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ORIGINAL ARTICLE

Predictive role of measurement of pelvic floor muscle thickness with static MRI in stress and mixed urinary incontinence

Levent Yaşar[1] · Serpil Ortakuz Telci[1] · Keziban Doğan[1] · Eyüp Kaya[2] · Murat Ekin[1]

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Abstract

Introduction and hypothesis To investigate the role of measuring the thickness of pelvic floor muscles with static MRI in the physiopathology of urinary incontinence in women with stress and mixed types of urinary incontinence diagnosed with urodynamic studies.

Methods A retrospective clinical study was designed in collaboration with the radiology department. We recruited only patients who had undergone static pelvic MRI to determine the etiology of pelvic pain and exclude gynecologic disorders. The study included 45 women diagnosed with stress or mixed-type urinary incontinence based on pelvic examination and urodynamic testing without symptomatic pelvic organ prolapse and 40 continent controls. We evaluated the images of pelvic static MRI of all patients to measure the thickness of the pelvic floor muscles with the radiologist by using an image analysis workstation retrospectively.

Results The right and left puborectalis parts of levator ani muscle thicknesses were significantly lower in the urinary incontinence group than in the control group ($p < 0.01$). The right and left PR/OI ratios were significantly lower than in the control group. ($p = 0.001$).

Conclusion Morphologic changes of pelvic floor muscle thickness can be demonstrated by a static pelvic MRI, and this can be used as a prognostic test in the treatment and follow-up of patients with stress or mixed urinary incontinence.

Keywords Urinary incontinence · Static MRI · Thickness ratios of pelvic muscles

Introduction

Pelvic floor dysfunctions, especially stress urinary incontinence (SUI), which is known as the involuntary loss of urine during increased abdominal pressure, are serious medical and social problems affecting many women [1].

Only a small proportion of women with SUI need surgical treatment, but it is difficult to define the most suitable treatment for patients because pelvic floor dysfunctions are not yet understood clearly. Today, radiologic imaging does not offer any well-standardized technique for the diagnosis of pelvic floor dysfunctions and urinary incontinence [2]. The decision for a conservative treatment or a specific surgical approach is affected by the morphology of the involved structures, static balance and mobility of the pelvic structures [3]. Dynamic and functional radiologic imaging techniques can provide useful information and can be necessary for effective and suitable treatment planning because the clinical examination alone cannot accurately estimate the extent of underlying pelvic floor pathology [4–6]. Pelvic floor dysfunctions have a complex anatomical structure, and many pelvic abnormalities can exist, so clinical symptoms can be related to a specific pathology involving the other pelvic parts [7]. The levator ani muscle has a key role in the function of the pelvic floor. It has been investigated in many magnetic resonance imaging (MRI) studies because of its complex anatomy and difficult accessibility [8]. MRI can provide an accurate and multiplanar overview of pelvic organs and pelvic floor muscles without

Synopsis The thickness ratios of the puborectalis and obturator internus muscles show statistically significant correlation with stress and mixed-type urinary incontinence.

✉ Serpil Ortakuz Telci
drserpil2000@gmail.com

[1] Bakirkoy Dr. Sadi Konuk Training and Research Center, Department of Obstetrics and Gynecology, University of Health Sciences, Istanbul, Turkey

[2] Bakirkoy Dr. Sadi Konuk Training and Research Center, Department of Radiology, University of Health Sciences, Istanbul, Turkey

ionizing radiation. Study with surface coils applying T1-weighted conventional sequences and spin-echo T2-weighted sequences allows accurate definition of the pelvic organs, fibromuscular system and ligamentous support anatomy [9]. In this study, we evaluated the muscle thicknesses of the puborectalis part of the levator ani and obturator internus using static two-dimensional MRI. We focused on comparison of the pelvic muscle thicknesses of both sides and especially the thickness ratios in patients with stress or mixed-type incontinence with those of healthy continent women to determine whether MRI provides a prognostic test in the treatment and follow-up of patients with stress or mixed-type urinary incontinence.

Methods

A retrospective clinical study was designed in collaboration with the radiology department. We recruited only patients who had undergone static pelvic MRI to determine the etiology of pelvic pain and exclude gynecologic disorders between 2010 and 2015. We called the patients back to our urogynecology clinics for pelvic examination and evaluation of urinary continence by using the cell phone records. We excluded patients with gynecologic disorders or histories of pelvic floor surgery. The study included 45 women diagnosed with stress or mixed-type urinary incontinence based on pelvic examination and urodynamic testing without symptomatic pelvic organ prolapse and 40 continent controls aged between 35 and 65 years without pelvic floor dysfunction. A total of 85 patients were enrolled in this study after obtaining informed consent.

We evaluated the images of static pelvic MRI of all patients to measure the thickness of pelvic floor muscles with the radiologist by using an image analysis workstation retrospectively. Puborectalis parts of levator ani and obturator internus muscles were measured bilaterally where they are the thickest in the middle part. The left and right ratios (PR/OI) were calculated by dividing the thickness of the puborectalis muscle by the ipsilateral obturator internus muscle thickness.

Imaging techniques

The examinations were performed in the supine position on a 1.5-T unit (Siemens Magnetom Verio 3 Tesla, Germany). All

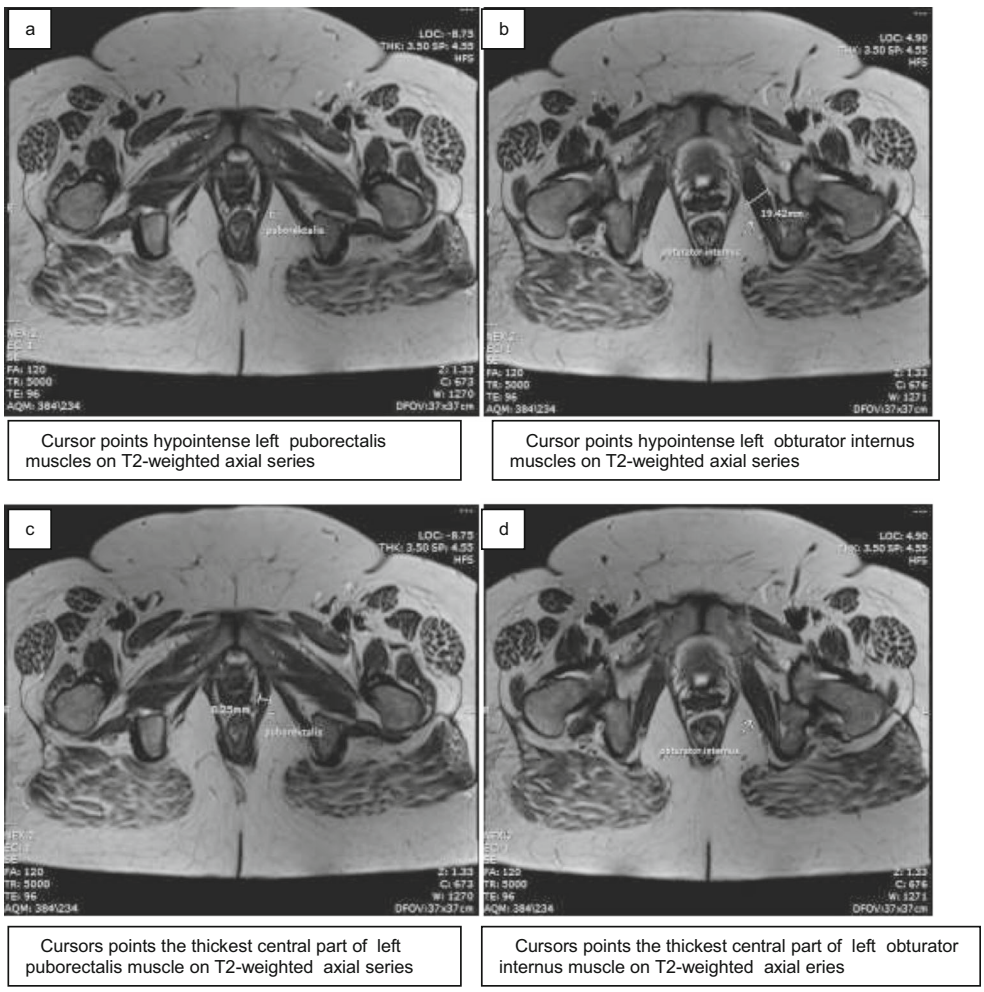


Fig. 1. **a** Cursor points to hypointense left puborectalis muscles on the T2-weighted axial series. **b** Cursor points to hypointense left obturator internus muscles on the T2-weighted axial series. **c** Cursor points to the thickest central part of the left puborectalis muscle on the T2-weighted axial series. **d** Cursor points to the thickest central part of the left obturator internus muscle on the T2-weighted axial series

Table 1 Patient characteristics

	Patients	Controls	*p* value
Age	35–65 (50) 50.00 ± 7.88	35–65 (51.5) 50.03 ± 8.45	0.989[a]
BMI (kg/m^2)	26.0–33.8 (30) 30.08 ± 1.82	24.632.5 (28.8) 28.96 ± 1.94	0.007[a]**
Parity	2–8 (5) 4.76 ± 1.68	0–13 (4) 4.40 ± 2.67	0.124[b]
Vaginal delivery	1–7 (3) 3.73 ± 1.59	0–7 (2) 2.53 ± 1.71	0.002[b]**
Cesarean section	0–2 (0) 0.29 ± 0.55	0–3 (0) 0.59 ± 0.79	0.052[b]
n (%)			0.693[c]
Perimenopause	16 (35.6)	12 (30.0)	
Menopause	16 (35.6)	13 (32.5)	
Postmenopause	13 (28.9)	15 (37.5)	

[a] *Student's t test*

[b] *Mann-Whitney U test*

[c] *Pearson chi-square test*

*$p < 0.05$

**$p < 0.01$

women were asked to relax the pelvic floor muscle during the MRI examination. Images were acquired without contrast medium administration using a multi-channel body coil placed in the pelvic area. All patients underwent a routine imaging protocol. First, images of the pubic symphysis, bladder neck, vagina and rectum were taken at the midline sagittal precursor containing the coccyx. Midline sagittal images through the endometrium perpendicular to the axial oblique section was planned, and T2-weighted images were obtained. Transverse T2 images of the distal portion of the pelvis were made with a slice thickness of 3.5 mm, slice gap of 0.7 mm, field of view of 350 mm, TR (time to repeat): 5000 ms and TE (time to echo): 96 ms. A total of 32 sections were obtained. The resulting sections were examined on the workstation by an expert radiologist blinded to the study groups.

An Syngo.vi image analysis workstation (Siemens Healthcare Germany) was used with software. Imaging findings in the evaluation of the first high-resolution T2-weighted images analyzing the fascia, ligaments and pelvic muscle lesions were identified. The morphology of the levator ani muscle and obturator internus muscle, thicknesses and signals were evaluated (Fig. 1a, b). The puborectalis part of the levator ani and obturator internus muscles were measured bilaterally where they are the thickest in the middle part (Fig. 1c,d). The left and right puborectalis muscles and obturator internus muscle ratios (PR/OI) were calculated by dividing the puborectalis muscle thickness by the ipsilateral obturator internus muscle thickness.

Table 2 Medians, ranges and statistical comparisons of the bilateral thickness of the puborectalis and obturator internus muscles

	Controls Median-ranges	Patients Median-ranges	*p* value
Right puborectalis	6.23 ± 0.73 (6.2)	5.18 ± 0.64 (5.2)	0.001**
Left puborectalis	7.00 ± 0.71 (6.9)	6.05 ± 0.61 (6.0)	0.001**
Right obturator int	19.20 ± 1.86 (19.2)	19.69 ± 1.99 (19.8)	0.248
Left obturator int	19.27 ± 1.85 (19.0)	19.83 ± 1.97 (19.7)	0.246

*$p<0.01$

Table 3 Right and left (PR/OI) ratios

		Patients($n = 45$) Median-ranges	Control ($n = 40$) Median-ranges	*p*
PR/OI ratio	Right	0.26 ± 0.02 (0.27)	0.32 ± 0.03 (0.32)	0.001
	Left	0.31 ± 0.03 (0.31)	0.36 ± 0.03 (0.36)	0.001

Mann-Whitney U test

$p < 0.01$

Statistical analysis

The Gpower 3.1.9.2 statistical power analysis system (Düsseldorf, Germany) was used for the post hoc analysis of the retrospective data, and the power of the study was calculated as 99%.

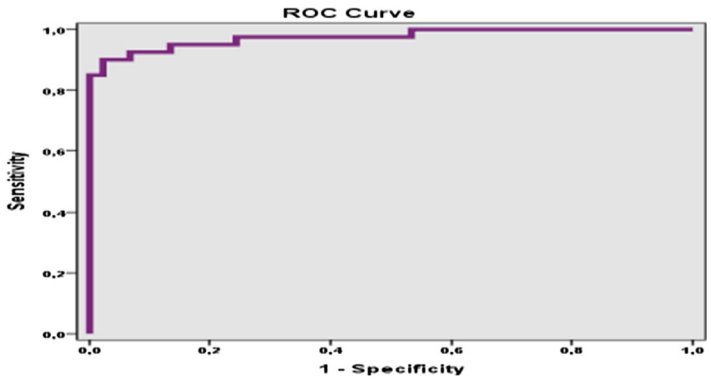
The 2007 Number Cruncher Statistical System (NCSS; Kaysville, UT, USA) for statistical analysis was used. Data were analyzed using descriptive statistical methods (mean, standard deviation, median, frequency, rate, minimum, maximum) and Student's t-test, which was also used for the two-group comparisons of parameters showing normal distribution for comparing quantitative data, while the Mann-Whitney U test was used for comparisons of parameters in abnormal distributions. Yates' correction continuity test (Yates chi-square) and Pearson's chi-square test were used to compare qualitative data. To evaluate intra-group variables, the Wilcoxon signed-rank test was used. Receiver-operating curve (ROC) analysis was used in diagnostic screening tests to determine the cutoff parameters (sensitivity, specificity, positive predictive value, negative predictive value), and significance was considered at $p < 0.01$ and $p < 0.05$. Gpower 3.1.9.2 was used for the post hoc analysis of the the data.

Institutional review board and study registration

All subjects were informed of the study protocol and potential risks and benefits of the study, and written informed consent was obtained from each subject before any study procedures were performed. The study was approved by the

Table 4 Right PR/OI ratio

	Diagnostic scan					ROC curve		*p*
	Cut off	Sensitivity	Specifity	Positive predictive value	Negative predictive value	Area	95% confidence interval	
Right PR/OI	*≤ 0.297*	97.78	90.00	91.67	97.30	0.974	0.944–1.000	*0.001**



*$p<0.01$

Ethics Committee of the University of Health Sciences, Bakirkoy Dr. Sadi Konuk Research and Training Hospital (2014/12; 15.09.2014).

Results

There were no statistically significant differences among the mean age, menopausal status, parity and cesarean deliveries of patients between the two groups ($p > 0.05$). Vaginal delivery ($p = 0.002$) and BMI ($p = 0.007$) were significantly higher in the urinary incontinence group (Table 1).

The mean muscle thicknesses of the right and left puborectalis parts of the levator ani were significantly lower in the urinary incontinence group than in the control group ($p < 0.01$). There were no statistically significant differences in the thickness of the right and left obturator internus muscles between the two groups ($p > 0.05$) (Table 2**).**

Table 5 Relationship of the right PR/OI ratio with the disease (cutoff value 0.297)

		PR/OI				*p*
		> 0.297		≤ 0.297		
		N	%	N	%	
Disease	(−)	36	*90.0*	4	*10.0*	0.001*
	(+)	1	*2.2*	44	*97.8*	

Yates's continuity correction test

*$p < 0.01$

The right ($p = 0.001$) and left PR/OI ratios ($p = 0.001$) were significantly lower in patients with urinary incontinence compared with the control group ($p < 0.01$) (Table 3**).**

Cutoff settings for the right and left PR/OI ratios

The right and left PR/OI ratios vary significantly according to the proportion of cases in the patient group, and these ratios were found to be lower than in the control group. The cutoff points were considered to be calculated based on this significance for the right and left PR/OI ratios, and ROC analyses were utilized.

A cutoff point for the right PR/OI ratio is determined by the presence of the disease in ≤ 0.297. The correct PR/OI ratio for the 0.297 cutoff value had 97.78% sensitivity, 90.00% specificity and 91.67% and 97.30% positive and negative predictive values, respectively. The resulting standard error of 97.4% in the area below the ROC curve was found to be 1.6% (Table 4**).**

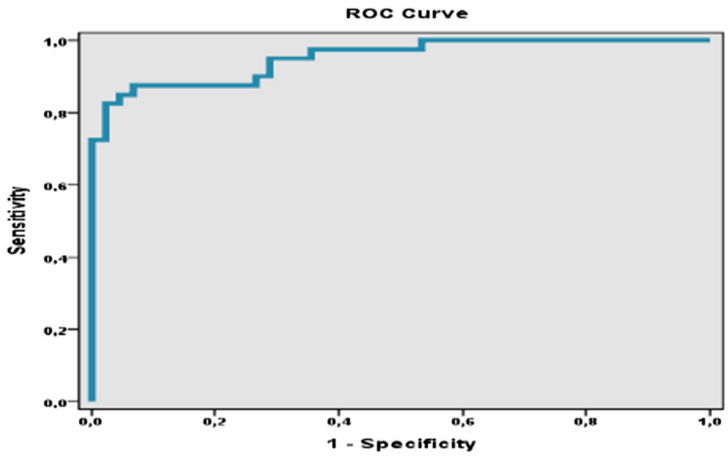
The right PR/OI ratio showed a statistically significant correlation between the presence of disease and a cutoff value of 0.297 ($p = 0.001$; $p < 0.01$). The odds ratio for the right PR/OI ratio ≤ 0.297 is 396.000 (95% CI: 42.363–3701.713) (Table 5).

A cutoff point for the left PR/OI ratio is determined by the presence of the disease in ≤ 0.334. The left PR/OI ratio for the 0.334 cutoff value has 93.33% sensitivity, 87.50% specificity, and 89.36% and 92.11% positive and negative predictive value, respectively. The resulting standard error of 95.2% in the area below the ROC curve was found to be 2.1% (Table 6).

The left PR/OI ratio shows statistically significant correlation between the presence of disease and a cutoff value of

Table 6 Diagnostic screening test and ROC curve results for the left PR/OI ratio

	Diagnostic scan					ROC curve		*p*
	Cutoff	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Area	95% Confidence interval	
Left PR/OI	***≤ 0.334***	93.33	87.50	89.36	92.11	**0.952**	0.910-0.994	***0.001****



*p<0.01

Table 7 Relationship of the left PR/OI ratio with the disease (cutoff value 0.334)

		Relationship of left PR/OI				*p*
		> 0.334		≤ 0.334		
		n	%	N	%	
Disease	(−)	35	*87.5*	5	*12.5*	*0.001**
	(+)	3	*6.7*	42	*93.3*	

Yates's continuity correction test

**p < 0.01*

0.334 ($p = 0.001$; $p < 0.01$). The odds ratio for the left PR/OI ratio ≤ 0.334 is 98.000 (95% CI: 21.867-439.205) (Table 7).

Discussion

There are few studies evaluating the role of MRI in the diagnosis of pelvic floor dysfunction [10–12]. The integrity of the levator plate was examined for the prediction of uterovaginal support in a study by Ozasa et al. In this study to exclude prolapse, they used a line extrapolated from the levator plate on the sagittal section that crosses the symphysis pubis [11]. Because of the anatomical localization of the levator plate, Kavita et al. hypothesized that weakness of the iliococcygeus muscle may result in pelvic organ prolapse, while weakness of the puborectalis muscle causes urinary incontinence [13]. Bo et al. studied the movements of the bladder neck and coccyx on midsagittal MRI sections and suggested that these movements reflect those of the levator ani muscle. They also postulated a concentric movement of the levator ani that lifts the coccyx upwards and ventrally. Kegel described the combined contraction of the pelvic floor muscles as squeezing with an inward lift. In this combined action of the levator ani muscles, the puborectalis component maintains the inward squeeze, and the iliococcygeus muscle makes the upward lift [12, 13]. In our study, we found a statistically significant thinning of the right puborectalis, like Fielding and Tunn, who observed an asymmetry of the puborectalis muscle [14, 15]. While Tunn et al. associated this asymmetry with the chemical shift artifact, we do not share this view, and we believe that this asymmetry cannot be explained only by a chemical shift. The reason for this asymmetry is the anatomical location of the puborectalis muscle, which lies in a lower plane than the iliococcygeus muscle. Because of this level difference, the puborectalis muscle is more vulnerable to damage during the second stage of labor [15].

In the literature, a higher prevalence of urinary incontinence is reported in parous compared with nulliparous women. Childbirth may be the reason for pelvic floor dysfunction because of damage to the pelvic nerves, pelvic muscles and connective tissue attachments [16, 17]. The pudendal nerve is responsible for the voluntary control of the striated urogenital sphincter muscles. Vaginal delivery may lead to pudendal neuropathy, interfering with the normal urogenital sphincter function. Compared with asymptomatic women, a higher rate

of prolonged pudendal nerve motor latency has been demonstrated after delivery in women with urinary incontinence [18]. In our study, the number of vaginal deliveries was significantly higher in patients with urinary incontinence than in the control group. The number of cesarean deliveries, while being lower than in the control group, was not statistically significant, although it was close to significance.

An increased body mass index (BMI) has been shown to be an independent risk factor for urinary incontinence [19, 20]. We also found higher BMI levels in the patient cases than in the control group.

Different techniques have been described in the evaluation of the levator ani muscle. Bernstein used trans-perineal ultrasonography to measure the thickness of the levator ani muscle, but the fiber direction angle and identification of the portion of the levator ani were limited because of the low resolution [21]. Aukee et al. evaluated the thickness of the distal part of the pubococcygeus muscle using static axial MR images. They found a significant correlation with EMG findings at maximal contraction [22]. In that study, measurements of the pelvic muscle dimensions were not three dimensional, and the relationship between the dimension and fiber direction was not defined. Three-dimensional reconstructed models were used by Hoyte et al. to measure the levator ani muscle volume and levator ani angle [23–25]. Their study revealed that the anterior portion of the levator ani muscle is bilaterally thicker in asymptomatic women compared with women with pelvic organ prolapse and unilaterally (right side) thicker in women with stress urinary incontinence [25]. Different from the study by Hoyte et al., we found that the puborectalis muscles of the levator ani are significantly thicker bilaterally in healthy continent women compared with women with SUI. The possible explanations for these findings are both muscle atrophy caused by pudendal nerve denervation and muscle loss caused by impairment of the insertion points for the puborectalis muscle [12]. Tunn et al. evaluated the levator geometry in nulliparous women and postulated that these findings can be regarded as normal variations in muscle parameters [7]. A decrease in levator ani muscle thickness is expected with aging [26]. Age and hormonal status are confounding factors in studies concerning levator muscle thickness measurements as the levator muscles contain estrogen receptors. In our study, the similar age and hormonal status in the patient and control groups allowed avoiding the effects of these confounding factors. We particularly evaluated the thicknesses of obturator internus muscles, which are not affected by childbirth trauma or active athletic lifestyles. We found no differences in the thicknesses of the obturator internus muscles between the groups as we predicted. Therefore, we preferred using the PR/OI ratio rather than the puborectalis muscle thickness as a cutoff value for the prediction of stress and mixed urinary incontinence to be more objective.

Three-dimensional (3D) ultrasound has become a novel examination tool for pelvic floor dysfunction with technologic improvements [27]. Translabial 3D ultrasound can display the whole levator hiatus and puborectalis muscle. Diagnosis of avulsions of the pelvic floor muscles and the dimension of the levator hiatus can be quantified with 3D ultrasound [28]. However, moderate agreement was reported in the diagnosis of the levator hiatus avulsion in 3D ultrasound and MRI in various studies [29, 30]. The studies concerning the relationship between levator tears and urinary incontinence have conflicting results. In a longitudinal cohort study of 191 patients by van Delft et al. [31], transperineal ultrasound was used to identify levator ani muscle avulsion in primigravida patients at 36-week gestation and at 3 months postpartum. Twenty-one percent of vaginal deliveries had levator ani muscle avulsion. Women who had sustained levator ani muscle avulsion had higher urinary incontinence scores, but the severity of the levator ani muscle avulsion was not correlated with urinary incontinence [31]. However, in another longitudinal cohort study including 168 women, 3D transperineal ultrasound was used to diagnose levator ani muscle lesions 36 months after delivery, and there was no difference in urinary stress incontinence between patients with and without levator ani muscle lesions [32]. Compared with MRI, 3D ultrasound has interobserver variability. It has a long learning curve, and the image quality varies with the type of ultrasound. In addition, the cost of MRI is comparable to that of 3D ultrasonography in our country, which shows that MRI is an attractive diagnostic tool.

Despite treatment, urinary incontinence has a significant recurrence rate and causes high economic costs. The precise diagnosis related to the etiology of urinary incontinence may help decrease the recurrence rate. We believe that nerve damage at labor may result in pelvic muscle dysfunction and urinary incontinence as the striated urogenital sphincter muscles are innervated through the pudendal nerve. MRI can be a useful tool in complex urinary incontinence and can have a predictive role when choosing the appropriate type of operation in relation to the success of the treatment. The studies concerning the role of MRI in the determination of the mechanism of stress urinary incontinence were all carried out in small populations, and the clinical significance of our postulation can be strengthened by high-powered studies in the future.

Compliance with ethical standards

Conflicts of interest The authors have no conflicts of interest.

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