Prolapse of pelvic organs in a female can be simple or complex. To make a definite diagnosis of pelvic prolapse preoperatively, dynamic magnetic resonance (MR) is an alternative to conventional fluoroscopic or sonographic examination, with the advantage of providing greater details, and thus helping the surgeon to have a good preoperative plan. Nine women suffering from pelvic prolapse with or without urinary stress incontinence underwent dynamic MR imaging examination (1.0T Magnex100/HP, Shimadzu, Kyoto, Japan) before surgery. All patients were examined in the supine position. A single-shot ultra-high speed scan (FE/8/3.02-20°, 128, 100%-100% 1 NEX 1 slice 10 mm L 1.0 second) was used to obtain midline sagittal images, with the patients at rest and during pelvic strain. MR images were then obtained every 4 seconds. Each examination was analyzed, based on specific measurements, to determine the presence and extent of prolapse of pelvic organs. The pubococcygeal, levator hiatus width and muscular pelvic floor relaxation lines, and the angle of the levator plate were identified. Based on these measurements, multicompartiment involvement in the pelvic prolapse was confirmed in five patients (5/9). Four patients (4/9) had single compartment involvement. Seven patients underwent surgery. All patients reported significant improvement in their symptoms and signs after surgical intervention. Two patients had an almost complete recovery. MR demonstrated simple or complex organ descent in all pelvic compartments, and may become a standard preoperative examination for pelvic floor abnormalities. The MR images facilitated comprehensive planning by the surgeon; thus, they can increase the success rate and help to accurately predict the outcome of the surgical intervention. The surgeons also expressed high postsurgical satisfaction with the information provided by dynamic MR.

Key Words: dynamic magnetic resonance, magnetic resonance imaging, pelvic prolapse

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Female pelvic prolapse can be simple or complex. Anatomic defects can include a combination of cystocele, uterine prolapse, enterocele, and rectocele. Accurate diagnosis of coexisting abnormalities is essential for planning reconstructive procedures so that the risks of recurrence and re-operation can be minimized.

In the United States, dynamic magnetic resonance imaging (MRI) has been used for many years as an important and practical examination for evaluating female pelvic prolapse [1]. The rapid T2-weighted imaging technique has made it possible to obtain urodynamic images with MRI, similar to conventional dynamic studies such as fluoroscopy and sonography. In Taiwan, the value of MRI is limited because of our

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national healthcare policy. Dynamic MRI is a relatively new technique here, and no standardized protocol or grading system is available.

After a review of the international literature, we performed dynamic MRI in nine patients, mainly as per the method of Comiter et al [1]. We would like to highlight the value of dynamic MRI, a noninvasive modality, for the preoperative diagnosis of pelvic prolapse. Dynamic MRI provides the surgeon with detailed information to help make a good preoperative plan.

**MATERIALS AND METHODS**

Nine female patients, who were known to have pelvic prolapse based on physical examination, received dynamic MRI examination (1.0T Magnex100/HP, Shimadzu, Kyoto, Japan) before surgery. No preparation was needed for the examination. Patients were not allowed to use the toilet before the examination to ensure that the urinary bladder was distended. Our MRI protocol included axial and sagittal planar screening of the pelvic cavity and a dynamic study. Coronal planar imaging was optional. The examination was completed within 15 minutes. All patients were examined in the supine position. A rapid sequence was used. An initial sagittal image of the patients at rest was taken with single-shot ultra-high speed scan (FE/8/3.02-20°, 128, 100%-100% 1 NEX 1 slice 10 mm 1.0 second), followed by a second series of images with the patients straining their pelvic floor muscles using Valsalva’s maneuver. The cycle was repeated two times. All phases of magnetic resonance (MR) images were obtained, taken every 4 seconds. Images in the sagittal plane best demonstrate the relationship of the pelvic organs to each other and the pelvic floor. The last sagittal slice was acquired during maximum pelvic strain. The dynamic and cycling MR images were compared (Figure 1).

We used the HMO (H-line, M-line, organ descent) classification, a straightforward and simple grading system, for evaluating pelvic floor relaxation and prolapse [1,2]. The radiologist identified and reported the following landmarks, lines, and angles: (1) pubococcygeal line (PCL)—a fixed anatomic reference joining the inferior border of the symphysis pubis to the junction of C1 and C2. This line represents the level of the pelvic floor. (2) The H-line (levator hiatus width)—measures the distance from the inferior margin of the symphysis pubis to the puborectalis sling (posterior rectoanal junction). (3) The M-line (muscular pelvic floor relaxation)—measures the shortest distance between the PCL and H-line. Both H- and M-lines are used for confirming pelvic floor laxity. Organ descent >1 cm below the PCL indicates pelvic floor laxity. Organ descent >2 cm is often indicative of the need for surgical intervention. During straining, the H- and M-lines are usually not more than 6 cm and 2 cm, respectively, in the normal population. The O-grading (organ prolapse distance) characterizes the degree of visceral prolapse beyond the PCL [2]. Organ descent <3 cm below the PCL indicates small prolapse. Organ descent of 3–6 cm means moderate prolapse. Organ descent >6 cm represents large prolapse. The levator plate should be parallel to the PCL in the normal state. An increased caudal inclination of the levator plate indicates a loss of posterior muscular support. Angulation >10° is indicative of significant posterior weakness. The PCL, H-line, M-line, angle of the levator plate, and organ prolapse distance from the PCL were identified on images obtained while the patients were at rest and during maximal pelvic strain (Figure 2). Each image was analyzed to determine the presence
and extent of the prolapse of pelvic organs based on those specific measurements.

Based on the MRI criteria, a cystocele or urethrocele was diagnosed when the base of the bladder or proximal urethra was below the PCL. If the vaginal vault or any part of the cervix descended below the PCL during straining, a prolapse of the vaginal vault or uterus was diagnosed. Rectocele was defined as a bulge >3 cm, measured as the distance from the extended line of the anterior anal canal border to the tip of the rectal descensus, using the criteria set by Lienemann et al [3]. A wide rectovaginal space or deep pouch of Douglas with the peritoneal contents (omentum, mesentery, sigmoid) with or without small bowel loops beyond the PCL was considered to be an enterocele.

**RESULTS**

In all patients, the study was considered to be satisfactory. All the female patients suffered from urethral hypermobility syndrome (Table). According to the MRI measurements, four patients (4/9) had single compartment abnormalities, i.e. cystoceles. Multicompartment involvement was confirmed in five patients (5/9). In three cases, there was joint prolapse of the anterior (cystocele) and middle (2 uterine prolapse and 1 enterocele) compartments (Figure 3), and in two cases, there was joint prolapse of the anterior (cystocele) and posterior (rectocele) compartments. Seven patients received surgical correction. All patients reported significant improvement of their symptoms and signs after surgical intervention. Five patients showed partial recovery. Two patients had complete recovery. High satisfaction was also recorded from the surgeon.

**DISCUSSION**

After childbirth, pelvic floor weakness may not always be a health problem. Thus, imaging of asymptomatic...
women is of limited value. Relevant symptoms and signs are found in 10–20% of parous women over 50 years of age; the most common symptoms include pelvic pressure, protrusion of tissue through the pelvic floor, and urinary incontinence [4,5]. Imaging studies are important for any interventional management. Traditionally, dynamic and conventional fluoroscopic or sonographic examinations have been used to evaluate pelvic prolapse in symptomatic women. In Taiwan, bead-chain cystourethrography is the most commonly chosen technique for examining women who have urinary stress incontinence [4,5]. Imaging studies are important for any interventional management.

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**Table. Summary of clinical cases**

<table>
<thead>
<tr>
<th>Case</th>
<th>Age, sex</th>
<th>Clinical finding</th>
<th>PH: ATH</th>
<th>MRI finding: compartment</th>
<th>Diagnosis</th>
<th>OP</th>
<th>Clinical outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>71, F</td>
<td>Urine leakage and mass protrusion from perineum for months</td>
<td>Yes</td>
<td>Single</td>
<td>SUI, cystocele</td>
<td>Yes</td>
<td>Partial recovery</td>
</tr>
<tr>
<td>2</td>
<td>63, F</td>
<td>Vaginal mass protrusion with frequency and urgency for 1 year</td>
<td>Yes</td>
<td>Single</td>
<td>SUI, cystocele</td>
<td>Yes</td>
<td>Partial recovery</td>
</tr>
<tr>
<td>3</td>
<td>66, F</td>
<td>Vaginal prolapse for years</td>
<td>No</td>
<td>Multiple</td>
<td>Cystocele, rectocele</td>
<td>Yes</td>
<td>Partial recovery</td>
</tr>
<tr>
<td>4</td>
<td>44, F</td>
<td>Urine leakage with pelvic pressure sensation for 2 years</td>
<td>No</td>
<td>Multiple</td>
<td>SUI, cystocele, uterine prolapse, ovarian cyst</td>
<td>Refused</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>70, F</td>
<td>Urine leakage and vaginal prolapse for years</td>
<td>No</td>
<td>Single</td>
<td>SUI, cystocele</td>
<td>Yes</td>
<td>Complete recovery</td>
</tr>
<tr>
<td>6</td>
<td>61, F</td>
<td>Pelvic bulging mass with voiding frequency and urgency for 1 year</td>
<td>No</td>
<td>Multiple</td>
<td>SUI, cystocele, uterine prolapse</td>
<td>Yes</td>
<td>Partial recovery</td>
</tr>
<tr>
<td>7</td>
<td>50, F</td>
<td>Urine leakage with vaginal bulging mass for years</td>
<td>Yes</td>
<td>Multiple</td>
<td>SUI, cystocele, rectocele</td>
<td>Refused</td>
<td>–</td>
</tr>
<tr>
<td>8</td>
<td>67, F</td>
<td>Mass protrusion from perineum for years</td>
<td>Yes</td>
<td>Multiple</td>
<td>Cystocele, rectocele</td>
<td>Refused</td>
<td>–</td>
</tr>
<tr>
<td>9</td>
<td>55, F</td>
<td>Urine leakage with vaginal bulging mass for years</td>
<td>No</td>
<td>Single</td>
<td>SUI, cystocele</td>
<td>Yes</td>
<td>Complete recovery</td>
</tr>
</tbody>
</table>

ATH = anterior total hysterectomy; MRI = magnetic resonance imaging; SUI = stress urinary incontinence.

**Figure 3.** A 58-year-old woman in whom sagittal magnetic resonance imaging T2-weighted image (T2WI) shows significant descending of the bladder base and uterus below the pubococcygeal line (PCL). It is defined as a multicompartament type of pelvic prolapse including the anterior and middle compartments.
the rectum. The endopelvic fascia and the levator ani muscles support each of these compartments. The two most important components of the levator ani supporting the pelvic organs are the iliococcygeal and the puborectal muscles. The iliococcygeal muscle fibers fuse anteriorly with the coccyx to form a midline raphe called the levator plate [4]. This is an important structure to monitor for pelvic floor weakness.

The mainstay of diagnosis in symptomatic pelvic floor damage is physical examination. According to one study, physical examination and MRI findings were very concordant in the diagnosis of pelvic prolapse, and statistical correlations with the stages of prolapse were established between both methods ($p<0.01$ for anterior and middle compartments, $p<0.05$ for posterior compartment) [6]. In fact, imaging is also useful in patients with equivocal findings at physical examination. MRI is more sensitive than physical examination for identifying enterocele, and it enables clinicians to rule out other concomitant pelvic pathologic processes. In addition to pelvic prolapse, other problems such as ovarian cysts and bladder stones were also found on MRI in our patients.

MRI is a noninvasive procedure compared to conventional fluoroscopic studies for pelvic floor prolapse. MRI provides a detailed anatomic overview, with depiction of all three pelvic compartments at perineal contraction and maximal pelvic strain. Prolapse involving the anterior pelvic compartment (cystocele), the middle compartment (vaginal prolapse, uterine prolapse, enterocele), and the posterior compartment (rectocele) can be easily demonstrated. Dynamic rapid MRI sequences are a major breakthrough in diagnostic imaging. Studies may be done during breath holding, allowing for images with exquisite anatomic detail. Dynamic MRI is now commonly used as an alternative to traditional methods for evaluation of pelvic floor prolapse [3,6-11]. It also discloses incidental pathologic features, such as uterine fibroids, ovarian cysts, hydroureters, urethral diverticula, vesicovaginal and vesicourethral fistulae, and foreign bodies. MRI allows clinicians to survey the whole pelvis in a single dynamic study. MRI, being relatively operator-independent and devoid of risks of irradiation, is ideal for the objective evaluation and follow-up of patients. Dynamic MRI obviates the need for cystourethrography, pelvic ultrasound, or intravenous urography, and is the study of choice at our institution for evaluating the female pelvis.

Past studies have shown that despite surgeons’ best efforts, a third of patients who undergo surgery for pelvic prolapse require re-operation [12]. Symptoms recur in 10–30% of patients, and the cause of the problem often involves compartments of the pelvic floor that were not repaired initially [13]. In such situations, MRI can be a useful preoperative planning tool, especially in complex cases where multiple compartments are involved. Specific muscular defects can be easily identified via dynamic MRI, which simultaneously demonstrates both the muscular and ligamentous structures, as well as the pelvic viscera. The use of fast breath-holding sequences can provide high-quality images both at rest and during maximal pelvic strain.

Based on the MRI findings using fixed and mobile anatomic landmarks, isolated or multicompartiment involvement in pelvic prolapse was diagnosed and quantified based on the grading of visceral prolapse. The PCL, H- and M-lines, and the angle of the levator plate with the PCL are helpful for confirming pelvic floor laxity and identifying compartment prolapse [4]. These measurements are easily obtained. The grading system is based on the degree of organ prolapse through the hiatus and the degree of puborectalis descent (M-line) and hiatal enlargement (H-line). The degree of descent of the bladder, vagina, and anorectal junction can be evaluated, as can the vertical distance between the PCL and the bladder base, the vaginal vault, and the anorectal junction, respectively. In healthy women, there is minimal movement of the pelvic organs, even with maximal strain. In a symptomatic patient, organ descent $>1$ cm below the pubococcygeal line indicates pelvic floor laxity, and organ descent $>2$ cm is often indicative of the need for surgical intervention [10]. A resting anorectal junction position of 3.0 cm or more below the ischial tuberosities, or an anorectal junction descent $>3.5$ cm during evacuation can define excessive pelvic floor descent [14]. In addition, MR-based 3D-modeling can also be used to evaluate levator muscle morphology and volume, as well as the integrity of pelvic floor support and its possible role in stress incontinence and prolapse [7]. It allows assessment of muscle trophicity. In fecal incontinence, weakness of muscles posteriorly is frequently a factor [15], with the levator plate probably being the single most important structure affected. Postoperatively, MRI allows assessment of surgical results, including failures or recurrences.
The basic MRI examination requires no patient preparation. The urinary bladder neck is easily identified in all women because of the high T2 signal of urine. Other important landmarks, such as the cervical and anorectal junctions, can be harder to identify. If a definite estimate of the locations of other relevant structures, e.g., urethra, bladder, vagina, and rectum, is needed, the examination can be performed by opacifying the relevant structures with mixtures of saline solution, gadolinium, or sonography gel as indicated in some reports [3,16]. In other studies, identification was facilitated by intubating a soft catheter into the urethral, vaginal or rectal lumen. This technique is not essential for defining the relationship between the PCL, H- and M-lines. In our nine patients, plain MR images were sufficient to visualize the anatomic landmarks and perform specific measurements.

Some reports suggest that the vertically open configuration magnet system shows promise for evaluation of the female pelvic floor, including urinary stress incontinence and prolapse [17]. The supine position is not any less effective for the diagnosis of symptomatic pelvic prolapse. Imaging with the patient in the supine position is perfectly satisfactory for evaluating symptomatic pelvic floor weakness, despite the fact that defects are most easily identified when the patient is upright [2,3,8,11,18–20].

A limitation of MRI is its high cost. Nevertheless, dynamic MRI is the study of choice for identifying simple or complex organ descent in patients with pelvic organ prolapse. MRI study is multiplanar, non-invasive, and easily applied to the exploration of multi-compartmental prolapse. We conclude that dynamic MRI may become a useful and standard method for diagnosing pelvic floor abnormalities. The technique will not only serve to increase the success rates of surgery, but will also help to accurately predict the outcome of surgical intervention. Further studies must be conducted to study its clinical implications and to formulate standardized practice guidelines.

**REFERENCES**

動態磁振造影在評估女性骨盤腔脫垂上的應用：九個案例的經驗

池永昌  陳欣宏

1 敏盛綜合醫院 放射線科
2 台安醫院 泌尿科

女性骨盤腔脫垂可能涉及單一或多器官的狀況，為了獲得手術前的確診診斷，動態磁振造影可能可以取代傳統 X 光透視攝影或超音波檢查，收集更足夠的資訊，允許外科醫生有一個有效的術前計劃。不管有沒有尿失禁的症狀，在手術之前，九名患有骨盤腔脫垂的婦女接受動態磁振造影檢查。這些患者全部採取仰臥的位置檢查。當患者的骨盤腔是在放鬆和繃緊期間，每相隔 4 秒，我們以超高速的掃描取得骨盤腔中央的矢狀合縫圖像。然後，再把各種動態磁振造影圖像，以特定的測量方法加以分析，呈現骨盤腔脫垂的多樣性和程度差異狀況。PCL 線、H 線、M 線和 levator plate 角度被分別記錄下來。根據這些測量數據，五名受檢者 (5/9) 被證實為多重器官的骨盤腔脫垂患者，四名受檢者 (4/9) 只是單一器官的骨盤腔脫垂患者。七名患者接受手術治療，手術後，所有患者的症狀都獲得重大改善。其中二名患者幾乎完全治癒。動態磁振造影檢查明確展示在骨盤腔內器官下降的簡單或複雜狀況。不僅增加手術的成功率，而且協助外科生做好術前計劃，準確地預測手術的結果。這些結果讓手術醫師高度滿意，動態磁振造影也許能成為骨盤腔脫垂手術前的標準檢查。

關鍵詞：動態磁振造影，骨盤腔脫垂

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