MRI in Stress Urinary Incontinence

Endovaginal MRI With an Intracavitary Coil and Dynamic Pelvic MRI

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Purpose: To evaluate both morphology of the urethra and its supporting structures using endovaginal magnetic resonance imaging (EV-MRI) and the grade of the bladder neck prolapsus using dynamic pelvic MRI (DP-MRI) in women with stress urinary incontinence (SUI).

Materials and Methods: We compared 25 women with SUI and 8 controls according to the different layers of the urethra, the degree of distortion in the periurethral, paraurethral, and pubourethral ligaments, the vesicourethral angle, the retropubic space, and the thickness of the puborectal muscle. The SUI group was also evaluated according to the number of deliveries and degree of the bladder neck prolapsus.

Results: Significant differences were found in the thickness of each three layers of the urethra between the two groups ($P < .05$). There was a significantly higher pubourethral ligament distortion ($P = .024$) and larger vesicourethral angle ($P = .000$) in women with SUI. In women with SUI, there was no significant relationship between the number of deliveries and the degree of the bladder neck prolapsus ($P > .05$).

Conclusion: The combined usage of the EV-MRI and DP-MRI can provide complementary information concerning certain structural abnormalities with specific dysfunction, such as vesicourethral angle increase and pubourethral ligament distortion in patients with SUI.

Keywords: urethra, stress urinary incontinence, magnetic resonance imaging, women

INTRODUCTION

Stress urinary incontinence (SUI) presents as involuntary voiding, which results in social and hygienic problems.[1] Impairment of the pelvic floor and supporting structures due to aging, obesity, pregnancy, and vaginal delivery can lead to urinary incontinence by weakening the support on the urethra.[2-4]

Treatment of SUI includes strengthening of urethral stability and restoring the functions of urethral supporting structures. The treatment options vary from the pelvic floor exercises to various surgical techniques, depending on the severity of structural abnormalities. Stress urinary incontinence has been linked to unequal urethral walls mobility, urethral instability,[5] and weakness in the pelvic supporting structures.[6,7] The comprehension of the normal disposition of the ligaments and anatomic defects in the suspensory system is essential because these are the surgically treatable factors in patients with SUI.[8] The definition of these ligaments supporting the urethra in women remains unclear as this area is difficult to dissect and examine by both anatomists and surgeons.[9,10]

Consequently, the previous reports concerning magnetic resonance imaging (MRI) in the urinary continence mechanism considered the urethra and underlying structures to function as a combined mechanism.[6,7] Furthermore, precise imaging of the urethra and its supporting structures is very important for treatment selection.[6] The specific anatomic defect in a specific patient with SUI should be defined using innovated imaging techniques for both diagnosis and treatment decision.[11] Among imaging modalities, with its soft tissue resolution and capacity of multiplanar imaging, pelvic MRI can be the preferred and efficient method in visualization of the pelvic structural alteration. Moreover, endoluminal coils provide higher resolution and signal to noise ratio and can assess very small anatomical structures in detail.[6,12-15]

Several studies have reported that endovaginal MRI (EV-MRI) is the best imaging technique to visualize the urethra and pelvic floor structures. Additionally, dynamic pelvic MRI (DP-MRI) helps determine the relaxation of the pelvic floor structures at rest and during Valsalva maneuver using ultrafast sequences.[7,14,16-18]

The aim of this study was to assess the convenience of combined use of the EV-MRI and DP-MRI to identify certain structural and functional abnormalities, such as vesicourethral angle increase and pubourethral ligament distortion in patients with SUI.

MATERIALS AND METHODS

Study Population

The study included 25 women with SUI and 8 continent controls who had never undergone surgery for the pelvic floor or gynecological disorders, recruited through urology and gynecology clinics. Study patients who met the above criteria were selected in a consecutive manner. Patients who were not married or did not accept the procedure were excluded.

Stress urinary incontinence was diagnosed by a 3-day diary and pelvic organ prolapse quantification exam (POP-Q) with Q-tip angle measurements during cough and Valsalva maneuver. The diagnosis was confirmed with urinary leakage caused by a sudden increase in intra-abdominal pressure during measurement with multi-channel urodynamic testing through an 8F micro-tip dual sensor and a 10F filling catheter when the bladder was retrogradely filled at 50 mL/min with normal saline for a total volume of 300 mL.

The control group were sent to department of radiology with suspicion of other gynecological benign diseases, including Bartholin cyst, diffuse vaginal inflammation, endometriosis, etc, and found to have any pathology on vaginal MRI.

The number of vaginal deliveries was documented in each subject. We classified the number of deliveries as deliveries between 1 to 3, and ≥ 4. Written informed consent was obtained from each participant and the Institutional Review Board approved our study. Each subject underwent EV-MRI using intracavitary coil and women with SUI had DP-MRI as well.

MRI Technique

Magnetic resonance imaging was performed following at least four hours of fasting. The subjects were requested not to void at least for two hours before procedure. The EV-MRI was performed by 1.5 Tesla magnet (25 mT/m: Magnetom Vision Plus; Siemens, Erlangen, Germany) using an intracavitary coil. In order to stabilize the coil efficiently inside the vagina and to increase the connection between the urethra and coil, the coil balloon was inflated with 60 to 100 cc air. The EV-MRI was performed in the axial, sagittal, and coronal imaging planes using T2-weighted turbo spin-echo [Repetition time/echo time: (TR/TE): 2800 to 3000/90 to 120 msec, slice thickness: 4 mm, slice number: 12, gap: 10%, Field of view (FOV): 160*160 mm, matrix: 186*256 acquisition time: 37 to 45 sec]. The slices started from the level of the bladder neck and extended to the external meatus level in planes perpendicular and parallel to the long axis of the urethra. Therefore, it was possible to visualize the entire length of the urethra.

In women with SUI, we also performed DP-MRI in sagittal and coronal planes with true fast imaging with steady state precession (true FISP) T2-weighted both at rest and during Valsalva maneuver. Examinations were performed in supine position using body coil and water resistant padding. Prior to the procedure, the subjects were informed about the maximum strain technique and were trained. In participants who were unable to produce enough strain, the sessions were repeated several times in order to achieve similar level of strain among subjects. During the sessions with 9-second duration, we obtained 6 slices in each plane.

Measurements

For the images obtained by EV-MRI, in order to standardize the measurements and definitions, we performed the assessments based on predetermined levels. These levels were determined based on the reference points reported by Kim and colleagues.[7] The straight and smooth muscle of the mucosa and submucosa layers were separately measured using predetermined levels. The supporting ligaments of the urethra were considered normal if they preserved their continuity throughout their entire length. The bending of the ligaments, the changes in signal intensity, and focal defects were considered as the distortion of the ligament.

The vesicourethral angle was assessed using sagittal MRI images. Two lines were drawn; one through the long axis of the urethra and one parallel to the bladder base, and the intersection of these lines determined the vesicourethral angle. We also used the sagittal images to measure the dimension of the retropubic space from the posterior wall of the symphysis pubis to the anterior urethral wall. The thickness of the two branches of the puborectal muscle was assessed by axial and coronal MRI images. The mean muscle thickness was calculated from the thickness of the branches of the puborectal muscle measured at 4 and 8 o'clock radiuses using axial images.

The degree of the bladder neck prolapsus in cases with SUI was assessed using DP-MR images. The diagnosis of the bladder neck prolapsus was made if the bladder floor was distal to the symphysis pubis. The pubococcygeal line that determines the pelvic floor level was defined as the line that connects the lower corner of symphysis pubis and left coccygeal articulation using sagittal MRI images obtained during rest (Figure 1). The degree of prolapsus was classified into two groups based on the distance between the pubococcygeal line and inferiorly extending bladder neck (mild to moderate: 1 to 20 mm, advanced: ≥ 21 mm).

The MRI images were interpreted by two independent radiologists (N.T. and K.S.), who were unaware of the clinical findings. If the two radiologists had different interpretations of an image, the final judgment was reached by the consensus.

Statistical Analysis

To compare the subjects with SUI and control group, we used student's *t* test to assess the differences in the thickness of each layer of the urethra, vesicourethral angle, dimension of the retropubic space, and thickness of the puborectal muscle. Chi-Square test was used to compare the distortion in periurethral, paraurethral, and pubourethral ligaments. In patients with SUI, the relationship between the number of deliveries and degree of the bladder neck prolapsus was determined by Fischer's Exact's test. *P* values less than .05 were considered statistically significant and all the results were reported with 95% confidence interval.

RESULTS

The mean age of the patients with SUI and controls was 49 years (range, 33 to 66 years) and 43.5 years (range, 38 to 53 years), respectively. The mean number of vaginal deliveries was 3.5 in patients with SUI compared to 1.75 in the control group.

Table 1 shows the mean thickness of each layer of the urethra in patients with SUI and in the control group. The thickness of three layers of the urethra particularly in the striated muscle layer of patients with SUI was lower than that of controls ($P < .05$; Table 1; Figure 2).

More distortion of the pubourethral ligament was noted in the group with SUI compared to the control group ($P = .024$). There were no significant differences in the distortion of the periurethral and paraurethral ligaments between the two groups ($P > .05$; Table 2; Figure 3).

The vesicourethral angle was significantly larger in the group with SUI compared to controls ($P = .000$). There were no significant differences regarding the dimension of the retropubic space and thickness of the puborectal muscle ($P > .05$; Table 3; Figure 4).

Bladder prolapsus was observed in all the subjects with SUI using DP-MRI. The degree of the blad-

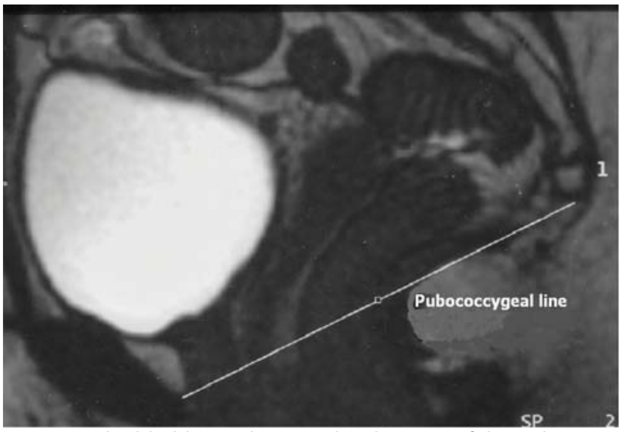

Figure 1. The bladder neck is visualized on top of the pubocoxygeal line in a patient with stress urinary incontinence at rest.

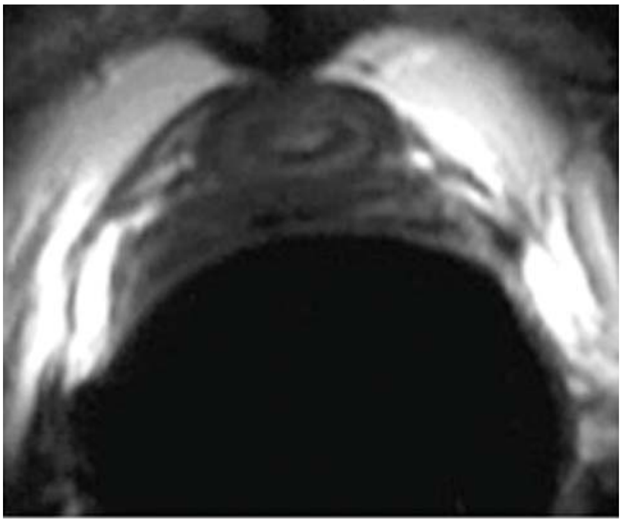
Figure 2. Thinning of the striated muscle of the urethra in a patient with stress urinary incontinence at T2-weighted image in axial plane, which was obtained by using endovaginal coil.

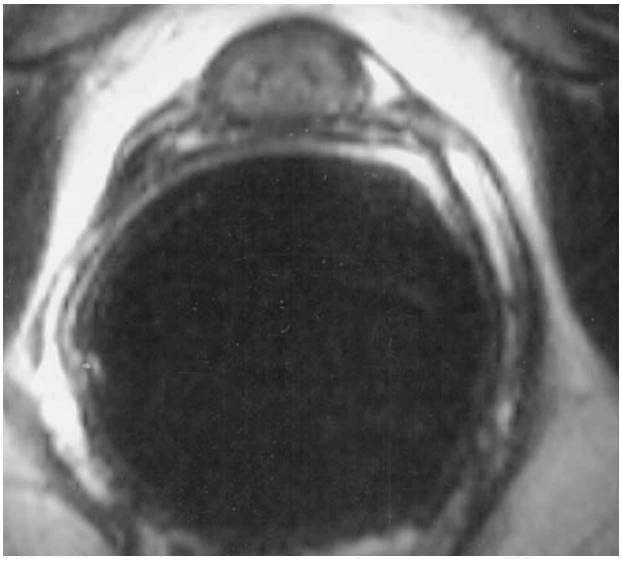
Figure 3. Normal urethral supporting ligaments.

der prolapsus was classified as mild or moderate in 19 patients and advanced in 6 patients (Figure 5). There were no significant correlations between the degree of the bladder prolapsus and number of deliveries using the two predefined groups (P >.05; Table 4).

DISCUSSION

It is important to visualize the urethra and its supporting structures in detail for SUI treatment selection.[15] Several studies reported that MRI could depict distinct abnormalities in SUI and change patient management.[19] Magnetic resonance imaging assessment of women with the pelvic floor dysfunction provided significant information, which changed clinical management in 41.6% of patients with SUI.[20]

The combined usage of EV-MRI and DP-MRI enables visualization of the urethra and its supporting structure morphology as well as identification of the changes in the pelvic floor structures at rest and during Valsalva maneuver using fast sequences.[6,7,14,16,18] Studies with EV-MRI have reported that there are significant differences in urethral intrinsic muscles and supporting ligaments between patients with SUI and asymptomatic women.[7,12,17]

These studies also reported that in patients with SUI, at least one of the urethral layers or all the layers could be thin. The endovaginal coil was not only able to visualize the urethra throughout its whole length, but to evaluate the striated, smooth muscle, mucosa, and submucosa as well.[7,12,17] In our study, the striated urethral muscles were significantly thinner in the group with SUI than the control group.

Similarly, a recent study using MRI analyzed the association between the urethral sphincter anatomy, urethral function, and pelvic floor function and reported that a smaller striated urogenital sphincter was related to SUI and poorer pelvic floor muscle.[21] In addition to differences in striated sphincter, our study revealed significant differences in the thickness of the urethral smooth muscle, mucosa, and submucosa layers between the two groups. This latter finding suggests that all layers of the urethra participate in the mechanism of incontinence.

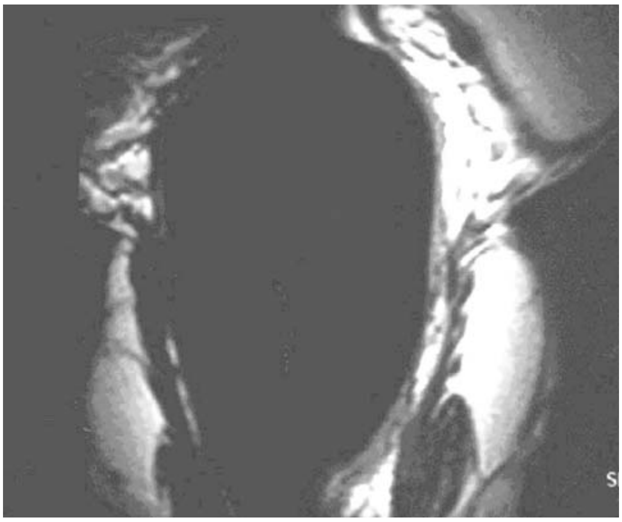

Figure 4. Asymmetrical thinning of the left puborectal sling in a patient with stress urinary incontinence.

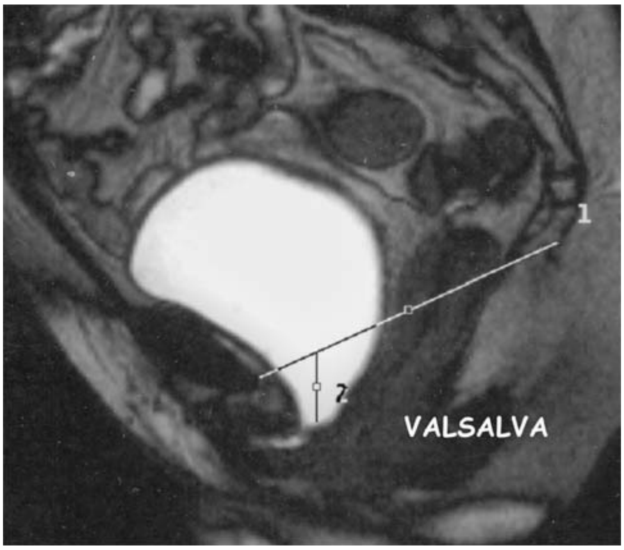

Figure 5. During Valsalva maneuver, the bladder neck can be identified below the puborectal line and the urethra becomes horizontally oriented distal to the pubic bone in a patient with stress urinary incontinence (T2-weighted sagittal image).

Anatomic and imaging findings demonstrating the position or location of the urethral suporting ligaments, may be the initial step in treatment of SUI as detailed understanding of the normal continence mechanism allows identification of abnormalities

Table 1. The thickness of the urethral layers in patients with stress urinary incontinence compared to controls

Urethral layers thickness (mean ± SD)†, mm	Patients with stress urinary incontinence (n = 25)	Control group (n = 8)	95% Confidence interval	*p**
Striated muscle	1.7 ± 0.2	2.3 + 0.2	- 0.80 to - 0.40	**.000**
Smooth muscle	3.1 ± 0.2	3.3 + 0.2	- 0.56 to - 0.06	**.024**
Mucosa and Submucosa	2.5 ± 0.2	2.7 + 0.1	- 0.31 to - 0.05	**.009**

†SD indicates standard deviation.

**P* < .05 is significant.

underlying incontinence process.[19]

Our study shows that distortion of pubourethral ligaments was significantly higher in individuals with SUI. This observation suggests that among the urethral supporting ligaments, the pubourethral ligament distortion plays an important role in the development of SUI. However, we did not find significant differences in the frequency of distortion of the periurethral and paraurethral ligaments between two groups.

The vesicourethral angle and dimension of retropubic space are closely related to the urethral supporting structures. In our study, we observed a significantly higher vesicourethral angle in patients with SUI compared to controls. Our findings are supported by some studies using static MRI and dynamic MRI, in which hypermobility has been reported as one of the causes of SUI.[22] The mean dimension of the retropubic space was larger in our group with SUI compared to controls. However, this difference was not statistically significant. It might be the expansion of endovaginal coil balloon with air that caused smaller measurements for the dimension of retropubic space. A defect in hammock structure consisting of anterior vaginal wall and pubourethral ligaments was shown in several studies.[20,22,23] Our findings confirmed these prior reports, as the grade of distortion in the pubourethral ligaments was significantly higher in individuals with SUI.

We did not find any significant differences in the mean thickness of the puborectal muscle and number of deliveries between the group with SUI and the control group. The two groups did not differ for the degree of the bladder prolapsus determined by dynamic assessment. These findings suggest that the number of vaginal deliveries and thickness of puborectal muscle are not individual determinants of the etiology of SUI. Consequently, our results demonstrate that the most determining parameter in the etiology of SUI is the thinning of the urethral layers, particularly in the striated muscle layer.

One of the limitations of our study is the fact that the assessments were performed in the supine po-

Table 2. Distribution of the distortion in the urethral supporting ligaments; comparison of patients with urinary incontinence and asymptomatic controls.

Distortion in the supporting ligaments of the urethra, n (%)	Patients with stress urinary incontinence (n = 25)	Control group (n = 8)	*p**
Periurethral ligaments	14 (56.0)	3 (37.5)	**> .05**
Paraurethral ligaments	25 (100)	6 (75.0)	**> .05**
Pubourethral ligaments	15 (60.0)	1 (12.5)	**.024**

**P* < .05 is significant.

Table 3. Comparison of the patients with urinary incontinence and asymptomatic controls regarding the mean values of vesicourethral angle, retropubic space, and puborectal muscle thickness

	Patients with stress urinary incontinence (n = 25)	Control group (n = 8)	95% Confidence interval	*p**
Vesicourethral angle (mean ± SD)†	146 ± 5.05	136 ± 3.84	5.26 to 13.23	**.000**
Retropubic space (mean ± SD), mm	4.46 ± 0.79	3.28 ± 0.83	0.43 to 1.909	**> .05**
Puborectal muscle thickness (mean ± SD), mm	3.676 ± 0.63	3.688 ± 0.65	- 0.53 to - 0.51	**> .05**

†SD indicates standard deviation.
**P* < .05 is significant.

sition. As compared to normal anatomical position, the investigations performed in supine position do not allow to assess the dynamic changes in the urethra and its supporting structures resulting from the changes of intra-abdominal pressure. Open MRI systems identify SUI more accurately due to gravity and increased intra-abdominal pressure in vertical or standing positions during Valsalva maneuver. In a study concerning the pelvic floor weakness imaging using 0.5 Tesla open magnetic system, all the pelvic floor structures except posterior urethrovesical angle were reported to be stable between supine and sitting positions.[24] Other investigators showed that assessments in supine position after maximum strain were more reliable.[25]

Another limitation of our study comes from the use of endovaginal coil technique, which supports the anterior wall of the vagina. The use of this coil technique can displace the vaginal walls laterally and visualize rather small defects in these structures. However, the capability of EV-MRI to assess the fascia and muscle structures accurately with high spatial resolution still presents as an advantage.

CONCLUSION

In conclusion, in patients with SUI, combined static EV-MRI and dynamic DP-MRI analysis provides complementary information and allows identification of certain abnormalities in urethral supporting structures and specific pelvic floor dysfunctions. However, we accept that the utility of static EV- or DP-MRI should be validated in accordance with comprehensive studies, which may assess the structural abnormalities directly related to the diagnosis and treatment of SUI.

CONFLICT OF INTEREST

None declared.

Table 4. Comparison of the degree of the bladder prolapsus and number of deliveries in patients with stress urinary incontinence.

Number of deliveries	Degree of the bladder prolapsus			
	Mild to Moderate, n (%)	Advanced, n (%)	Total	*p**
1 to 3	11 (78.6)	3 (21.4)	14 (100)	
≥ 4	8 (72.7)	3 (27.3)	11 (100)	**> .05**
Total	19 (76.0)	6 (24.0)	25 (100)	

**P* < .05 is significant.

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