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Role of MR Defecography in Assessment of Post-Operative Repair of Pelvic Floor Dysfunction

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Abstract
Anatomically and functionally, the female pelvic floor is intricate. Because the fasciae and muscles of the pelvic floor work together as a single functional unit, problems with one area can lead to issues with the others. For either conservative or surgical therapy to be successful, it is necessary to accurately diagnose the particular PFD and identify any related illnesses. Surgical intervention is considered the primary strategy in the management of pelvic floor disorders; non-surgical options abound. Surgical procedures for these conditions can be transvaginal or transabdominal, and their specificity depends on the patient's condition. For less severe or asymptomatic conditions, non-surgical options include (a) watching the patient closely or training the muscles in the pelvic floor; (b) using biofeedback to treat dyssynergia or spastic pelvic floor syndrome; or (c) inserting a pessary to correct prolapse in patients who are unable or unwilling to undergo surgery, are not good candidates, or are experiencing temporary prolapse. Accurate detection of problems in this context requires familiarity with the various surgical methods and the anticipated imaging appearances of these operations, as imaging may play a significant role in both preoperative planning and postoperative evaluation of outcomes and complications. In this medical context, a variety of imaging modalities may be used, including computed tomography (CT), voiding cystourethrography, ultrasonography, and magnetic resonance imaging (MRI).

Keywords : Pelvic floor, disorders, non- surgical options.

Introduction

Pelvic floor weakness is a common and disabling condition in women. It causes pelvic organ prolapse, fecal incontinence, and urine continence by disrupting the normal descent of the rectum, uterovaginal vault, and urinary bladder. An estimated $12 billion is lost every year due to pelvic floor weakness, which affects over half of women over the age of 50. Both the high rate of reoperations and the lifetime risk of 11.1% for pelvic organ prolapse and urine incontinence surgery make it a serious problem for women's health (1).

The root reasons of weak pelvic floors are many. Factors that cause a persistent increase in intraabdominal pressure, such as pregnancy, menopause, advanced age, obesity, connective tissue diseases, smoking, and chronic obstructive pulmonary disease, increase the likelihood of pelvic floor dysfunction. Age, sex, and vaginal parity are recognized risk factors, according to a declaration from the National Institutes of Health's consensus conference. Even while there is a correlation between vaginal birth and pelvic floor dysfunction, not all women who give birth vaginally end up with the condition, and not all women who don't have children at all don't have pelvic floor dysfunction either. Research and electromyographic investigations point to the fact that the pelvic floor suffers neuromuscular injury after a vaginal birth, which manifests long before any malfunction occurs. The ligaments, fascia, and muscles that support a woman's pelvis form an intricate web. When the pelvic floor organs don't have enough support from the ligaments, fascia, and muscles, it may lead to embarrassing incontinence, bowel or urine leakage, sexual dysfunction, and prolapse (2).

Our goal was to describe and show the results of magnetic resonance defecography (MR) of the pelvic floor in individuals who had various surgical procedures to fix pelvic floor dysfunction.

Anatomy

There are three sections to the pelvic floor. In the front, you'll find the urine bladder and urethra; in the center, you'll find the uterus, cervix, and vagina; and in the back, you'll find the rectum. Muscles, fascia, and ligaments link to the bony pelvis to provide support for these tissues. When evaluating women with symptoms of multicompartment prolapse prior to undergoing complicated pelvic floor surgery, MRI is very beneficial since it permits vision of all three compartments. Figures 1–3 show the anatomy of the pelvis and how the vagina, as the central viscera, is attached to the pelvic walls via ligaments and serves as the primary divider in cases of pelvic organ prolapse (3).

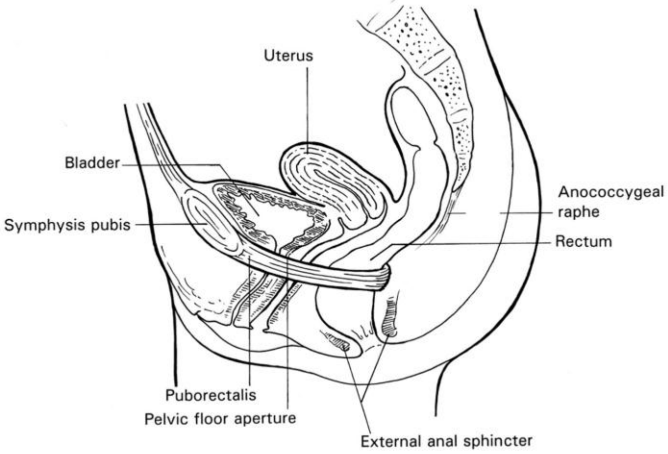

Fig. (1) Anatomy of the pelvic floor in women. Sagittal (A) and axial (B and C) line drawings show pubococcygeus and iliococcygeus muscles that are major component of levator ani muscles. Pubococcygeal line is drawn from most inferior portion of pubic symphysis to last horizontal sacrococcygeal line on midsagittal MR image. In contrast to what is shown on A, anococcygeal raphe, also known as levator plate, is usually parallel to pubococcygeal in normal subjects [4]

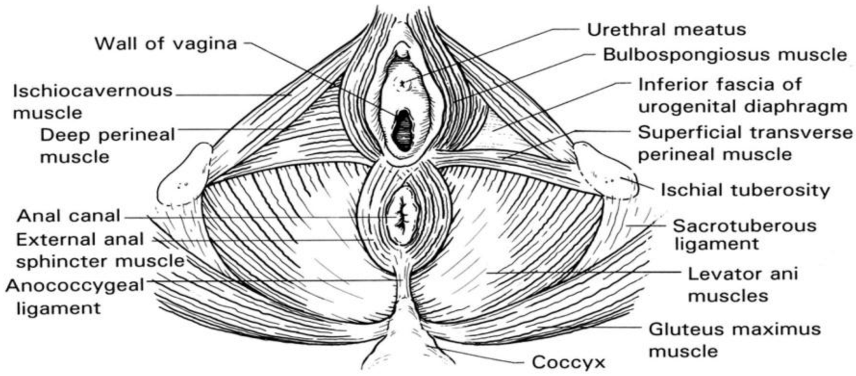

Fig. (2) Anatomy of the pelvic floor in women. Sagittal (A) and axial (B and C) line drawings show pubococcygeus and iliococcygeus muscles that are major component of levator ani muscles. Pubococcygeal line is drawn from most inferior portion of pubic symphysis to last horizontal sacrococcygeal line on midsagittal MR image. In contrast to what is shown on A, anococcygeal raphe, also known as levator plate, is usually parallel to pubococcygeal in normal subjects [4]

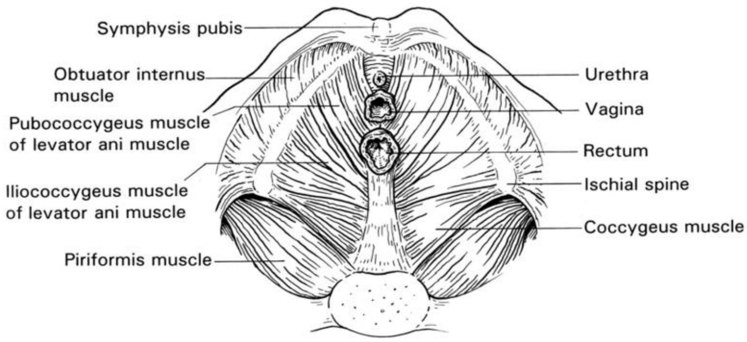

Fig. (3) Anatomy of the pelvic floor in women. Sagittal (A) and axial (B and C) line drawings show pubococcygeus and iliococcygeus muscles that are major component of levator ani muscles. Pubococcygeal line is drawn from most inferior portion of pubic symphysis to last horizontal sacrococcygeal line on midsagittal MR image. In contrast to what is shown on A, anococcygeal raphe, also known as levator plate, is usually parallel to pubococcygeal in normal subjects [4]

The main tissues that support the female pelvis are the fascia, the muscles of the pelvic floor, and the fascial condensations known as ligaments. Starting from the uterine artery and continuing cephalad till the vagina joins with the levator muscles below, the endopelvic fascia forms a continuous sheet and is the most superior layer. A continuous strip of endopelvic fascia encases the pelvic viscera and the levator ani muscles. The levator ani muscles are supported and attached laterally by the arcus tendineus, which is formed by the condensation of the endopelvic fascia. Additionally, the endopelvic fascia uses the elastic condensations called the paracolpium and parametrium to secure the cervix and vagina to the pelvic side wall, respectively. The uterine body is supported by the parametrium, which consists of the uterosacral ligament and the cardinal ligament. The vagina is stretched transversely between the rectum and the urine bladder by the paracolpium (5).

Intersecting the pubis, urinary bladder, and anterior vaginal wall is the endopelvic fascia, which creates a supporting layer known as the pubocervical fascia. In a similar vein, the rectovaginal fascia, which is formed posteriorly by the endopelvic fascia, acts as a support layer between the rectum and the posterior vaginal wall. This layer prevents the rectum from projecting forward and herniating inferiorly. It is possible to indirectly deduce the deficiencies of these fascial condensations from secondary observations, as they are not well-visible on standard MRI. Endovaginal coils, when positioned close to the target organ, provide superior signal-to-noise ratios (SNRs) and resolutions compared to surface or body coils, allowing for more precise viewing of these ligaments. When assessing stress urinary incontinence, this is particularly helpful for evaluating the urethra and its supporting tissues. Several structures immediately join to the distal vagina: the urethra in front, the perineal body in behind, and the levator ani muscles on each side (6).

Deep in respect to the endopelvic fascia are the levator ani muscles. The puborectalis and iliococcygeus muscles, which together make up the levator ani, provide the pelvic organs with the bulk of their support. As a sling around the rectum, the puborectalis opposes the pelvic floor orifices, elevates the bladder neck, and compresses it against the pubic symphysis, among other vital functions. The iliococcygeus is a horizontally oriented muscle that extends laterally from the external anal sphincter and attaches to the arcus tendineus. The levator plate, a hard raphe anterior to the coccyx, is formed when the iliococcygeus condenses posteriorly and in the midline. When it comes to avoiding prolapse of the posterior compartment, the iliococcygeus muscle is a crucial physical barrier. The levator plate and pelvic floor muscles are clearly visible on magnetic resonance imaging (7).

The perineal membrane divides the vagina from the rectum and is located underneath the levator ani muscles. The external urethral sphincter, the external anal sphincter, the levator ani, and the superficial muscles of the perineal membrane all enter into this thick tissue. In order to keep the urethra, vagina, and rectum from passing through the urogenital hiatus—the opening in the levator ani muscle groups—and the pelvic organs from protruding—the perineal body acts as a stopper. Episiotomies, which are performed during vaginal deliveries, may cause injury to the perineal membrane (8).

Pelvic floor relaxation is caused by a lack of strength in the muscles, fascia, and ligaments that support the floor. This decline may be associated with menopause or hypoestrogenemic conditions, which both occur with advancing age. Incontinence of urine may occur when the urinary bladder and urethra lose support, leading to prolapse and protrusion of the anterior vaginal wall, a condition known as cystocele. Cervix and uterine prolapse arise from paracolpium and parametrium weakening; rectocele and fecal incontinence might be the outcome of rectum prolapse and posterior vaginal wall protrusion due to rectovaginal fascia weakness. The development of an enterocele is caused by the small bowel protruding through the rectovaginal fascia. Prolapse of the vaginal apex, also known as apical prolapse, may occur in individuals who have had a hysterectomy due to paracolpium weakness (9).

Role of magnetic resonance (MR) imaging in diagnosis of pelvic floor dysfunction

- **Pelvic floor dysfunction**

A wide range of complicated illnesses may be characterized by symptoms that range from moderate low back discomfort to severe fecal or urine incontinence; these disorders are together referred to as pelvic floor dysfunction (PFD). While symptoms are often grouped into four broad categories—urinary problems, fecal disorders, sexual dysfunction, and pelvic aches—it is not uncommon for individuals to have a combination of symptoms from all four categories (10). Pelvic floor dysfunction is rather common. Take pelvic organ prolapse, for instance; it affects as many as half of all women. Because of this, people may be less able to participate in social activities and engage in physical activity, both of which have negative effects on quality of life (11).

- **Common pelvic floor disorders**

1. **Stress urinary incontinence (SUI)**

The involuntary and abrupt loss of pee that occurs as a result of a rise in intra-abdominal pressure, which may be caused by certain actions such as laughing, sneezing, straining, or exercising is known as a bladder stone. A dysfunctional urethral sphincter muscle or anatomical abnormalities in the urethral supporting structures may cause this syndrome (12).

2. Pelvic organ prolapses (POP)

When the ligaments or levator ani muscles weaken, the pelvic organs (bladder, uterus, vagina) fall out of their natural anatomical positions and into the vagina. This condition is known as pelvic floor weakness. It is possible to classify pelvic organ prolapse (POP) into different types based on the compartment of descent. For example, cystocele is a sign of anterior compartment descent, enterocele and rectocele are signs of posterior compartment descent, and middle compartment descent is seen in patients who have had a vaginal hysterectomy (13).

➢ **Anterior compartment**

▪ **Cystocele:**

When the ligaments or levator ani muscles weaken, the pelvic organs (bladder, uterus, vagina) fall out of their natural anatomical positions and into the vagina. This condition is known as pelvic floor weakness. It is possible to classify pelvic organ prolapse (POP) into different types based on the compartment of descent. For example, cystocele is a sign of anterior compartment descent, enterocele and rectocele are signs of posterior compartment descent, and middle compartment descent is seen in patients who have had a vaginal hysterectomy (13).

❖ **Grading of cystocele**

When a woman strains, her bladder base may drop as low as 1 centimeter below the PCL. Cystocele occurs when the base of the bladder drops more than 1 cm while the patient is straining to its utmost capacity (Figure 4).

- Grade 0: up to 1 cm below PCL
- Grade 1: 1.1 to 3 cm below PCL
- Grade 2: 3.1 to 6 cm below PCL
- Grade 3: greater than 6 cm below PCL [10].

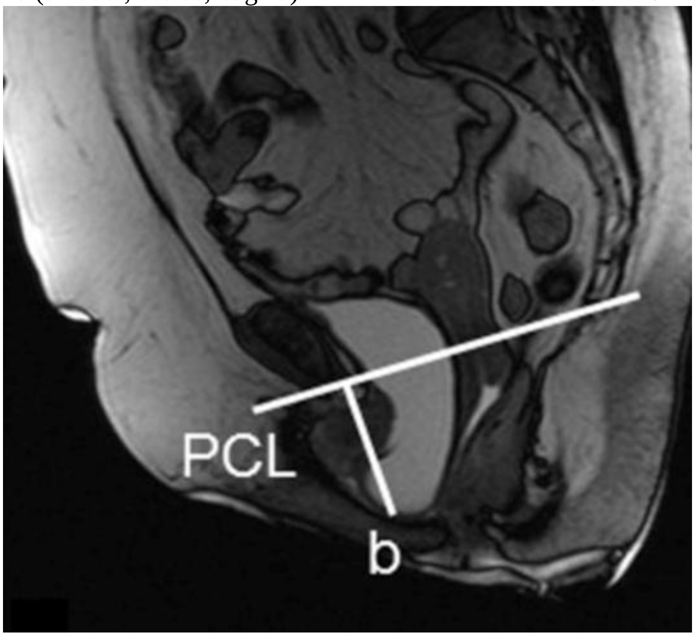

Fig. (4) Midline sagittal MRI (TRUFI T2WI) showing a large cystocele during maximum straining. (PCL = the pubococcygeal line, and b = cystocele) [10]

➢ **Urethrocele**

When cystoceles develop with urethrocele, the medical community refers to the condition as cysto-urethrocele (10).

➢ **Middle compartment**

▪ **Genital prolapse (Vaginal vault prolapse and uterine prolapse):**

Vaginal vault prolapse, in its mildest forms—characterized by the cuff's descent below the vaginal canal and uterine sagging through the vagina—typically causes no symptoms at all. However, in more advanced cases, symptoms such as dyspareunia, urinary retention, low back pain caused by stretched uterosacral ligaments, obstructive uropathy from ureteral blockage, or difficulty defecating may manifest in as much as a third of patients (13).

❖ **Grades of genital prolapse (Fig.** (5**)**

- Grade 0: above PCL.
- Grade 1: mild descent; (less than 3 cm below PCL).
- Grade 2: moderate descent; (3 cm to 6 cm PCL).
- Grade 3: severe descent; (more than 6 cm PCL).
- Grade 4: complete uterine prolapse [10].

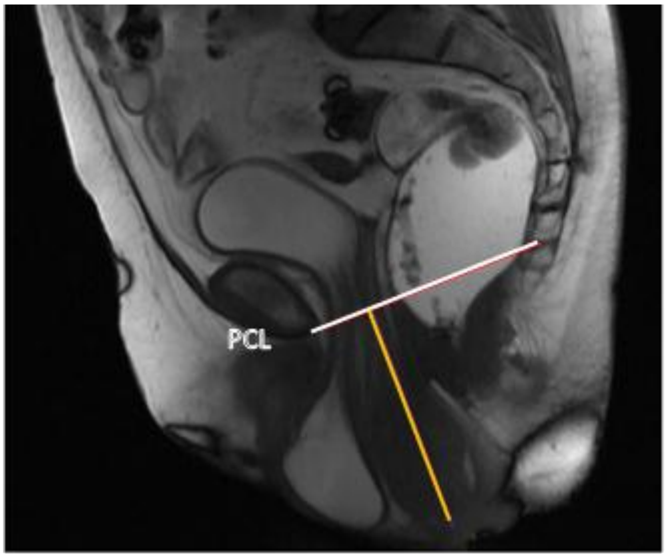

Fig. (5) Midline sagittal MRI (TRUFI T2WI) showing an everted uterus filling of the vaginal space, which extends below the distal third of the vagina [14]

- **Enterocele:**

When the small intestine descends into the lower pelvic cavity, it presses on the upper vaginal wall, bulging it out; this condition typically occurs with different kinds of vaginal walls, both anterior and posterior. Symptomatic enterocele may manifest in a variety of ways, including vaginal pressure, back or lower abdominal discomfort, a feeling of incomplete evacuation, extreme constipation, or even signs of bowel blockage, as well as other symptoms (15).

Posterior compartment

- **Rectocele**

A rectocele occurs when the anterior wall of the rectum extends into the posterior wall of the vagina. Up to 80% of people who do not have any symptoms may really have it. Dyspareunia, vaginal mass, dyspareunia, rectal splinting, tenesmus, and difficulty emptying the rectum are among symptoms that may be present (15).

Rectocele, defined as protrusion of the anterior rectal wall, is precisely measured during the stages of maximal straining and evacuation in order to make a diagnosis. Rectoceles are defined as rectal bulges that are located anterior to a line that is drawn upward through the anterior wall of the anal canal (Figure 6).

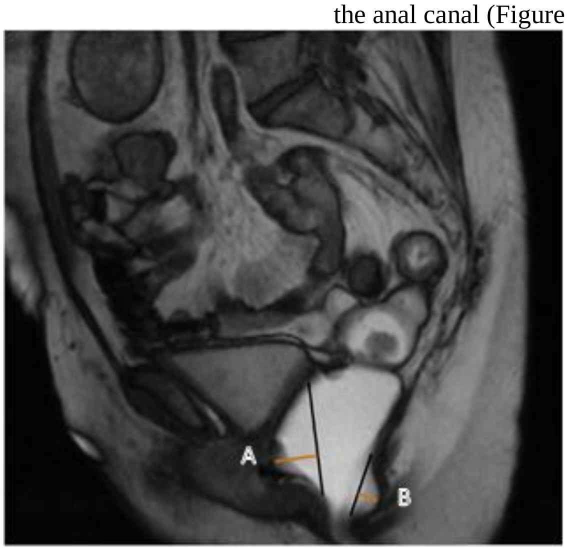

Fig. (6) Midline sagittal MRI (TRUFI T2WI) showing both anterior (A) and posterior small rectoceles (B) [16]

- **Grades of rectocele:**
  - Grade 0: no outpouching.
  - Grade 1: up to 2 cm.
  - Grade 2: between 2 cm and 4 cm.
  - Grade 3: greater than 4 cm.

Anterior rectal wall bulge should be reported as pathological if it is grade II and higher because grade I rectocele can be observed in most parous women [10].

- **Descending perineum syndrome (pelvic floor descent):**

It is defined as the descent of the anorectal junction (ARJ) greater than 3 cm below the PCL. ARJ is defined by the posterior impression of the puborectalis muscle at the most cranial extent of the anal canal. Usually generalized process with associated abnormal descent of middle and anterior pelvic floor compartments and often seen in combination with perineal ballooning, rectocele, intussusception, and impaired evacuation **(Fig.** (7**)** **[17]**.

Grades of descending perineal syndrome:

- Grade I: between 3 cm and 5 cm below the PCL.
- Grade II: with at least 5 cm [10].

Fig. (7) Midline sagittal MRI (TRUFI T2WI) showing marked descent of ARJ below the PCL [14]

3. Obstructed defecation

The blockage of the outlet may lead to constipation in several forms, one of which is obstructed defecation syndrome (ODS). Impairment of bowel movement is a frequent medical problem. Signs of this condition include involuntary bowel leaks, inadequate emptying, frequent ineffective urges, or the need to strain when defecating. This condition may be caused by underlying disease that is structural or functional (13).

Discrepancies in structure

This category includes conditions such as rectocele, external rectal prolapse, and rectal intussusception, also known as internal rectal prolapse. The former two types of intussusceptions are limited to the rectal ampulla, while the latter can extend into the anal canal (Figure 8).

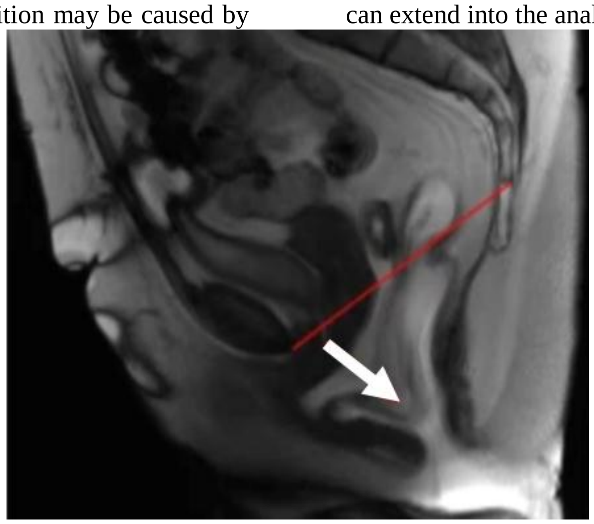

Fig. (8) Midline sagittal MRI (TRUFI T2WI) showing rectal intussusception extending through the anal sphincter during the evacuation phase(arrow) [18]

- **Functional abnormalities**

These conditions include (a) dyskinetic puborectalis, also known as spasmodic pelvic floor syndrome or anismus, and (b) spastic anal sphincter contraction, also known as spasmodic contraction of the anal sphincter or anal sphincter achalasia, both of which hinder normal rectal evacuation due to involuntary contraction of the puborectalis muscle. Resting anal canal pressure is much higher than normal on manometry, and patients often report painless constipation and what seems to be dry feces (Figure 9) (10).

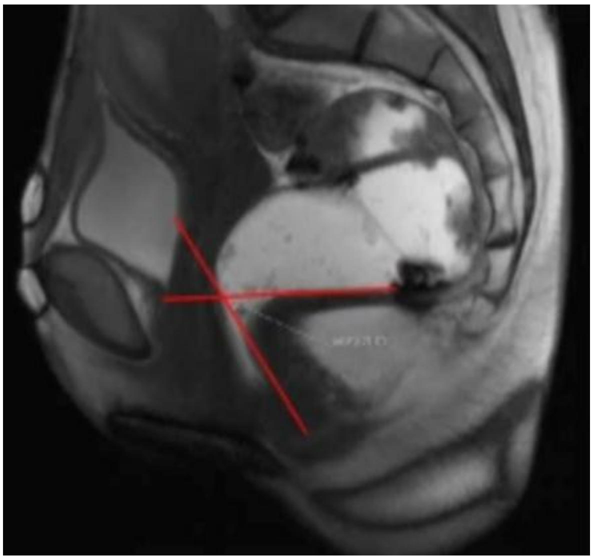

Fig. (9) Midline sagittal MRI (TRUFI T2WI) showing reduction of the ARA during the evacuation phase corresponding to a paradoxical contraction of the puborectalis muscle [18]

- **Structural and Functional abnormalities**

Solitary rectal ulcer syndrome, a well-known diagnosis that explains a mix of rectal prolapse and functional pelvic floor abnormalities, is an example of structural and functional disease. As a result of the forces created during defecation and the compression caused by paradoxical puborectalis contraction, the prolapsed rectal mucosa is pulled downwards. This compression causes mucosal ischemia and ulceration as a result of recurrent straining (10).

fecal incontinence (FI)

The uncontrollable or uncontrolled release of gas or fecal waste at an unsuitable location or time is called fecal incontinence. Due to societal shame, the underreporting of this condition's prevalence despite its very widespread occurrence (8–9% of the population is affected). Women make up the bulk of the patient population. Obstetric trauma accounts for 60% of these cases. Next on the list is anorectal surgery-related iatrogenic injury to the anal sphincter muscles, which accounts for 16% of cases. Incontinence may also be induced by neurogenic incontinence, injuries sustained from traffic accidents, inflammatory bowel disease complications, or the insertion of foreign materials into the rectum (19).

Magnetic resonance (MR) imaging of pelvic floor dysfunction

The sensitivity, specificity, and positive predictive value of magnetic resonance (MR) imaging for pelvic floor disorders (PFD) evaluations have been well-documented. This is because MR imaging can accurately determine the location of the pelvic floor disorder—whether it affects the anterior, middle, or posterior compartment—as well as the type of pelvic organ prolapse and the presence or absence of subcutaneous uterine infection (SUI). Additionally, it may detect problems with the pelvic organ support system, which includes the urethral and vaginal supporting structures, and utilize that information to tailor treatment to each individual problem, ultimately leading to the most appropriate surgical surgery (20).

- **MR imaging protocol**

In order to identify anatomical and functional pelvic floor muscle anomalies, MR defecography pictures are utilized in conjunction with dynamic and static imaging.

- **Static MR imaging sequences**
  - Utilising high-resolution T2-weighted turbo spin-echo sequences (TSE), we may examine the axial, coronal, and sagittal planes.
  - Furthermore, T2-weighted turbo spin-echo sequences (TSE) of the anal sphincter complex, with the imaging axes perpendicular and parallel to the anal canal axis (21).
- **Dynamic (kinematic) MR imaging sequences**
  - Kinematic imaging during evacuation, also called "MR imaging defecography," and "dynamic cine MR" imaging in three orthogonal planes during staining are what the name "dynamic" alludes to.
  - The best option for evacuation is to use steady-state pictures in the sagittal plane (22).

1. **Dynamic images**

To assess pelvic floor dysfunction, images will be obtained in all three dynamic planes (axial, coronal, and sagittal) utilizing TRUFI, which stands for true fast imaging with steady-state free precession sequence. The acquisition of these five sections will be carried out over the course of three phases:

While not in motion.

• While subjected to mild straining. • When subjected to extreme straining.

Because breathing is so important, the dynamic sequence shouldn't go on for more than 20 seconds at a time (23).

2. Evacuation phase (MR Defecography)

• The sagittal plane will be used to acquire the pictures using TRUFI, which stands for real fast imaging with a steady-state free precession sequence. The parameters used for this technique are identical to the ones discussed before. When the injected gel is seen flowing through the anal canal lumen, it was determined that the evacuation process was appropriate.

• If the abdominal wall moves visibly when you squeeze and strain, it becomes diagnostic.

To identify anomalies and the whole amount of POP, which only manifests following evacuation, MR defecography imaging requires the rectal gel to be evacuated.

• To exclude the possibility of rectal intussusception, repeat the evacuation cycle (which usually takes two or three minutes) until the rectum is empty.

• Anismus should be considered in cases when the evacuation of rectal material is either not performed at all or takes more than 30 seconds to expel two-thirds of the rectal gel (24).

Analysis of static MR images

- **The urethral supporting system**

There are many types of urethral ligament abnormalities that may be seen in the axial plane. One of them is distortion, which occurs when the ligaments' internal architecture changes due to waviness.

Discontinuity of the ligament allowing viewing of the torn portions defines the defect.

The drooping mustache sign, created by the fat in the pre-vesical cavity pressing on the bilateral sagging of the detached lower third of the anterior vaginal wall from the arcus tendineus fascia pelvis (ATFP), is a hallmark of a level III endopelvic fascial defect.

One way to identify a puborectalis muscle defect is if the normally symmetrical appearance of the muscle slings or their attachment to the symphysis pubis is disrupted (25).

· The structure that supports the vagina

When the posterior wall of the fluid-filled urinary bladder droops into the bilaterally separated vaginal supporting fascia from the lateral pelvic wall, a saddlebag sign is seen, indicating a Level I or II endopelvic fascial vaginal defect. The posterior wall of the urine bladder drooping also indicates the primary abnormality.

An evaluation of the iliococcygeus muscle is conducted to see whether it has lost its usual symmetrical look, has a defect, or has been disrupted in its connection to the obturator internus muscle (26).

Analysis of dynamic MR images

- **Sagittal plane**

The pubococcygeal line (PCL) serves as the reference line in the sagittal plane. This line went all the way from the front of the body to the back, ending at the coccyx, beginning at the lower edge of the symphysis pubis.

Below the PCL, the uterus, anorectal junction, bladder neck, and bladder base all descend.

The presence or absence of urine loss during MR imaging does not rule out patient complaints; nevertheless, a suction urinary incontinence (SUI) is documented when the urethral leakage is seen at maximal straining.

The H-line, which links the anorectal junction to the inferior border of the pubic symphysis, is one of the additional measures that may be found in the sagittal plane when straining is at its highest.

From the posterior side of the H-Line, the M-line is descended perpendicularly to PCL.

Within the space between the levator plate and the PCL (27), there is the levator plate angle.

Correlation between static and dynamic MR images

By comparing the results of static and dynamic magnetic resonance imaging (MR) scans taken of the same patient at the same time, we may identify the most severe pelvic supporting system deficiencies. According to the research, this fault is the most common one.

Using this method, we were able to determine whether pelvic organ prolapse (POP) was caused by weak levator muscles, endopelvic fascia deficiencies, or a combination of the two.Researchers discovered that structural abnormalities in the urethral supporting components, rather than bladder neck descent, were related with SUI. •By combining static and dynamic MR images, which previously recorded abnormalities independently, this imaging correlation creates a unified system that can better pinpoint the pelvic floor dysfunctional issue at its source (and even differentiate between similar symptoms in different patients) (28).

MR imaging in post-operative cases

- **Imaging indications**
  - Imaging is crucial for evaluating the postoperative condition, different kinds of surgical treatments, how well they address the underlying malfunction, and if symptoms worsen or return.
  - Finding problems that can arise after surgery, such as hematomas, infections, vascular damage, bladder injuries, bowel obstructions, or other fluid collections;

and finding problems that can happen later on, like misplaced or migrated bulking agent material, erosion or extrusion of implanted surgical material, or infections of mesh or slings.

- The physical examination conducted before to the procedure may have missed the presence of several compartments, which might explain why the prolapse surgery failed.
- Finding synthetic material and plotting a course for surgical investigation may be possible using imaging. When combined with the patient's medical history and the results of a physical exam, this data helps the surgeon decide if further surgical operations, such the excision of possibly harmful synthetic material, might be beneficial (29).

- **MR imaging protocol**

After surgery, magnetic resonance imaging (MR) of the pelvic floor is used to evaluate the mesh materials and the results of the operation in comparison to the clinical findings. This examination is both dynamic and anatomical in nature. To improve the chances of detecting synthetic materials, a customized high-resolution "mesh protocol" is used instead of the usual dynamic pelvic floor MR defecography protocol (30) when imaging patients who have had many previous surgeries for mesh and sling placement or removal.

In order to assess inflammation, collections, bone edema, or infection, the mesh protocol uses high-resolution 2D T2-weighted fast SE (TSE) sequences in the axial, sagittal, and coronal planes, as well as a 2D T2-weighted fat-suppressed fast SE sequence in the sagittal plane (Khatre et al., 13). In order to show the mesh and sling components, a 3D T2-weighted rapid SE sequence was performed in the axial plane, centered at the urethra and vagina.

In order to assess vulnerability associated with surgical sutures and clips, T1-weighted gradient-echo in-phase and out-of-phase magnetic resonance images are acquired.

To evaluate inflammation of the mesh and sling components, T1-weighted fat-suppressed gradient-echo MR images, both enhanced and non-enhanced, are acquired during the late arterial phase and then at 40, 90, and 120 seconds. The coronal and sagittal pictures should encompass the cranio-caudal region up to the L5 vertebral body, which includes the sacral promontory, where the prospective sacrocolpopexy mesh fixation site might be located.

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Table (1) Recommended mesh protocol for MR imaging [13]

MR Pulse Sequence	Imaging Plane	Field of View (cm)	Section Thickness (mm)	TR (msec)	TE (msec)	Flip Angle (°)	Matrix
2D T2-weighted fast SE	Sagittal	25	4	4575	130	90	356 × 356
2D T2-weighted fat-suppressed fast SE	Sagittal	25	4	4696	130	90	356 × 356
2D T2-weighted fast SE	Axial	18	4	7677	130	90	340 × 308
3D T2-weighted fast SE	Axial	20	2	1311	200	90	200 × 184
2D T2-weighted fast SE	Coronal	18	4	6483	130	90	340 × 308
2D T1-weighted gradient-echo OP/IP	Axial	30	5	149	1.15/2.3	55	256 × 256
3D nonenhanced T1-weighted fat-suppressed gradient-echo	Axial	24	3	5	1.28/2.3	10	200 × 160
3D gadolinium-enhanced T1-weighted fat-suppressed gradient-echo*	Axial	24	3	5	1.28/2.3	10	200 × 160

Imaging technique

To ensure the patient is as comfortable as possible during a pelvic MRI and is more likely to comply with the procedure, proper patient preparation and a reliable approach with a short acquisition time are essential. In order to avoid pelvic organ prolapse and a bloated bladder from hiding pelvic structures during the dynamic examination, the patient will be instructed to partly urinate before the procedure. Keeping a little pee in the bladder makes the bladder and prolapse of the anterior vaginal wall easier to see. A torso phased-array coil is used to complete the examination by wrapping it around the pelvis (31).

Due to their intrusive nature, endovaginal coils may reduce patient acceptability and compliance, despite the fact that they may enhance spatial resolution of the pelvis's tiny supporting ligaments. If a patient has a tiny pelvis, using an endovaginal coil might deform their pelvic tissues. There isn't usually enough room to see the puborectalis due to the narrow field of vision. A modest amount of intraluminal ultrasonic gel with a hyperintense T2 signal may be injected to enhance visibility of the vagina and rectum. Twenty milliliters of gel may be injected into the vagina using a small-caliber catheter-tip syringe, and sixty to one hundred and twenty milliliters into the rectum. Although dynamic MRI may be done without endoluminal gel, it leads to less than ideal straining, which hides the extent of pelvic organ prolapse and makes visceral descent invisible (16).

When it comes to dynamic MRI of the pelvic floor, our institution typically uses ultrafast, large-field-of-view, T2-weighted sequences like single-shot fast spin-echo (SSFSE) or half-Fourier acquisition turbo spin-echo (HASTE) on Siemens Medical Solutions scanners. There is also the option of doing real quick imaging during steady-state precession. Prior to the assessment, the patient should be instructed on how to correctly strain. Remind her to maintain her lower back flat on the table as she uses her internal organs exclusively for straining. The pelvic floor and the extent of pelvic organ prolapse may be seen in the sagittal plane pictures that are viewable in a cine loop (14).

It is recommended to take these pictures again after a patient with a rectocele has expelled their rectal contents. Assuming the magnet is well-prepared and the patient is cooperative, it is possible to record the evacuation procedure while the patient is in the magnet. If the patient is unable to defecate in the magnet, it may be required to use the commode for evacuation and then undergo repeated imaging. A noticeable rectocele will be defined by the residual contrast material. Patients with pelvic organ prolapse may benefit from obtaining coronal plane static pictures. The iliococcygeus muscle swells in these pictures, a symptom seen often in patients with perineal hernias and persistent constipation (31).

Following the completion of the dynamic examination, high-resolution images of the pelvic floor muscles and fascia, as well as the fascial condensations supporting the urethra, are obtained using small-field-of-view (20-24 cm) T2-weighted axial fast spin-echo (FSE, GE Healthcare scanners) or axial turbo spin-echo (TSE, Siemens Medical Solutions scanners) sequences. The acquisition time for this group of photos is around four minutes, although the lower pelvic images do not show breathing artifacts. To better understand the anatomy of the pelvis and its connections to the urethra and vagina, these high-resolution axial pictures are invaluable. Since the nearby muscles, fascia, and pubic bones have a hypointense signal compared to the hyperintense signal of the pelvic fat, fat saturation is often not applied to these sequences (32).

Interpretation of MRI findings

As previously mentioned, the pubococcygeal line may be used radiologically to demarcate the pelvic floor level on dynamic MRI in the midsagittal picture. The line begins from the inferior pubic symphysis and continues all the way to the final horizontal sacrococcygeal joint. This line is simple to draw and can be reliably reproduced in all patients using MRI. Typically, a healthy person's levator plate will lie perpendicular to their pubococcygeal line. In addition, the H and M lines are used as reference points, which might prove to be valuable in determining if the pelvic floor is relaxed or prolapsed. As a measure of the levator hiatus's anterior-posterior breadth, the H line on a midsagittal picture extends from the inferior symphysis pubis to the posterior anorectal junction. By drawing the M line perpendicular to the pubococcygeal line and continuing it to the furthest point of the H line, we can see how the levator hiatus descends from that point. The H line in healthy women was around 5 cm and the M line about 2 cm, according to the research (33).

When there is a severe prolapse of the pelvic floor, the levator plate will slope and the H and M lines will get longer, which means the levator hiatus will broaden and descend. The research does not provide much information on how to evaluate the degree of prolapse using the H and M lines as reference points, even if their elongation is a helpful sign of pelvic floor dysfunction and pelvic organ prolapse. Hence, the patient's clinical complaints should be considered with the MRI findings of pelvic organ prolapse (34).

Check for signal strength, symmetry, thickness, and fraying in the pelvic floor muscles using the high-resolution T2-weighted axial images. If a woman's anatomy is normal, her paracolpium should keep her vagina in a regular butterfly shape and her pelvis centered. The vagina is hung between the urethra and the rectum. Even though an endovaginal coil could make it hard to see the periurethral ligaments, it is nevertheless important to check their symmetry and integrity whenever feasible. This is particularly true for women who are experiencing urine incontinence symptoms (11).

Role of magnetic resonance (MR) imaging in postoperative repair of pelvic floor dysfunction

- **MR imaging of retropubic slings**

Magnetic resonance imaging (MRI) of retropubic slings improves periphery component visibility but reduces synthetic material detail resolution in the immediate periurethral region. A hypointense ribbon-like structure extending anteriorly from the urethra into the suprapubic area may be seen on T2-weighted MR imaging as a retropubic sling (Figure 10). You should be able to see the retropubic sling arms crossing the rectus abdominis in the front and the pubic bone and bladder at the back of your neck in the retropubic area. Magnetic resonance imaging (MR) scans taken in a coronal or sagittal plane may prove that a fat plane exists between the bladder and the sling arms (35).

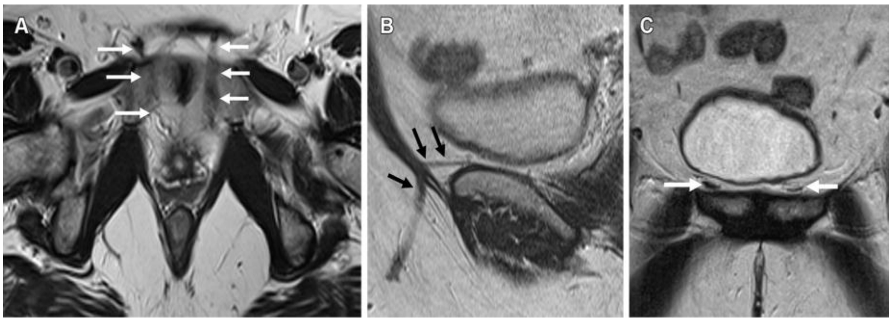

Fig. (10) Retro-pubic urethral sling. (A) Axial T2-weighted MR image shows a ribbonlike U-shaped retropubic urethral sling with arms overlying the pubic rami in the retropubic space (arrows). (B) The parasagittal T2-weighted image shows a hypointense band (arrows) traversing the retropubic fat between the pubic bone and bladder, traversing the rectus abdominis anteriorly. (C) Coronal T2- weighted MR image through the anterior pelvis shows the arms of the sling enface on either side of the midline in the retropubic space (arrows). Note the maintained fat plane between the sling arms and the bladder on B and C [35]

- **MR imaging of TOT slings**

As shown in Figure 11, TOT has arms that extend laterally toward the obturator foramina and a broader U-shaped or hammock-shaped structure surrounding the posterior urethra (36).

Transobturator slings are hypointense on T2-weighted MR images and run laterally from the periurethral space towards the obturator foramen; however, detecting TOTs with MR imaging is more challenging because of the absence of fat in the periurethral region. As they go caudally over the obturator muscles, they are visible. Imaging the transobturator tape arms from the side is challenging even with 3D MR and small incisions (37).

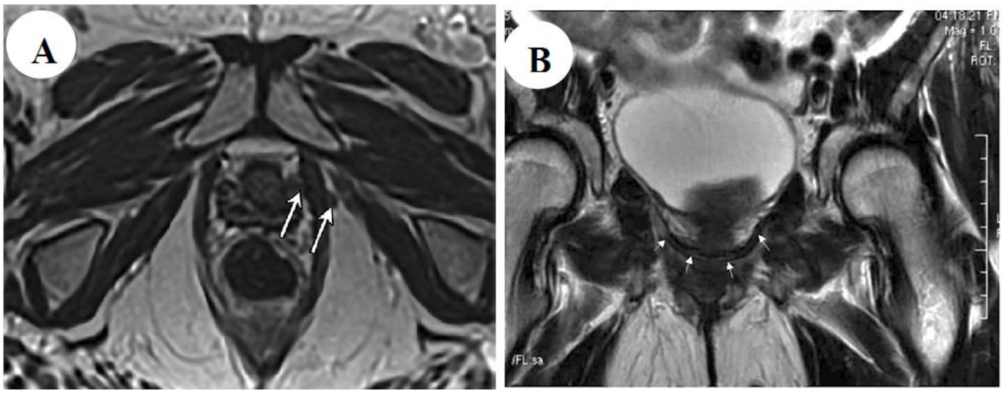

Fig. (11) Trans obturator sling. (A) Axial 3D T2-weighted MR image shows a bandlike hypointense structure (arrows) in the left periurethral space, extending laterally through the puborectalis muscle into the obturator foramen. (B) Coronal T2-weighted MR images showing the TOT which appears as a U-shaped sub-urethral tape from one obturator foramen to the other (Short arrows) [13]

On sagittal T2-weighted MR images, the transobturator slings appear as a thin hypointense band running along the back of the vagina, like tension-free vaginal tape in the middle. However, when viewed from a parasagittal angle, the arms can be seen as small comma-shaped structures on either side of the urethra, flowing into the obturator foramen. The presence of fibrosis may explain the low-grade increase found along the arms of mid-urethral slings (38).

- **Sling infection**

The most common causes of sling infections are bladder or vaginal exposure, extrusion, or fistulization. Magnet resonance imaging (MR) is the gold standard for detecting infection and inflammation along mesh arms. Although avid or early enhancement may indicate infection or inflammation, the specificity and sensitivity of this observation are yet unknown (Figure 12) (39).

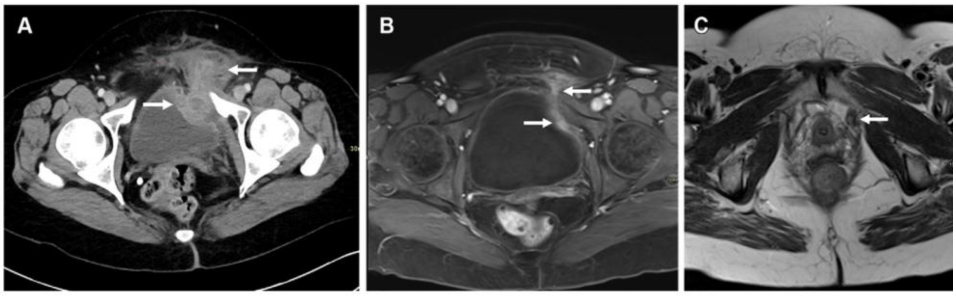

Fig. (12) Inflection of a retropubic sling. (A) Axial CT image shows an inflammatory mass at the left bladder wall and abdominal wall (arrows). (B, C) Axial MR images obtained approximately 6 weeks later after treatment show improved inflammation at the bladder and abdominal wall, with an asymmetrically thickened left-sided arm of the retropubic sling (arrows). The findings are consistent with sling infection [35]

- **MR Imaging of bulking agents**

Depending on the material injected and whether calcification has taken place, magnetic resonance imaging (MRI) of bulking agents shows thickening of the spongiform tissue around the urethra. The signal intensity varies, but on T2-weighted MR images, it is typically hyperintense compared to normal urethral tissue (Figure 13). In some cases, especially in the absence of post-contrast enhancement, the bulking agent might be mistaken for an enlarged urethra with clear borders forty.

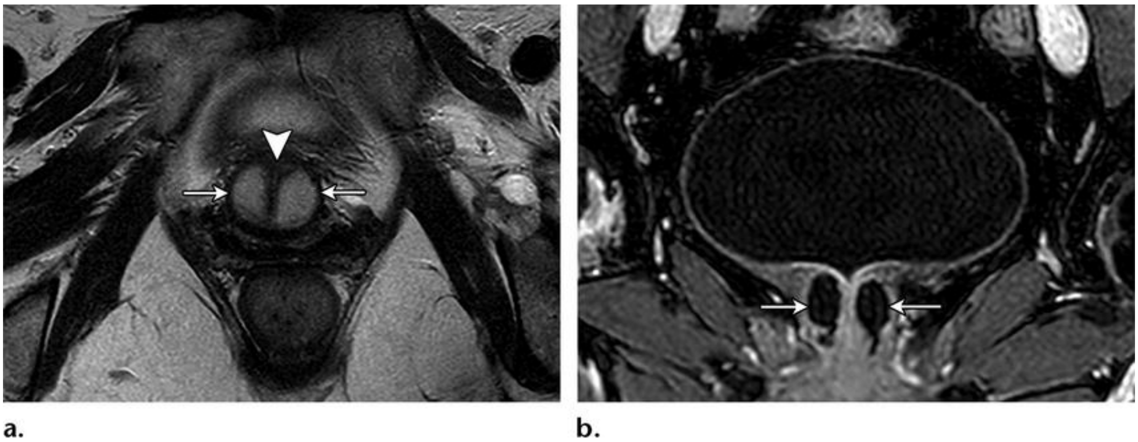

Fig. (13) Injection of silicone particles as a urethral bulking agent. (a) Axial T2-weighted fast SE MRimage shows hyperintense material (arrows) encircling the urethra;(b) Coronal 3D contrast-enhanced T1-weighted fat suppressed gradient-echo MR image shows the absence of central enhancement of the urethral bulking agent (arrows) [35]

- **MR Imaging of vaginal mesh**

On axial MR images, the mesh arms—shown as cordlike structures at the end, encircled by fat with a high signal intensity—may be the most easily discernible structures in the ischio-rectal fossae. As they pass through the sacrospinous ligaments or levator muscles, the arms appear as linear structures in sagittal and coronal magnetic resonance scans. Figure 14 shows that the thicker concentration of linear hypointense signal intensity along the front or posterior vaginal walls may be seen on axial and sagittal T2-weighted MR images, representing the mesh body (41).

If you see any unusual thickening along the vaginal mesh's arms or body, it's important to report it. This might be a sign of inflammation or mesh ejection. While magnetic resonance imaging (MR) was not shown to be particularly sensitive or specific in detecting extrusion, it is important to describe any regions of localized thickening that may help surgeons identify any abnormalities (42).

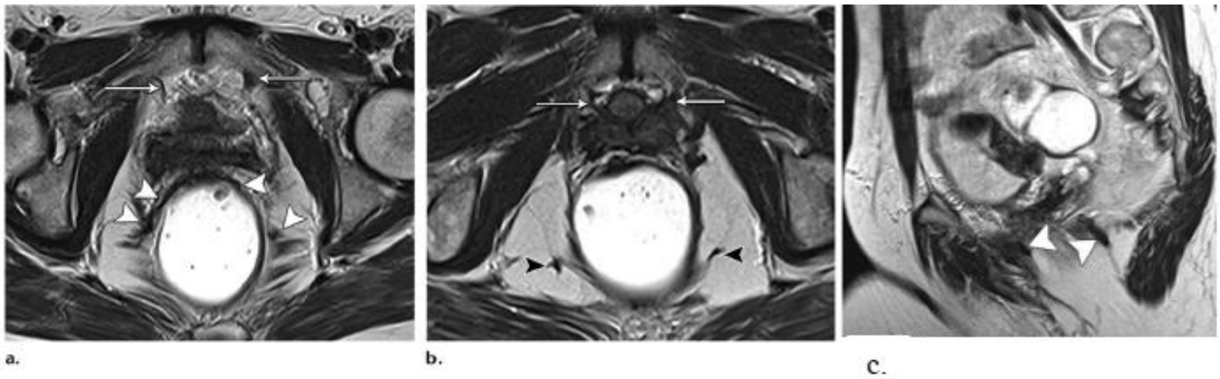

Fig. (14) MRI T2 WIs showing anterior and posterior vaginal mesh as well as retropubic sling. (a, b) Axial T2-weighted fast SE MR images show mid-urethral sling appears as a hypointense band (arrows on a, b) encircling the urethra and extending into the retropubic space. The posterior vaginal mesh (arrowheads on a, b) is depicted as a uniform band of hypointense signal intensity along the anterior portion of the rectum, with the arms traversing the levator muscles and ischiorectal fossae. © The right parasagittal T2-weighted fast SE MR image shows the anterior and posterior arms (arrowheads) of the vaginal mesh traversing the levator muscles and extending into the ischiorectal fossa [13]

- **Imaging of sacrocolpopexy mesh**

Because of its wider field of view, magnetic resonance imaging (MR) is a great tool for detecting the superior extension of the sacrocolpopexy mesh as it travels from the pelvis to the sacral promontory. Figure 15 shows that on T2-weighted MR images, normal sacrocolpopexy mesh typically looks like a thin cord or ribbon with hypointense signal intensity. In cases of supracervical hysterectomy, it extends from the cervix or vaginal apex; in cases of uterus preservation and Sacro hysteropexy, it starts from the posterior surface of the uterus and ends at the sacrum. The typical mesh, due to edge curling, might also seem flat or shaped like a "seagull" on axial MR imaging. Hemostasin deposition or suture material may cause signal voids or susceptibility artifacts to be apparent along the mesh (43)

Although the sacrocolpopexy mesh is typically positioned under tension and appears centrally inside the pelvis, it commonly exhibits a little rightward curve along the pelvic side wall. This observation is most clearly seen on coronal T2-weighted MR images. Inadequate support for the vaginal apex while standing could explain the abnormally bent path observed on supine MR images (44).

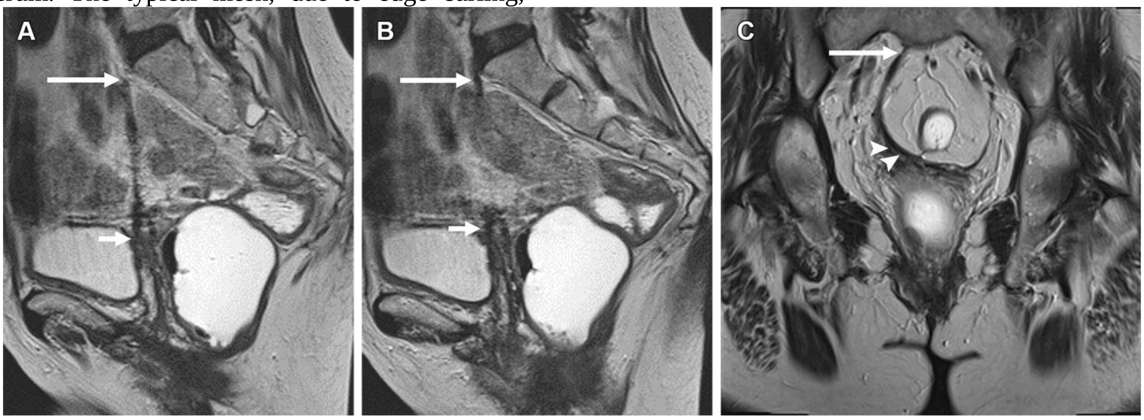

Fig. (15) (A, B) Sagittal T2-weighted MR images showing sacrocolpopexy mesh extending from the sacral promontory (long arrow) to the vaginal apex (short arrow). (C) coronal T2-weighted MR images showing sacrocolpopexy mesh passing slightly to the right of the midline [13]

- **Sacrocolpopexy mesh related complications**

If the mesh seems thicker with a high signal intensity on T2-weighted MR imaging, it might be a symptom of mesh infection. The sacrocolpopexy mesh may adhere to the sacral promontory or the level of the L5-S1 disk, which can lead to problems including discitis or osteomyelitis, as well as fluid collections. Magnetic resonance imaging (MR) may be utilized to identify potential causes of recurrent prolapse after sacrocolpopexy mesh installation, such as mesh ripping or detachment (Figure 16) (45).

Fig. (16) (a,b) Coronal and sagittal T2-weighted MR images show a thickened sacrocolpopexy mesh with hyperintense signal intensity along its course raising suspicion for infection (arrows) [35]

Conclusion:

MR defecography is an excellent modality for assessment of pelvic floor disorders. It has very good temporal resolution and high soft tissue contrast, also allows visualization of the pelvic floor function in real-time without any radiation load. Imaging the defecation process in real-time leads to a definitive diagnosis in cases of dysfunctional defecation and a precise diagnostic and pre-operative assessment in cases of organ prolapse. Since MR defecography can establish the entire pelvic floor when combined with static and dynamic sequences, it is a reliable alternative for noninvasive pelvic evaluation. This allows to identify the primary problem and provide patients with the best possible care before surgical intervention.

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