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RESEARCH

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MRI of the pelvic floor in female patients with stress urinary incontinence, pre- and postoperative and/or physiotherapy: analysis of the defect-specific approach

Sherif Fathy Abdelrahman[1*], Mohamed A. Abdelatty[1], Basma Amer[1], Sara Mahmoud Kamel[1], Ahmed Fathy Hussein[2] and Rania Farouk El Sayed[1]

Abstract

Background Stress urinary incontinence (SUI) is a common disabling pelvic floor dysfunction, particularly among aging women. Magnetic resonance imaging (MRI) with dynamic sequences has been proven reliable for detecting pelvic floor weaknesses, especially with multiple compartments defects. Since surgical and non-surgical management options exist, detailed imaging analysis and comprehension of the various surgical and non-surgical interventions are crucial for surgical planning and postoperative evaluation. However, patients often present with recurrent or new symptoms after surgery, where MR imaging is necessary to detect complications in this setting. We aimed to analyze MR images pre- and postoperative/intervention using the defect-specific approach aiming at better understanding of the underlying complication and/or the cause of recurrence.

Results Thirty female patients with SUI were included in the study; 20 underwent surgery, 6 were treated by physiotherapy only, while 3 patients underwent both surgery and physiotherapy and 1 patient was treated conservatively. According to their clinical symptoms, patients with successful surgical/physiotherapy outcome were 18 cases (60%), while unsuccessful group comprised of 12 cases (40%) is classified as follows: persistent complaints subgroup 7 patients (23.3%), de novo complaint subgroup 2 patients (6.7%), while the complicated subgroup is comprised of 2 patients (6.7%) and the persistent/de novo complaints subgroup of the unsuccessful group is composed of 1 case (3.3%). They all underwent MRI of the pelvic floor with a standardized technique, pre- and postoperative/physiotherapy. Changes in level III endopelvic fascia defects between the pre- and postoperative/physiotherapy studies were statistically significant ($p = 0.045$). Urinary bladder and uterine descent were also found statistically significant between the pre- and postoperative/physiotherapy studies ($p = 0.001$ and $p = 0.029$, respectively). Comparing successful and unsuccessful groups pre- and postoperative/therapy, levator plate angle (LPA) was found statistically significant as well ($p = 0.039$ preoperative and $p = 0.001$ postoperative).

Conclusions Analysis of the pre- and postoperative static and dynamic MRI sequences along with proper understanding of the preformed intervention can pinpoint the underlying pathology leading to the recurrent or de novo symptom and/or complications. The defect-specific approach can help determine the underlying pelvic floor defect by altering the MRI techniques tailored for each patient according to their complaint.

*Correspondence:
Sherif Fathy Abdelrahman
sfathy1977@kasralainy.edu.eg
Full list of author information is available at the end of the article

Keywords Pelvic floor dysfunction, Urinary incontinence, MRI

Background

Pelvic floor consists of different muscles, ligaments and connective tissues that support pelvic organs; damage to any of these structures may lead to pelvic floor dysfunction that may lead to abnormalities of bowel and bladder emptying and storage with or without accompanying pelvic pain [1].

A complete survey of the whole pelvic floor is essential for optimal patient management, especially before surgical correction is attempted. Thus, familiarity with normal imaging findings and features of pathologic conditions are important for radiologists [2]. MRI is commonly used not only to assess potential complications of the procedure postoperatively but also to evaluate functional disorders and recurrent prolapse as well [3].

MRI provides useful information that can identify the underlying anatomical defect responsible for symptoms in individual patients with PFD, possibly allowing differentiation of the underlying anatomical defect when comparing different patients with similar complaints. These MRI findings can lead to diagnosis of complex disorders and makes individualized defect-specific approaches possible for treatment that may minimize the risk of symptoms recurrence and need for reoperation [4].

Knowledge of the original pre-surgical complaints and the type of subsequent intervention performed is essential when interpreting imaging in the post-intervention setting as well as awareness of the possible imaging features of complications such as erosion or extrusion of implanted surgical material, or infection of mesh or slings [5].

The main objective of this study was to investigate the exact underlying etiology of the patient's complaints and how to guide the clinician to the proper management plan in sight of the imaging findings to guarantee a successful outcome, better quality of life and less recurrence rate. Owing to the paucity of research targeting the defect-specific approach, we aimed to study and apply this approach for better understanding of the complex nature of the pelvic floor dysfunctions.

Patients and methods

Patients: study population and study design

This study was performed over about 2 years and conducted on thirty female patients of age range from 18 to 55 years. Sample size was calculated using EPI INFO sample size calculator; 30 patients underwent pre- and post-intervention MRI examinations. The patients were referred from the urology department of a university hospital. This study is IRB-approved, and written informed consent was signed by all patients before the examination. Inclusion criteria were female patients complaining of urinary incontinence with or without pelvic organ prolapse, pelvic pain or heaviness. The exclusion criteria were absolute contraindications to MRI such as patients with cochlear implants, cardiac pacemaker, severe claustrophobia in addition to pregnant females on the other side. The full socio-demographic and clinical data including age and general examination of all patients were collected.

Methods

Patient's preparation

Patients performed pre- and postoperative/physiotherapy MRI on the same 1.5-T MRI machine (Achieva, Philips Medical system) with standardized technique. All patients were instructed to urinate 2 hours before to the study and had undergone a rectal enema with warm water the night before the MR imaging. The rectum was opacified with 90–120 mL of ultrasonographic gel.

This prospective study was conducted on 30 female patients in a university hospital using static and dynamic MRI of the pelvic floor; their mean age was 43.5 ± 8.7 years. All patients came complaining of variable degrees of SUI (stress urinary incontinence) with or without manifestations of pelvic organ prolapse (e.g., sense of pelvic heaviness or constipation).

MR imaging protocol

Using T2-weighted turbo spin-echo (repetition time msec/echo time msec, 5000/132; field of view, 240–260 mm; section thickness, 5 mm; gap, 0.7 mm; number of signals acquired, two; flip angle, 90°; matrix, 512 512; acquisition time, 3.12 min for each sequence), static images of the pelvis were first acquired in three planes. The anal sphincter complex was also imaged using T2-weighted balanced fast field echo (9.0/4.0; field of view, 220 mm; section thickness, 3 mm; number of signals acquired, eight; flip angle, 45°; matrix, 512 512; acquisition time, 2.12 min). Section orientation in this sequence was both parallel and perpendicular to the anal canal's plane. In the sagittal, axial, and coronal planes, dynamic MR imaging was carried out utilizing the balanced fast-field echo sequence. (5.0/1.6; field of view, 300 mm; section thickness, 6–7 mm; gap, 0.7 mm). Six phases were acquired in each plane, as follows:

(a) at rest, (b) during contraction of the pelvic floor (the patient was instructed to squeeze their buttocks as if trying to stop urine from escaping); (c) during mild straining; (d) during moderate straining; (e) during maximum straining; (f) during a repeated maximum straining sequence to ensure a maximal Valsalva maneuver (patient was asked to bear down as much as she could, simulating to be constipated and trying to defecate). BFFE was used in the sagittal plane to acquire the evacuation phase. Intravenous contrast was administered when there is clinical suspicion of postoperative local sepsis (gadolinium 0.1–0.2 mmol/kg) with T1 and fat-suppressed T1 axial and coronal planes.

Prior to the MR imaging, all participants received training on these instructions. A radiologist was present during each MR imaging to assure the woman's compliance by monitoring the movement of the anterior abdominal wall and the pelvic organs to reduce discrepancies between examinations.

Imaging analysis

(A) Analysis of the static MR images:

Image analysis was performed by two radiologists with 3 and 7 years of experience in pelvic floor imaging. Final MRI findings were approved by senior radiologist with 23 years of experience in pelvic floor imaging. Analysis of static images was based on the inspection of the urethral supporting system, the vaginal supporting system, and the anal sphincter complex.

The puborectalis muscle, level III fascial support, and ligaments constitute the urethral supporting structures. Urethral ligament abnormalities were categorized as deformed on images taken in the axial plane when internal architectural alterations and the waviness of the ligaments were visible and reported defective when there was discontinuity in the ligament with visualization of the torn portions. The "drooping moustache sign" was identified by fat within the pre-vesical space against the bilateral sagging of the detached lower third of the anterior vaginal wall from the arcus tendineus fascia, denoting a level III fascial lesion, while the loss of the symmetrical appearance of the muscle slings or disruption of the muscle's attachment to the pubic bone is a sign of a puborectalis (PR) muscle defect [6].

The iliococcygeus (IC) muscle, level I fascia (which suspends the upper portion of the vagina from the pelvic wall), and level II fascia (which attaches the midportion of the vagina to the pelvic wall more directly) are the vaginal supporting structures. The "saddlebags sign" or sagging of the posterior urinary bladder wall caused by the detachment of the vaginal supporting fascia from the lateral pelvic wall was used to identify a fascial defect in the axial plane. The iliococcygeus muscles were examined if the slings had lost their usual symmetry or if their attachment to the obturator internus muscle in the coronal plane had been disrupted [7].

Anal sphincter lesions were categorized based on the type of lesion (defect and/or scarring) and the part affected (PR muscle, internal or external anal sphincter). The muscle ring's discontinuity was referred to as a sphincteric defect, and low signal-intensity deformation of the muscle layer's typical pattern was referred to as scarring [7].

(B) Analysis of the evacuation phase:

In the sagittal plane, the pubococcygeal line (PCL) was used as the reference line. For each participant, the descent of the bladder neck, uterus, and anorectal junction below the PCL was recorded.

Enterocoele was diagnosed when small-bowel loops herniate into the recto-genital space beyond the PCL during evacuation, while peritoneocele was noted when the peritoneum prolapsed into the rectovaginal space and beyond the PCL but with no associated bowel herniation [8].

Rectoceles were diagnosed as an anterior rectal wall bulge. Typically, a line drawn through the anterior wall of the anal canal is extended upward, and a rectal bulge of greater than 2 cm to 3 cm anterior to this line is described as a rectocele [7].

(C) Analysis of dynamic MR images:

In the sagittal plane, the levator plate angle, which is enclosed between the levator plate and the PCL, was measured. In the axial and coronal planes, respectively, the width of the levator hiatus and the iliococcygeus angle were measured at rest and during maximum straining. These measurements of supporting structures were all considered to reflect the status and the weakness of the levator ani [8].

(D) Combined analysis of static and dynamic MR images:

Combining static and dynamic MR image analysis gives complementary information and enables the identification of certain structural abnormalities and their correlation with particular pelvic floor dysfunctions in patients with SUI and POP. A defect-specific approach to disease management and surgical procedure is made practical by this analytical approach, which provides insight into the diagnosis of these complicated conditions [7].

(E)Statistical analysis

Statistical calculations were done using computer program SPSS version 15 (Statistical Package for the Social Science; Chicago, IL, USA) with the statistical analyses made using statistical software (Minitab 17, Minitab Inc., USA). Statistically significant results were considered when the *p value* is *less than* 0.05.

Results

Twenty patients underwent surgeries (Fig. 1); 10 patients with uterine prolapse underwent reconstructive sacrocolpopexy procedure, 5 with midurethral sling, 2 with vaginal mesh, 2 with cystocele repair, and 1 had rectopexy for rectal prolapse, either through laparoscopic or through abdominal approaches. Six patients with mild-to-moderate muscular weakness were treated by physiotherapy only, while 3 patients were treated with surgery (sacrocolpopexy mesh placement, Fig. 2) and physiotherapy. Only 1 patient was treated conservatively.

Patients were classified according to their surgical outcome based on improvement in their symptoms and clinical assessment by a urologist subspecialized in pelvic floor dysfunctions into successful and unsuccessful groups. The successful group is composed of 18 cases (60%) while the unsuccessful group 12 cases (40%). Unsuccessful group was subdivided into persistent complaint (PC), de novo complaint (DC) and complicated (mesh erosion, infection) subgroups as detailed in Table 1.

The static MRI findings are summarized in Table 2 which includes level I, II and III endopelvic fascial defects: anal sphincter complex injury, PR defect and IC abnormalities such as tear, defect or thinning. Analyzing the static images of the successful group, the most common defect was level III endopelvic fascial defect (Fig. 3 and 4) with comparison between pre- and postoperative/physiotherapy data being of statistical significance ($p = 0.045$) (Fig. 5).

Abnormalities detected during the evacuation phase of all patients in both pre- and post-intervention are summarized in Table 3 which included peritoneocele, enterocele and intussusception in addition to spastic puborectalis. Regarding images analysis of the evacuation phase, comparison of the mean values of the bladder and uterine descent pre- and postoperatively was found to be statistically significant $p < 0.001$ and $p < 0.029$, respectively. Analysis of the dynamic sagittal MR images comparing the successful and unsuccessful outcomes revealed that LPA was significantly larger in unsuccessful group postoperative/physiotherapy $p = 0.001$.

Discussion

The pelvic floor dysfunction (PFD) is a common health problem affecting increasing number of females nowadays, thus warranting a more comprehensive and individualized approach in diagnosis and management of the underlying pelvic floor dysfunction. The usual tests and evaluation methods often do not produce satisfactory outcomes, resulting in high failure rates for surgical procedures and thus dysfunction recurrence [9, 10].

We aimed to determine the exact underlying cause of the symptom by analyzing static and dynamic MRI of the pelvic floor images pre- and postoperative and/or physiotherapy to yield successful management plan, better quality of life and less recurrence rates [7].

Analysis of the static images of patients with successful surgical outcome initially complaining of SUI

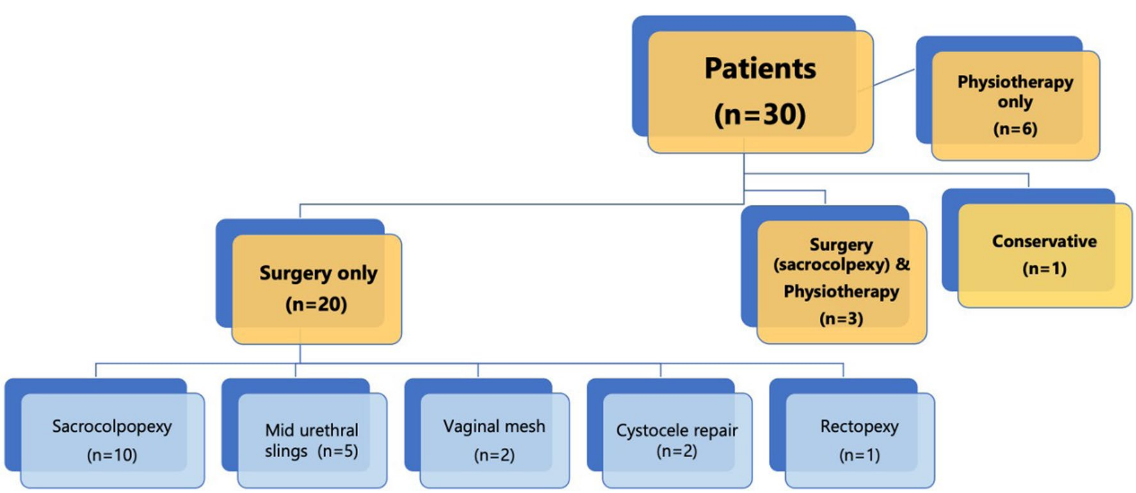

Fig. 1 Diagram illustrating the spectrum of patient according to their management

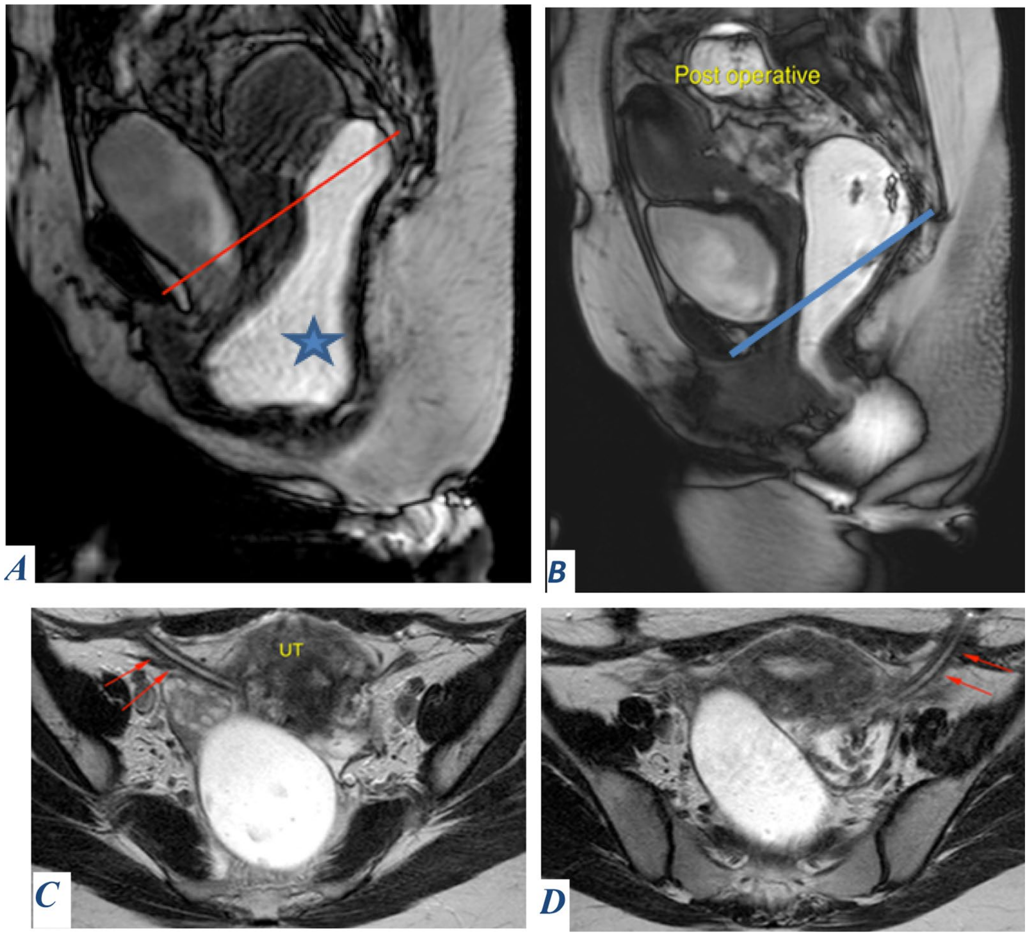

Fig. 2 A 48-year-old lady referred with symptoms of multi-compartmental pelvic floor descent. She underwent uterine mesh placement and had a successful outcome. **A** Sagittal BFFE MRD during evacuation shows mild uterine descent below PCL (red line) and a rectocele (blue star). **B** Postoperative MRD showing no major organ prolapse below PCL delineated by the blue line. **C**, **D** Axial TW2 MR images showing right and left uterine mesh arms (red arrows) with no structural abnormalities and no surrounding collections or smudging of fat planes

Table 1 Classification of patients according to their surgical outcome into successful and successful groups

	Count	%
Status details		
a. Successful outcome	18	60.0
b. Unsuccessful outcome	12	40.0
1. PC/DC	1	3.3
2. PC	7	23.3
3. DC	2	6.7
4. Complicated	2	6.7

only, we found that the most common fascial defect is level III endopelvic fascial defect, where those patients who underwent mid-urethral slings repair operations had favorable surgical outcome suggesting this as the preferred operation in cases of level III fascial defect. In comparison, patients among the unsuccessful groups, originally complaining of both SUI and POP had level I and II endopelvic fascial defects and underwent sacro-colpopexy mesh placement showed persistence of their symptoms. This might be attributed to the possibility that the applied mesh cannot reach those fascial levels.

Analysis of the dynamic images of patients with successful surgical outcome regarding muscle weakness, we found that 6 patients had mild to moderate weakness that underwent physiotherapy management either as a preoperative step (3 patients) or the definitive treatment (6 patients) with 5 of them improving clinically. Hence, suggesting physiotherapy could be an effective way to improve SUI symptoms non-invasively. One third of the studied patients (10 out of 30 patients) underwent sacro-colpopexy mesh placement with successful improvement in their clinical symptoms with

Table 2 Demonstration of static abnormalities detected on MRI of all patients in both pre- and post-intervention

		Preoperative/physiotherapy		Postoperative/physiotherapy		*p* value
		Count	%	Count	%	
Endopelvic fascia level I defect	Positive	9	30.0	4	13.3	0.117
	Negative	21	70.0	26	86.7	
Endopelvic fascia level II defect	Positive	17	56.7	12	40.0	0.196
	Negative	13	43.3	18	60.0	
Endopelvic fascia level III defect	Positive	12	40.0	5	16.7	0.045
	Negative	18	60.0	25	83.3	
Anal sphincter defect/scarring	Positive	2	6.7	1	3.3	1
	Negative	28	93.3	29	96.7	
Puborectalis defect	Positive	1	3.3	1	3.3	1
	Negative	29	96.7	29	96.7	
Iliococcygeus defect	Negative	30	100.0	30	100.0	–

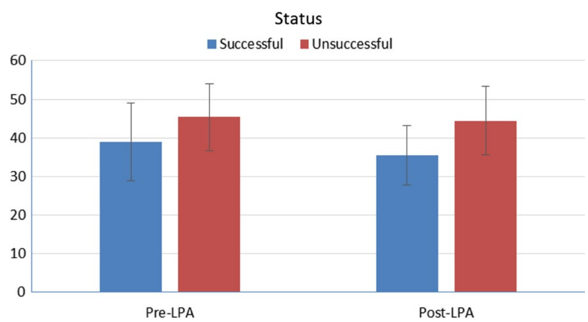

Fig. 3 Bar graph demonstrating level III negative and positive percentages before and after surgical interference

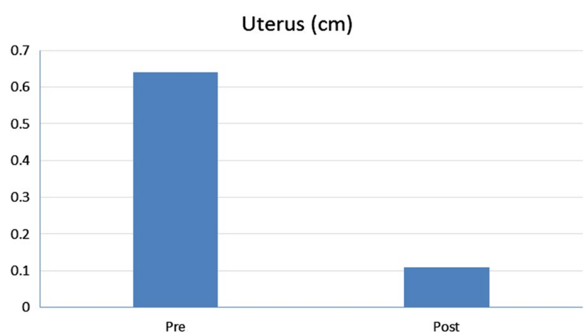

Fig. 4 Bar graph demonstrating the mean of uterine descent below PCL in both pre- and postoperative groups

evident radiological reduction in both bladder and uterine descent in the postoperative dynamic MRI scan during evacuation, since the mesh was targeted specifically to repair the defect.

Comparing the dynamic MR sagittal images during maximum straining between our two main groups of successful and unsuccessful outcomes, we found that LPA was significantly larger in unsuccessful group which might suggest that LPA can be an important risk factor for failure and possibly propose physiotherapy preoperative in patients with LP muscle weakness.

Regarding the unsuccessful groups particularly patients who complained of persistence of their initial complaints; they underwent different kinds of operations varying from slings, sacrocolpopexy and vaginal meshes, so the diversity of the surgical approach most likely increased the probability of their outcome failure. Conservative approach was recommended in one patient who complained of post-traumatic SUI, her MRI revealed an organized large pre-vesical and peri-urethral hematoma and thus a follow-up MRI was decided, and the patient's complaints were relieved.

Two patients had newly developed postoperative complaints (de novo complaint): one had urge urinary incontinence (UUI) and the other case complained of dyspareunia. Analysis of their static and dynamic images, we found that the cause of the UUI was misplaced suture detected on dynamic MR images. That patient complained dyspareunia was found to have infected operative bed that was diagnosed in the static axial MR images suggesting the importance of combining both static and dynamic MRI interpretation to diagnose postoperative complications (Fig. 6).

Among the complicated subgroup of the unsuccessful surgical outcome, patient presented with SUI, had a history of hysterectomy (8 years ago), and referred after sacrocolpopexy mesh insertion complaining of pelvic pain, foul vaginal discharge, and dyspareunia. Her dynamic MR images showed multicompartment POP images. Her post-IV contrast series revealed right sacrocolpopexy mesh sling with surrounding loculated fluid collection for which the patient underwent debridement while she was

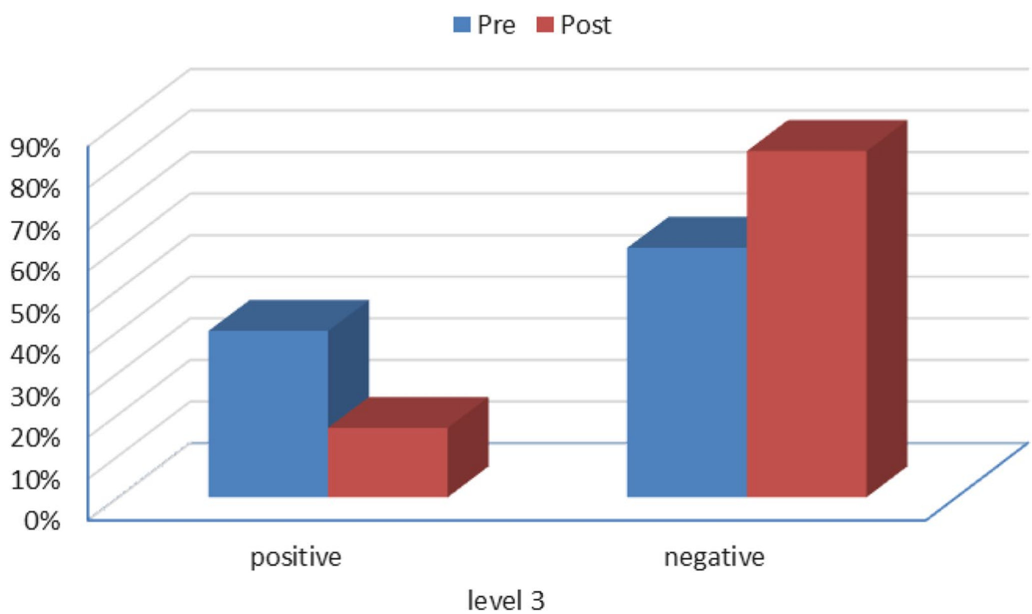

Fig. 5 Bar graph representing the mean of LPA in both successful and unsuccessful groups before and after surgical intervention

Table 3 Abnormalities detected during the evacuation phase of all patients in both pre- and post-intervention

		Preoperative/physiotherapy		Postoperative/physiotherapy		*p* value
		Count	%	Count	%	
Peritoneocele	Positive	2	6.7	1	3.3	1
	Negative	28	93.3	29	96.7	
Enterocele	Negative	30	100.0	30	100.0	–
Intussusception	Positive	1	3.3	0	0.0	1
	Negative	29	96.7	30	100.0	
Puborectalis spasm	Positive	1	3.3	0	0.0	1
	Negative	29	96.7	30	100.0	

Data are expressed as number (%)

$p < 0.05$ = significant

under antibiotic therapy (Fig. 7). Another patient presented with new symptoms after tension free vaginal tape for SUI after being diagnosed to have a cystocele with the postoperative MRI study showed urethral kink at the bladder base with a neighboring area of abnormal contrast enhancement suggesting infection (Fig. 8). Based on these findings, we propose the significance of tailored MRI technique according to the clinical complaint, in this case, the history given suggested an element of infection, thus when contrast was injected the infected mesh arm was depicted, explaining her newly developed complaint.

Another unsuccessful case had persistent postoperative SUI with newly developed obstructed defecation symptoms. Analysis of the postoperative dynamic MRI showed persistence of the uterine descent with a newly developed rectocele. Static images identified the persistence of level III endopelvic fascial defect and a PR defect, thus signifying the importance of combining the static and dynamic scans, where the MRD explained the cause of obstructed defecation and the static images explained the cause of persistence of her complaint which is level III defect, which supports the theory that pelvic floor should be dealt with and treated as a single entity rather that symptoms base [4].

Limitations of this study

The limitations are as follows: relatively small sample size; lack of unified time of examination between pre- and post-MRI (temporal separation); and highly dependent on the postoperative clinic visit. The used MR protocol

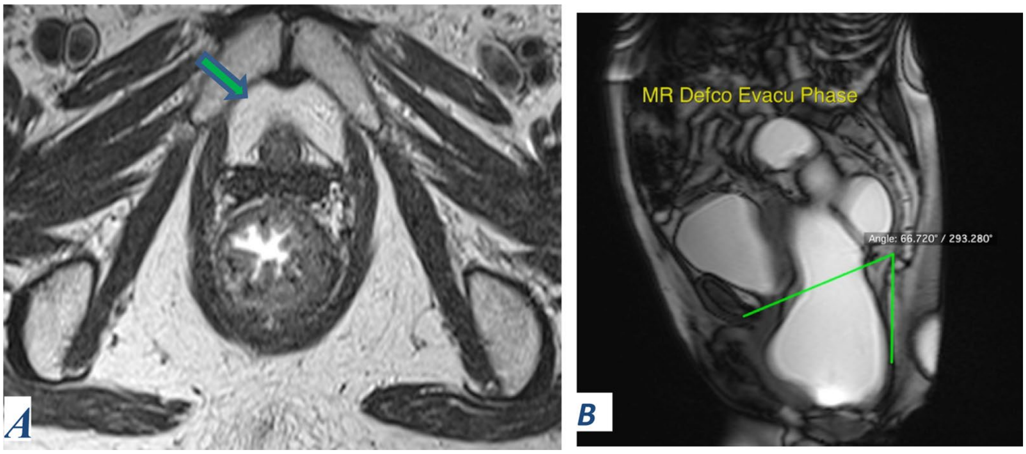

Fig. 6 A 51-year-old woman with 1st presentation of stress urinary incontinence showing: **A** Static axial T2-weighted TSE MR image showing the "drooping moustache sign," due to level III endopelvic fascial defect (green arrows). **B** Sagittal dynamic image of the same patient showing increased LPA denoting pelvic floor muscle weakness (the levator plate angle, is defined as the angle enclosed between the pubococcygeal line and the levator plate (green line)

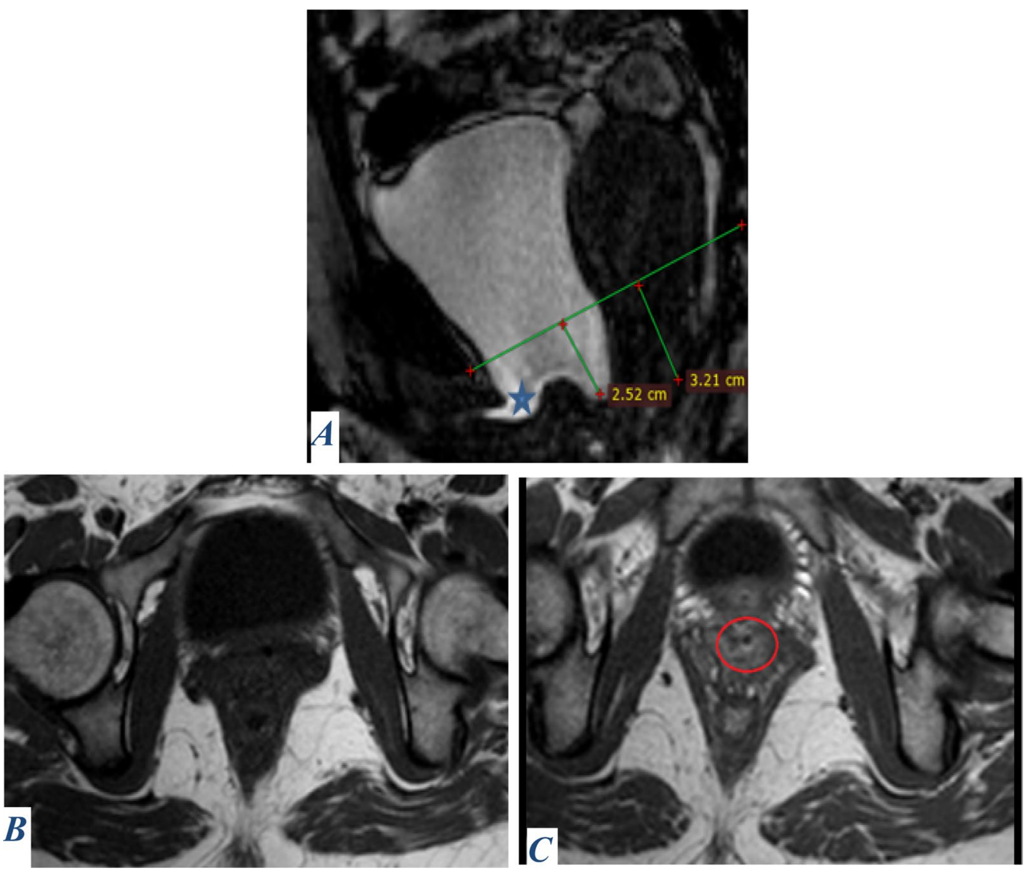

Fig. 7 A 40-year-old female with a history of hysterectomy and SUI, referred after sacrocolpopexy mesh insertion complaining of new pelvic pain, foul vaginal discharge and dyspareunia. Preoperative image: **A** Sagittal dynamic images showed a cystocele, a peritoneocele (PC) which is an extension of the pouch of Douglas below the upper third of the vagina and maybe containing fluid and rectocele (*). Postoperative images: **B**, **C** Axial T2 and post-T1 images showing an area adjacent to right mesh arm of fluid collection and abnormal contrast enhancement (black arrow) complicated right sacrocolpopexy mesh sling with surrounding loculated fluid collection

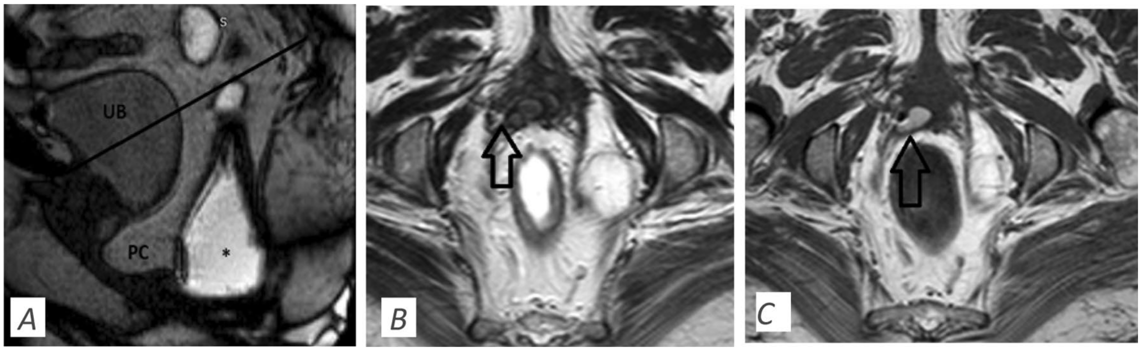

Fig. 8 A 40-year-old patient having new symptoms after tension free vaginal tape for SUI showing: **A** Sagittal BFFE MRD during evacuation showing a cystocele measuring 2.5 cm, uterine descent measuring (3.2 cm) below PCL (green line). Horizontal orientation of the urethra (*) with kink at the bladder base that was further studied and correlated with the static images. **B**, **C** Axial static T1W MR images pre- **B** and post- **C** IV contrast administration showing an area of abnormal contrast enhancement (red circle) denoting infection

had to be modified and tailored according to each case condition and postoperative complaints (e.g., contrast injection or intravaginal gel injection).

Conclusions

While there is plethora of operative management options in patients with SUI, there is evident lack of consensus; more defined surgical protocols and management plans can possibly be guided by preoperative/therapy static and dynamic MRI of the pelvic floor. Based on static MRI findings, in patients with successful surgical outcome, mid-urethral slings can be suitable for correction of level III endopelvic fascial defects. Dynamic MR imaging evaluation suggests that physiotherapy can be beneficial in cases of mild-to-moderate muscle weakness.

In summary, MRI can locate the exact underlying pelvic floor defect in patients with SUI and accordingly suggest a more fitted management plan found on the defect-specific approach. Correlation between static and dynamic MRI images is a key approach to identify the underlying pathology, especially in complicated cases.

Abbreviations

ARJ	Anorectal junction
ARJD	Anorectal junction descent
DC	De novo complaint
ICA	Ileococcygeal angle
LPA	Levator plate angle
MRD	Magnetic resonance defecography
MRI	Magnetic resonance imaging
PC	Persistent complaint
PFD	Pelvic floor dysfunction
POP	Pelvic organ prolapse
PR	Puborectalis
SUI	Stress urinary incontinence
UUI	Urge urinary incontinence

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Author contributions
RF had designed this study. BA, MA, SM, AF and SF contributed to the data collection, data analysis and processing. MA, BA, SM, SF and RF shared together in writing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The data supporting the conclusions of this article are available upon reasonable request from the authors.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethical Research Committee of Faculty of Medicine Cairo University in Egypt. The ethics committee reference number is not available. A verbal consent was taken from the legal guardians of all patients accepting to participate in our research work.

Consent for publication
The legal guardians of all patients included in this research gave written informed consent to publish the data contained within this study.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Radiology Department, Kasr Al-Alainy Faculty of Medicine, Cairo University Hospitals, Cairo University, El-Manial, Cairo 11956, Egypt. [2]Urology Department, Kasr Al-Alainy Faculty of Medicine, Cairo University, Cairo, Egypt.

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