INTRODUCTION

Urinary incontinence (UI) is the complaint of involuntary leakage of urine accompanied by or immediately preceded by urgency. [(1)]

Two generic conditions cause urinary incontinence: urethral sphincter abnormalities and bladder abnormalities. There are three main types of urinary incontinence: stress, urge and over-flow. [(2)]

Stress urinary incontinence (SUI), it has been defined as the complaint of involuntary leakage of urine under the stress of any sudden increase of intra-abdominal pressure which may put strain on pelvic organs, such as laughing, sneezing, coughing or exercising.[(3)]

Stress urinary incontinence is a sphincteric type of incontinence. Urge incontinence and overflow incontinence result from bladder abnormalities such as detrusor overactivity and low bladder compliance.

In urge incontinence there is leakage of large amounts of urine at unexpected times, when patients experience a sudden need or urge to urinate, including during sleep. The main cause of urge incontinence is damage to the nervous system leading to bladder instability, common in the elderly; in patients with multiple sclerosis, Parkinson's disease, or Alzheimer's disease; and after stroke or pelvic injury.[(3)]

In overflow incontinence there is unexpected frequent leakage of small amounts of urine with an over distended bladder. This results from weakening of bladder muscles seen in end-stage neurogenic disease or a blocked urethra. Overflow incontinence is rare in women. [(3)]

SUI which is our focus, as a sphincteric type of incontinence is related to intrinsic sphincter deficiency and urethral hypermobility. The common causes include loss of urethral compression and support after pelvic surgery, childbirth, and pelvic trauma; lumbosacral neuropathy; chronic intra-abdominal pressure increase from pulmonary disease; vigorous lifting; straining with bowel movement; and ageing with hypoestrogenic state. [(4)]

Intrinsic sphincter deficiency results from inadequate coaptation and compression due to loss of muscle strength and volume. In intrinsic sphincter deficiency, there is malfunction of the sphincter itself, which leads to an open vesical neck at rest and a low pressure Valsalva leak point. [(5)]

Urethral hypermobility results from weakening of urethral supporting structures leading to downward displacement and rotation of the urethra.[(6)] Both conditions leads to SUI, which results in leakage of urine with increase in intra-abdominal pressure when the urethra opens concomitantly. [(7)]

Stress urinary incontinence often appears for the first time during pregnancy, with a prevalence ranging from 16% to 67%. [(8)]

Postpartum incontinence and the delivery, itself, is also a cause of stress urinary incontinence. SUI is usually a complaint of multiparous women, associated with a degree of relaxation of the anterior vaginal wall leading to cystocele. [(9)]

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Anatomy

Bony scaffolding:

The maintenance of continence and prevention of pelvic organ prolapse rely on the support mechanisms of the pelvic floor. The bony pelvis consists of the 2 innominate bones, or hip bones, which are fused to the sacrum posteriorly and to each other anteriorly at the pubic symphysis. [10] The pelvis has 2 basins: the major (or greater) pelvis and the minor (or lesser) pelvis. The abdominal viscera occupy the major pelvis; the minor pelvis is the narrower continuation of the major pelvis inferiorly. The inferior pelvic outlet is closed by the pelvic floor. The female pelvis has a wider diameter and a more circular shape than that of the male. Numerous projections and contours provide attachment sites for ligaments, muscles, and fascial layers. [10]

Muscular Supports of the Pelvic Floor:

Pelvic Diaphragm

The levator ani and coccygeus muscles that are attached to the inner surface of the minor pelvis form the muscular floor of the pelvis. With their corresponding muscles from the opposite side, they form the pelvic diaphragm. The levator ani is composed of 2 major muscles from medial to lateral: the pubococcygeus and iliococcygeus muscles. Various muscle subdivisions have been assigned to the medial portions of the pubococcygeus to reflect the attachments of the muscle to the urethra, vagina, anus, and rectum.[11] These portions are referred to by some investigators as the pubourethralis, pubovaginalis, puboanalis, and puborectalis—or collectively as the pubovisceralis, because of their association and attachment to the midline viscera.[12]

The urethral portion forms part of the periurethral musculature, and the vaginal and anorectal portions insert into the vaginal walls, perineal body, and external anal sphincter muscle. [13]

The median raphe between the anus and the coccyx is called the levator plate and is the shelf on which the pelvic organs rest. It is formed by the fusion of the iliococcygeus and the posterior fibers of the pubococcygeus muscles. When the body is in a standing position, the levator plate is horizontal and supports the rectum and upper two thirds of vagina above it. Weakness of the levator ani may loosen the sling behind the anorectum and cause the levator plate to sag. This opens the urogenital hiatus and predisposes to pelvic organ prolapse (Figure 1). [13]

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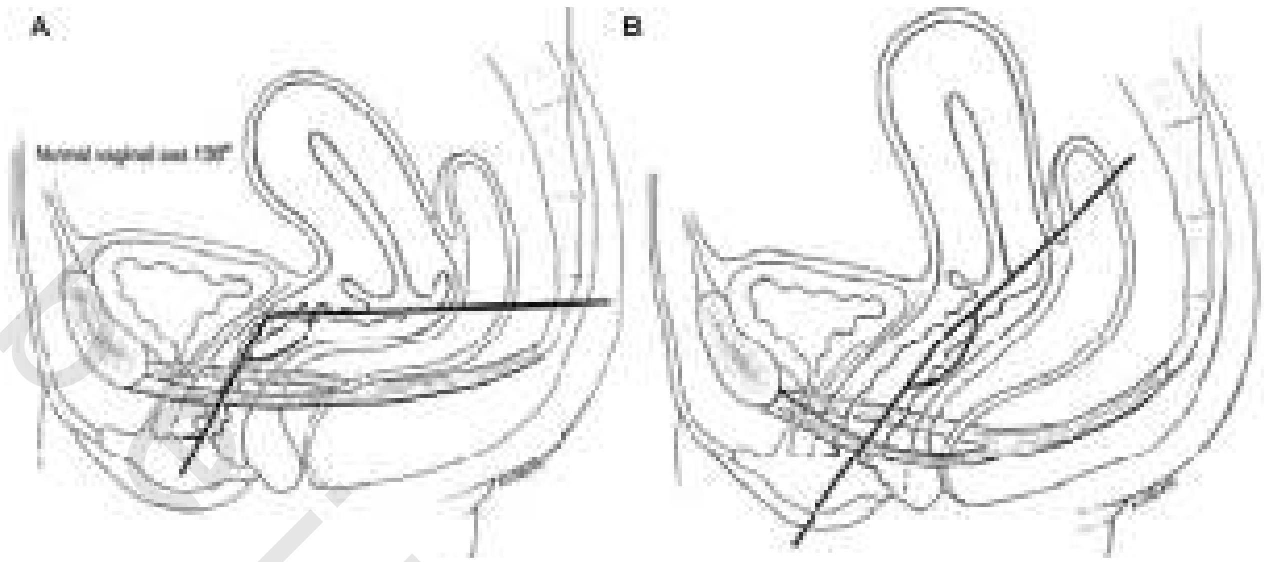

Figure 1. Pelvic floor support (midsagittal section of the pelvis): (A) normal tone in the levator ani with acute anorectal angle and horizontal levator plate; note the normal vaginal axis. (B) With loss of tone in the levator ani, there is change in the vaginal axis, sagging of the levator plate, and enlargement of the urogenital hiatus. [13]

Urogenital Diaphragm (Perineal Membrane):

Another musculofascial structure, the urogenital diaphragm, is present over the anterior pelvic outlet below the pelvic diaphragm. [14]

The more superficial ischiocavernosus and bulbocavernosus muscles, as well as the thin slips of the superficial transverse perinei, complete the inferior aspect of the urogenital diaphragm. The structure bridges the gap between the inferior pubic rami bilaterally and the perineal body. It closes the urogenital (levator) hiatus; supports and has a sphincter-like effect at the distal vagina; and, because it is attached to periurethral striated muscles, contributes to continence. It also provides structural support for the distal urethra. The posterior triangle around the anus does not have a corresponding diaphragm or membrane. The ischiorectal fossae are the spaces lateral to the anus below the pelvic diaphragm. [14]

Perineal Body:

The perineal body is a pyramidal fibromuscular structure in the midline between the anus and vagina with the rectovaginal septum at its cephalad apex. [14] Below this, muscles and their fascia converge and interlace through the structure. Attached to the perineal body are the rectum, vaginal slips from the pubococcygeus, perineal muscles, and the anal sphincter; it also contains smooth muscle, elastic fibers, and nerve endings. During childbirth, the perineal body distends and then recoils. [14] It is an important part of the pelvic floor; just above it are the vagina and the uterus. Acquired weakness of the perineal body gives rise to elongation and predisposes to defects such as rectocele and enterocele.[15,16] (Figure 2) demonstrates the pelvic organs with the 2 major levels of muscular support: the upper muscular structure, with the pelvic diaphragm, and the lower muscular structure, with the perineal membrane anteriorly and anal sphincter posteriorly.[17]

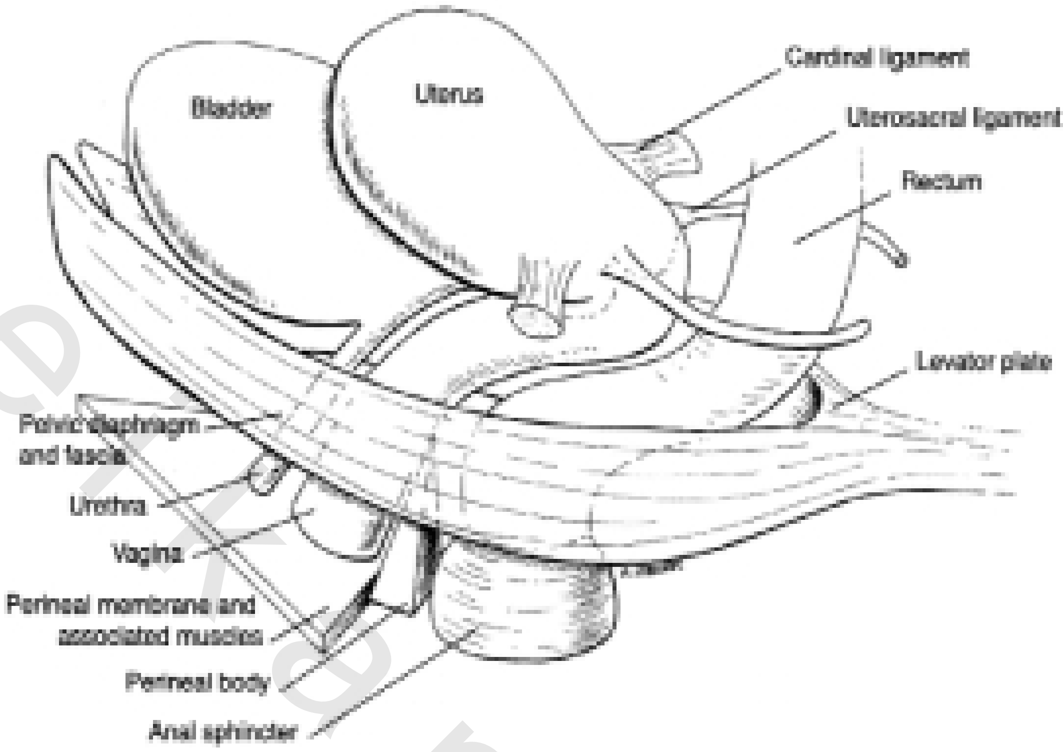

Figure 2: The 2 major muscular supporting structures: the upper, with the pelvic diaphragm, and the lower, with the perineal membrane (urogenital diaphragm) anteriorly and anal sphincter posteriorly.

Endopelvic Fascia and Connective Tissue Supports:

The bladder and urethra and the vagina and uterus are attached to the pelvic walls by a system of connective tissue that has been called the endopelvic fascia. This structure lies immediately beneath the peritoneum and is one continuous unit with various thickenings or condensations in specific areas. The endopelvic fascia is continuous with the visceral fascia, which provides a capsule containing the organs and allows displacements and changes in volume. The distinct regions of this structure are given individual names, specifically ligaments and fascia, with variable internal structure. Endopelvic fascia and ligaments are a mesh-like group of collagen fibers interlaced with elastin, smooth muscle cells, fibroblasts, and vascular structures.[18] Loss of this support can lead to hypermobility of the urethra, cystocele, urinary incontinence.[18]

Urethra:

Female urethra is thin-walled tubular muscular channel, measuring approximately 40 mm in length, coarsing antero-inferiorly from internal urethral meatus located at bladder trigone and terminating in an external urethral meatus anterior to the vagina. Tiny glands in the periurethral tissues (Skene glands) secrete mucus during sexual intercourse. The lower two-thirds of the urethra is lined by stratified squamous epithelium and the proximal onethird is lined by transitional epithelium. The urethra has 3 layers, including an inner mucosal layer, a vascular submucosal layer, and an outer muscular layer. Urethropelvic ligaments provide structural support to the urethra. T2-weighted sequence using endoluminal coils is best suited for demonstration the urethral zonal anatomy[19]. The zonal anatomy is almost similar to the vaginal layers on T2-weighted images, with low signal intensity inner mucosal layer, a high signal intensity vascular submucosal layer and low signal intensity outer muscular layer, giving a target appearance on transverse images[20].The intraluminal fluid or urine is high signal intensity on T2-weighted images[21]. The zonal anatomy is indistinct on noncontrast T1-weighted images with increased enhancement of the submucosal layer on postgadolinium T1-weighted images. In postmenopausal women, the zonal anatomy may be poorly defined. [21]

Anatomic properties of the urethral sphincter that promote continence are coaptation (mucosal seal, inner wall softness); compression (extracellular matrix, collagen, elastin, urethral smooth muscle, and urethral striated muscle); periurethral support; and neural control[21]. Coaptation and the status of the mucosa are best assessed with cystourethroscopy. Neural control can be assessed with sphincter electromyography. The muscular layers of the urethral wall contributing to the compression mechanism and periurethral support can be well assessed with MR imaging, best visualized on T2-weighted images. At the midurethral level, where the urethra has a target like appearance, the mucosa and submucosal layers are hypointense, the middle smooth muscle layer is hyperintense, and the outer striated muscle layer (urethral rhabdosphincter) is hypointense[22].

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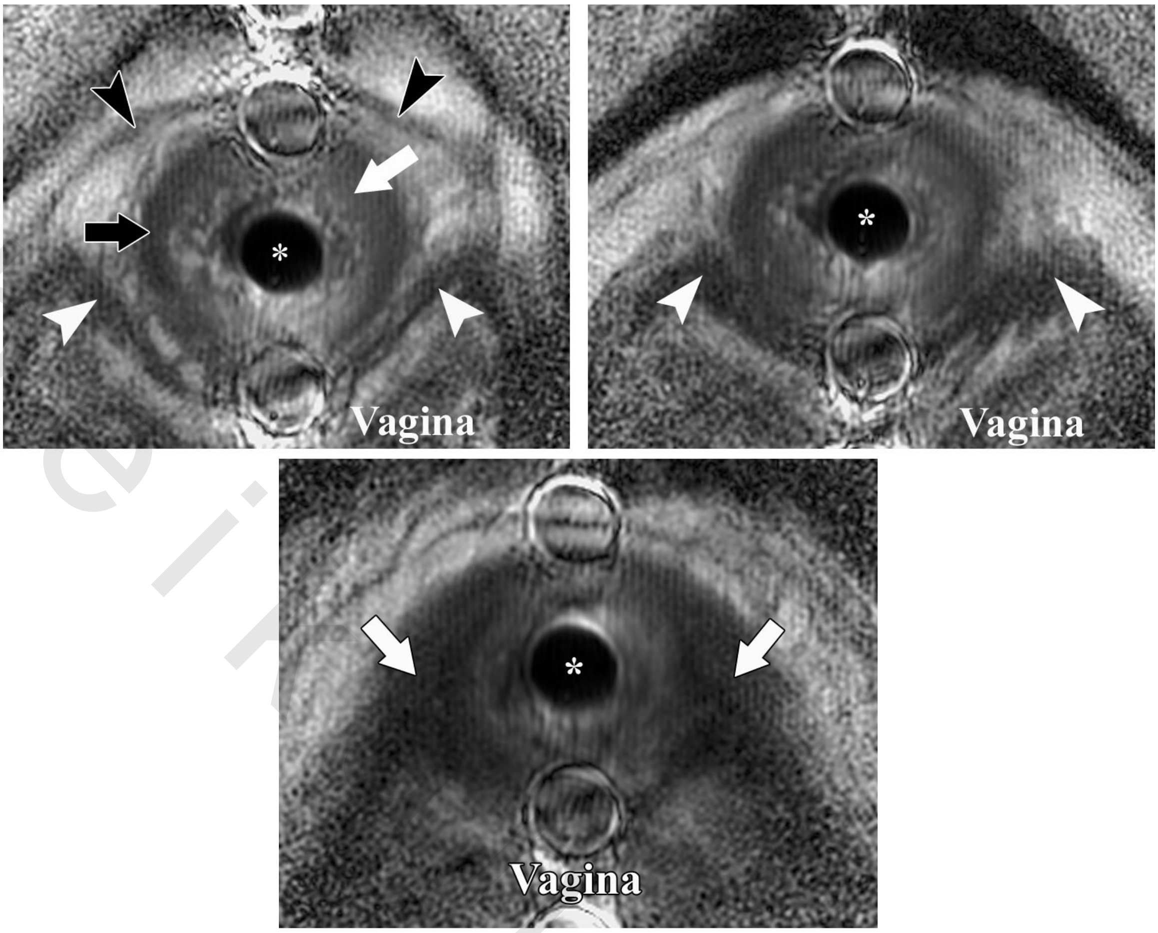

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Figure 3: Intraurethral MR images of an incontinent 72-year-old woman. The images were obtained with a 14-F endourethral coil (*). (a) Axial intensity-corrected T2-weighted fast spin-echo image of the midurethra shows a multilayered target like appearance: The inner smooth muscle layer (white arrow) has higher signal intensity, whereas the outer layer of low-signal-intensity tissue encircling the smooth muscle represents striated urogenital sphincter muscle (black arrow). The periurethral ligament (black arrowheads) is anterior to the urethra, and the pubourethral ligament (white arrow-heads) is posterior to the urethra and anterior to the vagina; these ligaments contribute to the hammock like support of the urethra. (b) Axial intensity-corrected T2-weighted fast spin-echo image of the distal urethra shows the pubourethral ligament (arrowheads) posterior to the urethra and anterior to the vagina. Dark striated muscle encircles the urethra. (c) Axial intensity-corrected T2-weighted fast spin-echo image shows the urethra at the level of the compressor urethrae. Note the fanning of the dark striated muscle (arrows) of the urethral sphincter around the urethra and extending toward the anterior vaginal wall.

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The striated urethral sphincter (urogenital sphincter) is divided into three components:

(a) the urethral sphincter surrounding the proximal and mid urethra circularly; (b) the urethrovaginal sphincter with fibers surrounding both the urethra and the vagina; and (c) the compressor urethrae with fibers running from the ischiopubic rami and also originating from the urogenital diaphragm itself to the anterior urethra, where they meet fibers from the opposite side, forming a broad arcing muscle (23). Functionally, the compressor urethrae can compress the urethra from its ventral position. Because it approaches the urethra parallel to the ischiopubic rami (at an angle of 130° to the urethra), it additionally can have the effect of pulling the urethral meatus caudally. In combination with the action of the pelvic diaphragm, which elevates the bladder, it assists in elongation of the urethra. The urethral elongation has been found important in providing continence (24).

The continuity of the urethrovaginal sphincter with the compressor muscle implies that they complement one another in compression, retraction, and elongation of the urethra. The urethra is inseparable from the anterior vaginal wall for the distal two-thirds of its course. Its sphincteric function depends on the integrity of the mucosa, submucosa, and smooth muscle layers as well as the striated extrinsic sphincter, which is responsible for compressing the urethra directly via its circular fibers (urethral and urethrovaginal portions) and for pulling it deeper into the anterior wall of the vagina through the arcing fibers of its compressor urethra portion.(25) By detailed visualization of the urethral muscle, the status of the muscle and its volume can be well assessed with MR imaging. Therefore, MR imaging can contribute important information to the diagnosis of urethral sphincter deficiency. (25)

Pathophysiology of Urinary Incontinence:

The dynamics of the intraabdominal cavity during a Valsalva maneuver (abdominal straining or cough) in a patient with a normal pelvic floor and with pelvic floor relaxation differ. When the bladder is properly positioned in the abdominal cavity, both the bladder and the bladder neck are above the pelvic floor. During a Valsalva maneuver, the intraabdominal pressure rises. This rise is reflected in the vesical pressure. If the bladder is properly suspended, the increased intraabdominal pressure is also reflected in the urethra. For a patient to remain dry, the pressure in the urethra should be equal to or greater than the vesical pressure during bladder filling.(25) When the bladder and urethra are in their proper anatomic place, any pressure increases in the abdominal cavity, from strain or any other cause, will also affect the urethra, preventing leakage. With aging, after childbearing, or after pelvic surgery, female pelvic floor relaxation may cause the base of the bladder and the bladder neck to fall below the pelvic floor level. The increase in abdominal pressure during a Valsalva maneuver will usually lead to pressures in the bladder being higher than in the urethra, resulting in stress incontinence(25). Also, pelvic floor laxity and defects in the ligaments supporting the urethra lead to inferior translation and rotation of the urethra, and resulting hypermobility causes urine leak with the increase of intra-abdominal pressures.(25)

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Imaging

Physical examination may provide an incomplete description of pelvic floor abnormalities. The traditional methods for evaluation of women with urinary incontinence include urodynamics with intraabdominal, intravesical, and intraurethral pressure measurements and urine flow analysis, cystourethroscopy, cystourethrography, and ultrasonography (US).[26]

Cystourethroscopy (cystoscopy):

It is endoscopy of the urinary bladder via the urethra. It is carried out with a cystoscope. It facilitates anatomical assessment of the bladder and the urethra. The precise role of cystourethroscopy in the evaluation of female urinary incontinence is controversial. It visualizes the bladder and urethra helping to detect some bladder lesions and identify some pathologies. Comparisons of cystourethroscopy and multichannel urodynamic studies show the latter to be more sensitive and specific in diagnosing stress incontinence and detrusor overactivity. Yet, cystourethroscopy can facilitate important anatomic and functional assessments of the lower urinary tract that can lead to diagnoses not evident on urodynamics. Thus, in combination with urodynamics, cystourethroscopy can aid in making a correct diagnosis. The main side effect of cystourethroscopy is that it is an invasive procedure, leading to difficulty to urinate, bleeding may occur, and infection. [26]

Voiding Cystourethrography (VCUG):

Radiography of the bladder and urethra during voiding after the bladder has been filled with a radiopaque contrast medium either by intravenous injection or retrograde catheterization. [26]

Blaivis Classification:

Type I: urethral hypermobility

Type II: hypermobility and intrinsic sphincter deficiency

Type III: Intrinsic sphincter deficiency.

In the evaluation of stress incontinence VCUG is limited because of detrusor instability producing urge incontinence and therefore resulting in false-positive stress incontinence. The anatomic measurements of posterior urethrovesical angle change, urethral descent, and urethral inclination as well as presence of urethrocele have limited ability in predicting stress incontinence. It also has the adverse effects of using contrast media, needs trained expertise, and the exposure to radiation. [27]

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Figure 4. Voiding cysturethrography in female with stress urinary incontinence: after reaching the functional bladder capacity, lateral projection VCUG with and without Valsalva maneuver in double exposure technique (two shots on the same X-ray film) is done. Apart from a slight vertical descent (x → y), imaging reveals an opening of the bladder neck (white → black line) [27]

Cystometry (cystometrography):

Cystometry is a technique of assessing the filling phase of bladder function. [28]

It is useful in cases to assess bladder capacity, bladder compliance, and the presence of phasic contractions. Much information can be gained during cystometry, including the diagnosis of bladder overactivity, bladder oversensitivity, sensory neuropathy, loss of compliance, and determination of bladder capacities. Abnormal cystometric findings should be consistent with the patient's clinical complaint. [28]

Ultrasound:

Different techniques of ultrasound examination are available for the assessment of the lower urinary tract in females [29]. Among them, intraurethral, Doppler and three-dimensional ultrasound [30].

Perineal and introital sonography have both become routine diagnostic techniques for assessing stress urinary incontinence and genitourinary prolapse. [31]

In women without stress urinary incontinence and prolapse, the posterior urethrovesical angle is 96.8◦ at rest and 108.1◦ during pressing, with a distance H between the bladder neck and lower edge of the pubic symphysis of 20.6 mm and 14.0 mm, respectively. Funneling of the urethra (vesiculation of the proximal urethra) is not present and there are no significant age-related changes in the above normal values. [32]

Introital and perineal ultrasound performed to females with stress urinary incontinence and genitourinary prolapse will yield information on the reactivity of the pelvic floor muscles and the location of fascial defects. [32]

The reactivity of the pelvic floor is assessed by determining the height of the bladder neck relative to the line through the lower edge of the pubic symphysis at rest and during maximum contraction of the pelvic floor muscles. An increase in the distance between the bladder neck and the lower edge of the pubic symphysis resulting from anterocranial displacement of the former indicates reactivity of the pelvic floor. [32]

Ultrasound during coughing frequently shows hypermobility of the urethra or funneling of the proximal urethra as an expression of connective tissue laxity. After all, ultrasound has limited role in defining the pelvic floor as one unit due to its limited field of view, it is only used since it is the cheapest and most rapid technique to exclude intrinsic sphincteric derangement which may be the underlying cause of the patient's symptoms before shifting to other imaging modalities which are more specific.[32]

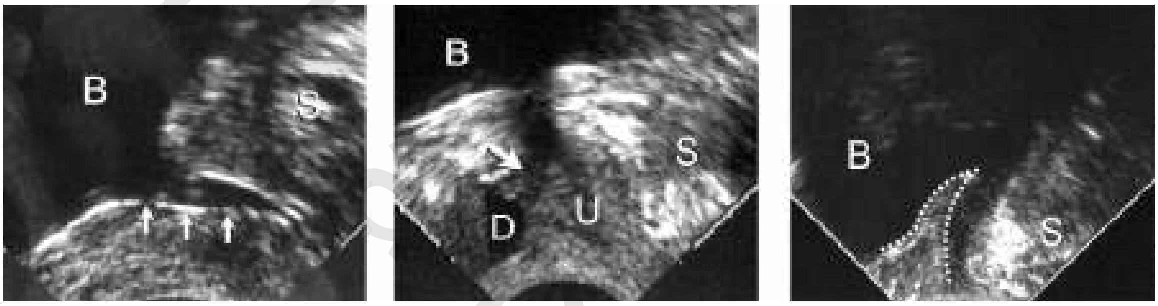

Figure 5: Introital ultrasound images in the midsagittal plane showing sonomorphological changes of the urethra. (a) Funneling of the proximal urethra (arrows) during the Valsalva maneuver. (b) Suburethral diverticulum (D) with neck (arrow) arising from the posterior wall of the urethra (U). (c) From a woman with a disturbed bladder voiding after abdominal colposuspension; there is retropubic scarring of the urethra and bladder resulting in overcorrection (acute retrovesical angle indicated by dotted line). B, bladder; S, pubic symphysis.[32]

MR imaging

Recently, MRI is becoming an important tool for assessing pelvic floor prolapse and stress urinary incontinence. [33]

Understanding of pelvic floor dysfunction pathophysiology and the high rate of recurrence and repeat surgery, imaging like dynamic magnetic resonance (MR) plays a major role in its clinical management, especially for the preoperative assessment of patients with multi-compartment defects and failed surgical repairs. [33]

T2-weighted fast spin-echo MR sequences can be used to delineate the multiple layers of the urethra and its supportive structures and for the detection of urethral diverticula which can be visualized with the body coil alone or with a phased-array or endoluminal coil. Faster MR techniques such as fast gradient-echo and echo-planar imaging allow dynamic imaging. [33]

With its excellent soft-tissue contrast and multiplanar acquisition, MRI enhances the ability to visualize the female urethra and periurethal tissues relevant to urinary incontinence [33]. Intracavitary MR coils, endovaginal and endorectal have subsequently allowed urethral MR imaging with both increased spatial resolution and high signal-to-noise ratio. [33] With the advent of the endourethral coil, ultra-high-resolution MR imaging of the female urethra became possible. [33]

Endoluminal MR imaging has been applied because of the high spatial resolution which permits detailed visualization of the pelvic floor [34] further improving anatomic evaluation. [25]

The spectrum of abnormalities detected at MR imaging in women with stress urinary incontinence are classified as (a) findings related to the urethral sphincter deficiency and (b) defects of the urethral support ligaments and urethral hypermobility. These abnormalities include a small urethral muscle volume or a short urethra, defects in the urethral sphincter, funneling at the bladder neck, distortion of the urethral support ligaments, cystocele, an asymmetric pubococcygeus muscle, abnormal shape of the vagina, enlargement of the retropubic space, and an increased vesicourethral angle.[33]

Imaging Protocols:

To evaluate the urethral sphincter muscle and the status of the urethral ligaments, high-resolution endocavitary imaging with a small field of view and high imaging matrix is the preferable method of imaging. The endocavitary imaging may include placement of the receiver MR coil in the urethra itself, in the vagina , or in the rectum[34]. Intraurethral imaging can be performed with a 14-F Intercept urethral internal MR coil, placed by using a sterile technique, like any other urethral catheter. T2-weighted images are obtained in three planes (axial, sagittal, and coronal). T2-weighted fast spin-echo axial image acquisition parameters are as follows: repetition time = 3000–6300 msec, echo time= 60–75 msec, six to 10 signals acquired, echo train length of 16–32, 2.5–3.0-mm section thickness, 0.5–2.0-mm spacing, field of view 5–6 cm, 256 x 256, average data acquisition duration 6 minutes 40 seconds. Endovaginal and endorectal imaging can be performed with the MRI coil (Medrad, Indianola, Pa). This endorectal coil is used in an off-label manner for endovaginal MR imaging in our patients. Our protocol includes fast spin-echo T2-weighted images in the axial, sagittal, and coronal planes; repetition time= 4000 msec, echo time = 70 msec, three or four signals acquired, 3.0-mm section thickness, 1-mm spacing, field of view= 12–14 cm, 256 x 256. [34]

For the dynamic pelvic floor imaging, fast T2- weighted imaging (single- shot fast spin echo, half- Fourier acquisition turbo spin echo) or gradient echo imaging can be performed during rest and strain. For good visualization of the rectum and vagina, we instill 120–150 mL of US gel endorectally and 20 mL of US gel endovaginally, and we image with the urinary bladder half full. Pelvic phased-array or torso coils can be used. Our standard protocol includes the following: single-shot fast spin-echo imaging, infinity/70, section thickness 6 mm, spacing = 2 mm, field of view= 26–32 cm, 256 x 193. We obtain eight to 10 images during strain in the sagittal plane in the midline section position for cine display of the urethral motion and bladder neck.[34]

Imaging Findings in Urinary Incontinence:

Imaging findings in the evaluation of female urethral sphincter anatomy and function can be divided into assessment of the status of the urethral sphincter muscle itself and the status of urethral support structures.[34]

Small Urethral Muscle Volume or a Short Urethra:

The urethral muscle volume depends on both the thickness of the muscle, both smooth and striated layers, and the length of the sphincter. The mean normal thickness of the urethral sphincter was reported as 4.3 mm x 0.9 (total striated and smooth muscle thickness anteriorly at the midurethra level), and the length of the urethra has been reported as 38 mm x 3[34]. With age, the relative volume of connective tissue increases and the volume of striated muscle and vascular tissue decreases. The decrease in the volume of striated fibers in the sphincter may account for a decrease in its functional capacity. Thinning of the striated sphincter muscle has been reported in patients with stress incontinence. Global decreased volume of the urethral sphincter has been reported to contribute to intrinsic sphincteric deficiency. [35] Patients with significant loss of sphincteric muscle or with a short urethra may suffer from intrinsic sphincter deficiency.[35]

Defects in the Urethral Sphincter:

A diverticulum may cause incontinence by weakening the sphincter wall. Urethral diverticulum occurs due to obstruction of the paraurethral glands with subsequent infection. Urethral diverticula usually develop in the dorsolateral aspect of the middle of the urethra and may or may not communicate with the urethral lumen[36]. The diverticulum usually has a horseshoe shape, surrounding the urethra in a circular fashion, or may manifest as a lateral outpouching. Visualization of the neck of the diverticulum may not always be possible; however, when the neck is revealed, its location should be reported to aid the surgical management. T2-weighted images show fluid encircling the urethra. The lack of continuity of the sphincter may contribute to loss of the coaptation and compression needed to maintain continence. However, on its own, urethral diverticulum does not have to cause incontinence. Most female patients with urethral diverticula have normal sphincteric function when presenting with dysuria or urinary tract infection; when the sphincter remains intact above the level of the diverticulum, continence is maintained.[36]

Funneling at the Bladder Neck:

Widening of the proximal urethra at the vesical neck, called funneling, was found to be the common denominator underlying stress incontinence [37]. It is thought to result from weakening of the proximal sphincter muscle and has been implicated in the development of intrinsic sphincter deficiency. Funneling can be seen during rest and can also develop during rotational descent of the urethra with strain. Funneling of the urethra can be attributed to gradual loss of urethral tone from a combination of repeated episodes of traction beyond the continence threshold, progressive postmenopausal atrophy, and gradual loss of pudendal nerve function[37] when the intrinsic closure of the urethra begins to weaken. Funneling of the urethra can be occasionally seen in patients who are continent[37].

Distortion of the Urethral Support Ligaments:

Three condensations of endopelvic fascia that form the urethral support ligaments are visualized at MR imaging: the periurethral ligament, paraurethral ligament, and pubourethral ligament. Normal ligaments are seen as continuous T2 hypointense bands of tissue stretched tight between the points of attachment. Disruption of the urethral ligaments may be complete or partial. In complete disruption, there is discontinuity of the ligament, complete attenuation of a portion of the ligament, or loss of its attachment. In partial disruption, fluttering of the lax ligament or focal thinning or attenuation can be seen. The failure of the urethral ligaments to hold the urethra in its normal anatomic location behind the pubic bone, where the pubourethral ligaments act as a fulcrum between the bladder and the external urethral meatus, may cause stress incontinence.[(38)]

Hypermobility of the Urethra:

The urethra exhibits a ventral concavity as it curves behind the pubic bone. In continent patients, the normal position of the urethra has been shown to be virtually entirely retropubic, meaning that the most inferior portion of the muscular urethra is above or at the inferior pubic level [(39)]. However, in patients with stress incontinence, there is an inferior translation of the urethra, with the lower segment of the urethra lying below the pubis. The larger the infrapubic component, the more extensive is the defect of the urethral support ligaments and paravaginal fascia. It has been shown that patients with urinary incontinence have more than 40% of the urethral length below the inferior border of the pubis in the supine position at rest [(39)].

Rotation of the urethra during strain over 30° from its resting axis defines urethral hypermobility [(40)]. It often accompanies moderate to severe bladder descent. Urethral hypermobility results from laxity of the suburethral supporting structures, the posterior pubourethral ligament, leading to urethral axis rotation from vertical to horizontal, so-called rotational descent. Urethral hypermobility is the most common presentation in patients with stress incontinence. It has been shown that the urethra rotates away from the pubis, initially as a single unit [(40)]. At a critical level of descent, the urethra stops rotating as a single unit, with the anterior wall arrested in its rotational descent (the anterior wall is in direct contact with the pubourethral fascial complex) and the posterior wall continuously rotating away from the pubis, frequently resulting in shearing of the posterior wall from the anterior wall leading to the opening of the internal urethral meatus. [(40)]

Cystocele:

Descent of the bladder base below the pubococcygeal line—which extends from the most inferior portion of the symphysis pubis to the last coccygeal joint and defines the level of the pelvic floor—either at rest or during strain is abnormal. The normal vertical distance between the pubococcygeal line and the bladder base at strain is no more than 1 cm below the line [(41)]. A cystocele forms when the bladder base descends below the pubococcygeal line. Most research has shown that the location of the urethrovesical junction is an important contributing factor to the overall maintenance of continence. However, continent cystoceles with inferior urethral displacement as far as the introitus have been reported. Hence, abnormal descent of the urethrovesical junction and formation of a cystocele alone may not be sufficient to account for incontinence. [(41)]

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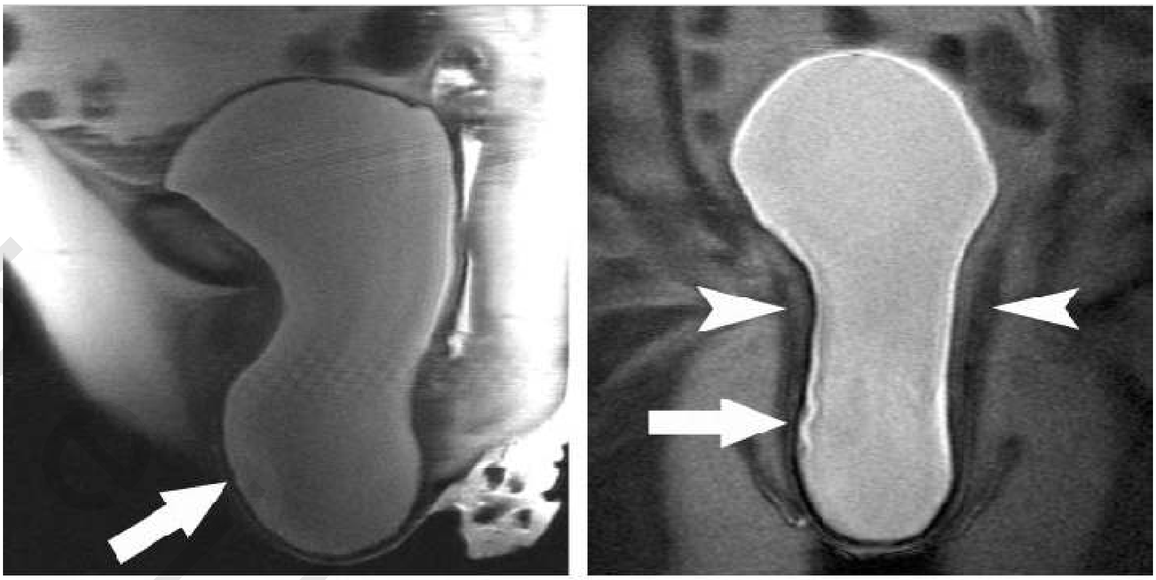

Figure 6: Cystocele in an 87-year-old woman with pelvic floor prolapse. (a) Sagittal single-shot fast spin-echo image obtained during straining shows a large cystocele (arrow) Note that the 10-cm-long cystocele fills the prolapsing perineum. (b) Coronal single shot fast spin-echo image obtained during straining shows the broad cystocele (arrow)، which resulted from a large central defect in the vesicopelvic fascia. Arrowheads level of the pelvic floor. [41]

Abnormal Shape of the Vagina:

The vagina with maintained paravaginal attachments assumes an H-shaped configuration. Alteration of the morphologic features of the vagina may be indicative of paravaginal tears. These tears lead to urinary incontinence by weakening the urethral support mechanism provided by the vagina to the middle and distal portions of the urethra embedded in the anterior wall of the vagina [42]. With the loss of paravaginal attachments, the vagina has a flattened appearance due to the detached wall of the vagina being displaced posteriorly. [42]

The distance between the lateral vaginal wall and pubococcygeus muscle and the pubic bone may increase. [42]

Advantages of MRI

Traditional imaging methods in the assessment of patients with urinary incontinence include cystourethroscopy,cystourethrography, and US. [42]

Cystourethroscopy is used to assess the coaptation and the status of the urethral mucosa. Cystourethrography allows evaluation of the urethral malfunction (hypermobility, bladder neck funneling, cystocele) but does not allow direct visualization of the sphincteric anatomy. In the setting of urinary incontinence, US can be used to assess the urethral mobility and the status of the internal meatus during strain [43], as well as the presence of diverticulum. [43]

Three-dimensional US has been used to evaluate the urethral muscle thickness and volume, as well as the pelvic floor and endopelvic fascia [43]. The advantages of US are low cost and real-time imaging, but the disadvantages are operator dependence as well as limited tissue penetration that does not allow detailed assessment of the urethral support ligaments. MR imaging allows direct visualization and dynamic evaluation of all the morphologic elements of the sphincteric mechanism in a single imaging session. The female urethra and its supporting structures work in a balanced relationship contributing to the urinary continence mechanism. In the incontinent patient population, the morphologic status of each anatomic component may vary and different combinations of findings can be observed. [44]

The cause of the incontinence is usually multifactorial, and the additional information on the status of the urethral sphincter and supporting ligaments provided by high-resolution MR imaging may contribute to the diagnosis and staging of urinary incontinence in the female population. Dynamic evaluation of the urethral sphincter during strain is possible with MR imaging, and simultaneous functional and morphologic assessment may assist in classification of incontinent patients into hypermobility and intrinsic sphincter deficiency categories, which currently is possible only with urodynamic studies. Treatment of patients with urinary incontinence depends on the type of sphincter abnormality. [44]

MR imaging contributes findings that characterize the urethral dysfunction and may guide the choice of therapy and post-treatment follow-up in the future. [44]

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