying urogenital atrophy involves performing a vaginal wet prep, vaginal maturation index, or vaginal pH. These are simple, inexpensive tests that can be performed in the physician's office.

Vaginal wet prep. With this test, which is similar to an evaluation for vaginitis, urogenital atrophy is identified by a preponderance of intermediate and parabasal cells. These are small oval cells with large nuclei relative to the typical large squamous cells with pyknotic nuclei. In advanced stages of inflammatory atrophy, an abundant inflammatory infiltrate can be seen as well.

A vaginal maturation index is performed in a manner similar to a Papanicolaou smear. It is a quantitative test in which a pathologist counts the number of superficial, intermediate, and parabasal cells on the smear. An index can be calculated based on the relative presence of those cells. Various formulas are used for calculation of a maturation index. In vaginal atrophy, few, if any, superficial cells are noted, with more

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than 50% of the cells being intermediate or parabasal.

Vaginal pH can also be very helpful. It is assessed with regular (fresh) litmus paper. Vaginal atrophy is associated with an increase in vaginal pH above 5.

These tests can all be used to identify atrophy as well as to quantify the degree of atrophy during treatment.

Treatment of urogenital atrophy

Appropriate preparation of epithelial tissues for reconstructive pelvic surgery can be crucial to reducing postoperative complications. This is especially true if synthetic grafts will be used in the reconstructive procedure. Any bacterial or monilial vaginal infection should be treated and resolved before surgical therapy. Any patient who previously wore a vaginal pessary should be monitored for the presence of ulceration, which should be completely healed before surgery. A pessary should be removed at least 1 week prior to a reconstructive procedure.

Tissues with significant urogenital atrophy should be pretreated with local estrogen. It is well recognized that low-dose local estrogen therapy can be administered such that it does not result in any significant systemic absorption.[3] Therefore, women with urogenital atrophy who have contraindications to estrogen therapy can be treated with local estrogen without prompting concerns over significant systemic absorption. If necessary, avoidance of such absorption can be documented by measuring the serum estradiol level before and after therapy. For appropriate preoperative tissue preparation, at our institution we recommend at least 6 weeks of local therapy in order to reverse the changes of atrophy and revascularize the vaginal epithelium. Local estrogen treatment options available in the United States are listed in Table 1.

Most patients who are referred with advanced degrees of prolapse have significant atrophy. At our institution, we recommend using local estrogen cream as the quickest means of achieving the desired mucosal changes. We prescribe 1 g of cream (Estrace or Premarin) for intravaginal application on 2 nonconsecutive nights per week. Patients are instructed to apply the cream upon lying down to prevent extrusion of the cream. Often patients need to be instructed by a nurse on how to insert the cream appropriately. We have found this method of administration to be much more effective for treating urogenital atrophy than introital digital administration, which can be used for treating urinary urgency and frequency.

Estradiol tablets (Vagifem) also can be used intravaginally. These cellulose-based tablets dissolve in the vagina and coat the vaginal surface. We have found that reversal of atrophic changes is slower with this form of therapy, although tablets may be more acceptable to patients since they are associated with less extrusion of cream and since their applicator is smaller and easier for most patients to use. Systemic absorption has been demonstrated with Vagifem, and since its dose is less adjustable, we recommend using cream in patients who strongly wish to avoid systemic absorption.

Use of a low-dose estrogen-containing ring (Estring) is also an option. Because the ring is left in the vagina for 3 months at a time, it is particularly useful for women wearing a pessary, as it can be inserted ahead of the pessary. However, lack of systemic absorption has also not been well documented with the ring.

TABLE 1
Delivery options for local estrogen therapy

Formulation	Dosage	Systemic absorption
Cream (Estrace, Premarin)	1 g 2 nights per week or 0.5 g every other night	None to minimal
Tablets (Vagifem)	1 tablet 2 nights per week	Minimal
Ring (Estring)	Change ring every 3 months	Minimal

INTRAOPERATIVE PREVENTION OF COMPLICATIONS

Our institution strictly follows a protocol aimed at preventing perioperative complications (Table 2).

Preoperative evaluation. The protocol begins with an appropriate preoperative evaluation from both the urogynecologic and medical standpoints. Urogynecologic evaluation involves a detailed pelvic examination as well as urodynamic testing, as indicated. All of our patients also obtain medical clearance from their internist to minimize problems related to any concomitant medical conditions.

Antibiotic prophylaxis. Preoperative use of prophylactic antibiotics administered intravenously is routine in pelvic surgery.

Prevention of thromboembolism. Intraoperative use of pulsatile antiembolism stockings is important, even for patients at low risk of embolism. The stockings should be applied and turned on before the start of surgery, as their mechanism of action involves release of thrombolytic substances in the vessel walls

TABLE 2
Perioperative care protocol

Preoperative evaluation • Urogynecologic evaluation, including urodynamic studies • Medical clearance
Prophylactic antibiotics preoperatively
Pulsatile antiembolism stockings
Allen stirrups
Regional anesthesia
Postoperative care • Vaginal packing for 24 hours • Early ambulation • Laxatives/stool softeners • Suprapubic catheter for bladder retraining • Limit exertion (no lifting > 5 lbs for 6 weeks)

in addition to physical compression. In high-risk patients, including those with previous thrombosis or who have received prior anticoagulation therapy (eg, because of the presence of a cardiac valve), we use pulsatile antiembolism stockings as well as low-dose heparin or enoxaparin.

Patient positioning. Patient positioning is crucial to avoiding neuropathies involving the lower extremities and pelvis. We strongly recommend positionable stirrups, such as Allen stirrups, rather than "candy-cane" or low stirrups. Access to the pelvis by the surgeon and surgical assistants must be finely balanced with the need to prevent femoral and sciatic neuropathies. Allen stirrups allow for raising and lowering of the legs as necessary for complex reconstructive surgeries, which may include both an abdominal and a perineal approach. For patients with previous lower-extremity surgery or back pain, positioning while awake, prior to anesthesia, may reduce the risk of intraoperative positional complications.

Regional anesthesia. Since most reconstructive surgeries are now done via the vaginal or perineal route, we advocate the use of spinal or epidural anesthesia along with intravenous sedation. In elderly patients, this is associated with a marked reduction in the postoperative cognitive dysfunction that can be associated with general anesthesia.[4] We rarely need to convert a patient from regional anesthesia to general anesthesia.

Postoperative care. After the surgery, our protocol includes leaving the vaginal packing in for 24 hours. Once the packing is removed, ambulation and bladder trials are begun. We use patient-controlled narcotic analgesia pumps in the immediate postoperative phase along with intramuscular or intravenous ketorolac tromethamine. We then switch the patients to oral narcotics. If we are performing an abdominal sacrocolpopexy, we will initiate feeding very slowly, restricting dietary intake to clear liquids for the first 48 to 72 hours.

TREATMENT AND PREVENTION OF GRAFT-RELATED COMPLICATIONS

The expanded use of biologic and synthetic grafts in reconstructive surgery has brought about an entire new series of perioperative issues with which most surgeons are not yet familiar. Primary among them is selection of the appropriate graft material. While that topic is beyond the scope of this article, surgeons must avail themselves of published literature that describes the safety, tolerability, and longevity of a selected graft. Many theoretical benefits ascribed to a specific graft do not translate into clinical benefits. Because this is an evolving field, surgeons must peruse the recent literature for their resources.

Current understanding of the treatment of graft-related postoperative complications is improving. Healing difficulties should be tracked and recorded with various factors in mind (Table 3). The remaining discussion is best divided into complications associated with biologic grafts and those associated with synthetic grafts.

Complications associated with biologic grafts

Biologic grafts are less likely than synthetic grafts to lead to severe complications. They are less prone to erode into adjacent viscera or into the vagina. The primary concerns regarding their use involve immune reaction to the graft, infection, or the carrying of infectious particles from the donor.

To date, there has been no evidence of transmission of prions, viruses, or other organisms with a transplanted graft. Host reactivity to the graft can vary from a minimal inflammatory infiltrate to quite significant inflammation and development of granulation tissue. Some inflammatory reaction is necessary, as the use of a non–cross-linked graft requires that fibroblasts enter the graft substance in order to deposit a new layer of collagen. The concept of a biologic graft being a collagen matrix is dependent on the ability of host cells to penetrate the graft. As such, non–cross-linked grafts have recently achieved greater acceptance. Cross-linked grafts do not allow prompt penetration of the graft by host cells; rather,

TABLE 3
Relevant factors in graft-related healing assessment

- Timing relative to surgery
- Location of exposure (at incision vs other site)
- Presence of inflammatory changes (granulation vs no inflammation)
- Organ in which exposed (vagina vs viscera)

they tend to become encapsulated by host collagen deposition around the graft. This can be problematic if the graft shrinks over time, leaving unexposed areas adjacent to the graft.

The likelihood of significant immune reaction to currently available grafts is low. Careful technique in graft implantation, use of intravenous prophylactic antibiotics, and possibly soaking the graft in antibiotic solution have all been found to be useful in preventing graft infection. We will routinely place a circumferential suture around the anal opening (anal cerclage) to prevent fecal contamination of the graft.

The most common healing problem related to biologic grafts is separation of the suture line overlying a graft. This typically results from formation of a hematoma in the surgical area. Most biologic grafts behave much like the host biologic tissue, so there is no need to re-cover the graft with sutures; instead, the area should be allowed to heal by secondary intention.

If the reaction to an implanted graft includes significant granulation tissue, purulence, or both, infection must be suspected. A course of systemic or local vaginal antibiotics may be helpful. However, because of the decreased vascularity of the graft, it may be difficult to eradicate the infection and, in rare circumstances, some or all of the graft must be removed. We have not found this to be the case in our use of non–cross-linked biologic collagen matrices, including bovine pericardium or porcine dermis. Seromas have been noted to develop with small intestinal submucosa (SIS), although the mechanism behind their development is unclear. Most have been noted to occur in the subcutaneous fat layer along the anterior abdominal wall from suburethral sling procedures or other abdominal procedures. It has been suggested that the SIS ends of the graft be trimmed at the level of the fascia rather than at the skin to reduce the risk of seroma formation, but this has not been confirmed. The seromas appear to be sterile and resolve over time. A course of antibiotics is recommended, but if the seroma does not resolve within 4 to 6 weeks, exploration of the area should be considered and any exposed graft removed.

FIGURE. Posterior vaginal wall exposure along suture line.

Complications associated with synthetic grafts

The use of large-pore monofilament and multifilament polypropylene mesh materials has significantly reduced the incidence of complications related to synthetic grafts. In the past, synthetic grafts with small pores (ie, Gortex) or impregnated with a biologic material such as collagen (ie, ProteGen) have resulted in significant graft-related infections and subsequent rejection or graft removal.

Currently, most synthetic graft-related healing difficulties involve exposure of the ends of the graft through the vaginal epithelium (Figure). Early in the postoperative course, they tend to occur along the suture line. Later they can also present at a site remote from the suture line. Fortunately, most of these are simply exposures of the graft rather than true infectious or inflammatory erosions. If new composite grafts incorporating polypropylene and other materials become available, concerns about graft infection may resurface.

Treatment of an exposed edge of a polypropylene graft can be undertaken in the office or the operating room. If there is no granulation tissue and no purulent infiltrate, the graft's exposed edges should simply be trimmed and the rest of the graft buried. In the office setting, the exposed edges of the graft can be cut and local estrogen cream therapy initiated. Under most circumstances, with thickening of the vaginal epithelium, the edges of the graft will be spontaneously covered. If a larger area of graft is exposed, placement of one or two interrupted sutures to reapproximate the vaginal epithelium may be necessary. If the exposure recurs, if there is significant epithelial induration around the graft, or if the area of exposed graft is quite large, treatment in the operating room may be necessary. In the operative setting, the vaginal epithelium can be undermined lateral to the area of exposed graft. At this point, the exposed mesh can be trimmed and the mobilized epithelial edges can be approximated with interrupted sutures. This will usually result in satisfactory healing. Local estrogen therapy can be started once the sutures are dissolved.

If the sutures used to implant the synthetic graft are not monofilament sutures, any inflammatory response may be due to the sutures rather than the graft. It is therefore important to differentiate between a reaction to a graft and a reaction to a suture. This is especially true if braided multifilament permanent sutures (eg, Ethibond sutures) are used.

Palpable graft edges without symptoms. It is not uncommon for an edge of polypropylene mesh to be palpable during a postoperative pelvic examination in an asymptomatic patient. Under these circumstances, we commonly choose to observe the patient over time. We have observed spontaneous regrowth of epithelium over the graft as well as continuous, unchanged exposure of the graft. In rare instances there is an increase in the size of the exposed graft. As long as these patients remain asymptomatic, it is appropriate to simply monitor them on a long-term basis.

Urethral and bladder erosion. Erosion of a graft into adjacent viscera is managed on the basis of the viscera involved. Erosion into the urethra or bladder, as long as it is not associated with significant granulation or inflammatory tissue, can be managed by simply trimming the exposed visible mesh. For urethral erosion, this can be done using a hysteroscope or a small nasal speculum to visualize the graft, place it under tension, and cut the exposed area. We have not found it necessary to open the urethra or perform any more radical procedures. Typically, the urethral mucosal defect will heal spontaneously. We consider it important to leave the rest of the sling graft alone in order to help maintain urethral support.

Fortunately, most patients remain continent after removal of the exposed urethral mesh.

Exposure of a mesh within the bladder lumen can likewise be handled in a fairly conservative fashion. As long as it can be clearly visualized, the exposed mesh can be trimmed using an operative cystoscope in an office setting. Another reported technique involves placement of a suprapubic laparoscopic 5-mm trocar into the bladder to provide traction for cutting of the exposed mesh; a laparoscopic grasper is then used to pull the mesh medially, and scissors placed through a cystoscopic port can be used to cut the exposed mesh.[5] This technique may be preferable since most tension-free retropubic sling grafts that erode into the bladder will do so in the lower third of the bladder, which can be difficult to visualize and reach with the rigid cystoscope in the office.

Rectal erosion. Fortunately, mesh erosions into the rectum are rare. If rectal perforation occurs, it should be identified intraoperatively. Rectal examination following mesh augmentation procedures is strongly recommended. We have not seen an erosion into the rectum that has occurred postoperatively. If an erosion is identified, the same principles should be followed as for treatment of bladder erosion. However, there is a high likelihood of an associated infection of the fibrous connective tissue around the graft, which may require excision of that section of the graft and infected tissue. Extreme care must be taken in managing that tissue and closure in order to prevent development of a rectovaginal fistula.

SUMMARY

Most perioperative complications related to graft use can be prevented by appropriate preoperative and postoperative tissue management. Intraoperative cystoscopy should be a routine part of most pelvic reconstructive procedures. A rectal examination should be performed at the end of each surgical procedure to document rectal integrity. Under most circumstances, graft erosions can be managed without the need to remove the entire graft or jeopardizing the surgical repair.

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