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Preoperative and Postoperative Magnetic Resonance Imaging of Female Pelvic Floor Dysfunction: Correlation with Clinical Findings

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Abstract

Objective:
To determine the role of magnetic resonance imaging (MRI) in surgical planning for females with pelvic floor dysfunction.

Methods:
This study included 29 females, 17 nulliparous females considered as control subjects and 12 patients with different varieties of pelvic floor dysfunction. Evaluation included history, clinical examination, and magnetic resonance imaging (static and dynamic). In the symptomatic patients, magnetic resonance imaging was repeated within 6 to 12 months following surgical treatment.

Results:
Preoperative magnetic resonance imaging added information that changed the management of five symptomatic women. Postoperative magnetic resonance imaging depicted a nearly normal pelvic floor in each patient with resolution of symptoms (n = 5), whereas abnormal imaging findings were found in patients with persistent postoperative or de novo complaints (n = 7).

Conclusion:
Magnetic resonance imaging can accurately localize pelvic floor defects, evaluate success or failure of surgical procedures, and identify complications. It is essential to consider all pelvic floor compartments as one unit during surgical correction to avoid the appearance or exaggeration of other compartment dysfunction, as magnetic resonance imaging can predict the need for more extensive reconstruction.

Key Words: Magnetic resonance imaging, pelvic floor dysfunction, preoperative and postoperative

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INTRODUCTION

The causes of pelvic floor dysfunction (PFD) are numerous as are the methods to evaluate the severity of this disease.[1] Morphologic evaluation of urinary incontinence is often performed using fluoroscopic cystourethrography[1] whereas dynamic proctography and defecography are used for assessing rectocele and enterocele.[2] Pelvic organ prolapse is more commonly staged by physical examination.[3]

Imaging is obtained at the discretion of the clinician, usually in complex cases such as patients undergoing repeat surgery, or in patients in whom the symptoms are unexplained by the physical examination. Defects in multiple pelvic floor compartments often exist in patients with prolapse. This suggests that more precise anatomic information is required before repair.[4] In addition, postoperative recurrence rates of 30% in population-based studies,[5] and more than 50% in females presenting to tertiary referral centers[6] suggest that advances in the diagnosis and management of these disorders are warranted.[4]

Static and dynamic magnetic resonance imaging has been shown to elegantly depict the muscular anatomy and movement of visceral organs of the pelvic floor.[7-9] There have been few studies done comparing the preoperative and postoperative appearance of the pelvic floor.[1,10,11] The goal of this prospective study was to demonstrate the

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value of magnetic resonance imaging (MRI) in surgical planning using a rigorous comparison to clinical findings, surgical approach, and patient symptoms.

SUBJECTS AND METHODS

Subjects

This prospective study included 29 females, age range (18–60 years); mean (37.3) SD ± 13.4. They were divided into two groups. All healthy subjects were volunteers. Symptomatic subjects underwent MR imaging as part of their clinical care. Because our institution is a university teaching hospital, informed consent is obtained from each patient for her entire inpatient treatment regimen. Our University ethics board approved this study. group I included 17 healthy nulliparous asymptomatic volunteers as a control group, mean age (25.5) SD ± 3.85. Each was assessed by a detailed questionnaire and MRI examination (static and dynamic). group II included 12 females, mean age (40.25) SD ± 11.13; all except one patient were multiparous, parity range (2–7). These females presented to their physicians with signs and symptoms of pelvic floor dysfunction.

Maglinte and Kelvin[12] have reported multiple pelvic floor compartment defects in up to 95% of cases. However, to make the results more clinically relevant, the patient group in the current work was subdivided according to their chief complaint: group IIA, stress urinary incontinence without prolapse (n = 3); group IIB, stress urinary incontinence as the chief complaint with bladder or genital prolapse (n = 7); and group IIC, genital prolapse as the chief complaint with or without urinary incontinence (n = 2) (Table 1).

Clinical Examination

An experienced urogynecologist examined the patients in groups IIA, B, and C. The evaluation included a documentation of the patient's complaints (a questionnaire was administered that queried bowel and bladder habits, obstetrics history, and history of previous pelvic surgery) and the physical findings. During the pelvic examination the Valsalva maneuver was performed, and the results of clinical stress test, the degree and type of prolapse were recorded and graded as follows: 0 = normal; Grade I = minimal descent; II = descent half way to the introitus; III = descent to the introitus; IV = descent beyond the introitus. The anal sphincter tone, anal sphincter defects, levator ani tenderness, and defects and degree of relaxation of the puborectalis were noted.

Magnetic Resonance Imaging

Standardized MRI was performed with a 1.5-T unit (Gyroscan Powertrak 6000, NT release 6.2.1; Philips Medical Systems, Best, The Netherlands) (gradient echo strength, 23.0 mT/m; rise time, 0.2 ms; slew rate, 105 T/m/s). Imaging was done with the patient in the supine position with comfortably full bladder (as the patient was asked to void 2 hours before the examination); a multicoil phased array wrapped around the pelvis. The MR imaging protocol requires no oral or intravenous contrast agents. Opacification of the rectum was routinely done in all patients using 90 mL to 120 mL of ultrasound gel, except in the presence of painful perianal conditions or if the patient refused. In these cases (n = 4) and in the volunteers no comment on the presences or absence of rectocele was included in our report unless the rectum was clearly delineated by air.

Axial, coronal, and sagittal T2-weighted Turbo spin echo (TSE) images of the pelvic region were acquired with a slice thickness 5 mm and gap of 0.7 mm, TR/TE 5000/132, Field of view (FOV) 240 mm to 260 mm. Next, dynamic MRI was done in the sagittal, axial, and coronal planes, using a T2-weighted rapid pulse sequence, balanced fast filled echo (BFFE) (Philips Medical Systems). Imaging parameters were slice thickness 6 mm to 7 mm and gap 0.7 mm, TR/TE 5.0/1.6 ms, 300 mm to 345 mm field of view. As a modification of the technique described by Fielding,[13] in our dynamic technique we acquired five static and six dynamic slices in each plane [El Sayed RF et al.,

Journal of
WOMEN'S
IMAGING

Volume 7, Number 4
December 2005

TABLE 1. Symptomatology, MRI Findings, and Treatment of 12 Patients With Pelvic Floor Pathology

Group	No. of Cases	Symptoms	MRI Findings (static and dynamic images)	Management Decision	Treatment Outcome
IIA	Case no 1 45-year-old	SUI Gr.I	Static axial T2WI TSE: bilateral level III, almost normal level I and II vaginal fascial support. Dynamic sagittal BFFE: minimal bladder neck descent.	Bladder neck sling using Proline mesh 10 × 1.5 cm	Successful operation plus de novo complaint
IIA	Case no 2 50-year-old	SUI Gr.I	Static axial T2WI TSE: mild level III, almost normal level I and II vaginal fascial support. Dynamic sagittal BFFE: no excessive bladder neck descent.	Bladder neck sling using Proline mesh 10 × 1.5 cm	Persistent complaint
IIA	Case no 3 45-year-old	SUI Gr.II	Static axial T2WI TSE: bilateral level III, mild level II vaginal fascial support defect. Dynamic sagittal BFFE: bladder neck descent.	Tension-free vaginal tape (TVT)	Successful operation
IIB	Case no 4* 42–year-old	SUI Gr.I	Static axial T2WI TSE revealed distortion of urethral supporting ligament on the right side, moderate level I and II vaginal fascial defects. Dynamic sagittal BFFE: bladder neck descent. MRI was the only positive investigation; the stress test and urodynamic studies (abdominal leak point pressure) were negative.	Tension-free vaginal tape (TVT)	Successful operation
IIB	Case no 5 40-year-old	SUI Gr.I	Static axial T2WI TSE revealed asymmetry of the urethral supporting ligament on the right side, moderate level I and II vaginal fascial defects. Dynamic sagittal BFFE: bladder neck descent.	Modified Burch colposuspension	Persistent complaint
IIB	Case no 6* 40-year-old	SUI Gr.II	Static T2WI TSE: distortion of the urethral ligaments, plus moderate to marked level I and II vaginal fascial defects. Dynamic sagittal BFFE: bladder neck descent. The MR images in the three orthogonal planes added significant information to ACU where a cystic lesion was found exactly in the mid line centered on the levator plate; this was diagnosed clinically as rectocele.	Combined surgery: Burch colposuspension by the urologist, and enucleation of the mass by the coloproctologist in the same sitting	Successful operation

(*continued on next page*)

TABLE 1. (*continued*) Symptomatology, MRI Findings, and Treatment of 12 Patients With Pelvic Floor Pathology

Group	No. of Cases	Symptoms	MRI Findings (static and dynamic images)	Management Decision	Treatment Outcome
IIB	Case no 7* 51-year-old	SUI Gr.II	Static axial T2WI TSE added information of marked lateral vaginal defect and moderate level I and II vaginal fascial support defect, plus defect of the puborectalis muscle on the right side (hence the choice of physiotherapy was excluded). Sequence of the anal canal revealed asymmetrical appearance of the external anal sphincter muscle on the right side. Dynamic sagittal BFFE: revealed pelvic organs prolapse and a peritoneocele.	Tension-free vaginal tape (TVT)	Persistent complaint plus de novo complaints
IIB	Case no 8* 44-year-old	Post-traumatic SUI Gr.I	Static T2WI TSE, Dynamic T2 BFFE in the three orthogonal planes revealed the presence of an organized large prevesical and periurethral collection. The MRI signal intensity suggested the possibility of organizing hematoma.	Based upon the MRI findings conservative measurement was decided. Plus follow-up MRI.	Relief of the patient's complaints, accompanied by resorption of the collection with minimal residue on the 1-year follow-up MRI examination
IIB	Case no 9 55-year-old	SUI Gr.II	Static axial T2WI TSE: bilateral level III, moderate level I and II fascial vaginal support defect. Dynamic sagittal BFFE: bladder neck descent, and peritoneocele not diagnosed by clinical examination.	Tension-free vaginal tape (TVT)	De novo complaints
IIB	Case no 10 26-year-old	SUI Gr.II grade II UD (not included in the patient main compliant)	Static T2WI TSE, level III vaginal fascial support defect, moderate level I and II defects. Dynamic BFFE in the three orthogonal planes revealed grade II uterine descents and muscle weakness; however no muscular defect or tear was found.	Burch colposuspension, sacrocolpopexy	Successful operation

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Volume 7, Number 4
December 2005

TABLE 1. (*continued*) Symptomatology, MRI Findings, and Treatment of 12 Patients With Pelvic Floor Pathology

Group	No. of Cases	Symptoms	MRI Findings (static and dynamic images)	Management Decision	Treatment Outcome
IIC	Case no 11 27-year-old	Uterine Descent	Static T2WI TSE, atypical MRI appearance of level III fascial support; however, no gross defect was visualized. Marked level I and II fascial defects. Dynamic MRI with using our technique with 5 slices in each plane, plus the bladder neck descent, added the presence of obvious focal thinning of the left iliococcygeus muscle very well demonstrated in the parasagittal plane during straining, beside the presence of grade II uterine descent.	Sacrocolpopexy	Successful operation
IIC	Case no 12* 18-year-old Traumatic POP	Uterine descent and continuous dripping of urine.	Static T2WI TSE, Dynamic T2 BFFE in the three orthogonal planes revealed very good demonstration of a urethrovaginal fistula, grade III uterine descent. Sigmoidocele was suspected and a small rectocele was diagnosed.	Sacrocolpopexy plus closure of urethrovaginal fistula	De novo complaints

*Patients in whom the MRI added information to the clinical examination.
ACU, ascending cystourethrography; BFFE, balanced fast filled echo; SUI, stress urinary incontinence; TSE, turbo spin echo; T2W1, T2-weighted image.

presented in 2004 at the 11th annual meeting of the European Society of Urogenital Radiology. Eur Radiol, November supplement abstract YR 06]. These images were obtained while the patient was at rest during mild, moderate, and maximum straining and during withholding (the patient was instructed to squeeze the buttocks as if trying to prevent the escape of urine or watery stool when having diarrhea). The maximum straining sequence was repeated to ensure maximal Valsalva (the patient was instructed to bear down as much as she could as if during vaginal delivery or as if constipated and trying to defecate).

To image the anal canal we used a modification of the T2-weighted balanced fast filled echo with thinner slice thickness (3 mm) and a smaller field of view (220 mm) [El Sayed RF et al., 2004 ESUR meeting]. Off-axis imaging parallel and perpendicular to the plane of the anal canal was employed to improve identification of the anal sphincter.

This same sequence of images was performed 6 to 12 months postoperatively for all patients in group II, and correlated with clinical findings and symptoms.

Image Analysis and Diagnostic Criteria

In the axial static images, the normal and abnormal pelvic supporting elements either vaginal,[14] or urethral,[15,16] as well as the anal sphincter complex[17–20] were studied in a control group of 17 asymptomatic women to be compared with the findings in the symptomatic subjects.

In the presence of normally attached lateral vaginal support, the MRI scans demonstrate the normal transverse placement of the lateral supporting ligaments at each of the three levels I, II, III. When these supports are detached bilaterally, however, defects of various sizes occur at these levels. These are reflected in the MRI scans as small, medium, and large triangular-shaped defects whose size depends on the level of the vagina from which they are detached.[14] The characteristics of good bladder neck support seen on MRI include: (1) Symmetrical urethral ligaments on an axial scan with no distortion (defined as an internal configuration change of the ligaments) or defect (defined as discontinuity of the ligament with visualization of the torn parts); (2) A bladder neck positioned close to the pubis symphysis; and (3) A vaginal lumen with a widened H appearance in cross-section.[15,16] The anal sphincter complex defect was defined as a discontinuity of the muscle ring. Scarring was defined as a hypointense deformation of the normal pattern of the muscle layer or localized atrophy.[17–20]

In the sagittal plane, we used the pubococcygeal line to delineate the pelvic floor. This extended from the inferior border of the symphysis pubis anteriorly to the tip of coccyx posteriorly. Using the latter point we were sure that the levator plate and all the pelvic organs supported by the iliococcygeus muscle were above our modified reference line. The descent of the bladder neck and base and uterus below the pubococcygeal line was recorded as was the angle of urethral inclination, between the urethral axis and the longitudinal axis of the body (Fig. 1). The presence and grade of enterocele or rectocele as well as the levator plate angle were also evaluated (Tables 2–5). Criteria that have been used to diagnose enterocele include (1) bowel between the vagina and rectum, (2) bowel below the pubococcygeal line, (3) widening of the rectovaginal space, and (4) abnormal deepening of the cul-de-sac while 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.[13,21–23] The levator plate angle was plotted and measured as shown in (Fig. 1).

The preoperative and postoperative MRI scans were read by the same investigators; both readers had supervised and interpreted more than 50 cases. Preoperative and postoperative clinical findings as well as the surgical history were available to the readers.

RESULTS

Symptoms, MRI findings, and clinical management are delineated in Table 1. In the judgment of the referring physician, MRI added information to the clinical examination in five cases. MR findings ranged from transection of supporting urethral ligaments to identification of a single unsuspected rectocele. In general, patients with loss of vaginal support as demonstrated on axial MR images (n = 6) and mild to moderate stress incontinence (n = 9) were treated using a sling procedure with either tension-free tape or proline mesh. Three Burch colposuspension procedures were performed and one patient was treated conservatively (case no 8, group IIB). Patients with thinning or tear of the levator ani and descent of the uterus or rectum (n = 3) were treated with combined procedures, all involving a sacrocolpopexy.

Magnetic resonance measurements (mean) for each patient group are presented in Table 2. They are grouped by clinical result—patients with complete resolution of symptoms (n = 6), patients with persistent complaints (n = 3), and patients with new complaints associated with the genitourinary tract following surgery (n = 4). One of this latter group of patients had resolution of stress incontinence but new dyspareunia.

In Table 3, measured MR variables are compared between preoperative and postoperative images in all patients using the paired T-test. Decrease of both bladder neck descent and angle of urethral inclination were

Journal of
WOMEN'S
IMAGING

Volume 7, Number 4
December 2005

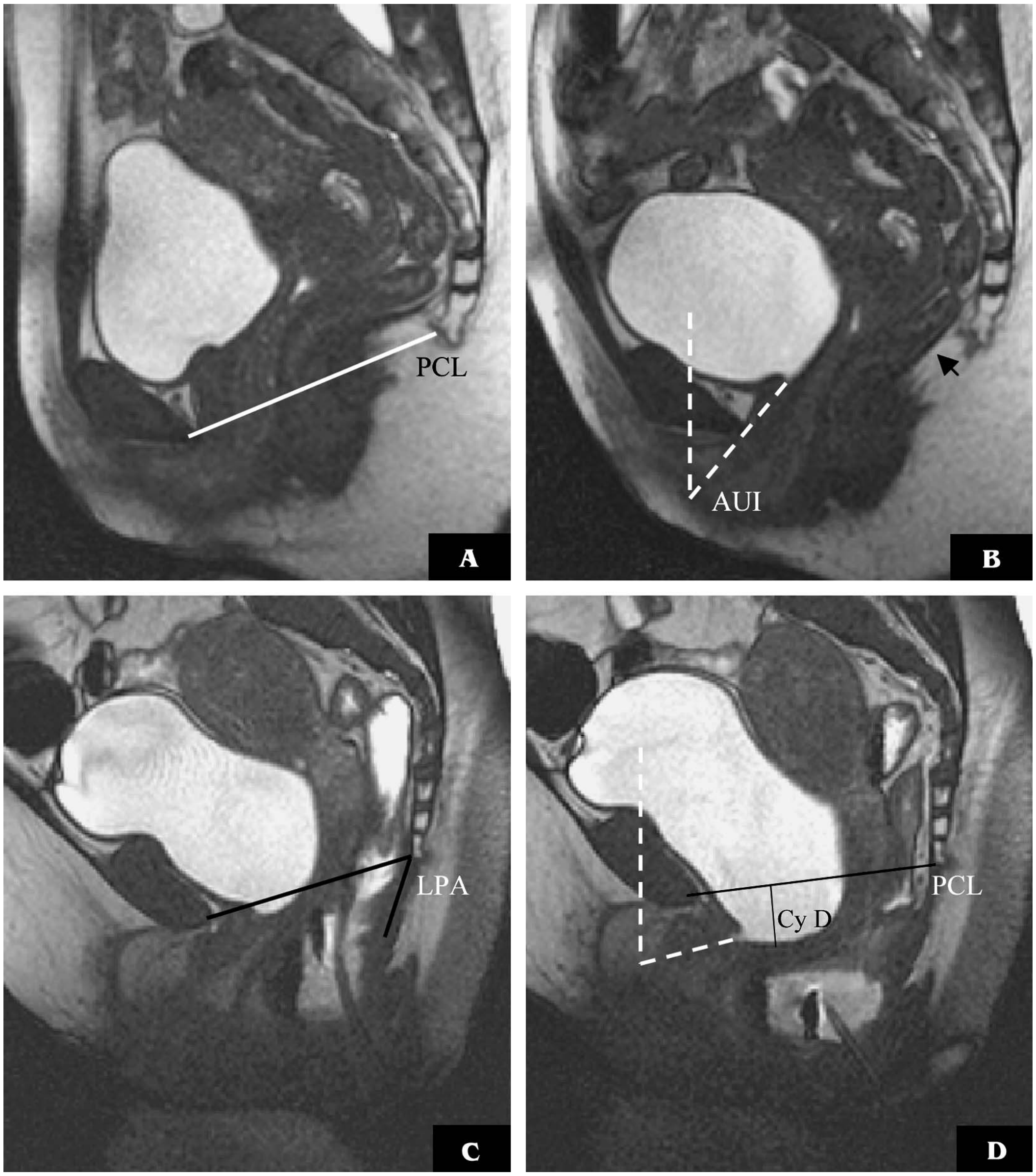

FIGURE 1. Images from a 25-year-old volunteer and from a 42-year-old female with stress urinary incontinence (SUI) grade II illustrating the parameters measured in the control and the patient groups. (A,B) Sagittal Balanced Fast Field Echo MR images of the female volunteer (5/1.6 [repetition time (ms)/echo time (ms)]) (A) at rest and (B) at strain. C,D, Sagittal Balanced Fast Field Echo MR images of the patient with SUI using the same pulse sequences as A and B, (C) at moderate straining and (D) at maximum straining. AUI, angle of urethral inclination; Cy D, cystocele descent; LPA, levator plate angle; arrow in (B) points to the levator plate; PCL, pubococcygeal line.

found to be statistically different ($P < 0.05$) in the postoperative group.

When all measured MR variables in the dynamic sagittal images (Tables 4 and 5) and the static axial MR findings (Table 6) are compared between the postoperative group and the control group, there was no significant difference between the dynamic imaging findings except for the angle of the levator plate with respect to the pubococcygeal line, which remained significantly greater in the postoperative group ($P < 0.05$) (Table 4). Subdivision of the postoperative groups into those with a successful outcome and those with persistent complaints revealed that the latter group had greater descent of the bladder

TABLE 2. Preoperative and Postoperative MRI Findings of Each of the Patient Groups

			Preoperative MRI Findings in the 3 Compartments							Postoperative MRI Findings in the 3 Compartments							
			Anterior		Middle			Posterior			Anterior		Middle			Posterior	
Group	**No**	**C/O**	**BN d**	**Au I**	**Cy d**	**U D**	**Per**	**Rec**	**LPA**	**C/O**	**BN d**	**Au I**	**Cy d**	**U D**	**Per**	**Rec**	**LPA**
Successful operation (cases no 1,3, 4,6,10,11)	6	SUI I–II 1 case UD	−1.2	70.4	−1.3	−2.4	−ve	2.8	40	SUI 0	0.46	41.2	−0.55	−0.77	−ve	2.6	39.6
Persistent complaints (cases no 2,5,7)	3	SUI I–II	−0.8	55.4	−1.9	+ve in 1 case	+ve in case no 7	2.7	46.5	SUI I	−0.78	51.7	−1.2	−+ve in 2 case −0.76	+ve in case no 7	2.3	50.5
De novo complaints (cases no 1,7,9,12)	4*	SUI I–II 1 case UD	−1.51†	69.2†	−0.31†	−1.56	+ve in case no 7	1.64	47.25	Different C/O‡	−0.63†	53.4†	−1.1†	−0.9	+ve in case no 7	1.9	46.4

Au I, angle of urethral inclination; BN d, Bladder neck descent below pubococcygeal line (PCL) measured in cm; Cy d, cystocele descent below PCL measured in cm; En, enterocele; C/O, complaints; LPA, levator plate angle; Per, peritoneocele; Rec, rectocele; SUI, stress urinary incontinence; UD, Uterine descent below PCL measured in cm.

*Two patients (cases no 1 and 7 Table 1) are common between the first two groups and the last group with de novo complaints. Case (no 1) complained from de novo dyspareunia, no stress urinary incontinence; case (no 7) beside her recurrent urinary incontinence, complained from de novo fecal incontinence with attacks of constipation that obstruct urinary and fecal flow. The measured criteria of both cases were included in the calculated mean values of the last group as well.

†In the patient with history of trauma and catheter in the urinary bladder the criteria of the anterior compartment could not be measured, and were not included in the mean of this group.

‡The four patients in this group complained from dyspareunia, severe urge incontinence plus detrusor instability, fecal incontinence and attacks of constipation, and the last patient complained from mass protruding posteriorly plus SUI grade I.

NB: Preoperatively and postoperatively, the pelvic organ descent below the pubococcygeal line measured in cm is indicated by negative value.

Journal of
WOMEN'S
IMAGING

Volume 7, Number 4
December 2005

TABLE 3. Comparison of MRI Findings Preoperatively and Postoperative Intervention (n = 12)

Measured Variables	Preoperative Mean	Preoperative SD	Postoperative Mean	Postoperative SD	Paired T-Test
Bladder neck descent	−1.18	±0.87	−0.5	±1.27	0.006*
Angle of urethral inclination	66.58°	±18.1	47.06°	±24	0.025*
Cystocele descent	−1.39	±1.13	0.86	±1.12	0.065
Uterine descent	−0.46	±1.13	−0.6	±0.87	0.753
Rectocele	1.48	±1.46	1.49	±1.51	0.948
Levator plate angle	38.33°	±18.12	38.74°	±17.86	0.746

*Significant.
NB: Preoperative and postoperatively, the pelvic organ descent below the pubococcygeal line measured in cm is indicated by negative value in tables 3, 4, 5.

neck and cystocele, and increased angle of urethral inclination. The angle of the levator plate and descent of the uterus were similar. Because of the small number of patients in each group, no statistical significance can be inferred (Table 5). For the static MR images, the main difference between the patient and the control groups was the absence of gross urethral ligament abnormalities as well as level III fascial defects in the control group versus the patient group preoperatively (Table 6).

DISCUSSION

In 5 of 12 patients with urinary incontinence MRI provided significant information that altered clinical management. This was true for patients with moderate urinary incontinence and those with associated trauma. In these cases unsuspected damage to the pelvic floor, the presence of hematoma, and a cystic mass wrongly diagnosed as rectocele by clinical examination (Fig. 2) changed surgical approach. The higher prevalence of lesions of the urethral supporting elements (ligaments and level III endopelvic fascia) in our patients with stress urinary incontinence compared with the control group has been previously reported.[14–16] Moreover, the ability of MRI to alter the surgical managements of pelvic floor disorder in 41.6% of our cases conforms to the findings of Kaufman et al.[4] These authors found that the dynamic images MRI and cystocolpoproctography (CCP) led to changes in the initial operative plan in 9 of 22 patients (41%), 5 by MRI and 4 by cystocolpoproctography. MRI added little to the treatment of those patients with mild stress incontinence.

TABLE 4. Comparison of MRI Findings in the Sagittal Dynamic Images Preoperatively and Postoperative Intervention (n = 12) Against the Control Group (n = 17)

Measured Variables	Control Mean	Control SD	Preoperative Mean	Preoperative SD	Postoperative Mean	Postoperative SD	Paired T-Test Control vs. Preoperative	Paired T-Test Control vs. Postoperative
Bladder neck descent	0.08	±0.913	−1.18	±0.87	−0.5	±1.27	0.011†	1.000
Angle of urethral inclination	35.4	±14.6	66.58°	±18.1	47.06°	±24	0.001†	0.386
Cystocele descent	−0.36	±0.55	−1.39	±1.13	−0.86	±1.12	0.026*	0.544
Uterine descent	−0.35	±0.63	−0.46	±1.13	−0.6	±0.87	1.000	1.000
Levator plate angle	16.86	±16.6	38.33°	±18.12	38.74°	±17.86	0.009†	0.008†

*Significant; †Highly significant.

TABLE 5. Comparison of Dynamic MRI Findings Between Control Subjects and Those With Successful Postoperative Outcomes and Persistent Symptoms

Measured Variables	Control		Postoperative (successful operation)		Postoperative (persistent symptoms)	
	Mean	SD	Mean	SD	Mean	SD
Bladder neck descent	0.08	±0.913	0.46	±0.85	−0.78	±1.52
Angle of urethral inclination	35.4°	±14.6	41.23°	±14.5	51.7°	±35.5
Cystocele descent	−0.36	±0.55	−0.55	±0.88	−1.2	±1.4
Uterine descent	−0.35	±0.63	−0.77	±0.85	−0.76	±0.68
Levator plate angle	16.86	±16.6	39.6°	±16.4	33.7°	±30.4

It would seem reasonable to use MRI to assess those patients with complex pelvic floor injuries including multi-compartment damage due to childbirth.

It is worthwhile to mention here that in an ideal research setting, all subjects would have been treated with a single operation; however in the hospital setting of pelvic floor defects, women often require multiple and diverse surgical operations. This is particularly true in the case of trauma. The focus of this article is not to compare surgical approaches, but

TABLE 6. Comparison of MRI Findings in the Static Axial Images Between Control Subjects, Patient Groups Preoperative and Postoperative

MRI Findings	Control	Patients Groups: Preoperative	Patients Groups: Postoperative
Urethral supporting ligaments	No gross abnormality in all volunteers	Distortion and asymmetry of the ligaments in 3 patients (no. 4, 5, 6)	Persistent abnormal configuration in patient no 5 (group IIB). Other 2 patients no. 4, 6 (group IIB), restoration of a well-supported proximal urethra by the operative procedure (Figs. 7A, B).
Vaginal Supporting fascia level III	No gross abnormality in all volunteers	Typical defects in patients (no. 1, 3, 9, 10), while mild in patient no 2	The main difference was the relatively repositioned bladder neck close to the symphysis pubis in patients (no. 1, 2, 3, 10) (Figs. 7C, D). In patient no 4, added right lateral endopelvic fascial defect (Fig. 3C). In patient no. 7 (Fig. 5D) although improved, persistent loss of the normal H-shaped vagina was detected (Fig. 5D).
Vaginal Supporting fascia level I and II	Mild and moderate to marked paravaginal defects were found in 6 of the volunteers	Mild, moderate, and marked paravaginal defects were found in 8 of 12 patients	According to the operative procedure, the main change at these levels was observed in patients 10 (group IIB) and 11 (group IIC), as the degree of the defects was reduced compared to the preoperative findings at the same axial levels (Figs. 7E, F).

Journal of
WOMEN'S
IMAGING
Volume 7, Number 4
December 2005

FIGURE 2. Images from a 40-year-old female with stress urinary incontinence and a posterior compartment mass. An atypical rectocele likely containing debris or tissue was diagnosed on clinical examination. A, B, Sagittal balanced fast field echo MR images (5/1.6 [repetition time (ms)/echo time (ms)]) at rest (A) and at strain (B) show an ovoid mass of intermediate signal intensity that moves with the levator plate (arrows). C, D, Axial pre- and post-contrast T1-weighted TSE MR images (550/14 [repetition time (ms)/echo time (ms)]) show no enhancement or wall nodularity to suggest a neoplasm (dashed arrows). Benign cystic mass lesion was the leading diagnosis. E, F, Sagittal Balanced fast field echo MR images (5/1.6 [repetition time (ms)/echo time (ms)]) at rest (E) and at strain (F) show an intact levator plate (arrows) following excision of the mass, identified as a simple epidural cyst at surgery.

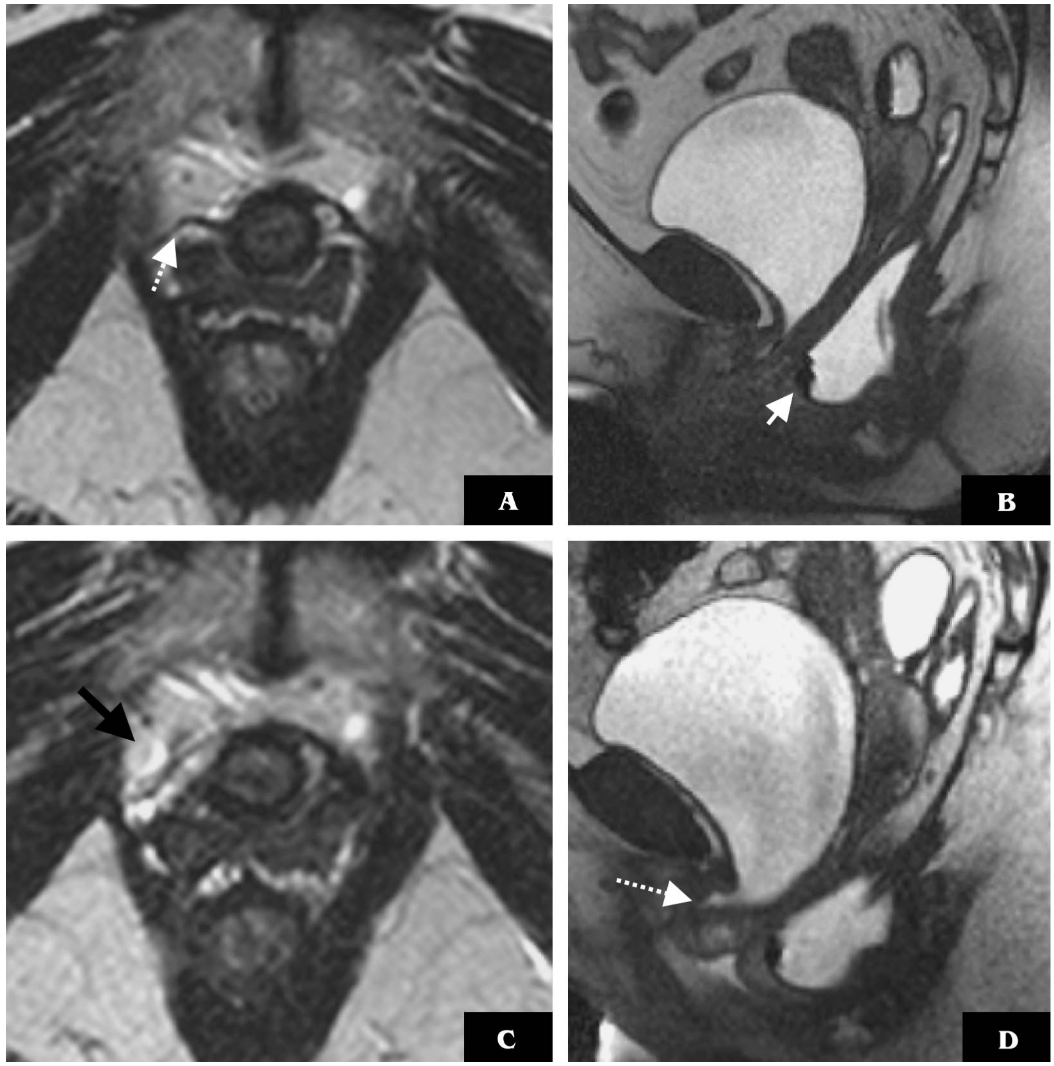

FIGURE 3. Images from a 40-year-old woman with persistent postoperative (modified Burch colposuspension) stress urinary incontinence. A, B, Preoperative static Axial T2-weighted TSE MR images (5000/132 [repetition time (ms)/echo time (ms)]) and sagittal balanced fast field echo MR images during straining (5/1.6 [repetition time (ms)/echo time (ms)]) show abnormal configuration and asymmetry of the right lateral supporting ligaments of the urethra (A) (dashed arrow), and abnormal descent of the bladder neck with rectocele (short arrow) (B). C, D, Postoperative axial and sagittal MR images using the same sequences as in A and B show persistent transection of supporting ligaments of the urethra plus lateral endopelvic fascial defect (arrow). The rectocele had not been repaired and there was persistent rotation and descent of the urethra and bladder base (dashed arrow).

rather to demonstrate the value of MRI in determining surgical planning according to the significance of the added preoperative information and secondly to show how MRI can help in diagnosing postoperative complications irrespective of the type of the operation.

Postoperative MR imaging when compared with healthy subjects showed that in patients with resolution of symptoms, MR findings are similar. The only exception is that of the angle of the levator plate with the pubococcygeal line. It is possible that this angle remained increased because few of these patients had posterior repairs. Patients with poor outcomes had persistently abnormal MR findings, particularly increased descent of the bladder neck and cystocele, as well as the urethral angulation with the

Journal of
WOMEN'S
IMAGING

Volume 7, Number 4
December 2005

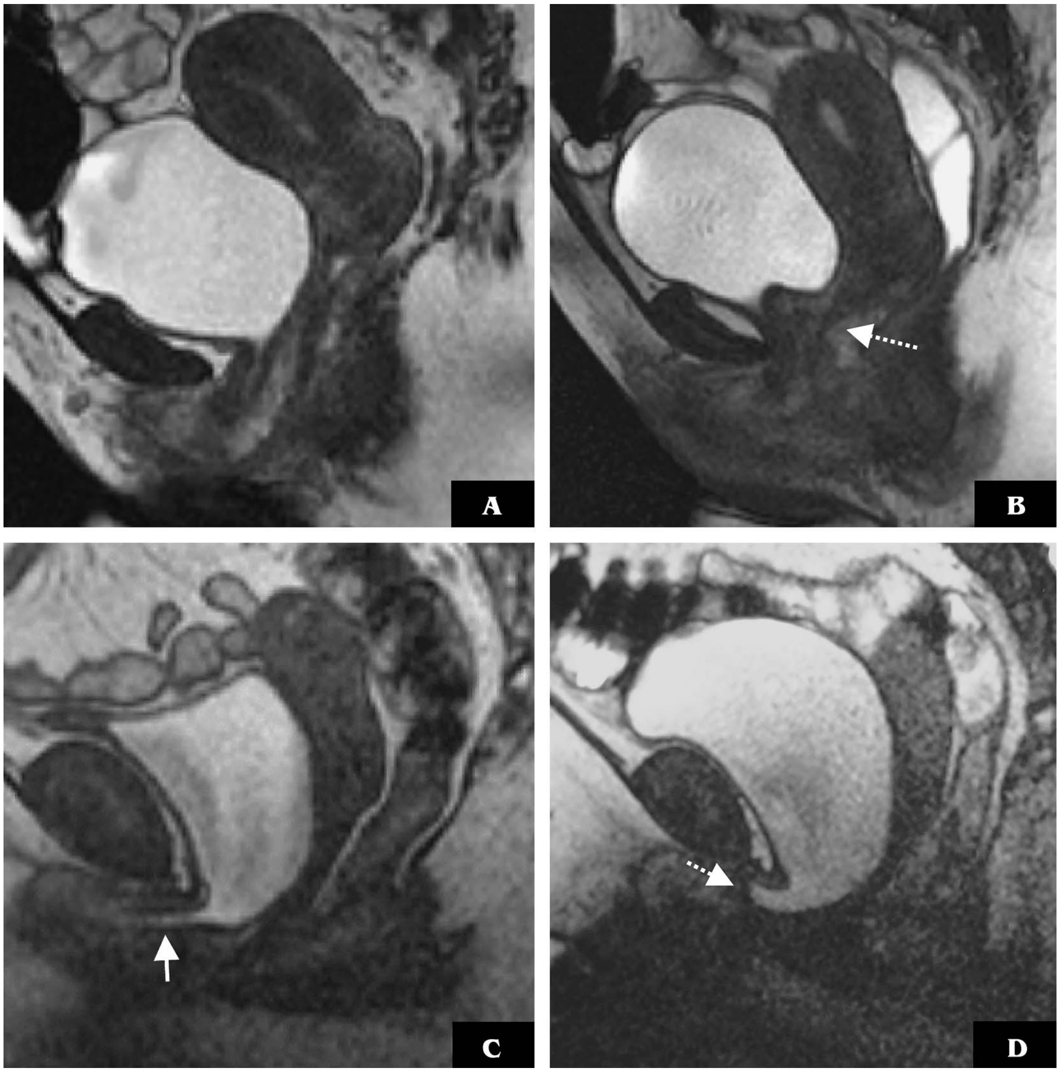

FIGURE 4. Images from a 45-year-old and from a 55-year-old woman with postoperative de novo dyspareunia and detrusor instability respectively. A, B, Preoperative and postoperative sagittal balanced fast field echo MR images (5/1.6 [repetition time (ms)/echo time (ms)]) of patient (no. 1, group IIA) with dyspareunia at strain, compared with the preoperative image (A); in the postoperative image (B) there is obvious traction on the anterior vaginal wall (dashed arrow). C, D, Preoperative and postoperative sagittal MR image of patient (no. 9, group IIB) with detrusor instability at strain using the same pulse sequence as in A and B; preoperative image (C) shows obvious urinary leakage (arrow), and opacification of the urethra to the external urinary meatus. However, postoperatively (D) the bladder neck is still widely patent, and there is a distal urethral kink (dashed arrow) due to misplaced low tape at the distal urethra.

vertical (Fig. 3). The detection of postoperative pathologic findings by MRI in patients with persistent complaints was also reported by Gufler et al.[11] in 3 of 5 patients who were complaining of first-degree stress urinary incontinence. Dynamic MRI revealed increased angle of urethral inclination and bladder neck descent. Although the differences between the control and subject groups in Table 3 were small, it is likely that improved compression of the bladder neck between the symphysis and puborectalis improved urinary continence. A normal-appearing MRI of the pelvic floor thus correlates with the postoperative relief of the patient's complaints (Figs. 2E and 2F).

In the two groups of patients with poor outcome (including persistent and de novo complaints), 2 patients' postoperative de novo complaints of dyspareunia and urge incontinence (Table 2) were likely the result of operative technique. MR images of the first patient revealed marked traction on the anterior vaginal wall likely due to a misplaced suture (Figs. 4A and 4B) whereas in the other patient a low misplaced TVT at the distal urethra resulted in a urethral kink (Figs. 4C and 4D). Thus in these two cases, although preoperative MRI did not affect the choice of the operative procedure; the postoperative MRI findings offered functional insight into the nature of the complications.

In the patient with persistent stress urinary incontinence (SUI) (case no. 2, group IIA), the preoperative MRI findings of a well-supported bladder neck at maximum straining probably should have raised the possibility of intrinsic sphincteric deficiency. In the remaining cases in the two groups the presence of marked fascial defects and muscular injuries including anal sphincter tear in case number 7 (Fig. 5) (Tables 1 and 2) likely warranted a more complete reconstructive surgery rather than the tension-free vaginal tape procedure. Similarly in case number 12 (Fig. 6) (Tables 1 and 2), the pelvic floor descent during Valsalva maneuver indicated multiple compartment damage requiring an extensive repairs. Moreover, in this case it is worthy to mention that the MRI findings of the widened upper part of the rectovaginal space while

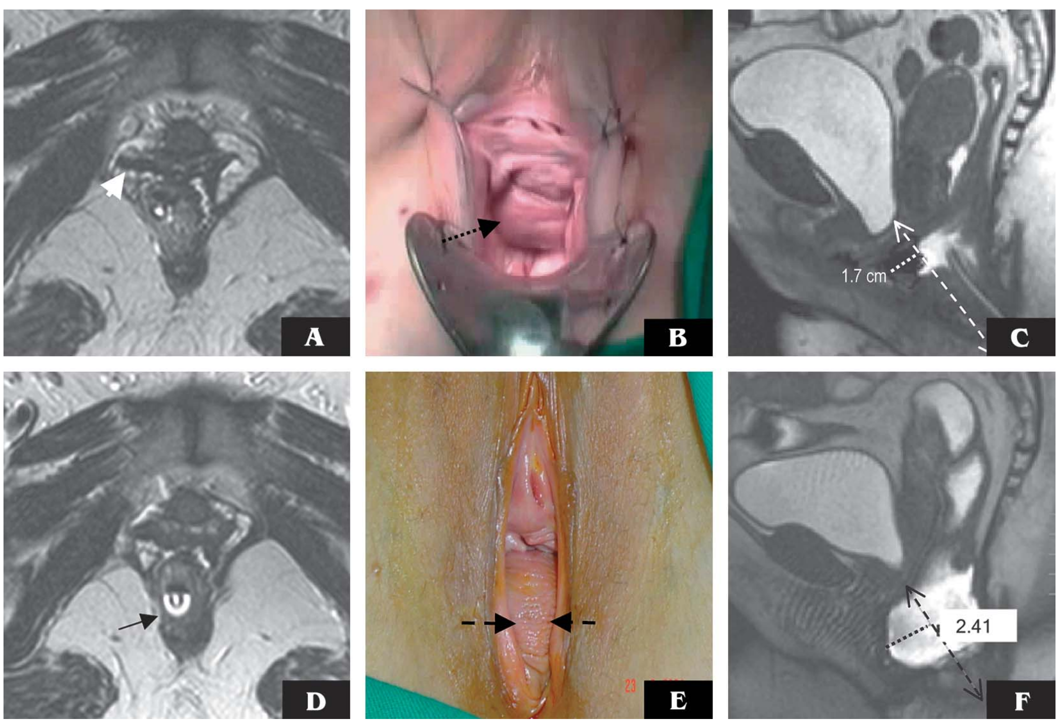

FIGURE 5. Images from a 51-year-old woman with postoperative recurrent stress urinary incontinence and de novo fecal incontinence with attacks of constipation. A, Preoperative axial T2-weighted TSE MR image (5000/132 [repetition time (ms)/echo time (ms)]) shows right paravaginal endopelvic fascial defect, evident by the loss of the H-shaped vagina on the right side (short arrow) perfectly correlating with the intraoperative findings in the photograph of the pelvic floor (B) (dashed arrow) with the patient in the lithotomy position (dashed arrow). C, Sagittal balanced fast field echo MR image during straining (5/1.6 [repetition time (ms)/echo time (ms)]) reveals urethral hypermobility, cystocele, uterine descent, and rectocele. D, Postoperative Axial T2-weighted TSE MR image (5000/132 [repetition time (ms)/echo time (ms)]) shows a persistent endopelvic fascial defect, and suspected external anal sphincter defect on the right side at 9 o'clock (arrow). E, F, Postoperative photograph of the pelvic floor with the patient in the lithotomy position (E) and sagittal balanced fast field echo MR image during straining (5/1.6 [repetition time (ms)/echo time (ms)]) (F), show marked exaggeration of the previous rectocele not included in the operation, which could explain the attacks of constipation (dashed arrows) (E); (calipers) (C and F).

its lower part is obliterated by the rectocele should warrant careful interpretation of such MRI findings, and to call the clinician's attention to carefully exclude the presence of sigmoidocele after reduction of the rectocele. This was done by our urologist and confirmed the MRI findings (Fig. 6D). Patient complaints were the result of exaggeration of compartmental dysfunction not included in the primary operative reconstruction.

The aforementioned conditions illustrate the need for a treatment approach based upon both the symptom complex and the specific anatomic and structural abnormality

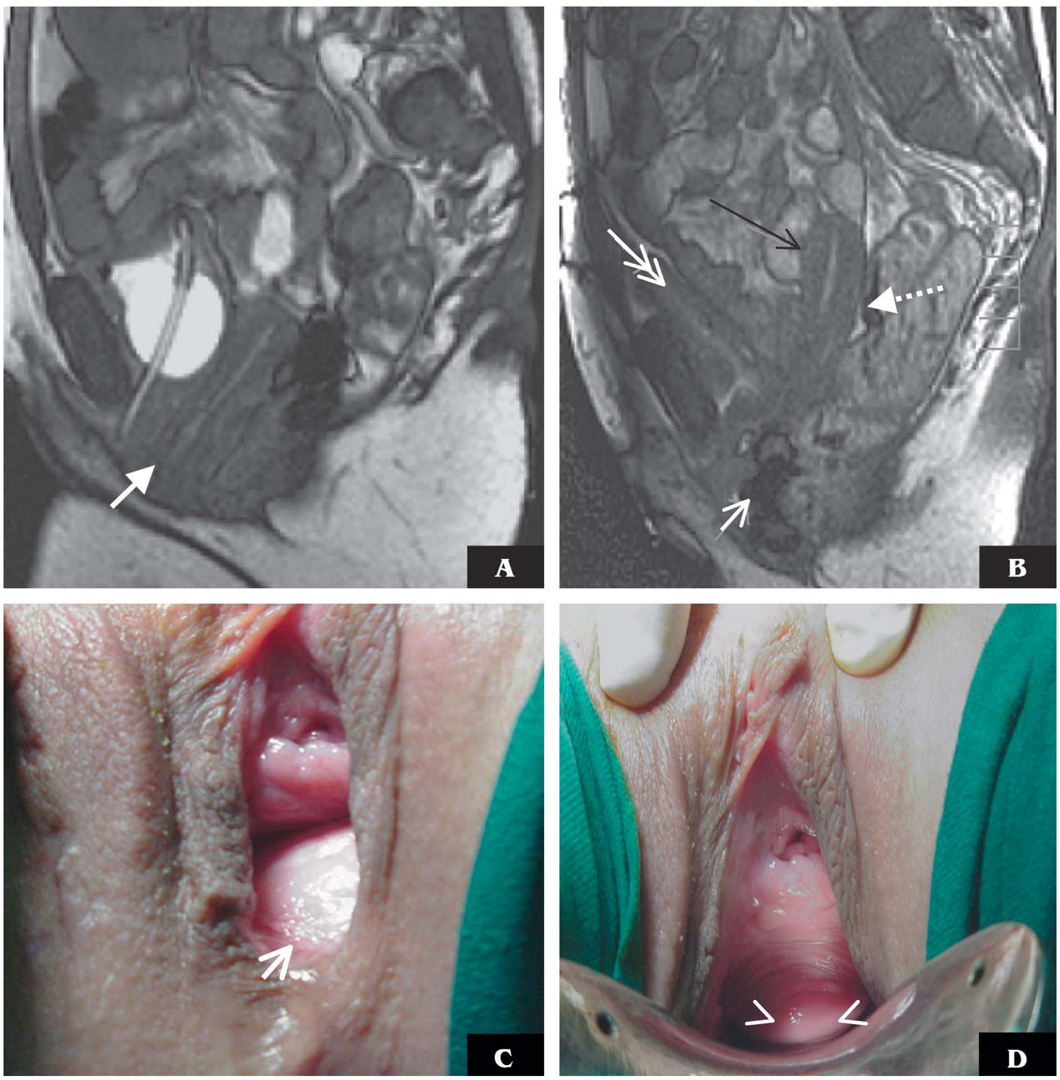

FIGURE 6. Multi-compartment pelvic floor dysfunction in an 18-year-old woman who suffered trauma during a car accident. A, Sagittal balanced fast field echo MR image (5/1.6 [repetition time (ms)/echo time (ms)]) obtained at strain shows significant descent of the uterus (arrow) below the bladder base (arrow). A catheter identifies the high signal urine-filled bladder. B, Following sacrocolpopexy, repeat MR at strain using the same pulse sequence as in A shows development of a rectocele (short arrow), as reduction of the rectocele was likely achieved at least in part by compression of the adjacent uterus. MRI finding of widened upper part of the rectovaginal space (dashed arrow) suggested rectovaginal fascial tear. The uterus is now in the appropriate position (long arrow), urinary bladder (double headed arrow). C, D, Photograph of the pelvic floor with patient in lithotomy position (during follow-up examinations after sacrocolpopexy) show bulging of an anterior rectocele (arrow) (C), and a sigmoidocele was noted (arrow heads) (D) after reduction of the rectocele, corroborating findings of MRI.

found in each individual patient. A three axis perineal anatomic approach has been defined by Beco and Mouchel as "Perineology".[24] This approach is the result of the fusion between the disciplines of urogynecology and coloproctology. The aim of perineology is the restoration of the anatomy in the respect of biomechanics and physiology; so that each defect must be corrected without inducing troubles on the other levels. Therefore, if reconstructive surgery is to be performed for patients with pelvic organ prolapse, then correction of all anatomic defects should be achieved to prevent subsequent recurrence or exaggeration of other compartment defects. This calls for noninvasive preoperative and postoperative imaging methods that can depict the three pelvic compartments simultaneously. MRI is ideal for this purpose (Fig. 7).

A limitation of this study was the small sample size. The rigorous nature of the study with correlation among clinical symptoms, surgical findings, and postoperative MR imaging compared with a normal control group

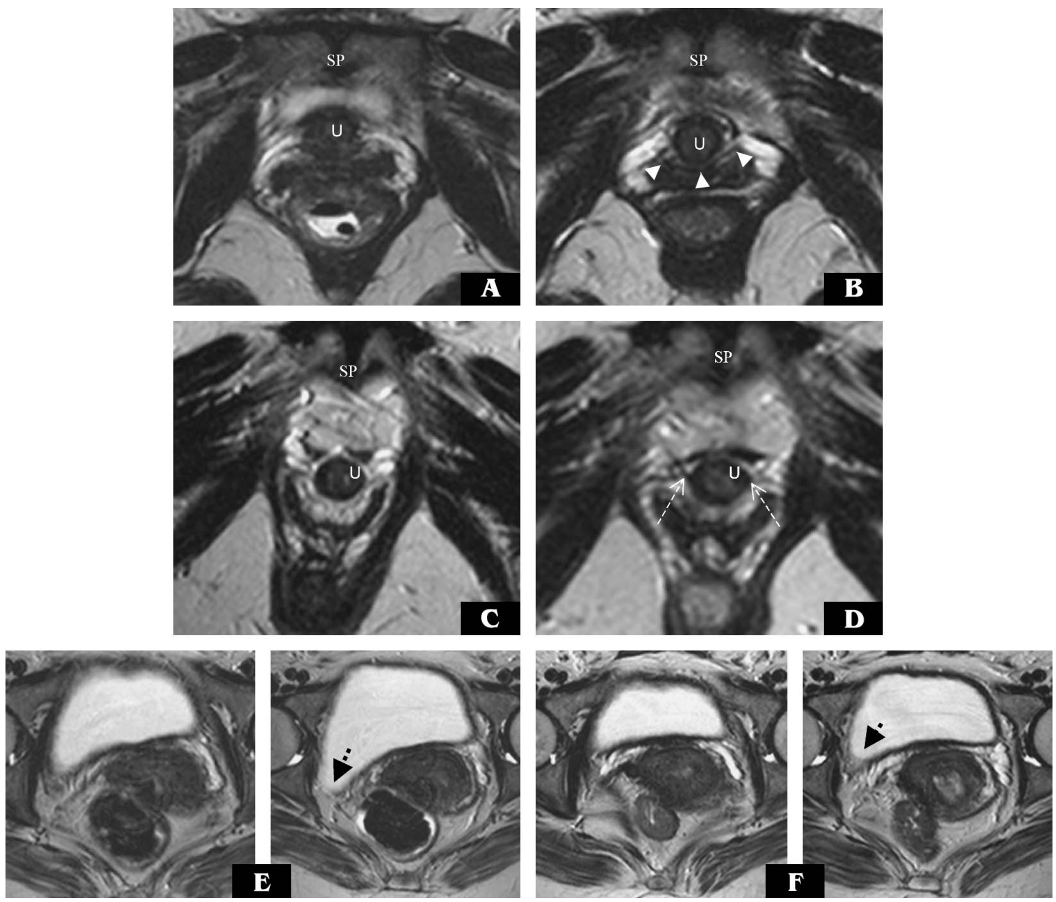

FIGURE 7. Preoperative and postoperative static MR findings of the pelvic supporting elements in two 45-year-old females (patients no. 4 and 1) treated with tape and mesh respectively to elevate the bladder, and a 27-year old female (patient no. 11) after sacrocolpopexy. A–F, Preoperative and postoperative axial T2-weighted TSE MR images (5000/132 [repetition time (ms)/echo time (ms)]) (A,B) show restoration of a well-supported proximal urethra by the applied tape (arrow heads) clearly visualized in the postoperative image (B). C, D, show relatively diminished space of Retzius with repositioning of the proximal urethra (U) close to the symphysis pubis. The proline mesh applied in this patient is also well visualized (dashed arrows) (D). E, F, Sequential preoperative (E) and postoperative (F) MR images almost at the same levels, illustrating the improvement in the size of the right level I & II vaginal fascial defect, demonstrated in the postoperative MR images by the diminished size of the sagging posterior urine-filled urinary bladder wall bulging in the defect (dashed arrows). U, urethra; SP, symphysispubis.

however makes the results compelling. Therefore while encouraging as to the use of MRI in planning pelvic floor surgery our results lack the statistical power to be generalized to the entire female population.

In conclusion, preoperatively MRI can detect the exact location of pelvic floor dysfunction, including fascial and urethral support system defects. Images can be used to assess patients postoperatively, explain success or failure of surgical procedures, detect complications, and suggest the most appropriate method of management.

Our postoperative follow-up indicated that it is essential to consider all three pelvic compartments as one unit, because reconstruction of one compartment in isolation may result in de novo dysfunction or exaggeration of the already present dysfunction in one or both of the other compartments as detailed MR examination can predict the need for more extensive reconstruction.

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