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MR Imaging of Levator Ani Muscle Recovery Following Vaginal Delivery

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Abstract: Our aim was to quantify the changes that occur in the levator ani muscles (LA) after vaginal delivery using magnetic resonance imaging. Fourteen women underwent MRI 1 day postpartum. Six of them were also scanned 1, 2, 6 weeks and 6 months after delivery. LA signal intensities and thickness, in areas of the urogenital and the levator hiatus were assessed in the transverse plane. Perineal body position was measured in the sagittal plane. One day postpartum a higher T_2-signal intensity of the LA compared to the obturator internus muscle was found in all women and a lower T_1-signal intensity in 8 of 12 women. By 6 months these differences were present in only 1 woman in the left LA. An elevation in perineal body position of 13.4 ± 7.3 mm ($P < 0.05$), as well as a decrease in the area of the urogenital hiatus by 27% ($P < 0.05$) and of the levator hiatus by 22% ($P < 0.05$) by 2 weeks postpartum suggest a return of normal LA geometry. LA thickness showed interindividual variations, and a complete loss of LA tissue was found in 1 woman. Changes in LA signal intensity, topography and thickness during the puerperium can be documented using MR imaging.

Keywords: Follow-up in puerperium; Levator ani muscle; MR imaging

Introduction

The time in a woman's life when the LA is most susceptible to injury is during vaginal delivery. Extreme muscular distension, ischemia and neural trauma are all possible mechanisms by which injury can occur. Despite the vulnerability of this important muscle at this precisely defined time, little is known about the muscle changes resulting from delivery and the process of successful or failed repair.

The effect of vaginal delivery on pelvic floor function has been studied using EMG, ultrasonography and urodynamics. These tests help to quantify the function of different elements of the pelvic floor, but they do not allow changes in the structure of the LA to be examined. Because MRI provides clear images of pelvic floor structures [1–4], it could prove helpful in understanding the anatomical changes found in women with pelvic organ prolapse and stress urinary incontinence.

We reviewed serial MR images originally obtained to study involution of the uterus [5] after vaginal delivery and postpartum changes in pelvic organ positions [6]. It became evident from these images that significant and potentially important changes were visible in the LA during the first 6 months after delivery. The goal of this study was to prove that MR imaging can reveal systematic changes in the LA from 1 day to 6 months after spontaneous vaginal delivery, to describe a system for quantifying those changes, and to test its reliability in practice.

Materials and Methods

Observations were made on a set of MR images (1.5-T Magnetom 4000 SP; Siemens Medical Systems, Iselin, NJ; all images were made in the supine position) previously obtained for other purposes [5,6].

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T_1-weighted spoiled gradient echo (fast low-angle shot, TR/TE 130/4.5) sequences were used to describe changes in signal intensity. The imaging parameters were as follows: 80° flip angle, one signal acquired, 300–375 mm field of view, and 8 mm thick sections with a 20% gap.

The measurements and evaluations of muscle signal intensity changes were made on T_2-weighted fast spin echo images. The imaging parameters were as follows: 3500/100 echo train length of eight, one signal acquired, 300–375 mm field of view, 6 mm thick sections with a 20% gap.

The images had been obtained in 14 women who delivered vaginally and ranged in age from 19 to 33 years (mean 23, SD ± 5). Of these women, 6 were para 1, 3 para 2, 3 para 3 and 2 para 4.

All 14 (women 1–14) underwent examinations on day 1 postpartum. Six of these women (women 1–6) were also examined 1 week, 2 weeks, 6 weeks and 6 months after delivery (4/6 women were para 1, 1/6 para 3, 1/6 para 4; without specific selection). Four women had a midline episiotomy, including 2 with third-degree perineal laceration. None of the subjects complained spontaneously of urinary or fecal incontinence, but they were not formally questioned about these symptoms. Details of the MR techniques used are provided in the references quoted above.

LA Signal Intensity

The intensity of the MR signal emanating from a structure reflects the chemical composition of that structure. Striated muscle tissue shows low signal intensity (dark), whereas fatty tissue has high signal intensity (bright). Changes in chemical structure result in either darkening (lower intensity) or lightening (higher intensity) of the image of that structure. We examined changes in signal intensity of the LA in the transverse plane at the level of the proximal (T_2-weighted sequence) and middle (T_1- and T_2-weighted sequences) urethra. The signal intensity from the LA was compared to that of the obturator internus muscle, as we did not observe changes in obturator internus and externus muscle signal intensity during the puerperium. Furthermore, the obturator internus muscle was included in the used field of view. The signal intensity of the LA was described qualitatively as being the same, higher or lower.

Muscle Topography

The size of the urogenital hiatus was measured. The LA begins anterior to the pubic bones and passes behind the viscera. The muscle length reflects the size of the urogenital and levator hiatuses. To measure the size of these apertures, the transverse and sagittal diameters of each hiatus were measured on transverse sections at the level of the middle urethra (Fig. 1).

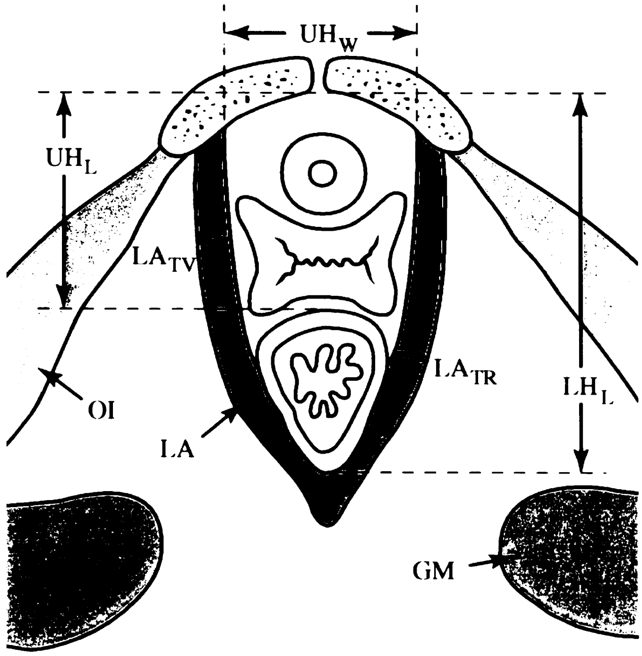

Fig. 1. Schematic drawing of a transverse section through the pelvis at the level of the middle urethra, showing the measurements of the levator hiatus and urogenital hiatus and the LA thickness (LA_{TV} = paravaginal, LA_{TR} = pararectal).
UH_L, length in urogenital hiatus;
UH_W, width in urogenital and levator hiatus;
LH_L, length in levator hiatus;
OI, obturator internus muscle;
GM, gluteus maximus muscle.

The widths of the urogenital hiatus and levator hiatus were also measured between the medial margin of the right and left LA at the level of the lateral vaginal wall. The length (sagittal diameter) was measured from the symphysis to the perineal body for the urogenital hiatus. The distance from the pubic bone to the posterior rectal wall was also measured to assess the size of the levator hiatus.

The width and length of the hiatus were then used to calculate the roughly oval area of the urogenital hiatus and levator hiatus.

Pelvic Floor Descent The position of the perineal body relative to the pelvis was measured to assess the degree of pelvic floor descent after vaginal delivery. Measurements were made in the midsagittal plane (Fig. 2). Perineal body position was measured relative to a line drawn between the sacrococcygeal articulation and the inferior point of the pubis (SCIPP line). A perpendicular line was drawn between the SCIPP line and the anterior margin of the anal sphincter muscle. This distance, plus the orthogonal distance between the perpendicular line and the pubic bone along the SCIPP line, allowed the coordinates of this point to be placed in the midsagittal plane relative to the bony pelvis (Fig. 2). These coordinates were measured at each follow-up examination.

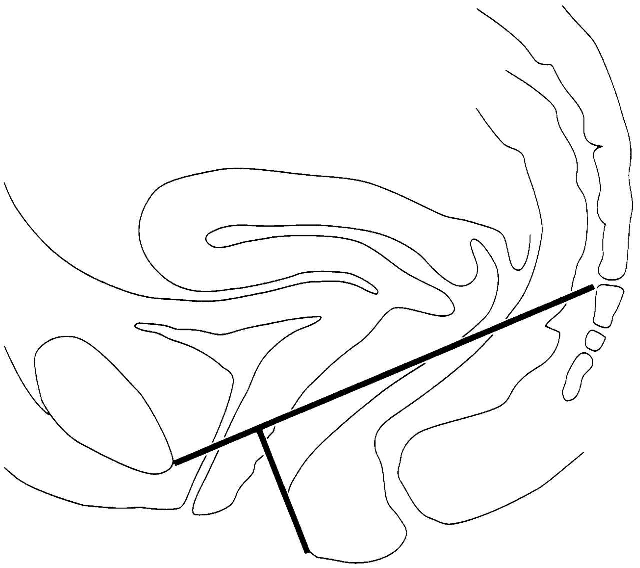

Fig. 2. Schematic representation of a midsagittal section through the pelvis, showing the coordinates of the perineal body relative to the SCIPP line.

Muscle Thickness

Muscle Thickness Measurement LA thickness was measured adjacent to the lateral vaginal (LATV) and rectal walls (LATR) (Fig. 1). The measurements were made in the transverse plane at the level of the middle and proximal urethra on both the right and the left sides.

Statistical Analysis Descriptive statistics were generated for each measurement parameter. Changes between baseline and follow-up examinations were tested using repeated measures analysis of variance. *P* values smaller than 0.05 were considered statistically significant.

Intra- and Interobserver Measurement Reproducibility The first author performed the measurements twice. A second investigator, blinded to the results, repeated the measurements. The upper and lower limits of agreement were calculated from the mean of the paired difference ± 2 SD [7]. A plot of the paired difference between the values was made against the mean to show the measurement agreement.

Results

Muscle Signal Characteristics

Changes in MR signal intensity were visible in the LA during the puerperium. The intensity of the LA signal on T_2-weighted sequences was higher than that of the obturator internus muscle in all 14 women 1 day after delivery (Table 1, Fig. 3a, c). By 6 months postpartum the same signal intensity was found in all women on the left at the level of the middle urethra (Fig. 3b); a higher signal intensity persisted only in 1 woman, at the level of the proximal urethra (Fig. 3d). A higher signal intensity on the right side persisted at the level of the middle urethra in 3 of 6 women, and at the level of the proximal urethra in 4 of 6 women.

Table 1. T_2-weighted signal intensity (SI) of the LA compared to the obturator internus muscle evaluated at the level of the middle urethra

Women 1–6	SI	1 day*	1 week	6 weeks	2 weeks	6 months
Right LA	Same	0	0	2	1	3
	Higher	6	4	4	5	3
Left LA	Same	0	0	4	2	6
	Higher	6	4	2	4	0

* Two women were not scanned 1 week postpartum.

One day postpartum the signal intensity of the LA on both sides was lower on the T_1-weighted sequences compared to that of the obturator internus muscle in 4 women, and the same in 2 of women 1–6. The women had the same signal intensity compared to the obturator internus muscle by 2 weeks after delivery. A lower signal intensity persisted in 1 woman 6 months after delivery. For women 7–14 the T_1-weighted sequences were available in 6. The signal intensity of the LA was lower in 4 of them, the same in 1 and higher in 1, compared to the obturator internus muscle.

Muscle Topography

The area of the urogenital hiatus decreased by 27% ($P<0.05$) and that of the levator hiatus by 22% ($P<0.05$) at 2 weeks, compared to 1 day postpartum (Fig. 4). There was considerable variation in the urogenital hiatus area 1 day postpartum (Fig. 5b,d; range 7.5–13.3 cm^2) and a decrease in the area of the urogenital hiatus (range 1%–36%) 6 weeks postpartum. One day after delivery the mean area in all 14 women was 11.7 ± 3 cm^2 for the urogenital hiatus and 18.7 ± 3.9 cm^2 for the levator hiatus.

The perineal body approached the SCIPP line during the puerperium (Figs 6, 7). Sagittal image analysis over the subsequent period revealed an average decrease in the distance between the perineal body and the SCIPP line at 2 weeks, of 13.4 ± 7.3 mm ($P<0.05$). The decrease in this distance between 2 weeks and 6 months was 2.6 ± 5.8 mm (NS), mainly associated with a dorsal translation of the perineal body of 11.5 ± 6.7 mm ($P<0.05$; Fig. 6). As can be seen, the degree of elevation and anteroposterior location varied among women, as did the position of the perineal body 1 day after delivery (Fig. 5a,c).

A dorsally displaced perineal body and a large urogenital hiatus area led to a depressed perineal body and a larger urogenital hiatus 6 months after delivery, compared to the other women.

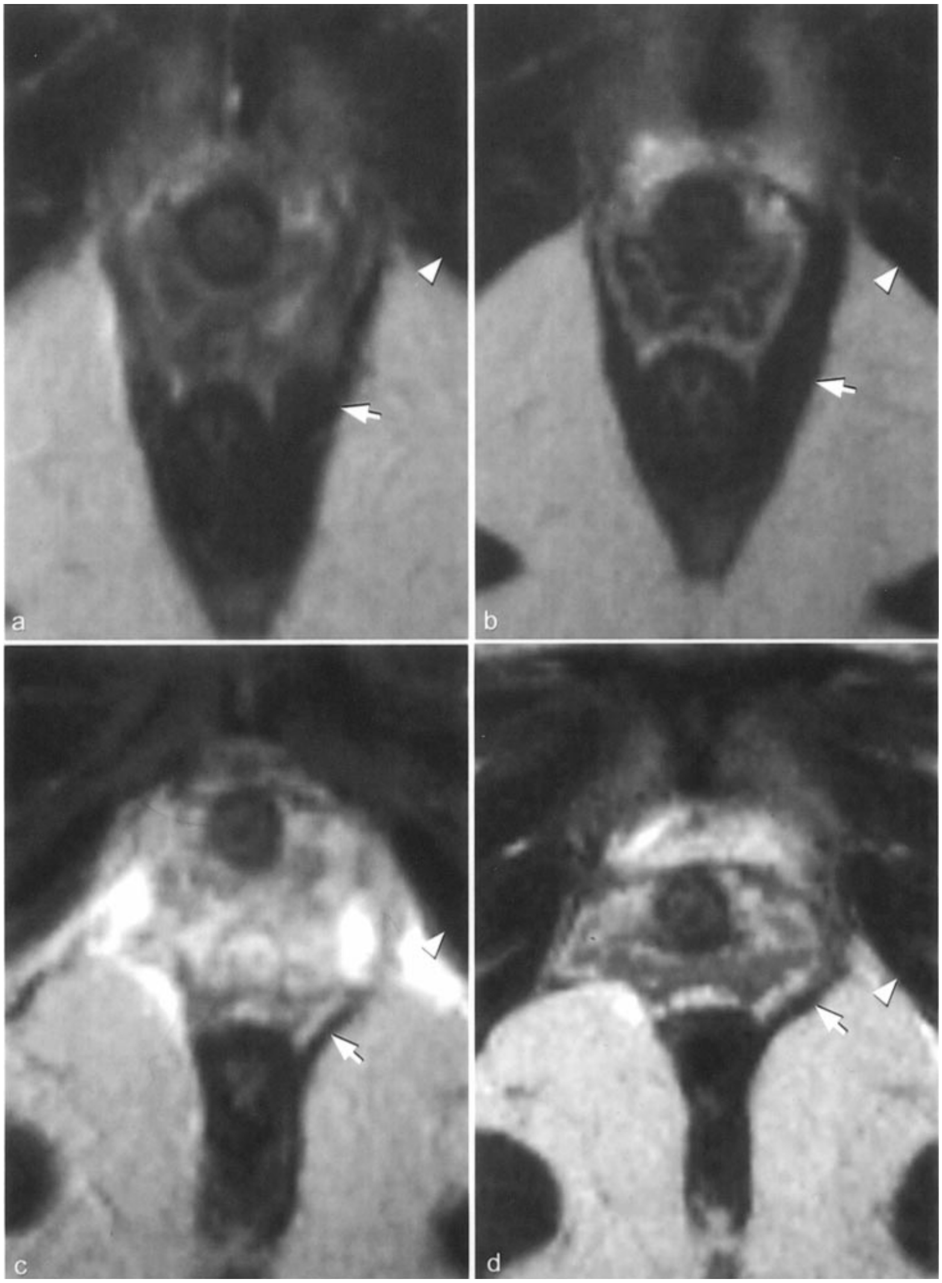

Fig. 3. Changes in T_2-signal intensity of the LA (arrow) on transverse sections following spontaneous vaginal delivery. A 32-year-old woman, para 3, (a, b) with higher signal intensity 1 day postpartum (a) and normal muscle signal intensity 6 months postpartum (b) compared to the obturator internus muscle (arrowhead). A higher signal intensity of the LA is seen 1 day (c) and 6 months (d) postpartum in a 19-year-old woman, para 1, midline episiotomy.

Muscle Thickness

LA thickness varied considerably among the women. With the limited power of this sample size there were no statistically significant differences in LA thickness over time (Table 2). LA thickness measured at the level of the middle urethra did not differ significantly compared to that measured at the proximal level of the urethra. There was a tendency toward a slight decrease in LA thickness 1 week postpartum on both sides. Six months after delivery the mean thickness of the right LA was lower and that of the left LA was thicker than 1 day after delivery.

In 1 woman a complete loss of striated muscle tissue was observed on the right 6 months after delivery (Fig. 8). No significant differences in the measured were found between intra- and interobserver measurements.

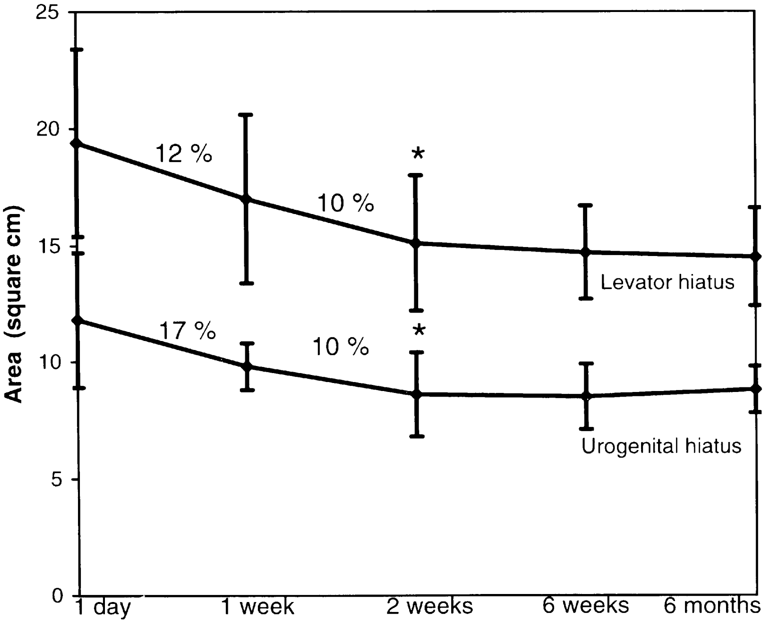

Fig. 4. Mean area of the levator hiatus and urogenital hiatus at the different follow-up examinations in women 1–6. Bar denotes SD. * Significant changes in area within 2 weeks.

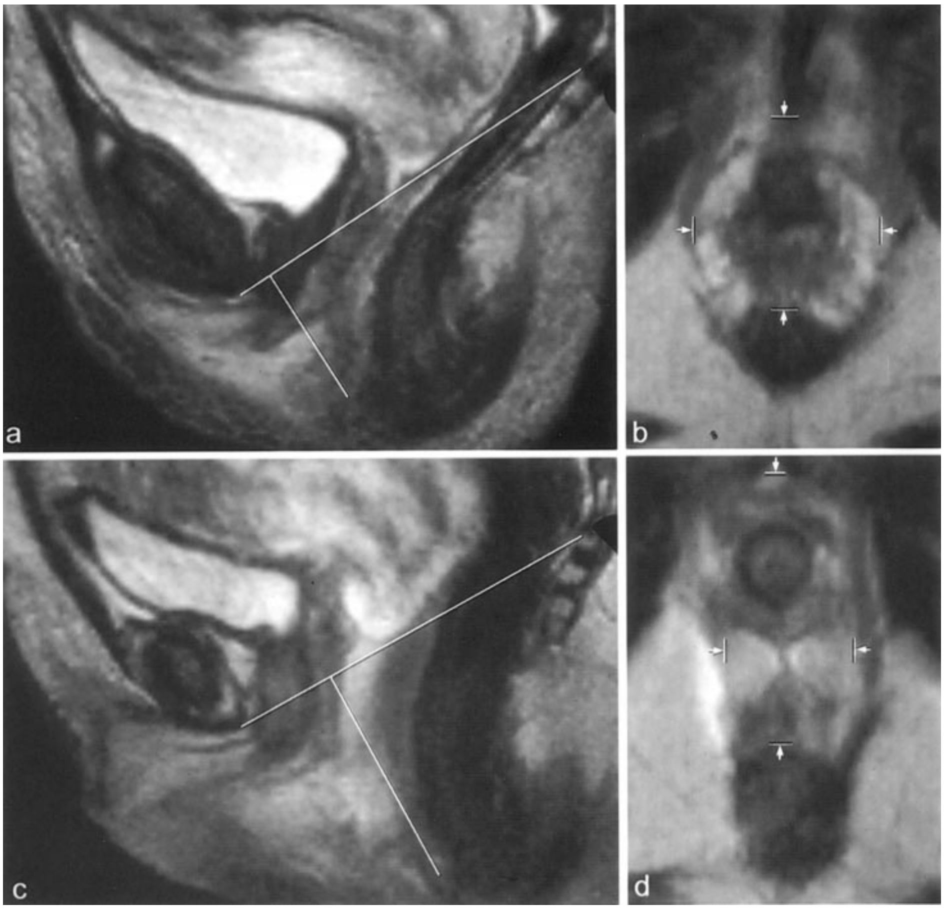

Fig. 5. Examples of sagittal (a, c) and transverse (b, d, at the level of the proximal urethra) T_2-weighted sections to show the variety in tissue stretching 1 day postpartum. Stretching in width (Fig. a, b; 24-year-old woman, para 4) and in length (Fig. c, d; 22-year-old woman, para 2) of the levator hiatus are seen.

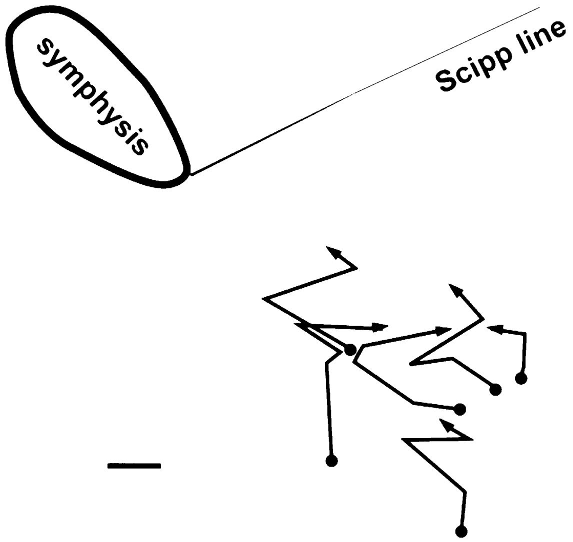

Fig. 6. Displacement of the perineal body at each follow-up examination in women 1–6. One line for each woman; bar shows location of the perineal body 1 day postpartum, arrow denotes 6 months postpartum, kinks in line denote location 1, 2 and 6 weeks postpartum.

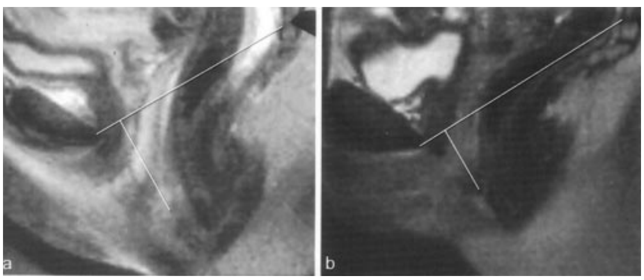

Fig. 7. T_2-weighted sagittal sections of an 18-year-old woman, para 2, 1 day (a) and 6 months (b) after spontaneous vaginal delivery. The perineal body–SCIPP line distance (perpendicular line to SCIPP line) and the length of the levator hiatus were diminished 6 months postpartum compared to 1 day postpartum.

Correlations Between MRI Findings and Patients' Histories

Parity The increased LA T_2-signal intensity compared to that of the obturator internus muscle disappeared in para 1 woman 2 weeks (n = 2) or 6 weeks (n = 2) after delivery. In para 3 (n = 1) and para 4 women (n = 1), on the other hand, the signal intensity returned to that of the internal obturator muscle only after 6 months. Parity did not affect LA thickness and topography (size of the urogenital hiatus, levator hiatus, pelvic floor descent).

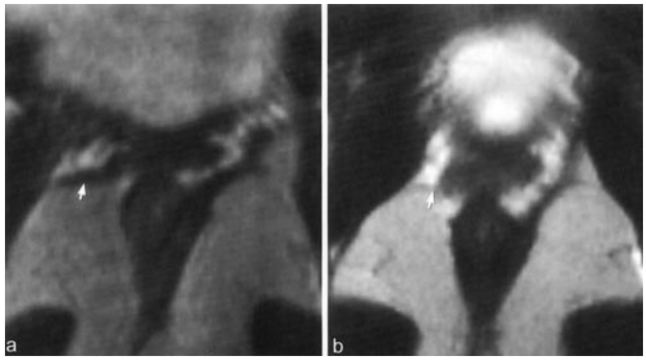

Fig. 8. T_2-weighted transverse sections at the level of the bladder neck of a 20-year-old woman, para 1, after spontaneous vaginal delivery, showing disappearance of LA signal at different follow-up times. (a) Disrupted LA signal in the paravaginal region on the right (arrow) is seen 2 weeks postpartum. (b) Lack of visible signal in the area of the right LA (arrow) 6 months postpartum suggests atrophic changes.

Third-Degree Perineal Laceration A third-degree perineal laceration (n = 2) did not affect the MRI findings of the LA.

Midline Episiotomy In women with midline episiotomy (n = 4) a larger area of the urogenital hiatus (14.6 ± 3.4 cm^2) was seen compared to the women without episiotomy (n = 10; 10.5 ± 2.0 cm^2; $P<0.05$) 1 day postpartum.

Birthweight A higher birthweight correlated with a larger area of the urogenital hiatus 1 day postpartum (n = 12; $P<0.016$). Birthweight had no effect on the decrease in the urogenital hiatus area at the different follow-up times (n = 6).

Discussion

Our results have shown that it is possible to record changes in a number of features of the LA in puerperal women using MRI. They have revealed several interesting phenomena. First, the change in MR signal intensity suggests a change in the chemical composition of the muscle during the first 6 months after delivery.

Table 2. Mean LA thickness (mm) at the level of the proximal urethra at the different follow-up times. Data are presented as mean ± SD

Level and side of LA		Women 1–14 1 day	Women 1–6				
			1 day	1 week	2 weeks	6 weeks	6 months
LATV	Right	4.5 ± 2.1	3.8 ± 2.2	3.5 ± 1.3	4.0 ± 1.7	2.8 ± 1.6	2.7 ± 1.8
	Left	6.3 ± 2.3	5.8 ± 3.2	4.8 ± 2.6	5.6 ± 0.9	4.7 ± 1.1	6.2 ± 0.6
LATR	Right	4.3 ± 1.7	4.2 ± 2.5	2.8 ± 1.0	3.6 ± 1.2	3.0 ± 1.6	3.3 ± 1.4
	Left	5.7 ± 1.6	5.4 ± 2.1	5.1 ± 2.9	4.9 ± 2.1	5.7 ± 1.7	5.9 ± 3.4

LATV, levator ani muscle thickness paravaginal; LATR, levator ani muscle thickness pararectal.

Secondly, return of the normal muscle structure with elimination of postpartum sagging and widening hiatus can be quantified using this technique. Not only can changes in LA thickness be measured, it is also possible to directly assess the size of the urogenital hiatus. Finally, specific localized muscle injury can be seen.

Changes in the size of the urogenital hiatus and in the position of the perineal body relative to the SCIPP line yield information on LA topography. A significant decrease in the area of the urogenital hiatus and a decrease in the distance between the perineal body and the SCIPP line suggest a return to normal LA geometry (resting tone of striated muscle) 2 weeks postpartum. A subsequent significant displacement of the perineum towards the sacrum persisting for up to 6 months after delivery suggests a delayed recovery of connective tissue and smooth muscle in the area of the perineal body and sacrouterine liagment (limitations: patients examined in the recumbent position).

There are several possible explanations for the changes in LA signal intensity that we observed. For example, an increase in water and/or fat content, an increase in extracellular fluid, glycogenolysis and accumulation of lactate are known to cause changes in muscle signal intensity. These changes are reflected by an increase in signal intensity on T_2-weighted sequences (lighter muscle) and a decrease in signal intensity on T_1-weighted sequences (darker muscle) [8–10]. Our results showing the time course of muscle recovery using T_1- and T_2-weighted images agree with those of De Smet [11], who described similar recovery times after skeletal muscle tears. The mechanisms underlying these changes remain to be clarified. Changes in muscle signal intensity have also been studied in other areas of the body. For example, muscle denervation or infarction can cause decreased signal intensity on T_1-weighted images and increased signal on T_2-weighted images [12]. Following resolution of the paralysis or the infarction, a return of the high signal intensity to normal was observed after about 2.5–3 months [13]. Nerve injury [14] and transient ischemia are known to be associated with vaginal delivery. It is thus plausible that the changes we observed in muscle signal intensity reflect changes in muscle structure.

It is interesting that different MRI characteristics of the LA had different time courses of recovery. Although the elongation of the muscle, as evidenced by the increased size of the urogenital hiatus and descent of the perineal body, returns to normal (in the resting supine position) relatively rapidly, the internal chemical changes are not completely back to normal (compared to the obturator internus muscle) as late as 6 months after delivery. This may reflect different types of injury. Intracellular disaggregation of sarcomeres is repaired within a few weeks, whereas neurologic damage, especially if it occurs near the spinal cord, may take months to recover [15]. Tracking the time course of these changes may help us to deduce what type of injury is responsible for each type of damage.

Complete recovery of normal LA contractility is known to take 6 months [16].

The MRI techniques we used also identified isolated injuries. For example, we observed a complete loss of the right proximal paravaginal LA (iloecoccygeal muscle) in 1 woman 6 months after delivery (still partly present after 2 and 6 weeks) and an increase in the thickness of the left LA. This observation might be due to partial peripheral denervation, or a tear of that muscle. De Smet [11] described atrophy after muscle injury and a compensatory hypertrophy of adjacent muscles, but the MRI appearance of the injured muscle was variable. He emphasized that the muscle may remain disrupted, may atrophy at the site of tear, or may remain unchanged in size. However, muscle function cannot be inferred from an image.

A slight reduction in LA thickness 1 week postpartum depends on the decrease in edema. Acute intramuscular hemorrhage can cause an enlarged muscle, and resorption of the hematoma will result in a thinner muscle [17].

The right–left differences in LA thickness, particularly of the paravaginal part of the LA, result from the presence of chemical shift artifacts [18], which we have noted on these scans.

The chemical shift artifact also affects the subjective assessment of the signal intensity. In particular, the muscle signal intensity on the right side must be interpreted with caution. MRI studies without the right–left chemical shift artifact (i.e. using left-to-right phase-encoding direction) are necessary to avoid these limitations in image quality. Computer-measured values were not available, therefore slight signal intensity changes were not recognized during the follow-up examinations. In the investigators' experience evaluation of the MR images 1 day after delivery is difficult because of tissue stretching and edema.

In addition, this retrospective study, with its limited power of the sample size and heterogeneity both in parity and subpartal management, and missing clinical investigations to objectify pelvic floor dysfunctions, does not allow functional interpretation of the MRI findings. However, changes in levator ani muscle signal intensity, topography and thickness during the puerperium were successfully documented using MRI. The correlations seen between MRI findings and parity, birthweight and intrapartal management are a preliminary confirmation that MRI is a useful tool to obtain more information about intra- and postpartum changes in LA. The correlations found between birthweight and size of the urogenital hiatus were not surprising, but they had no effect to the extent of LA recovery. The prolonged persistence of changes in LA signal intensity in multiparous women suggests a change in LA tissue structure compared to nulliparous women.

As one might expect from clinical experience, remarkable variations in LA structure changes are found among different individuals. One woman's delivery may leave the pelvic floor almost unchanged, whereas others may have profound changes in muscle geometry and signal intensity. Larger studies are necessary to define the variations of what is normal recovery and what injury is associated with long-term symptomatic problems.

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EDITORIAL COMMENT: MRI has become a valuable research tool for the understanding of the pelvic floor in health and disease. This paper reports on the levator ani muscle from the immediate postpartum period to 6 months later. The results suggest a return to normal within 2 weeks after delivery in most patients. Significant decreases occurred in the urogenital hiatus and the levator hiatus, along with an elevation in perineal body position. Studies such as this are welcome and add significantly to our understanding of the pathophysiology of the pelvic floor.

Review of Current Literature

Behavioral vs Drug Treatment for Urge Urinary Incontinence in Older Women: A Randomized Clinical Trial

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JAMA 1998;280:1995–2000

Over 38% of older community-dwelling women have incontinence. This study was a randomized comparison of biofeedback-assisted behavioral treatment, drug therapy, and placebo for urge incontinence. Thorough evaluation preceded treatment. Patients were given 2 weeks of diaries. Urodynamic evidence of bladder dysfunction was a requirement. The baseline bladder diaries were used to stratify subjects as having mild, moderate or severe incontinence. Patients completed a daily diary throughout treatment. Subjects had only four clinic visits, with biofeedback sessions being used at two of them. Home exercises were performed using 45 pelvic muscle exercises every day. Drug treatment was titrated on a per-patient basis, but oxybutynin was commenced at 2.5 mg three times daily. After treatment subjects completed another diary and had a cystogram. The attrition rate was 6.2% in the behavioral group, 17.9% in drug treatment, and 18.5% in controls. Behavioral training resulted in 80% improvement, and more patients in this group had 50% and 75% reduction of incontinence.

Comment

Biofeedback-assisted behavioral training is an effective and conservative treatment for large numbers of patients with urge incontinence. Many subjects (10.4%) were unable to continue Ditropan therapy. The significant improvement in the control group was observed with some interest. The bladder diary was the predominant outcome measure.