Three-dimensional magnetic resonance imaging assessment of levator ani morphologic features in different grades of prolapse

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OBJECTIVE: The study was undertaken to identify the morphologic changes in the levator ani in different grades of prolapse by using reconstructed three-dimensional models of magnetic resonance images (MRI) and to subclassify prolapse into different categories on the basis of their levator ani morphologic characteristics.

STUDY DESIGN: Sixty-one women were studied, 8 women in stage I, 15 women in stage II, 22 women in stage III, 7 women in stage IV prolapse, and 9 asymptomatic volunteers with stage 0 prolapse. Axial, sagittal, and coronal T2-weighted pelvic magnetic resonance scans were obtained with the patient in the supine position. The three-dimensional models were reconstructed from the source images by using manual segmentation and surface modeling. The morphologic characteristics of the puborectalis were assessed on these reconstructed models by measuring (1) the levator symphysis gap, (2) the width of the levator hiatus, and (3) the length of the levator hiatus. To assess the iliococcygeus, we measured (1) the maximum width of the iliococcygeus, (2) the direction of its fibers that was assessed by measuring the iliococcygeal angle, and (3) the levator plate angle. Nine nulliparous asymptomatic women were studied as controls.

RESULTS: Alterations in levator ani morphologic features are not dependent on the grade of the prolapse, and not all women with pelvic floor prolapse have abnormal morphologic features. In healthy control subjects, the iliococcygeal width measured less than 40 mm and the iliococcygeal angle measured less than 20 degrees. On the basis of the MRI findings, four patterns of changes in the levator ani have been identified. Both the levator symphysis gap and the levator hiatus, which is dependent on the puborectalis function, widen with increasing grade of prolapse.

CONCLUSION: It is possible to subclassify prolapse on the basis of morphologic changes in the levator ani by using MRI. This may be a very useful predictor as to which patients have recurrent prolapse develop after surgery. (Am J Obstet Gynecol 2003;188:910-5.)

Key words: Magnetic resonance imaging, pelvic floor, levator ani, prolapse

The levator ani plays an important role in supporting the pelvic organs. Cadaveric studies of the levator ani muscle are tedious because it lies hidden in the pelvis. Visualization with magnetic resonance imaging (MRI) enables a clear assessment of the pelvic floor architecture, muscles, and fascia. Strohbehn et al9 reported a good correlation between the cadaveric dissection and MRI findings. Ozasa et al10 studied the integrity of the levator plate as a predictor of uterovaginal support. Kirshner-Hermanns et al11 reported increased signal intensity on MRI as evidence of muscle atrophy. Tunn et al12 have highlighted the effects of childbirth on the levator ani. The three-dimensional modeling is an advancement in the presentation and interpretation of the MRI images. It allows volumetric analysis to be performed and clarifies the spatial relationship of anatomic structures. Fielding et al13 have used three-dimensional MRI analysis to study the levator ani volume and have produced estimates of the normal range of levator volume (39-57 mL) in a group of asymptomatic women. Hoyte et al14 studied the levator volume in different subgroups of women with pelvic floor dysfunction and found that the levator volume was lowest in women with prolapse. Subsequently, they compared the morphologic features of this muscle in normal, continent, and prolapse patients and highlighted the importance of the levator symphysis gap (LSG) in the development of stress incontinence.15

We understand that the levator ani is important for pelvic floor function and support. We do not know whether all women with pelvic floor prolapse have identi-
fiable morphologic changes in the levator ani or whether the changes in the levator ani vary with the grade of prolapse.

We compared the morphologic features of the levator ani of women with uterovaginal prolapse with those of asymptomatic nulliparous women. We have correlated these morphologic changes in different grades of uterovaginal prolapse.

**Material and methods**

There were 61 women in this study; a control group of 9 women and a study group of 52 women. All were selected from the gynecology outpatients at Royal Free Hospital, London, United Kingdom. Ethical permission was obtained. The women in the study group had upper vaginal prolapse, with recurrent prolapse or with multi-compartment uterovaginal prolapse. There were 8 women in stage I, 15 women in stage II, 22 women in stage III, and 7 women in stage IV prolapse. The control group consisted of healthy nulliparous, premenopausal (age range 23-42 years) volunteers with no previous pelvic surgery. No other risk factors such as constipation, previous hernia repair, varicose veins, or chronic cough were present. A vaginal examination was not performed and in view of the selection criteria were assumed to have no pelvic organ prolapse.

All symptomatic women had a standardized assessment of their symptoms and grading of their pelvic floor prolapse (International Continence Society 1996). All the patients were examined in the left lateral and supine position. Pelvic Organ Prolapse Quantification was not repeated in the upright position as all the MRI scans were also performed in the supine position. Each subject gave informed consent before having the MRI scans, and any woman with a contraindication to MRI was excluded from the study.

MRI was performed with a 1.5 T Philips Gyroscan (Philips, Amsterdam, The Netherlands) in the supine position in three different planes (coronal, axial, sagittal). Static T2 turbo spin echo images were obtained at 5-mm slice thickness with no gap, with a field of view of 280, matrix 230 × 512, TR 6086/TE150, 4NEX, and 4.5 minutes acquisition time per plane. Only static images were analyzed in this study because there are difficulties in standardizing the Valsalva strain effort during an MRI scan. The MRI data were electronically transferred to a Sun Ultraspare-30 graphics

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**Fig 1.** Three-dimensional model of levator ani and obturator ani in anteroposterior view showing measurements of width of ilio-coccygeus. IC, ilio-coccygeus; PR, puborectalis; OI, obturator internus; ICW, ilio-coccygeus width.

**Fig 2.** Three-dimensional model of levator ani and obturator ani in posteroanterior view showing measurements of ilio-coccygeal angle. IC, ilio-coccygeus; PR, puborectalis; OI, obturator internus; ICA, ilio-coccygeal angle.

**Fig 3.** Three-dimensional model of levator ani in axial view showing measurement of levator symphysis gap (white arrow) and levator hiatus (dotted black arrow). pr, Puborectalis; ic, ilio-coccygeus.
computer workstation (Sun Microsystems, Mountain View, Calif). The levator ani, pubic symphysis, ischial spines, and the sacrococcygeal bone were segmented from the coronal, axial, and sagittal slices and then labeled by using a combination of semiautomated and manual editing. The data were manually segmented by using advanced multiplane image analysis software (3D Slicer, Massachusetts Institute of Technology, Boston, Mass) developed inhouse. We generated three-dimensional surface models from the outlined structures by the use of a weak gaussian smoothing, followed by a pipeline that consisted of the marching cube, triangle reduction, and a triangle smoothing algorithm and a surface-rendering method. The final results were viewed on a workstation with graphics acceleration, and specialized measurement software was used to compare the linear and volume measurements of the on-screen rendering. Alterations in the configurations of the puborectalis and iliooccygeus were studied separately.

MRI parameters of measurements in this study

The width of the iliococcygeus. The width of the iliococcygeus was measured on both sides at the level of the ischial spines in a coronal view of the generated models. This corresponded to its posterior most fibers (Fig 1).

The iliococcygeal angle. The iliococcygeal angle is the angle formed between the maximum width of the pelvic surface of iliococcygeus and the interspinal plane in a coronal view of the generated models (Fig 2). It assesses the slope of the iliococcygeus.

The levator-symphysis gap. The levator-symphysis gap was measured on both sides as the distance from the anterior most aspect of the levator ani sling to the closest point of the symphysis pubis on axial view (Fig 3).

The levator hiatus. The levator hiatus was measured from the back of the inferior border of symphysis to the curve of the levator ani on the axial plane. This assesses the anterior-posterior dimensions of the puborectalis. The widest transverse diameter of the levator hiatus on the axial plane was also measured (Fig 3).

The levator plate angle. The levator plate angle was measured on the midsagittal plane as the angle between the levator plate and the pubococcygeal plane (Fig 4). Any asymmetry of the muscles was also noted.

Statistical analysis. The Minitab statistical package (State College, Pa) was used to analyze the data. Descriptive statistics were calculated for each of the above-described measurements and stratified on the basis of subject group. The results are given as mean values with SD. Statistical significance was assigned to a P value of less than .05. Kruskal-Wallis analysis of variance (nonparametric analysis) was used to assess the significance of changes in the measurements in different stages of prolapse.

Results

All the subjects tolerated the MRI scans well. Good quality of source images were obtained and we were able generate the three-dimensional models and perform the measurements without any difficulty.

The levator ani model in a healthy woman is shown in Fig 1, A. The puborectalis was oriented along an inferior and medial plane and the iliococcygeus along a superior and lateral plane. The puborectalis was oriented vertically as a sling around the midurethra, vagina, and the anorectum, whereas the iliococcygeus had a horizontal upwardly biconvex shape resembling the appearance of a “butterfly wing.” The iliococcygeus was narrow anteriorly and broadened posteriorly with the maximum width at the level of the ischial spines. There was a sharp angulation between the puborectalis and the iliococcygeal part of the levator ani. The iliococcygeal angle (ICA), which measured the slope of the iliococcygeus, measured less than 20 degrees in all women in the control group with a mean of 14.8 de-
degrees. The maximum width of the iliococcygeus was more than 40 mm in all the women in the control group with mean width of 46.8 mm. The levator ani was symmetric on both sides in all the controls. The mean levator symphysis gap was 17.7 mm.

In the study group the shape of the iliococcygeus was abnormal in all patients but there were different abnormalities depending on the grade of prolapse. The mean ICA and iliococcygeus width (ICW) in stages I, II, III, and IV are presented in Table II. The changes in the ICA were not statistically significant with increasing severity of the prolapse ($P = .7$). The alteration in the ICW also did not significantly change with increasing severity of prolapse ($P = .4$) but was related to the change in the iliococcygeal angle. As the ICA increases there is decrease in the horizontal orientation of the iliococcygeal and it becomes more vertically aligned and makes the pelvic diaphragm adopt a concave upward slope like a basin. As the horizontal configuration of the iliococcygeal changes, the ICW also decreases. On the basis of the ICA and the ICW, we were able to see four patterns of changes in the iliococcygeal morphologic features in different categories of prolapse (Table III) (Fig 5, A, B, C, and D).

The levator ani morphologic characteristics of all the nulliparous controls belonged to group 1. Group 2 represented changes in the angle of the iliococcygeus where the ICW is maintained. In group 3 there is alteration in both the angle and the ICW. Group 4 is the rarest, where there is decrease in the ICW but it was still horizontally oriented (ie, the ICA is maintained). Both these women were nulliparous. There were no nulliparous women in the other groups.

When women with prolapse were classified according to the configuration of their iliococcygeus, we found that all cases with advanced stage prolapse (stage III/IV) had abnormal levator ani morphologic features. Not all cases

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**Table II. MRI measurements are shown as the mean value in different stages of prolapse**

<table>
<thead>
<tr>
<th>Stage (n = 61)</th>
<th>ICA</th>
<th>ICW (mm)</th>
<th>LSG</th>
<th>Levator hiatus (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>0 (n = 9)</td>
<td>Mean</td>
<td>14.6 15</td>
<td>48.4 45.3</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>15 18</td>
<td>49 45</td>
<td>18</td>
</tr>
<tr>
<td>I (n = 8)</td>
<td>Mean</td>
<td>23 27.6</td>
<td>43.1 19.3</td>
<td>19.3</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>23.5 24</td>
<td>41.5 39</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>7.5 9.4</td>
<td>8.4 12.56</td>
<td>6.2 8.3</td>
</tr>
<tr>
<td>II (n = 15)</td>
<td>Mean</td>
<td>24.4 25.5</td>
<td>37.6 36.1</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>23 22</td>
<td>36 37</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>11.8 12.4</td>
<td>10.1 10</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>9-52 11-50</td>
<td>22-57 21-55</td>
<td>10-50</td>
</tr>
<tr>
<td>III (n = 22)</td>
<td>Mean</td>
<td>33.7 32.7</td>
<td>38.9 38.64</td>
<td>22.8</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>31.5 31</td>
<td>37.5 37</td>
<td>22.5</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>10.9 11</td>
<td>7.5 9</td>
<td>8</td>
</tr>
<tr>
<td>IV (n = 7)</td>
<td>Mean</td>
<td>34.7 38.1</td>
<td>37.7 33.9</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>34 35</td>
<td>39 31</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>17.5 20.2</td>
<td>8.2 8.1</td>
<td>12.7 10.7</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>1-50 6-69</td>
<td>29-51 25-48</td>
<td>7-12</td>
</tr>
</tbody>
</table>

AP, Anteroposterior distance.

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of early-stage prolapse (stage I/II) had abnormal morphologic features. In early-stage prolapse, the different patterns of change in the iliococcygeus were more variable. In stage I prolapse, the changes in the iliococcygeus were distributed equally in all four groups. In stage II prolapse, 27% (4/15) women had normal configuration of the iliococcygeus but 60% (9/15) were in group 3. In advanced stages of prolapse (III/IV), there were no women in group 1 (ie, there was alteration in the iliococcygeal morphologic characteristics in all the women) and 69% (20/29) were in group 3.

The levator symphysis gap (LSG) increases with increasing stage of prolapse, which may indicate decompensation of the continence mechanisms with increasing severity of prolapse (Table II).

In all controls, the muscle morphologic features were symmetric, whereas 15 of 52 women with prolapse exhibited asymmetry caused by deficiencies in the puborectalis sling.

The levator hiatus is dependent on the puborectalis function but no statistically significant increase in the levator hiatus was seen with the increasing stage of prolapse ($P = .1$).

This was a pilot study and the number of subjects under study were small. If the differences observed in this study between stage 0 and stage IV were real, the difference between groups could be detected with 90% power at the 5% significance level if 16 subjects had been recruited in each group.

**Comment**

On the basis of the MRI findings, four patterns of levator ani changes have been identified in women with uterovaginal prolapse. The alterations in the levator ani morphologic characteristics are not dependent on the severity of prolapse, and not all women with pelvic floor prolapse have abnormal morphologic features of the levator ani. In early stages (stage I) of prolapse the normal morphologic characteristics (group 1) of the levator ani are maintained, whereas all women with advanced stage of prolapse (stages III/IV) have abnormal levator ani morphologic features. The majority of patients with advancements prolapse (stages III/IV) had group three morphologic changes of their levator ani.

The decision regarding the type of repair surgery does not always take into account the preoperative condition of the pelvic floor muscles. Clinical assessment grades the prolapse on the basis of the severity of pelvic organ descent but cannot identify the causative lesion for prolapse. Even though the current study is just pilot data and does not yet support any change in clinical practice or standard of care, the preoperative anatomic assessment of the levator ani may prove to be a prognostic indicator for recurrent prolapse. There is not only a high rate of recurrence of prolapse after surgical repair, the time interval between repeat procedures also decreases with each successive repair.$^{18}$ So far decision making in pelvic reconstructive surgery has been exclusively on the basis of clinical and functional assessment, which have a limited role in assessing the pathomorphologic changes leading to pelvic floor dysfunction. Assessment of the anatomic alterations and evaluation of function should both form part of a preoperative assessment of the pelvic floor.

The three-dimensional reconstruction allows a spatial assessment of the pelvic floor, which facilitates visualization of the causative lesion of prolapse. There are different alterations in the configuration of the levator ani in different women with a similar grade of prolapse. We put forward the proposal that women with a normal configuration of their iliococcygeus (group 1) may require a fascial repair only, when the configuration is altered then they may require a compensatory corrective surgery involving suspension or use of a supportive prosthesis. In vivo imaging of the muscle using magnetic resonance...
may thus enable the assessment of the changes in the configuration of the levator ani muscle, which may influence the further management of these patients.

The levator ani though regarded as a single muscle is composed of two functional components (1) a supportive component that is horizontally oriented (ie, the iliococcygeus) and (2) the sphincteric component that is vertically oriented (ie, the puborectalis). Weakness of levator ani may result in pelvic floor prolapse or the weight of the prolapsed pelvic organ may cause the horizontal component to become more vertical. The order of change in the levator ani morphologic features that we have shown may enable us to identify the pathogenesis of the urovaginal prolapse. First of all, the ICA increases, resulting in the iliococcygeus becoming less horizontal. Further, there is a decrease in the ICW. As the horizontal component of the levator ani becomes incorporated into the vertical component, there is an apparent increase in height of the puborectalis (Fig 6), which may be associated with perineal descent. Alterations in the levator ani morphology (group 4) as seen in the two nulliparous women may also assist our understanding of the pathophysiology of prolapse in these women. Because both these women had chronic constipation and normal genital hiatus with markedly reduced ICW, it is right to say that only the supportive component of the levator ani is altered in women with prolapse resulting from increased intra-abdominal pressure, whereas prolapse resulting from childbirth affects both the components of the levator ani.

Hanzal et al have correlated the long-term outcome of vaginal repair surgery with levator ani morphology on muscle biopsies taken preoperatively and found it an important prognostic factor in the final outcome of the repair surgery. Hoyte et al in their comparison of normal, incontinent, and prolapse patients demonstrated the widest LSG in the prolapse patients (15.6, 20.3, and 23.8). Our study demonstrates an increase in the LSG with increasing severity of prolapse (17.4, 19.9, 25.9, 27.3, 28.1 in stages 0, I, II, III, IV prolapse). The LSG reflects the function of the puborectalis component of the levator ani, which maintains the function of the urethra and external anal sphincter and constricts the vagina. Hoyte et al have shown that MRI assessment is an important component to the management of women with urinary incontinence. When the LSG is maintained, patients may benefit from conservative treatments but if the LSG is defective, then physiotherapy may not be useful in the management of these women. The levator hiatus is dependent on the puborectalis function and also progressively increased with increasing stage of prolapse.

MRI assessment of the pelvic floor muscles is an important component in the evaluation of the women with pelvic floor disorders. Subclassifying prolapse on the basis of their levator ani morphologic features on MRI may be a predictive factor indicating a course of progression of the severity of the prolapse and may be a marker for recurrence after corrective surgery. It may thus help in planning the type of prolapse surgery offered to a patient.

REFERENCES